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Floristic Diversity in Uttara Kannada District, Karnataka

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ABSTRACT

The forests are valuable resources on innumerable counts *viz.*, as sources of various useful products to humans, for their environmental and ecosystem services (soil and water conservation, regulation of water flow, carbon sequestration, nutrient cycling, etc.) and as centres of biodiversity. Out of the total 329 million ha land area of India, 43 per cent is under cropping and 23 per cent classified as forests. The total area of forest cover in India, as per the latest assessment is about 692,027 km^2 or 21.05 per cent of the total geographical area.

The Western Ghats range of hills, running close and parallel to the Arabian Sea along the western Peninsular India for about 1600 km from the south of Gujarat to Kanyakumari, covers an area of about 1,60,000 sq.km. This region harbours very rich flora and fauna and there are records of over 4,000 species of flowering plants (38 per cent endemics). Western Ghats is among the 34 global biodiversity hotspots on account of exceptional plant endemism and serious levels of habitat degradation. The complex geography, wide variations in annual rainfall from 1000-6000 mm, and altitudinal decrease in temperature, coupled with anthropogenic factors, have produced a variety of vegetation types in the Western Ghats. While tropical evergreen forest is the natural climax vegetation of the more humid western slopes, along the rain-shadow region eastwards vegetation

changes rapidly from semi-evergreen to moist and dry deciduous forests, the last one being characteristic of the semi-arid Deccan region as well. Lower temperature, especially in altitudes exceeding 1500 m, has produced a unique mosaic of montane 'shola' evergreen forests alternating with rolling grasslands, mainly in the Nilgiris and the Anamalais. All these types of natural vegetation are prone to or have already undergone degradations due to human impacts.

Uttara Kannada district with 76 per cent of its 10,291 sq.km area covered with forests has the distinction of having highest forest area. This is the northernmost coastal district of Karnataka State (13.9220° N to 15.5252° N and 74.0852° E to 75.0999° E) has a geographical area of 10, 291 km^2. Topographically the district can be divided into three zones – the narrow and relatively flat to low hilly coastal along the west of Karwar, Ankola, Kumta, Honavar and Bhatkal taluks; the precipitously rising main range of Western Ghats towards the eastern interior of these taluks, the crestline zone composed of Sirsi, Siddapur Supa and Yellapur taluks and Haliyal and Mundgod taluks towards the north-east flattening and merging with the Deccan Plateau. The district can be divided broadly into five vegetation zones namely: Coastal, Northern evergreen, Southern evergreen, Moist deciduous and Dry deciduous. The evergreen to semi-evergreen forests form major portion of the district especially towards the more rainy western parts. Towards the eastern rain-shadow portion, the forests change rapidly into moist and dry deciduous types.

Whereas substantial areas of natural forests, through forestry practices over a period of more than one century, have been converted into monoculture tree plantations of teak, eucalypts (in the past) and into Acacia plantations in recent decades, there also remained in many places blocks of ancient patches of evergreens, known as *kans*, which were or still are sacred to the local people being the seats of village deities. These are relatively less impacted areas of climax evergreen forests, being sacred groves protected by the people through generations. Being preserved forests from ancient times these *kans* or their remains still might harbor rare species of plants, with high degree of Western Ghats endemism, and also endemic faunal elements. *e.g.*, Asollikan (Ankola), Kathalekan (Siddapur), Karikan (Honavar) etc.

Slash and burn cultivation that prevailed almost till close of 19th century, especially in the heavy rainfall zone created considerable areas of secondary forests that replaced primary evergreen. Wherever clear felling has taken place in the past in the heavy rainfall belt, for shifting cultivation or under forestry operations, very sensitive evergreens and those without coppicing character tend to vanish. Old growth forests in stages of late secondary almost resemble the primary forests. But conspicuously absent in them are climax evergreen forest trees like *Dipterocarpus indicus, Vateria indica, Palaquium ellipticum,* and species confined to *Myristica* swamps like *Myristica fatua* (*M. magnifica*), etc. The forests bearing centuries of history is a grant mosaic of evergreen and semi-evergreen to secondary moist deciduous (in the high rainfall areas) to deciduous types. These are intermingled in many places with degraded stages like savannah, and scrub or entirely changed into grassy blanks used for cattle grazing, which within forest zone also have crucial role of supporting wild herbivores.

Karnataka has five National Parks and 21 Wildlife Sanctuaries. Uttara Kannada has mainly two important protected areas namely Anshi National Park and Dandeli Wildlife Sanctuary. These two PA's are brought together under

Dandeli-Anshi Tiger Reserve with focus on tiger conservation. The DATR presently covers an area of 1365 sq.km. in the taluks Joida, Karwar and Haliyal. We could not carry out forest studies within the DATR due to want of permission from the Wildlife wing of Forest Department. However, prior to the imposition of restrictions on studies within Tiger Reserves we had carried out a study on the grassland resources within the Reserve. Recently (in 2011) Attivery Bird Sanctuary was declared in Mundgod taluk covering 2.23 sq.km area, mainly composed of a reservoir and its peripheral areas.

Conservation Reserves are a new concept within the framework of PAs under the Wildlife (Protection) Amendment Act of 2002. They seek to protect habitats that are under private ownership also, through active stakeholder participation. They are typically buffer zones or connectors and migration corridors between established national parks, wildlife sanctuaries and other RFs. They are designated as conservation reserves if they are uninhabited and completely owned by the government but used for subsistence by communities, and community reserves if part of the lands are privately owned. Administration of such reserves would be through joint participation of forest officials and local bodies like gram sabhas and gram panchayats. They do not involve any displacement and protect user rights of communities. In Uttara Kannada, four such Conservation Reserves were set up by the Government of Karnataka:

1. **Aghanashini LTM Conservation Reserve** (299.52 sq.km), to protect Lion tailed macaque and Myristica Swamps.
2. **Bedthi Conservation Reserve** (59.07 sq.km) as Hornbill habitats and for medicinal plant species like *Coscinium fenestratum*.
3. **Shalmala Riparian Eco-system Conservation Reserve** (4.89 sq.km) for conservation flora and fauna of a riverine ecosystem and
4. **Hornbill Conservation Reserve** (52.5 sq.km) covering part of Kali River basin for specifically hornbill conservation.

The current study investigates *floristic diversity associated with different forests and computes basal area, biomass and carbon sequestration in forests. Apart from this inventorying and mapping of endemic tree species has been done to find out areas of high endemism and congregations of threatened species. A set of criteria for holistic conservation of forest ecosystems, particularly of high endemism of Western Ghats has been prepared based on field investigation, interaction with stakeholders (researchers working in this region, forest officials, local people, subject experts).*

Forests of all major kinds were studied using transect cum quadrat methods (altogether 116 transects, each transect with five quadrats of 400 sq.m each for tree vegetation, 10 sub-quadrats each of 25 sq.m for shrubs and tree saplings and 20 subquadrats of one sq.m for herb layer diversity. Out of 116 transects 8 were studied using point-centre quarter method). Altogether for tree vegetation 540 quadrats, each of 400 sq.m were studied. Necessary permission was, however, not granted for forest studies within the Dandeli-Anshi Tiger Reserve areas.

Altogether 1068 species of flowering plants were inventorised during the study period, through sample surveys and opportunistic surveys outside the transect zones. These species represented 138 families. Of these 278 were trees species (from 59 families), 285 shrubs species (73 families) and 505 herb species (55 families). Moraceae, the family of figs (*Ficus* spp.), keystone resources for animals, had maximum tree sp (18), followed by Euphorbiaceae (16 sp.), Leguminosae (15 sp.), Lauraceae (14 sp.), Anacardiaceae (13 sp.) and Rubiaceae (13 sp.). Shrub species richness was pronounced in Leguminosae (32 sp.), Rubiaceae (24 sp.) and Euphorbiaceae (24 sp.). Among herbs grasses (Poaceae) were most specious (77 sp.), followed by sedges (Cyperaceae) with 67 sp. Orchids (Orchidaceae) were in good number.

Tropical forests are major reservoirs of carbon in the terrestrial areas of the planet which is confronted with the prospects of imminent climatic change. World over all countries need to be alert to this major catastrophe. Apart from regulating pollution levels from various sources carbon sequestration in biomass has to be increased considerably. Our estimates on carbon sequestration based on tree biomass estimates from 116 forest samples show that the average carbon sequestration per hectare of forest (barren areas, scrub and grasslands excluded from sampling) was 154.251 ha.

It is a significant find that the sacred *kan* forests of pre-colonial era, despite their merger with state reserved forests, and subjection of most to timber extraction pressures in the post-independence era, continue to lead the chart of sites having some of the highest carbon sequestration per unit area. Thus the *kan* forest adjoining the Karikanamman temple in Honavar taluk had the highest carbon sequestration at 363.07 t/ha in the tree biomass alone. This is followed by Tarkunde-Birgadde in Yellapur (357.67 t/ha), and some of the swamp-stream forest samples in Kathalekan (299.66 t/ha, 275.18 t/ha, 259.21 t/ha etc.). Likewise Kanmaski-Vanalli in Sirsi had 242.43 t/ha of carbon.

The lowest carbon sequestered was found to be in the savannized forests, for obvious reasons of low to very low number of trees in them. These savannas whether they be in high evergreen forest belt (in Siddapur or Joida for instance) or be in drier zone of Haliyal or Mundgod have carbon storage of <50 t/ha in the tree biomass. Savannization was a necessity in the past for agricultural occupation of humans in the Western Ghats, for cattle grazing and slash and burn cultivation. Today the process is repeating to some extent still as forest encroachments have happened rampantly in all taluks increasing the porosity of otherwise in tact forests. Most bettalands allotted to arecanut orchard owners for exercising the privilege of leaf manure collection are in poor state of biomass and carbon sequestration (*e.g.*, 14.19 t/ha in Gondsur-Sampekattu betta in Sirsi, Talekere betta in Siddapur 41.47 t/ha).

The study highlights the importance of conservation of riparian forests occurring along streams and swamps, not only from high species endemism but also for higher carbon sequestration. A very detailed study in Kathalekan involving nine samples of such forests versus nine samples away from such water courses reveal that the average carbon sequestration in the former was 225.506 t/ha against 165.541 t/ha in the latter. This is despite the fact both types occur within what is traditionally designated as a *kan* forest. We therefore recommend that forests adjoining or covering streams, swamps and riverbanks of the Western Ghats be considered sacrosanct and as critical areas for hydrology not only of the coast but of the entire Indian peninsula.

As regards trees are concerned, in principle, there are close associations between areas of rich tree endemism and occurrence of RET tree species. Forests with high tree endemism also tend to shelter endemic/RET non-tree species and fauna- especially fishes and amphibians- which are indicators of other such organisms as well. Tree species in danger of local or total extinction mainly exist

in and closer to the Myristica swamps. These include *Syzygium travancoricum* (Critically Endangered), *Myristica fatua* (*M. magnifica*) (Endangered), *Gymnacranthera canarica* (Vulnerable), *Semecarpus kathalekanensis* (newly discovered), *Mastixia arborea* (rare endemic) etc. *Madhuca bourdillonii*, a Critically Endangered tree, was not in our samples, but occurred very sparingly close to some Myristica swamps. The Kathalekan swamp forest sheltered at least 35 species of amphibians, most of them within a range of few hundred meters. While 26 species (74 per cent) of them were Western Ghat endemics, one species *Philautus ponmudi* is Critically Endangered and five species each were Endangered and Vulnerable. Scores of *Myristica* dominated forest swamps would have perished in the Western Ghats in past centuries having given way to human impacts, notably due to reclamation of primeval forest clad valleys for making rice fields and arecanut-spice orchards. The last remains are also under threat, mainly being looked upon for areca orchards by encroachers. Swamps being excellent sources of perennial streams we recommend tracing out all such swamps and potential swamps (of degraded vegetation or waters diverted for agriculture) for hydrological needs. The swamps along with their catchments, even if they have secondary forests, need to be safeguarded as prime areas of hydrological significance and as the last refugia of rain forests in the central Western Ghats.

Keywords: Floristic diversity, Biodiversity, Western Ghats.

Introduction

The forests are valuable resources on innumerable counts *viz.*, as sources of various useful products to humans, for their environmental and ecosystem services (soil and water conservation, regulation of water flow, carbon sequestration, nutrient cylcing etc.) and as centres of biodiversity (Ramachandra, 2007). A wide range of benefits to mankind particularly comes from the tropical forests. Estimating the 'total economic value' of forests has become a popular topic and research discussion in the conservation community (Lele *et al.*, 2000). Out of the total 329 million ha land area of India, 43 per cent was under cropping and 23 per cent classified as forests (Ministry of Environment and Forests, 1999). The total area of forest cover in India, as per the latest assessment by Forest Survey of India (2011), has been put at 692,027 km^2, or merely 21.05 per cent of the total geographical area. Indian forests were classified by Champion and Seth (1968) into four major groups, namely, tropical, sub-tropical, temperate, and alpine. These were further divided into 16 type groups: Tropical (wet evergreen, semi-evergreen, moist deciduous, littoral and swamp, dry deciduous, thorn, dry evergreen), Sub-tropical (broad leaved hill forests, pine, and dry evergreen), Temperate (montane wet, Himalayan moist temperate, Himalayan dry temperate), and Alpine (sub-alpine, moist alpine and dry alpine scrub). Of these 16 types, tropical dry deciduous constitute the major percentage of the forest cover in India.

The Western Ghats range of hills, running close and parallel to the Arabian Sea along the western Peninsular India for about 1600 km from the south of Gujarat to Kanyakumari, covers an area of about 1,60,000 sq.km. (Ramachandra, 2007). It is among the 34 global biodiversity hotspots on account of exceptional plant endemism and serious levels of habitat degradation. The complex geography, wide variations in annual rainfall from 1000-6000 mm, and altitudinal decrease in temperature, coupled with anthropogenic factors, have produced a variety of vegetation types in the Western Ghats. While tropical evergreen forest is the natural climax vegetation of the more humid western slopes, along the rain-shadow region eastwards vegetation changes rapidly from semi-evergreen to moist and dry deciduous forests, the last one being characteristic of the semi-arid Deccan region as well. Lower temperature, especially in altitudes exceeding 1500 m, has produced a unique mosaic of montane 'shola' evergreen forests alternating with rolling grasslands, mainly in the Nilgiris and the Anamalais. All these types of natural vegetation are prone to or have already undergone degradations due to human impacts (Pascal, 1986; 1988).

The Western Ghats harbours very rich flora and fauna and there are records of over 4,000 species of flowering plants (38 per cent endemics), 330 butterflies (11 per cent endemics), 156 reptiles (62 per cent endemics), 508 birds (4 per cent endemics), 120 mammals (12 per cent endemics), 135 amphibians (75 per cent endemics) and 289 fishes (41 per cent endemics) (Daniels, 2003; Gururaja, 2004; Sreekantha *et al.*, 2007; Ramachandra *et al.*, 2007).

The major forests and associated vegetation types of the Western Ghats are the following:

1. Tropical wet evergreen forests – natural climax of high rainfall areas (>200 cm/year)
2. Semi evergreen forests – natural climax of moderate rainfall areas (150-200 cm/year) and caused also by disturbances to evergreens
3. Moist deciduous forests – natural to 100-150 cm rainfall areas and anthropogenic factors, especially fire in higher rainfall zones
4. Dry deciduous forests – in areas with less than 100 cm/year rainfall
5. Shola forests – stunted evergreens in the wind protected high altitude valleys (>1500 m)
6. Shola grasslands and grassy blanks – former in high altitude exposed slopes and tops and latter anywhere else due to human impacts
7. Savannas – manmade alterations in natural forests; composed grasslands with distantly placed trees
8. Scrubs and thickets in highly disturbed areas.

Profile of Uttara Kannada Forests

The Uttara Kannada the northernmost coastal district of Karnataka State (13.9220° N to 15.5252° N lat. and 74.0852° E to 75.0999° E long.) has a geographical area of 10, 291 km^2. Topographically the district can be divided into three zones – the narrow and relatively flat to low hilly coastal along the west of Karwar, Ankola, Kumta, Honavar and Bhatkal taluks; the precipitously rising main range of Western Ghats towards the eastern interior of these taluks, the crestline zone composed of Sirsi, Siddapur Supa and Yellapur taluks and Haliyal and Mundgod taluks towards the north-east flattening and merging with the Deccan Plateau. Forest Survey of India (2011) reveals 76 per cent of the district's area as covered by forests. Akbar Shah

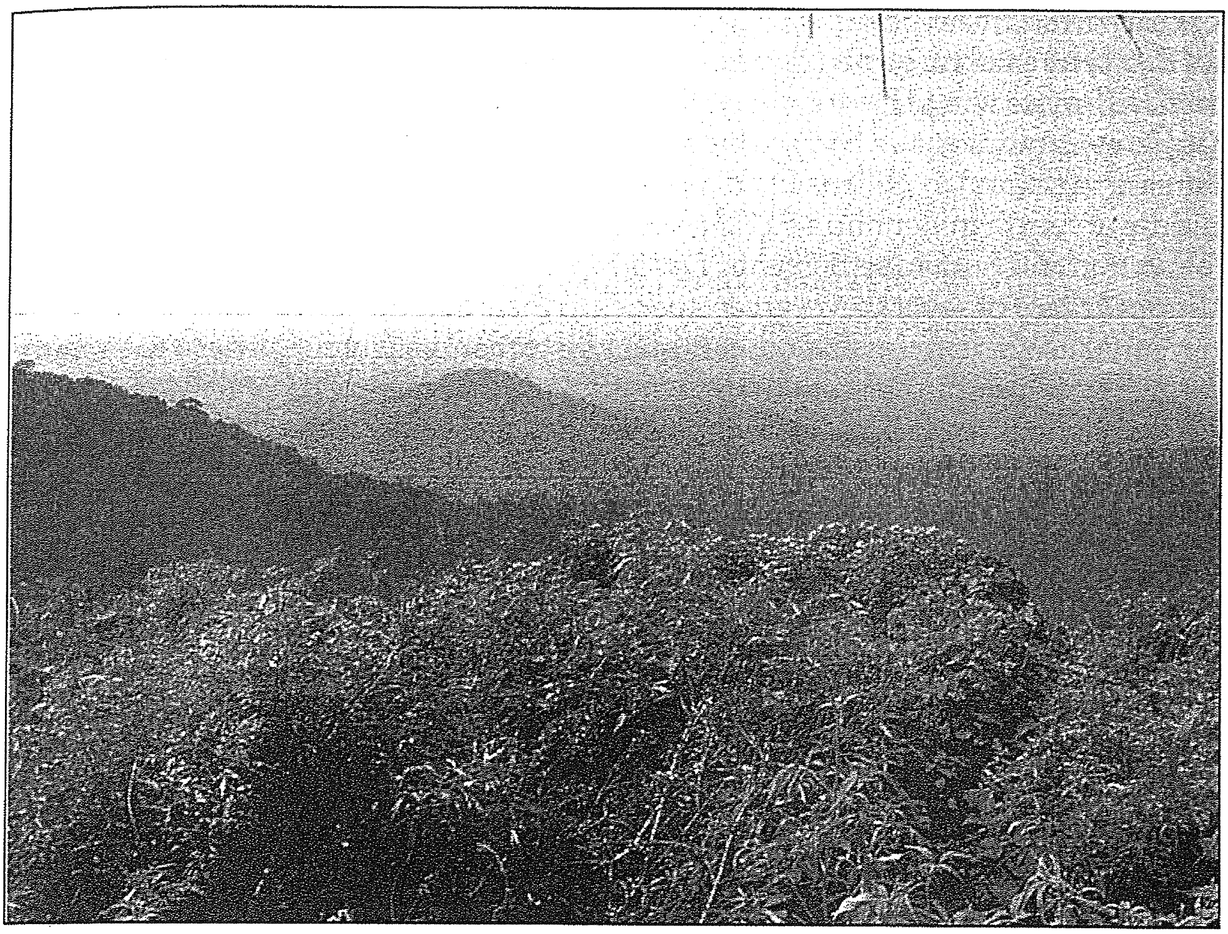

Figure 1.1: Evergeen to Semi-evergreen Forest Clad Hills in Honavar Taluk.

(1988) treated 1388.89 km^2 of the district's forests as partially open, 1646.16 km^2 as of medium density and only 714.55 km^2 as closed forest. Daniels *et al.* (1989; 1993) divided Uttara Kannada vegetation into 5 broad zones namely – Coastal, Northern evergreen, Southern evergreen, Moist deciduous and Dry deciduous zones. The evergreen to semi-evergreen forests (Figure 1.1) form major portion of the district especially towards the west which experiences heavy rainfall. With the decline of rainfall towards the eastern portion, the forests change rapidly from moist deciduous to dry deciduous types. Most of the forests towards the western are considered to be of secondary nature owing mainly to the slash and burn cultivation practices which were widely prevalent up to the mid of 19th century and thereafter in an attenuate form until the close of the century. These forests today are in different stages of secondary succession, and in many places old growth forests would appear like the primary forest itself (Chandran 1997, 1998; Chokkalingam *et al.*, 2000).

The earlier accounts of vegetation studies from this district include details of botanical excursions by Santapau (1955) followed by Puri (1960) who gave a general account of the forests of this district. Champion and Seth (1968) classified the vegetation of western and crestal Uttara Kannada as west coast evergreen/ semi-evergreen forest while Pascal (1982, 1984; Pascal *et al.*, 1982) in his vegetation maps (on 1: 250000 scale) classified the forests in the high to moderate rainfall areas of Uttara Kannada as mainly *Persea macrantha-Diospyros* spp.-*Holigarna* spp. type along with fragments of *Dipterocarpus indicus-Diospyros candolleana-Diospyros oocarpa* types towards the southern portions, mainly in the Siddapur hills. Chandran (1995) pointed out that before the entry of agricultural and pastoral people, over three millennia ago, primary forests would have covered the district, and quotes palynological evidences based on Caratini *et al.* (1991), which highlighted the decline in forest pollens and increase in savannah pollens from marine core studies from Karwar coast towards middle of fourth millennium BP. The forest clearances could have been for shifting cultivation and human settlements. Daniels *et al.* (1995) attributes the reasons for the disappearance of several evergreen species to their inability to coppicing following industrial usages and several other human disturbances. There is a need to monitor the history of fire episodes for different forest types in order to interpret the changes in the semi-evergreen forests. Most of the remnants of good forests could have been converted to secondary forests due to large scale human activities. Based on regeneration patterns of forests in Uttara Kannada and afforestation of almost 6500 ha of land in the post1980's, Bhat *et al.* (2000; 2001) gave good prospects for secondary forests. Based on land cover and land use analysis of remote sensing data Ramachandra (2007) observed that high anthropogenic pressures in the district are causing slow transformation of evergreen forests to semi-evergreen and other human impacted landscape elements.

Uttara Kannada possessed many forests traditionally designated by locals as '*kans*' which were relatively less impacted areas of climax evergreen forests, being sacred groves protected by the people through generations. *Kans* were referred to first, in the travel account of Francis Buchanan, a British officer designated by Lord Wellington to study the newly conquered British territories along south-west India (Buchanan, 1870; Chandran and Gadgil, 1998). Buchanan found these *kans* as lofty evergreen forests preserved for growing pepper amidst relative barrenness of the coastal hills. Near Karwar the locals claimed the sacredness of forests to them (referring obviously to the *kans*) and the need for permission from the village headman, also the priest to village deities, for any inevitable tree cutting which was otherwise considered a taboo. Wingate (1888), the then forest settlement officer of the district noted that the *kans* were of "great economic and climatic importance and favored the existence of springs, perennial streams and generally indicated the proximity of valuable spice gardens, which derive from them both shade and moisture."

The *kans* were large sacred groves, each covering few to few hundred hectares in their original state. There were many such sacred *kans* in the rest of the evergreen forest belt of the district as well as in other Malnadu districts of Karnataka (Chandran and Gadgil, 1993; 1998). About 4,000 ha of *kans* from Sirsi and Siddapur taluks were included in a forest working plan for extraction of industrial timbers (Shanmukhappa, 1966). Siddapur taluk of Uttara Kannada, in the Bombay Presidency under the British regime, had 113 *kans* according to Village Forest Registers (Gokhale, 2001). Some *Kans* of southern Uttara Kannada, harbour fragments of *Myristica* swamps, an endangered and ancient habitat of high watershed value (Chandran and Mesta, 2001). Gadgil and Chandran (1989) noted that *Dipterocarpus indicus* of Western Ghats had its northern limits in Uttara Kannada with some of the *kans* being the only refuge for it. Chandran *et al.* (2010) studied the detailed ecology including species diversity, basal area, biomass and carbon sequestration of the swampy relic forests of Kathalekan in Uttara Kannada. The study revealed that this forest harbored relic trees such as *Dipterocarpus indicus* (Endangered) and *Palaquium ellipticum* and has a network of perennial streams and swamps sheltering endemic and rare population in the world of the tree *Semecarpus kathalekanensis* (new discovery by Dasappa and Swaminath, 2000), *Syzygium travancoricum* (Critically Endangered), *Myristica magnifica* (Endangered), *Gymnacranthera canarica* (Vulnerable).

The notable tree species found in the different forests are:

Evergreen Forests

Dipterocarpus indicus (in few locations only), *Ficus nervosa, Palaquium ellipticum, Syzygium gardenerii, Holigarna grahamii, Artocarpus hirsutum, Dysoxylum malabaricum, Lophopetalum wightianum, Diospyros sylvatica* etc. are found as emergent species. In the second strata that make an unbroken canopy are medium height trees like *Actinodaphne agustifolia, Cinnamomum* spp., *Diospyros candolleana, Hopea ponga, Myristica* spp., *Garcinia* spp., *Knema attenuata,* etc. In the lowermost woody strata occur smaller trees and shrubs such as *Aglaia anamalayana, Diospyros saldanhae, Syzygium laetum,* and some palms like *Arenga wightii* and *Pinanga dicksonii.* Lianas are many as well as canes. Most ancient patches of climax forests alone have *Myristica* swamps and *Dipterocarpus indicus.*

Semi evergreen Forests

Forests in heavy to moderate rainfall areas subjected to human pressures currently, or in the past due to shifting cultivation etc. tend to be semi-evergreen in nature. These share most evergreen tree species with the evergreen climax forests, but are distinguished by the presence of certain deciduous trees such as *Lagerstroemia microcarpa, Terminalia* spp. *Schleichera oleosa, Stereospermum personatum, Tetrameles nudiflora, Vitex altissima* etc. In addition some evergreen species like *Alstonia scholaris, Holigarna arnottiana, Mammea suriga, Carallia integerrima* etc. are more characteristic of the latter. Climbers and lianas and canes are abundant.

Moist Deciduous Forests

Natural moist deciduous forests occur along the rainshadow region where annual rainfall is less than 1500 mm., especially in the taluks of Yellapur east, Haliyal and western parts of Mundgod. Secondary moist deciduous forests could occur anywhere as regeneration in fire affected areas (Mesta, 2008). The species that frequently occur here are *Adina cordifolia, Aporosa lindleyana, Careya arborea, Dillenia pentagyna, Lagerstroemia microcarpa, Spondias* spp., *Strychnos nux-vomica, Terminalia paniculata, T. tomentosa, Xylia xylocarpa* etc. Teak, *Tectona grandis,* occurs naturally along with bamboos, especially *Bambusa arundinacea* and *Dendrocalamus strictus.* Teak plantations are plentiful in this zone. Climbers and lianas are present in these forests but lesser in diversity compared to the evergreen-semievergreen forests.

Dry Deciduous Forests

In plains and undulating terrain in Mundgod and eastern Haliyal, where rainfall drastically reduces to less than 1000 mm, these forests constitute the natural climax. Trees mainly found here are *Albizzia* spp., *Anogeissus* spp., *Careya arborea, Bauhinia racemosa, Bombax ceiba, Bridelia retusa, Dalbergia latifolia, Diospyros melanoxylon,* *D. montana, Lagerstroemia parviflora, Tectona grandis, Terminalia paniculata, Terminalia tomentosa,* etc. Teak trees here do not attain large girths and these forests were formerly also known as 'teak pole' forests.

Scrub-Savannas

These are formations owing their origin to severe human impacts of past and present. They occur anywhere in the district. The scrub is characterized by shrubby plants, often thorny and spinous ones, with stunted trees. The latter include *Careya arborea, Lannea coromandelica, Phyllanthus emblica, Sapium insigne, Sterculia urens, Strychnos nux-vomica, Terminalia chebula, Zanthoxylum rhetsa* etc. Of the shrubby plants are *Embelia tsjeriam-cottam, Grewia microcos, Helectris isora, Ixora coccinia, Leea macrophylla, Tephrosia purpurea* etc. The thorny/spinous shrubs and climbers include *Capparis spinosa, Zizyphus rugosa, Plectronia parviflora* etc.

Forest Plantations

Over a period of more than a century monoculture forest plantations have been raised in the district. The earliest plantations were of teak and *Casuarina,* the latter along the sandy coastal stretches, especially in Karwar and Kasarkod (in Honavar taluk). Teak plantations became widespread throughout the district in an effort to meet the rising timber needs and for raising revenues. In the 1960's began plantations of eucalypts and *Acacia auriculiformis* a couple of decades later. Mixed plantations of utility trees are being raised in the degraded forests in the vicinity of villages through the involvement of village forest committees.

Objectives of the Study

- ☆ Floristic diversity associated with different forests
- ☆ Basal area, biomass and carbon sequestration in forests
- ☆ Presence and quantification of endemic tree species and find out areas of high endemism and congregations of threatened species
- ☆ Presence of rare habitats
- ☆ Prepare a set of criteria for holistic conservation of forest ecosystems, particularly of high endemism of Western Ghats.

Literature Review of Vegetation Studies in different Forest Habitats of Uttara Kannada

The earliest record of the plants from Uttara Kannada was provided by Buchanan (1870) wherein he gave a brief general account of the plants he encountered in the course of his journey through the district. The district's flora was covered in the works of Hooker (1872-1897), Cooke (1901-1908), Talbot (1909) and Saldanha (1984). Account of status and working prescriptions for the forests were available from numerous forest working plans for the district, through a period of about the last 110 years. In addition, numerous works such as monographs, research papers etc. carried valuable information about the districts' plants and forest ecology. Bhat *et al.* (1985) carried out plant diversity studies in the forests of Uttara Kannada covering some reserved forest and minor forest areas. Shastri *et al.* (2002) in their study recorded a total of 144 species of trees from the Sirsimakki village ecosystem in Uttara Kannada district out of which 93 tree species were found in agro-ecosystem area (including home gardens, paddy and areca garden boundary) and 104 species were recorded from non-agricultural lands such as *soppina betta*, minor and reserve forest. Rao *et al.* (2008) documented the floristic diversity of 29 different wetlands in 9 taluks of Uttara Kannada district wherein 167 plant species belonging to 32 families were recorded. Chandran *et al.* (2008) rediscovered the occurrence of two Critically Endangered tree species *Madhuca bourdillonii* and *Syzygium travancoricum* from some relic forests of Uttara Kannada, almost 700 km north of their recorded home range in southern Kerala. Ali *et al.* (2010) reported the occurrence of *Burmannia championii* Thw., a saprophytic herb, for the first time in Karnataka from a *Myristica* swamp in Uttara Kannada district, thereby extending its northern limit of distribution in Western Ghats. During a botanical exploration in Anshi National Park, Uttara Kannada district, Punekar and Lakshminarasimhan (2010) observed and described a new species *Stylidium darwinii* Punekar & Lakshman belonging to family Stylidaceae.

Effects of Mega Projects on Forest Ecosystems

Ever since the arrival of early agriculturists in Uttara Kannada, over three millennia ago, forest have undergone substantial changes because of shifting cultivation and clearance of valley forests for garden cultivation and rice fields. The savannisation of coastal lateritic hills for shifting cultivation, savannization for cattle grazing had beginnings in the pre-historical Uttara Kannada (Chandran, 1997, 1998). However, the early settlers came into equilibrium with nature and Uttara Kannada remained till modern days as one of the most forested districts in the country. Another wave of serious alterations in forests began with the British arrival when timber became a major commodity for sale. The early depletion of natural teak by the close of 19th century was followed by widespread deforestation for raising teak monoculture plantations, not only in its natural deciduous forest zone but also in the heavy rainfall western parts of the district, upsetting ecological conditions substantially.

The post-independence era saw arrival of forest based megaprojects which due to non-sustainable use of timber and bamboo caused considerable forest impoverishment. These industries were given raw materials at abysmally low rates prompting non-sustainable and exhaustive harvesting of resources. The earliest megaproject, Indian Plywood Company started in 1940's in Dandeli. When the prime timbers from deciduous forests were exhausted the factory was given leases for timber from evergreen forest zone. The system of selection felling in the climax evergreen forests had devastating effects on the forest ecosystems. The factory was eventually closed when it could not get adequate raw materials. The West Coast Paper Mills set up at Dandeli in 1958 was given bamboo at very low rates. As lakhs of tons of bamboo were harvested bamboo resources got depleted, forcing the factory to get bamboo from elsewhere and later switching onto pulpwood. Matchwood companies and packing case units were also given concessional timber. All this went on until late 1980's when the Government prohibited all kinds of green fellings in the forests (Gadgil and Chandran, 1989). Considerable areas of land, including good share of forests, were released for various developmental projects (Table 1.1).

Table 1.1: The Extent of Forest Areas Released for other Purposes from 1956

Sl.No.	Particulars	Area in Ha.
1.	The forest area released for cultivation by 3 member committee from 1964 to 1969	6042.500
2.	Forest area released as per special G.O.No.AFD.116 of 16/4/69	11593.342
3.	Forest area released as per G.O.No.AFD-282-FGL74 of 17/19-12-1974	3399.400
4.	Forest area released for long lease	162.100
5.	Hangami Lagan in Notified area	8034.450
6.	Extension of Gouthana	390.400
7.	Forest area released for township	1096.900
8	Mining area leased and area actually in operation	1591.250
9.	Released to House sites to Houseless (1972-1979)	366.000
10.	Rehabilitation of Tibetans, displaced Ryots of Sharavathi Ghataprabha and Malaprabha, Gowli families etc.	4548.170
11.	Area under submersion and other Project	
	1. Kali Hydro Project	14602.000
	2. Bedti Project (for colony)	300.000
	3. Other irrigation tanks etc.	303.365
12.	Released to KSFIC for Napier Hybrid grass cultivation (Sirsi Division)	441.450
13.	Released to KAMCO (Dairy and fruit processing Unit)	153.993
14.	Released to KSFIC for Pineapple cultivation	163.320
15.	Karnataka State Veneers Ltd.	24.000
16.	Power transmission lines	677.979
17.	For establishment of Industries	95.000
18.	Area released to Horticulture department (1969-70)	71.847
19.	Released to Agricultural University, Dharwad	214.000
20.	Sharavathi Tail Race	700.000
21.	Kaiga Atomic Power Project	732.000
22.	Sea Bird Naval Base Project	2259.000
23.	Rehabilitation of Sea Bird out seas	643.720
24	Area released for non-agriculture and other purposes	394.870
25.	Konkan Railway	272.140
26.	Area released for improvement and widening of Ankola-Hubli Road	49.431
27.	Area released for rehabilitation of displaced persons of KHEP and Kaiga Project	316.410
28.	Area released to regularise the encroachments, which have taken place before 27-04-1978	2845.446
29.	Area released to construction of 400 KVDC alternate transmission line between Kaiga NPP and 200 KV sub-station at Narendra in favour of M/s. P.G.C.I.L, Karnataka	330.00
	TOTAL	**62814.483**

**Source*: Forest working plan of Kanara circle (year 2009-10).

Methods and Study Area

The forest vegetation was sampled using transect-based quadrats, a method found useful especially in surveying forested landscaped of central Western Ghats (Chandran and Mesta, 2001; Ramachandra *et al.*, 2006; Ali *et al.*, 2007). Remote sensing imageries were used and ground surveys made to select sample plots (Figure 1.2 for locations). Along a transect of 180 m, 5 quadrats each of 20x20 m were laid alternatively on the right and left, for tree study (minimum girth of 30 cm at GBH or 130 cm height from the ground), keeping intervals of 20 m length between successive quadrats. Within each tree quadrat, at two diagonal corners, two sub-quadrats of 5 m × 5 m were laid for shrubs and tree saplings (< 30 cm girth). Within each of these 2 herb layer quadrats, 1 sq.m area each, were also laid down for herbs and tree seedlings (Figure 1.3). Climbers and other associated species were noted. A rapid assessment was made to track vegetational changes from the densely populated coast through the rugged mountainous terrain to the undulating and drier eastern lands using point-centred quarter method along line transects inAnkola (coastal) and Yellapur (hilly to undulating) taluks. Sampling efforts were higher in high endemism areas (*e.g.*, Kathalekan in Siddapur). Details of formulas used for various calculations are given in the Table 1.2.

The data collected was analyzed to calculate the species diversity using Shanon-Weiner's diversity index, Simpson dominance index, IVI, regeneration status, basal area, biomass and carbon sequestration potential. The Pearson Correlation Matrix with probabilities was calculated by using the 'R' software. A Principal Component Analysis (PCA) was carried out using the package PAST version 2.16. This ordination technique was used to analyze the relationship between the samples and to understand the main factors influencing the forest vegetation in Uttara Kannada (Table 1.2). In addition, the loading score for each variable was calculated; the values were then converted into conservation scoring system and added to the respective variable (next section).

The above ground standing biomass of trees is referred to the weight of the trees above ground, in a given area, if harvested at a given time. The change in standing biomass over a period of time is called productivity. The standing biomass helps to estimate the productivity of an area and also gives information on the carrying capacity of land (Ramachandra and Kamakshi, 2005). It also helps in estimating the biomass that can be continuously extracted. Carbon storage in forests is estimated by taking 50 per cent of the biomass as carbon. The mathematical equations for biomass estimations of trees have been developed and used by many researchers for different biogeography regions. For the current study, the standing above-ground biomass was calculated using the basal area equation and indirect estimation was done for calculating below ground biomass (Brown, 1997; Ravindranath *et al.*, 1997; Murali *et al.*, 2005; Ravindranath and Ostwald, 2008). The resultant total biomass was multiplied by 0.5 for estimating the carbon storage.

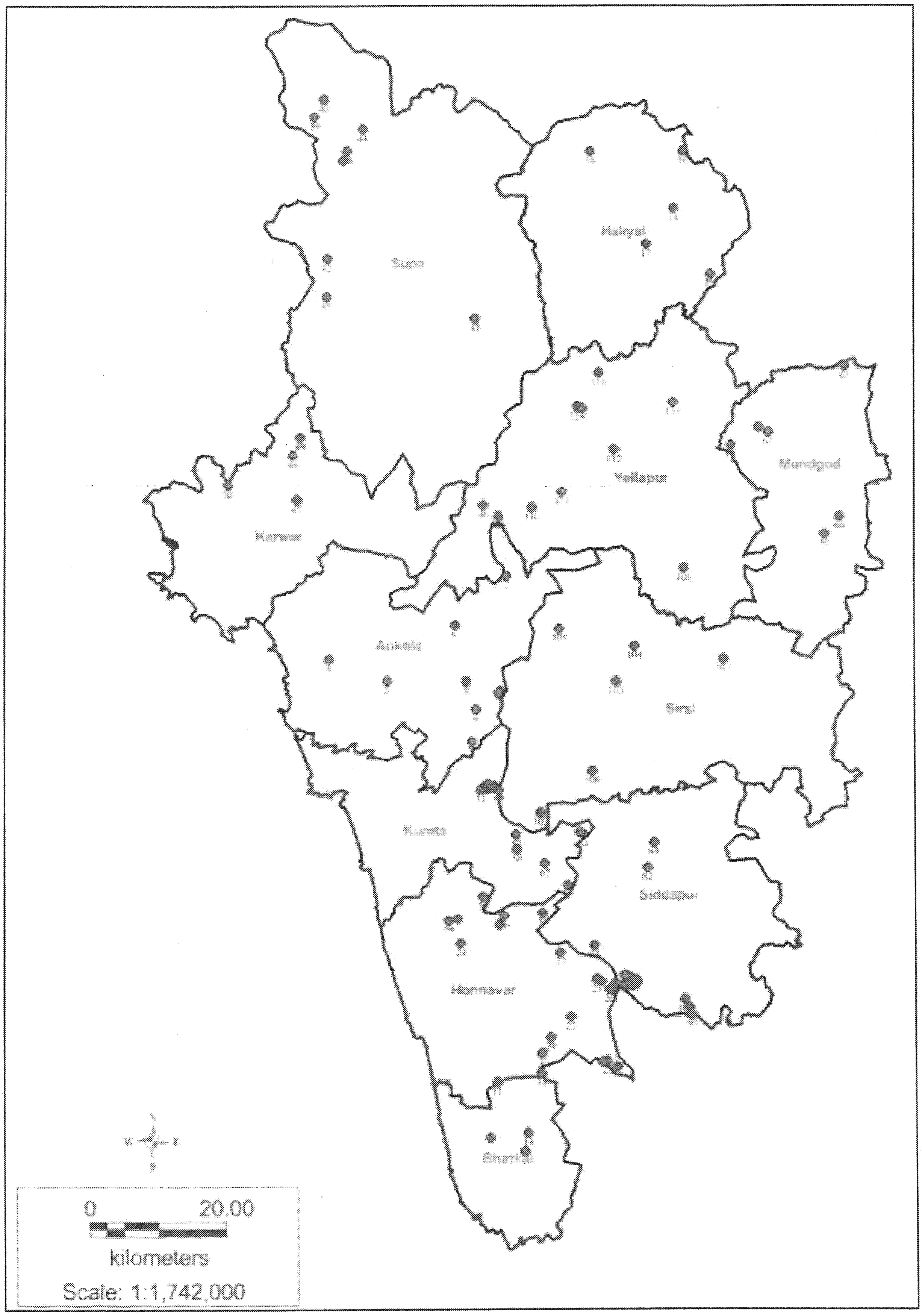

Figure 1.2: Distribution of Sample Study Sites in Uttara Kannada Forests.

Table 1.2: Details of Indices and Calculations and Softwares Used

Index	Equation	Notes
Per cent Evergreenness (trees)	$\frac{\text{No. of evergreen trees X 100}}{\text{Total no. of trees}}$	To estimate how evergreen a forest is.
Per cent Endemism (trees)	$\frac{\text{No. of endemic trees X 100}}{\text{Total no. of trees}}$	Percentage endemism of a forest patch
Basal area (m^2)	$(GBH)^2/4\pi$	
Important Value Index	R. density + R. frequency + R. basal area	To know dominant and co-dominant species
Density	No. Species/Total no. of trees	Provides information on the compactness with which a species exists in an area.
Relative Density	$\frac{\text{Density of Species A X 100}}{\text{Total density of all species}}$	
Frequency	$\frac{\text{No. points with Species A}}{\text{Total No. points Sampled}}$	Provides information on the repeated occurrence of a species
Relative Frequency	$\frac{\text{Frequency of Species A X 100}}{\text{Total Frequency of all Species}}$	
Relative basal area	$\frac{\text{Basal area (m}^2\text{) of Species A X 100}}{\text{Total basal area of all species}}$	
Shannon Weiner's diversity index	$H' = -\sum_{i=1}^{s} p_i ln p_i$	The value of Shannon's diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5.

Contd...

Table 1.2–*Contd...*

Index	*Equation*	*Notes*
Simpson's dominance index	$SIDI = 1 - \sum_{i=1}^{N} p_i \times p_i$.	
Above Ground Biomass (AGB) (t/ha)	-2.81 + 6.78 (BA)	
Below Ground Biomass (BGB) (t/ha)	0.26 * AGB	
Carbon storage	(AGB + BGB) * 0.5	
Pearson correlation matrix	R software	To estimate correlations between the parameters under consideration
Principal component analysis	Package PAST version 2.16	to analyze the relationship between the samples; to understand the main factors influencing the forest vegetation
Composite conservation index	Ranking of sites based on values assigned to key parameters of trees. Valuation system adopted for based on principal component analysis with loading score	PCA was used to analyze relationship between samples and to understand main factors influencing forest vegetation. Loading score obtained was added to a relative valuation score of key parameters decisive for conservation. Degree of correlation between key parametes was arrived at through Pearson correlation matrix. As evergreenness and endemism are strongly correlated, only one parameter (per cent endemism) was assigned a conservation value. The rest- height, basal area and diversity index having relatively lesser importance in endemism were given lesser values. Presence in a site of IUCN Red Listed tree species given higher valuation related to degree of threat.

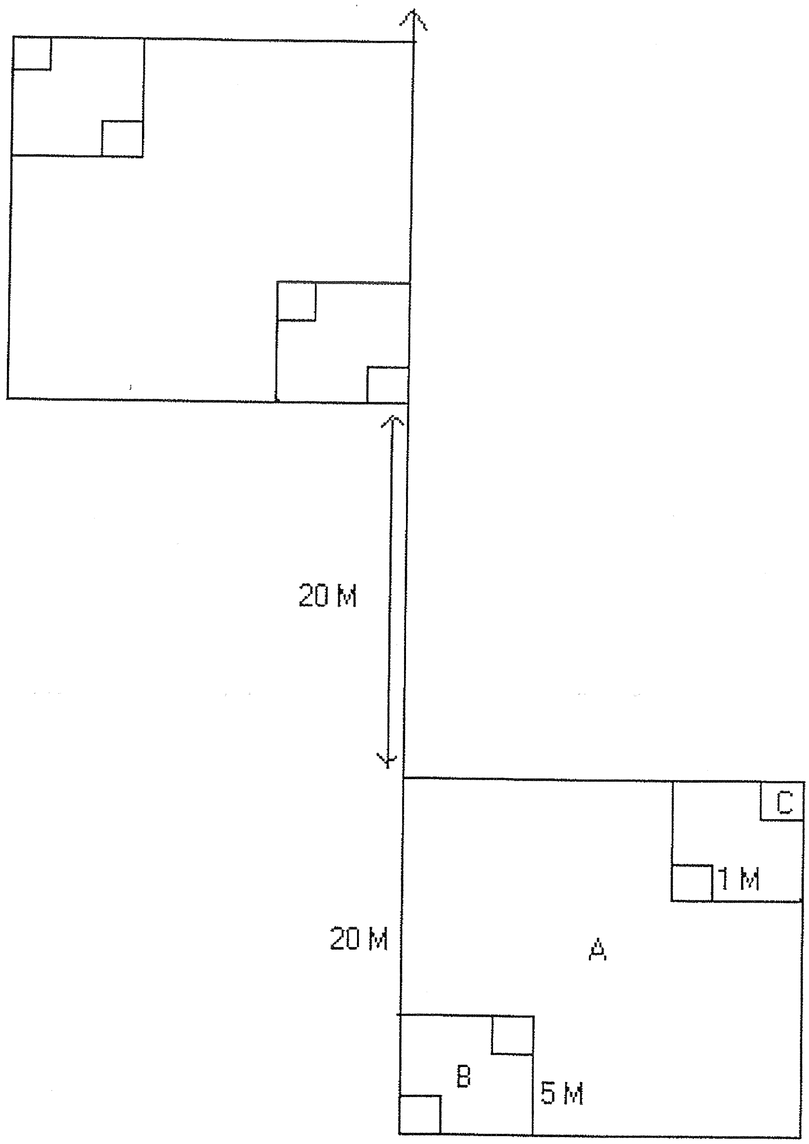

Figure 1.3: Design of Transect cum Quadrats (2 of 5 quadrats of 20x20 m only shown).

Results and Discussion

Floristic Richness

A total of 116 transects studied along with opportunistic surveys yielded a list of 1068 species of flowering plants (about 25 per cent of Western Ghat species) from 138 families. Of these 278 were trees species (from 59 families), 285 shrubs species (73 families) and 505 herb species (55 families) (Figure 1.4). Among trees Moraceae had maximum representation (18 sp.), followed by Euphorbiaceae (16 sp.), Leguminosae (15 sp.), Lauraceae (14 sp.), Anacardiaceae (13 sp.) and Rubiaceae (13 sp.) and so on (Figure 1.5). The genus *Ficus*, members of which are considered as keystone resources for large number of birds and mammals, was the most well represented of Moraceae.

In Shrubs Leguminosae (32 sp.), Rubiaceae (24 sp.), Euphorbiaceae (24 sp.) were the leading families in species richness (Figure 1.6). Grasses (Poaceae) were most speciose (77 sp.) among herbs, followed by sedges –Cyperaceae- (67 sp.) and orchids –Orchidaceae- (35 sp.) (Figure 1.7). Grasses occur everywhere, except underneath the

Figure 1.4: Family and Species Number for Trees, Shrubs and Herbs.

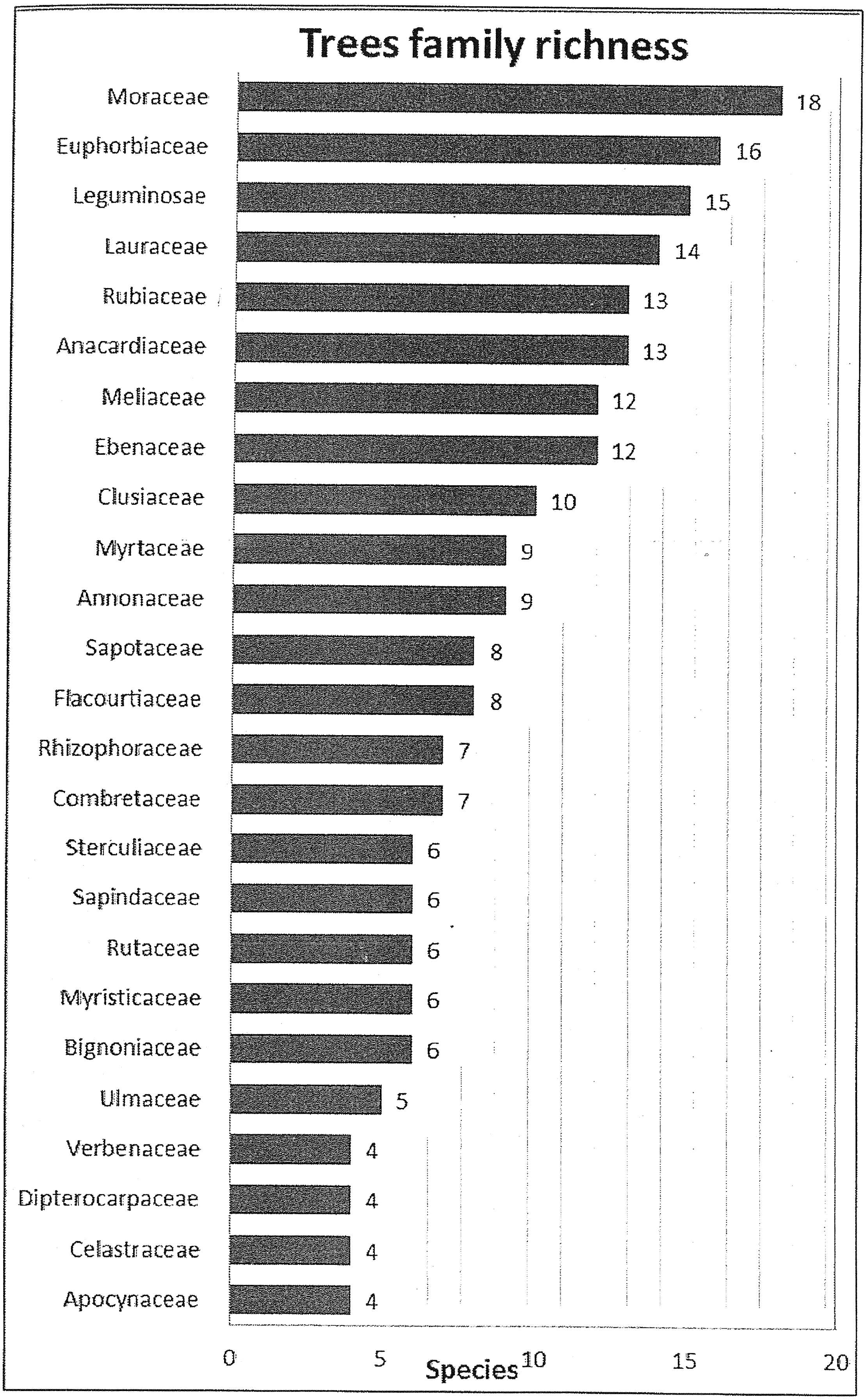

Figure 1.5: Richness of Families in Tree Species (Families with above 3 species shown).

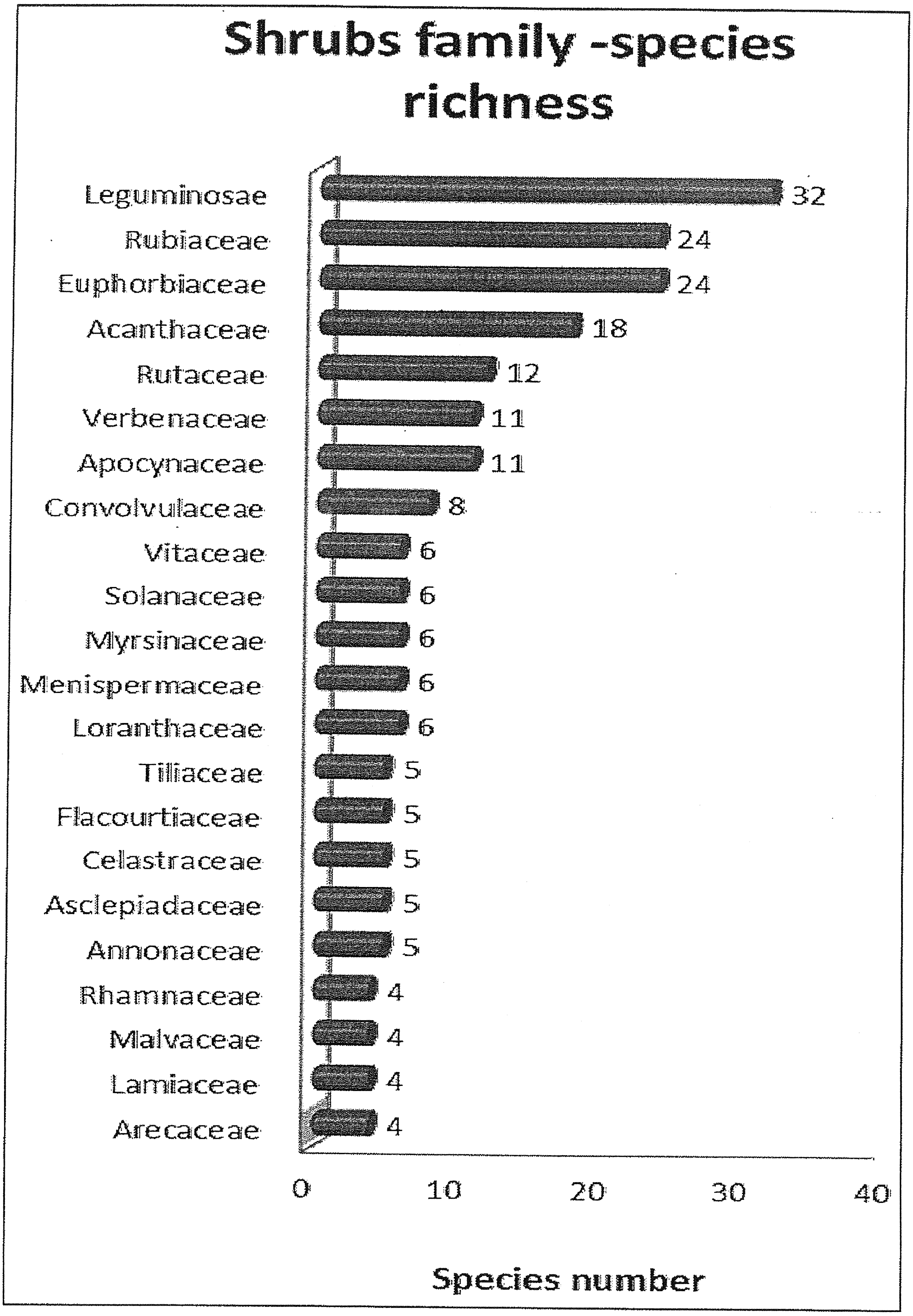

Figure 1.6: Richness of Families in Shrub Species (Those with 4 or more species only shown).

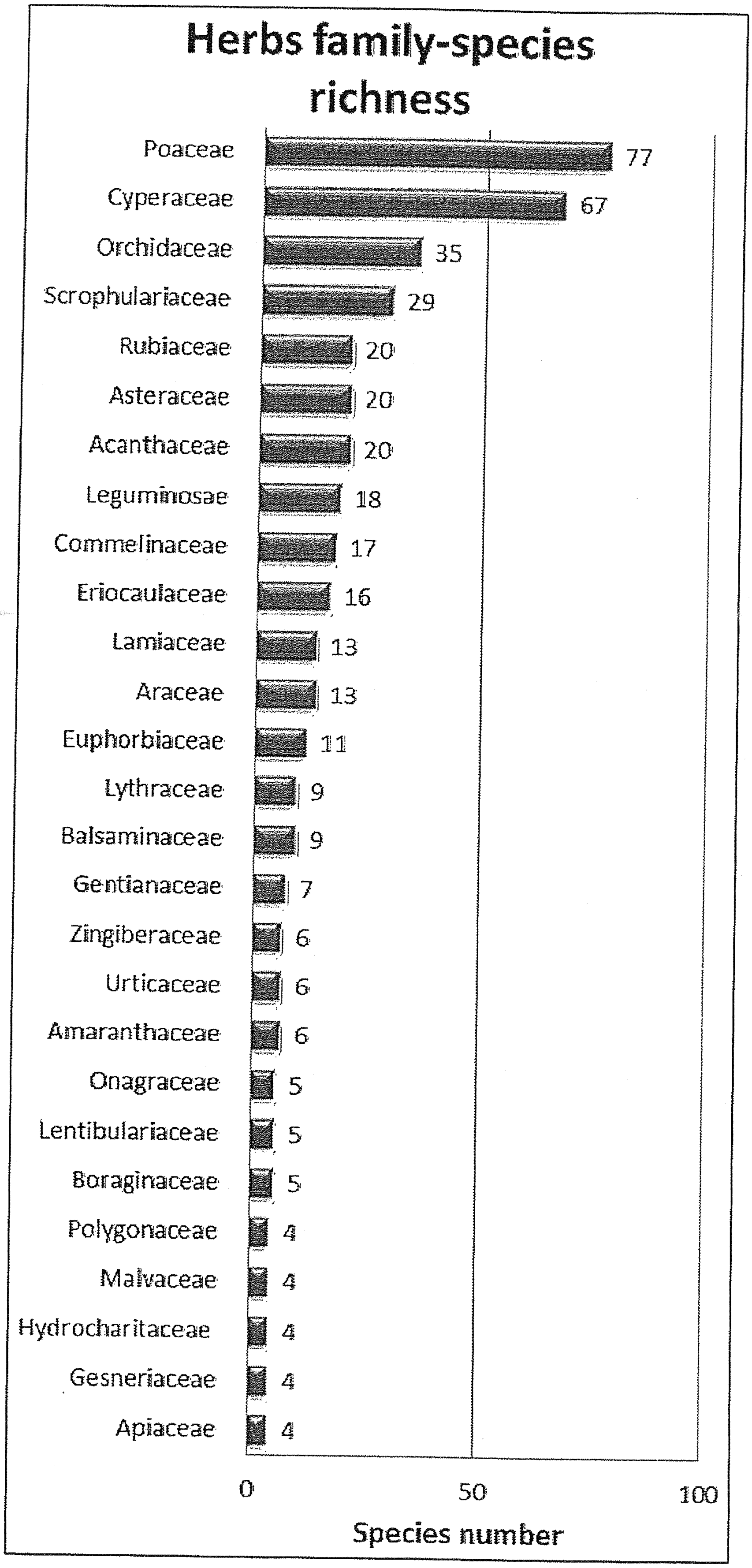

Figure 1.7: Richness of Families with Herb Species (Only families with 4 or more species given).

dark canopy of evergreen forest. Most of wetlands and very moist areas were under the dominance of Cyperaceae and to some extent under Scrophulariaceae.

Basal Area and Height

Details of transect-wise localities depicting tree species/transect, average height and estimated basal area/ha are given in the Table 1.3. Hadgeri-1 had the highest average tree height (21.82m) followed by Halsolli and Ambepal. These areas were characterised by lofty individuals of *Dipterocarpus indicus, Syzygium gardnerii* etc., the mature trees often attaining over 30 m. Most forests in Honavar and Siddapur taluks had greater heights owing to their predominantly evergreen and semi-evergreen forests.

The forests in general were mosaic of poor and mighty ones as far as tree heights and basal areas estimated/ha are concerned. Lowest average heights were seen in savanna and disturbed moist deciduous forests (*e.g.*, hill top savannas of Sirsi, Siddapur and stretches of forests in Joida which were under extensive shifting cultivation until end of the 19th century). Teak mixed forests and highly disturbed semi-evergreen forests (*e.g.*,Talekere) had lower height. Basal areas were also higher for *Dipterocarpus indicus* dominated areas of Karikan (85.41 sq.m/ha) and Kathlekan swamps dominated by swamp species like *Gymna cranthera* and in the nearby by other immense sized *Calophyllum tomentosum, Lophopetalum wightianum, Dipterocarpus indicus, Palaquium ellipticum,* (Figures 1.8 and 1.9) etc. Kushavali of Joida with large

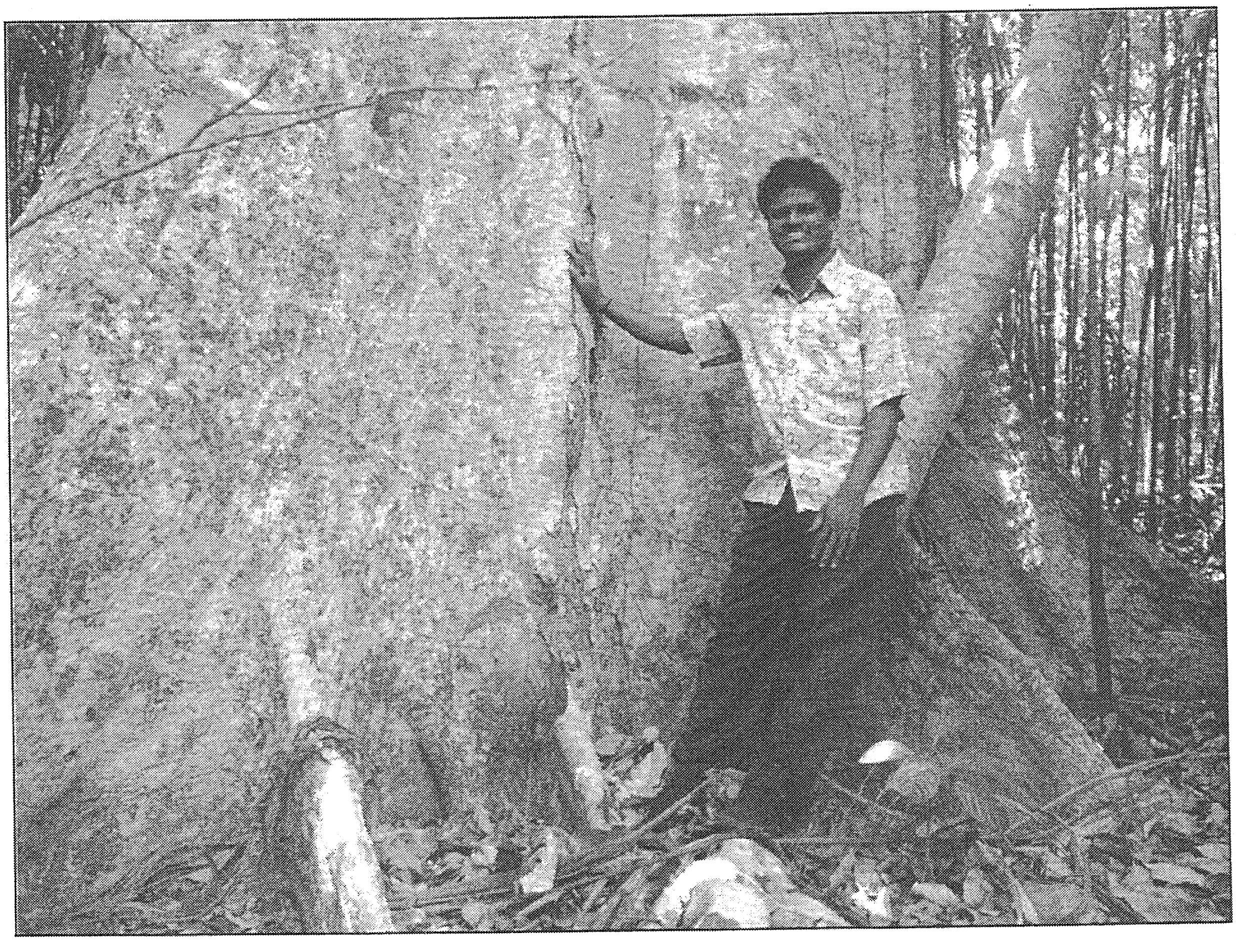

Figure 1.8: ***Lophopetalum wightianum*** **in Kathalekan, Siddapur.**

Table 1.3: Transect-wise Numbers of Tree Species, Average Height and Estimated Basal Area per ha and Biomass-Carbon Sequestration

Sl.No.	Locality Name	Taluk	Tree Species	Average Height	Basal Area (m^2/ha)	Above Ground Biomass (t/ha)	Below Ground Biomass (t/ha)	Total Biomass (t/ha)	Carbon Sequestration (t/ha)
1.	Asolli-1	Ankola	23	17.1	38.28	256.70	66.74	323.44	161.72
2.	Asolli-2	Ankola	33	17.4	38.73	259.75	67.53	327.28	163.64
3.	Hosakere	Ankola	30	16.0	37.62	252.28	65.59	317.87	158.94
4.	S1-Katangadde-Agasur	Ankola	40	9.6	9.08	58.75	15.28	74.03	37.01
5.	S2-Balikoppa-Badgon	Ankola	31	13.6	20.39	135.43	35.21	170.65	85.32
6.	S3-Hegdekoppa-Kasinmakki	Ankola	35	14.6	30.41	203.37	52.88	256.25	128.12
7.	S4-Vajralli-Ramanguli	Ankola	31	13.9	18.8	124.65	32.41	157.06	78.53
8.	Kachinabatti	Ankola	13	15.5	18.39	121.90	31.69	153.60	76.80
9.	Maabagi	Ankola	33	16.4	40.78	273.67	71.15	344.82	172.41
10.	Dakshinakoppa	Bhatkal	12	16.1	34.83	233.35	60.67	294.02	147.01
11.	Gujmavu (semi evergreen)	Bhatkal	33	15.8	32.97	220.75	57.40	278.15	139.07
12.	Hudil (evergreen)	Bhatkal	14	17.3	35.82	240.02	62.40	302.42	151.21
13.	Hudil (semi evergreen)	Bhatkal	27	15.8	46.11	309.81	80.55	390.36	195.18
14.	Golehalli	Haliyal	16	9.54	15.64	103.20	26.83	130.03	65.02
15.	Kudalgi-Tatigeri	Haliyal	12	10.98	17.79	117.84	30.64	148.48	74.24
16.	Magvad	Haliyal	19	14.9	23.90	159.21	41.39	200.60	100.30
17.	Sambrani	Haliyal	11	12.59	31.91	213.54	55.52	269.06	134.53
18.	Yadoga	Haliyal	13	14.3	26.30	175.53	45.64	221.17	110.58
19.	Ambepal-1	Honavar	25	19.2	31.49	210.66	54.77	265.43	132.72

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Table 1.3–*Contd...*

Sl.No.	Locality Name	Taluk	Tree Species	Average Height	Basal Area (m^2/ha)	Above Ground Biomass (t/ha)	Below Ground Biomass (t/ha)	Total Biomass (t/ha)	Carbon Sequestration (t/ha)
20.	Ambepal-2	Honavar	32	19.6	48.80	328.07	85.30	413.36	206.68
21.	Chaturmukhabasti	Honavar	23	15.0	27.76	185.38	48.20	233.58	116.79
22.	Gersoppa	Honavar	31	18.2	30.13	201.47	52.38	253.85	126.93
23.	Gundabala	Honavar	32	15.4	29.05	194.16	50.48	244.65	122.32
24.	Hadageri-1	Honavar	23	21.8	53.69	361.20	93.91	455.11	227.56
25.	Hadageri-2	Honavar	19	19.3	45.53	305.85	79.52	385.38	192.69
26.	Halsolli	Honavar	9	20.5	30.64	204.93	53.28	258.21	129.11
27.	Hessige-1	Honavar	28	18.1	44.25	297.21	77.27	374.48	187.24
28.	Hessige-2	Honavar	27	16.6	48.87	328.52	85.42	413.94	206.97
29.	Hessige-3	Honavar	25	16.9	31.46	210.47	54.72	265.19	132.60
30.	Hessige-4	Honavar	30	17.4	51.56	346.77	90.16	436.93	218.46
31.	Kadnir	Honavar	24	16.0	38.17	255.96	66.55	322.51	161.25
32.	Karikan-lower slope	Honavar	28	13.6	41.87	281.10	73.09	354.19	177.09
33.	Karikan-semievergreen	Honavar	23	14.4	33.98	227.57	59.17	286.74	143.37
34.	Karikan-temple side-diptero patch	Honavar	21	17.9	85.41	576.29	149.83	726.12	363.06
35.	Mahime	Honavar	18	16.8	30.44	203.57	52.93	256.50	128.25
36.	Sharavathy-viewpoint	Honavar	28	17.7	34.70	232.47	60.44	292.92	146.46
37.	Tulsani-1	Honavar	27	17.3	36.44	244.26	63.51	307.77	153.89
38.	Tulsani-2	Honavar	23	17.1	30.86	206.44	53.68	260.12	130.06
39.	Castlerock IB	Joida	28	16.0	55.68	374.67	97.41	472.09	236.04

Contd...

Table 1.3–*Contd...*

Sl.No.	Locality Name	Taluk	Tree Species	Average Height	Basal Area (m^2/ha)	Above Ground Biomass (t/ha)	Below Ground Biomass (t/ha)	Total Biomass (t/ha)	Carbon Sequestration (t/ha)
40.	Castlerock-moist-dec.	Joida	22	9.4	12.16	79.64	20.71	100.34	50.17
41.	Castlerock-semi everg	Joida	24	15.4	26.27	175.31	45.58	220.89	110.44
42.	Desaivada-Nandgadde	Joida	12	16.87	36.96	247.81	64.43	312.24	156.12
43.	Gavni-Kangihole-Joida	Joida	35	15.2	48.70	327.37	85.12	412.49	206.25
44.	Ivolli-Castlerock	Joida	19	13.7	33.99	227.62	59.18	286.80	143.40
45.	Joida-deciduous	Joida	21	16.9	39.44	264.62	68.80	333.42	166.71
46.	Kushavali	Joida	30	16.4	75.04	505.93	131.54	637.48	318.74
47.	Shivpura	Joida	12	15.90	33.79	226.26	58.83	285.09	142.55
48.	Gopishetta	Karwar	23	15.1	32.21	215.58	56.05	271.63	135.82
49.	Goyar-moist dec	Karwar	18	15.0	37.99	254.77	66.24	321.01	160.50
50.	Kalni-goyar	Karwar	32	17.3	45.05	302.66	78.69	381.35	190.67
51.	Karwar-moist dec	Karwar	17	10.8	13.48	88.61	23.04	111.65	55.82
52.	Devimane-Campsite	Kumta	36	16.7	42.99	288.63	75.04	363.67	181.84
53.	Devimane-Sirsi side	Kumta	30	14.4	40.28	270.31	70.28	340.59	170.30
54.	Devimane-temple	Kumta	29	14.8	39.54	265.30	68.98	334.27	167.14
55.	Devimane-with myristicas	Kumta	30	15.0	45.86	308.15	80.12	388.27	194.14
56.	Hulidevarakodlu	Kumta	34	18.2	43.53	292.35	76.01	368.36	184.18
57.	Kalve	Kumta	28	16.2	27.38	182.82	47.53	230.35	115.17
58.	Kalve-moist dec.	Kumta	22	14.3	28.76	192.18	49.97	242.14	121.07
59.	Kandalli-Devimane	Kumta	28	16.14	41.54	278.84	72.50	351.33	175.67

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Table 1.3–*Contd...*

Sl.No.	Locality Name	Taluk	Tree Species	Average Height	Basal Area (m^2/ha)	Above Ground Biomass (t/ha)	Below Ground Biomass (t/ha)	Total Biomass (t/ha)	Carbon Sequestration (t/ha)
60.	Mastihalla-Devimane arch	Kumta	26	15.27	48.04	322.92	83.96	406.87	203.44
61.	Mathali-Kandalli-Devimane	Kumta	29	15.6	41.61	279.34	72.63	351.96	175.98
62.	Soppinahosalli	Kumta	15	14.5	25.43	169.60	44.09	213.69	106.85
63.	Surjaddi	Kumta	28	17.3	35.75	239.58	62.29	301.88	150.94
64.	Surjaddi-Morse	Kumta	30	17.2	29.40	196.53	51.10	247.63	123.82
65.	Attiveri-teakmixed-drydec	Mundgod	20	10.1	11.85	77.54	20.16	97.70	48.85
66.	Godnal	Mundgod	13	15.6	43.09	289.36	75.23	364.59	182.30
67.	Gunjavathi	Mundgod	9	14.3	20.44	135.78	35.30	171.08	85.54
68.	Karekoppa-Gunjavathi	Mundgod	11	17.0	36.72	246.15	64.00	310.15	155.08
69.	Katur	Mundgod	15	16.69	28.05	187.35	48.71	236.06	118.03
70.	Katur to Gunjavathi	Mundgod	17	9.07	29.08	194.37	50.54	244.91	122.46
71.	G1-Kathalekan-nonswamp	Siddapur	41	14.4	32.31	216.25	56.23	272.48	136.24
72.	G2-Kathalekan-nonswamp	Siddapur	39	16.2	39.14	262.58	68.27	330.86	165.43
73.	G3-Kathalekan-nonswamp	Siddapur	37	15.6	45.41	305.09	79.32	384.42	192.21
74.	G4-Kathalekan –nonswamp	Siddapur	38	16.7	35.87	240.42	62.51	302.93	151.46
75.	G5-Kathalekan-nonswamp	Siddapur	39	14.1	39.84	267.28	69.49	336.77	168.39
76.	Kathalekan-savanna	Siddapur	5	6.1	1.59	7.98	2.08	10.06	5.03
77.	G6-Kathalekan-nonswamp	Siddapur	23	17.8	50.86	342.04	88.93	430.97	215.48
78.	G7-Kathalekan-nonswamp	Siddapur	44	16.8	28.22	188.52	49.02	237.54	118.77
79.	G8-Kathalekan- nonswamp	Siddapur	34	16.1	41.24	276.80	71.97	348.77	174.38

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Table 1.3–*Contd...*

Sl.No.	Locality Name	Taluk	Tree Species	Average Height	Basal Area (m^2/ha)	Above Ground Biomass (t/ha)	Below Ground Biomass (t/ha)	Total Biomass (t/ha)	Carbon Sequestration (t/ha)
80.	G9-Kathalekan-nonswamp	Siddapur	18	16.0	39.63	265.88	69.13	335.01	167.51
81.	Hartebailu-soppinabetta	Siddapur	23	11.5	17.80	117.87	30.65	148.51	74.26
82.	Hutgar	Siddapur	25	15.9	30.54	204.22	53.10	257.32	128.66
83.	Joginmath-1	Siddapur	35	17.1	31.48	210.65	54.77	265.42	132.71
84.	Joginmath_2-semievergreen	Siddapur	25	17.7	42.12	282.74	73.51	356.25	178.12
85.	Kathalekan-1	Siddapur	44	16.8	28.22	188.49	49.01	237.50	118.75
86.	Kathalekan-2	Siddapur	39	16.7	30.67	205.10	53.33	258.43	129.21
87.	Kathalekan –swamp-1	Siddapur	37	16.7	43.16	289.85	75.36	365.21	182.60
88.	Kathalekan –swamp-2	Siddapur	27	15.1	40.02	268.53	69.82	338.34	169.17
89.	Kathalekan –swamp-3	Siddapur	32	16.0	70.57	475.65	123.67	599.32	299.66
90.	Kathalekan –swamp-4	Siddapur	29	17.0	61.10	411.45	106.98	518.43	259.21
91.	Kathalekan –swamp-5	Siddapur	21	15.4	43.47	291.92	75.90	367.81	183.91
92.	Kathalekan –swamp-6	Siddapur	30	15.8	40.15	269.43	70.05	339.49	169.74
93.	Kathalekan –swamp-7	Siddapur	37	15.4	31.80	212.78	55.32	268.10	134.05
94.	Kathalekan –swamp-8	Siddapur	29	18.2	55.05	370.41	96.31	466.71	233.36
95.	Kathalekan –swamp-9	Siddapur	33	18.4	64.84	436.80	113.57	550.37	275.18
96.	Kathalekan-3	Siddapur	45	16.1	29.13	194.71	50.62	245.33	122.67
97.	Malemane-1	Siddapur	33	16.6	37.54	251.70	65.44	317.15	158.57
98.	Malemane-2	Siddapur	33	18.5	38.41	257.63	66.98	324.62	162.31
99.	Malemane-3	Siddapur	28	17.6	42.63	286.24	74.42	360.66	180.33

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Table 1.3–*Contd...*

Sl.No.	*Locality Name*	*Taluk*	*Tree Species*	*Average Height*	*Basal Area (m^2/ha)*	*Above Ground Biomass (t/ha)*	*Below Ground Biomass (t/ha)*	*Total Biomass (t/ha)*	*Carbon Sequestration (t/ha)*
100.	Siddapur evergreen	Siddapur	26	18.0	30.20	201.95	52.51	254.46	127.23
101.	Talekere	Siddapur	14	10.6	10.12	65.82	17.11	82.94	41.47
102.	Bugadi-Bennehole	Sirsi	36	15.21	56.15	377.90	98.25	476.15	238.08
103.	Gondsor-sampekattu	Sirsi	10	8.7	3.74	22.52	5.86	28.37	14.19
104.	Hulekal-Sampegadde-Hebre	Sirsi	40	15.40	50.93	342.47	89.04	431.51	215.75
105.	Kanmaski-Vanalli	Sirsi	26	15.2	57.17	384.82	100.05	484.87	242.43
106.	Khurse	Sirsi	26	11.2	22.39	149.01	38.74	187.75	93.87
107.	Masrukuli	Sirsi	15	14.9	42.36	284.41	73.95	358.36	179.18
108.	Hiresara-bettaland	Yellapur	14	11.9	41.73	280.12	72.83	352.95	176.47
109.	S5-Gidgar-Yemmalli	Yellapur	39	19.1	43.54	292.39	76.02	368.41	184.21
110.	S6-Tarukunte-Birgadde	Yellapur	41	19.5	84.15	567.73	147.61	715.34	357.67
111.	S7-Arlihonda-Nandvalli	Yellapur	48	15.5	30.55	204.32	53.12	257.44	128.72
112.	S8-Yellapur-Mavalli	Yellapur	39	17.3	35.59	238.49	62.01	300.50	150.25
113.	S9-Kiruvatti	Yellapur	16	16.6	11.99	78.48	20.41	98.89	49.44
114.	Hasrapal-evergreen	Yellapur	24	19.1	34.79	233.05	60.59	293.65	146.82
115.	Hulimundgi-semievergreen	Yellapur	27	17.3	33.63	225.23	58.56	283.79	141.89
116.	Lalguli-moist-dec	Yellapur	15	16.9	42.32	284.10	73.87	357.96	178.98

Figure 1.9: ***Dipterocarpus indicus* in Karikan Sacred Grove.**

sized *Dysoxylum malabaricum, Holigarna grahamii* etc., had higher basal area (75.08 sq.m/ha). Hill slopes and sacred groves had higher basal areas. Places like Kanmaski-Vanalli and Bugadi of Sirsi, characterised by *Diospyros candolleana, Tricalysia spearocarpa, Pterygota alata* had higher basal areas of 57.17 sq.m/ha and 56.15 sq.m/ha respectively. Lowest basal areas were for savannised places (such as Gondsur-Sampekatte, in coastal stretches of Ankola (Ankola and Ramanguli ranges) and in samples of deciduous to dry deciduous forests between Kirwatti and Kalghatgi. The bettalands, allotted to areca gardeners for leaf manure extraction also have unsatisfactory biomass.

Biomass and Carbon Sequestration in Uttara Kannada Forests

Global climate change is one of the major causes of concerns of this century, the leading reason being the phenomenal burning of fossil fuels, releasing enormous quantities of carbon to the atmosphere. Land-use changes such as the conversion of forests to croplands may also contribute to increasing atmospheric carbon, forests being one of the major storehouses of carbon since plants absorb atmospheric carbondioxide during photosynthesis and fix the carbon in sugars, starches, cellulose, lignin and numerous other bio-molecules, thereby transferring carbon from atmosphere into the biological systems. Approximately 40 per cent of terrestrial carbon storage is in the tropical forest vegetation biomass, and 30-35 per cent of land surface photosynthesis happens here (Dixon *et al.*, 1994; Malhi and Grace, 2000). If such forests are disturbed or destroyed much more carbon is released than fixed (Palm *et al.*, 1986). While estimates of standing biomass in forests help to understand the carbon stocks, the knowledge of dynamics is useful to assess C-fixation potential of the stand and categorize them as C-source, C-sink or in C-steady state (Bhat *et al.*, 2002a, 2002b; Bhat and Ravindranath, 2011).

India ranks 10th amongst the most forested nations of the world (FAO, 2005) with 23.4 percent (76.87 million ha) of its geographical area under forest and tree cover (FSI, 2008). These forests provide various critical ecosystem goods and services for the population of the country. The role of forests in carbon storage and sequestration has increased appreciation of their importance manifold bringing them to the centre-stage of climate change mitigation strategies. Over the past few decades, national policies of India aimed at conservation and sustainable management of forests have transformed India's forests into a net sink of CO_2. The biomass carbon stock in India's forests was estimated at 7.94 MtC during 1880 and nearly half of that after a period of 100 years (Richards and Flint, 1994). The earliest available estimates for forest carbon stocks (biomass and soil) for 1986, were in the range of 8.58 to 9.57 GtC (Ravindranath *et al.*, 1997; Haripriya, 2003; Chhabra and Dadhwal, 2004). As per FAO (2005), the total forest carbon stocks in India have increased over a period of 20 years (1986-2005) to 10.01 GtC. The carbon stock for the period 2006–30 was projected to increase substantially with forest cover becoming more or less stable, and new forest carbon accretions coming from the current initiatives of afforestation and reforestation programme (Ravindranath *et al.*, 2008).

It is interesting to recall some earlier studies of biomass and carbon stocks in the Uttara Kannada forests. Prasad *et al.* (1987) estimated the average total standing biomass for reserve and minor forests at 248.68 and 142.54 t/ha respectively (minor forests set aside for meeting the biomass needs of village communities were exhaustively used and greatly degraded). The average annual productivity for these was estimated at 5.395 and 2.596 t/ha/yr respectively for reserved and minor forests. Bhat *et al.* (2000; 2002a; 2002b) monitored carbon stock dynamics in Uttara Kannada district for 10 years on 8 one ha sample forest plots of different management categories. Overall carbon stocks increased at an average rate of 1.008 t/ha/yr. The minor forests, under human pressure, had negative growth of 0.237 t/ha/yr whereas reserve forests had carbon assimilation rate of 1.31 tons/ha/yr. Monitoring for 25 years (from 1984 to 2009) in six 1-ha permanent forest plots in Uttara Kannada, under different levels of anthropogenic pressure, revealed that the above-ground showed that carbon accumulation was to the tune of 1.13 t C /ha /yr, of which, 0.58 ± 1.18 t C /ha/year was contributed by surviving trees and 0.55 ± 0.33 t C/ha/year was added by recruits (Bhat and Ravindranath, 2011). Study of relic evergreen forests with swampy areas in Kathalekan of Siddapur taluk showed higher above ground biomass (349.52 ± 110.79 tons/ha) and carbon storage (174.76 ± 55.39 tons/ha) for forests alongside streams and swamps and lesser above ground biomass (263.32 ± 42.04 tons/ha) and carbon storage of 131.66 ± 21.02 tons/ha for forests away from these water courses (Chandran *et al.*, 2010). Based on the basal area study sites are grouped in to High Disturbance (< 20 m^2/ha), Moderate Disturbance (20 – 40 m^2/ha) and Low Disturbance (> 40 m^2/ha) localities. It was observed that out of the total studied localities, 10 were highly disturbed, 56 were moderately disturbed and 50 localities had low disturbances (Figure 1.10).

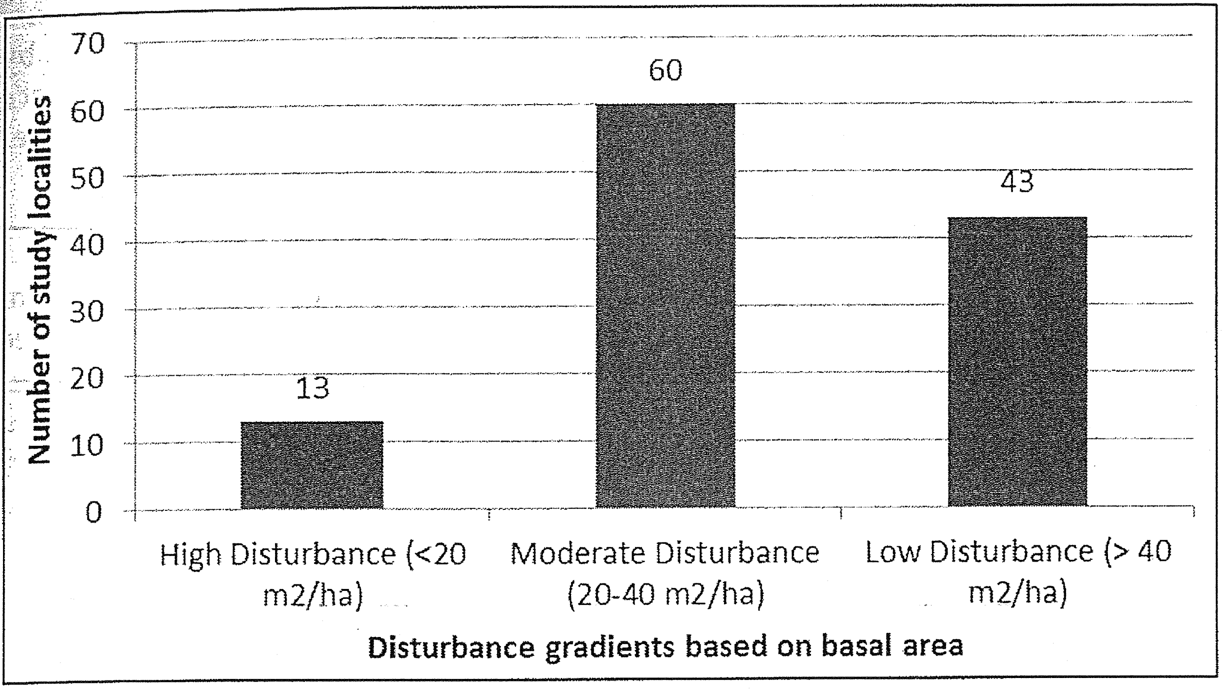

Figure 1.10: Basal Area/ha Based Sample Study Sites.

The total biomass for all the studied localities in the district as shown in Table 1.3 is the sum of estimates of above-ground and below-ground biomass for any particular site. The study sites in Kathalekan and Karikan sacred groves had the highest total biomass (749.08 and 726.12 t/ha respectively) and carbon storage (374.54 and 363.06 t/ha respectively). These forests have been protected for long because of the cultural and religious significance attached to them and hence, were relatively less disturbed than others. This allows the trees to grow to their fullest and accumulate significantly more biomass than in most other areas, prone to ongoing human pressures, or in combination with disturbances in the past (as in a savannized land). The congregation of RET species and rarer endemics such as *Dipterocarpus indicus* (Endangered), *Syzygium travancoricum* (Critically Endangered), *Myristica magnifica* (Endangered), *Myristica fatua* and *Hopea ponga* (Endangered), *Gymnacranthera canarica* (Vulnerable) along with other climax evergreen species like *Holigarna*.

Tree Species Richness, Diversity and Dominance

Kathalekan non-swamp forests were notable for their higher Shannon diversity values for trees (within 3-4), compared to swamp areas in the same may be due to special adaptations required for trees to survive in hypoxic soil conditions. Interestingly *Dipterocarpus* dominated portion of Karikan, a non-swamp sacred forest, despite high basal area (85.41 sq.m/ha), also had lower diversity of 2.24. Most other non-swamp evergreen-semi-evergreen forests had diversity values between 3 and 4. The moist deciduous forests in the rugged terrain of Ankola-Yellapur areas had higher diversity, compared to such forests in plainer areas. This is due to greater heterogeneity of the hilly landscapes. Lower Shanon diversity was found in dry deciduous and highly disturbed forests such Desaivada-Nandgadde (1.50) of Joida, Gunjavathi of Mundgod (1.51), Sambrani (1.61) of Haliyal, Katur (1.70) of Mundgod, etc. These forests were not only disturbed but were extensively used for teak monoculturing. These forests had also prolific growth of weeds such as *Eupatorium sp* and several thorny shrubs. Some evergreen forests (*e.g.*, Talekere) dominated by *Hopea ponga* had lower Shannon diversity (1.47) and highest Simpson dominance (0.43). Hudil-evergreen and Tulsani-2 had higher Simpson dominance and lower diversities due to more of *Knema attenuata*, a Western Ghats endemic (Table 1.4).

Evergreenness and Endemism

More the evergreenness of a forest greater are the endemics contained in them (Table 1.5 and Figure 1.11). Seven transects had 100 per cent evergreeness (all the tree individuals being evergreen) and in 60 transects evergreenness was above 90 per cent. 16 transects where only 50-90 per cent of trees were evergreen are considered here as semi-evergreen forests. Remaining transects with evergreeness below 50 per cent are considered moist to dry deciduous, the latter practically without any evergreen species or poor in evergreens (Figure 1.12). The southern forests (of Bhatkal, Honavar, Siddapur and Kumta) tend to have more evergreenness than central (of Sirsi, Ankola and Yellapur) and of northern forests (Karwar, Supa taluks). Mundgod and Haliyal in the north-east are dominated by deciduous forests. Eastern parts of Sirsi and Yellapur tend to be of deciduous nature (Figure 1.12). The high endemism areas for

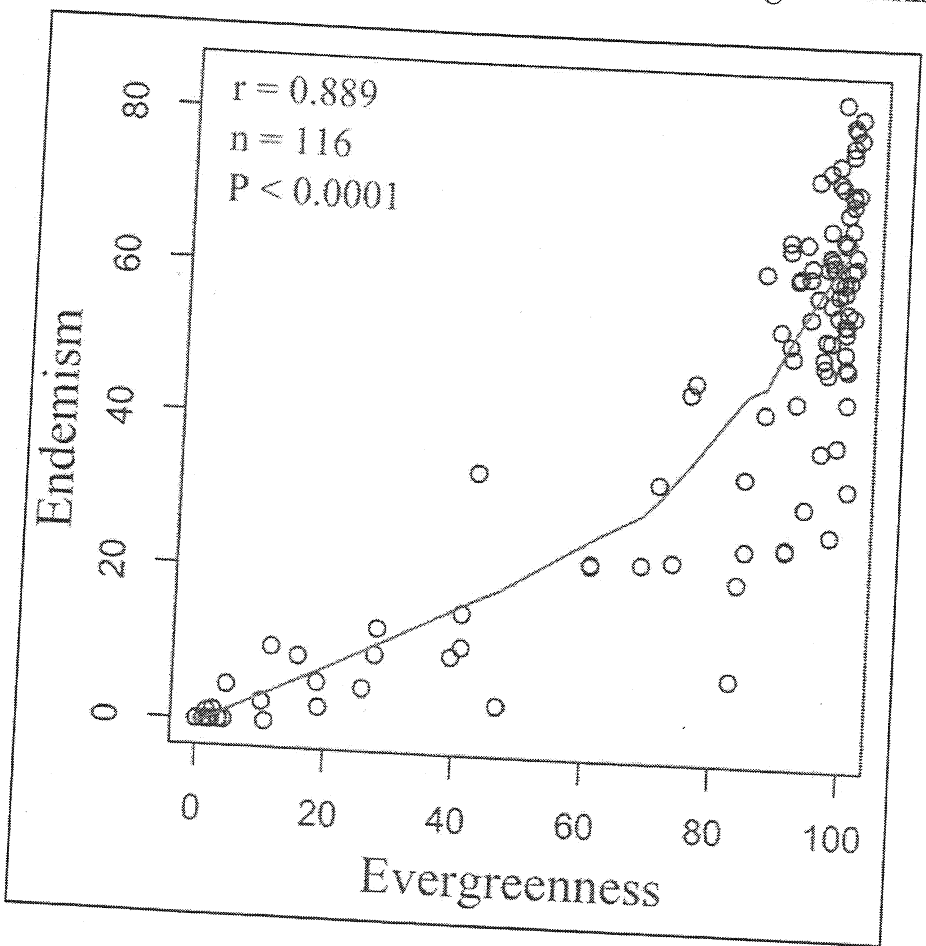

Figure 1.11: Correlation between Forest Stand Evergreenness and Western Ghat Endemism.

Table 1.4: Species Richness, Diversity, Dominance and Evenness

Sl.No.	Locality Name	Taluk	Sps. Richness	Shannon	Simpson Dominance	Simpson Diversity	Pielou Evenness
1.	Asolli-1	Ankola	5.03	2.78	0.08	0.92	0.89
2.	Asolli-2	Ankola	6.56	2.89	0.09	0.91	0.83
3.	Hosakere	Ankola	5.94	2.62	0.15	0.85	0.77
4.	S1-Katangadde-Agasur	Ankola	8.19	3.34	0.05	0.95	0.90
5.	S2-Balikoppa-Badgon	Ankola	6.28	2.73	0.11	0.89	0.80
6.	S3-Hegdekoppa-Kasinmakki	Ankola	7.10	3.08	0.07	0.93	0.87
7.	S4-Vajralli-Ramanguli	Ankola	6.28	2.90	0.09	0.91	0.85
8.	Kachinabatti	Ankola	2.96	2.14	0.15	0.85	0.83
9.	Maabagi	Ankola	6.99	3.19	0.05	0.95	0.91
10.	Dakshinakoppa	Bhatkal	2.78	1.74	0.31	0.69	0.70
11.	Gujmavu (semi evergreen)	Bhatkal	6.77	2.82	0.11	0.89	0.81
12.	Hudil (evergreen)	Bhatkal	2.87	1.61	0.37	0.63	0.61
13.	Hudil (semi evergreen)	Bhatkal	5.30	2.77	0.10	0.90	0.84
14.	Golehalli	Haliyal	3.46	2.15	0.20	0.80	0.78
15.	Kudalgi-Tatigeri	Haliyal	2.38	1.71	0.25	0.75	0.69
16.	Magvad	Haliyal	3.80	1.95	0.26	0.74	0.66
17.	Sambrani	Haliyal	2.32	1.61	0.29	0.71	0.67
18.	Yadoga	Haliyal	3.12	2.16	0.17	0.83	0.84
19.	Ambepal-1	Honavar	5.31	2.82	0.08	0.92	0.88
20.	Ambepal-2	Honavar	6.69	3.08	0.06	0.94	0.89
21.	Chaturmukhabasti	Honavar	5.42	2.71	0.10	0.90	0.86
22.	Gersoppa	Honavar	7.16	3.07	0.07	0.93	0.90

Contd...

Table 1.4–*Contd...*

Sl.No.	Locality Name	Taluk	Sps. Richness	Shannon	Simpson Dominance	Simpson Diversity	Pielou Evenness
23.	Gundabala	Honavar	6.98	3.08	0.07	0.93	0.89
24.	Hadageri-1	Honavar	4.91	2.76	0.08	0.92	0.88
25.	Hadageri-2	Honavar	4.06	2.39	0.13	0.87	0.81
26.	Halsolli	Honavar	2.13	1.62	0.26	0.74	0.74
27.	Hessige-1	Honavar	5.84	2.79	0.08	0.92	0.84
28.	Hessige-2	Honavar	5.20	2.79	0.09	0.91	0.85
29.	Hessige-3	Honavar	5.04	2.49	0.14	0.86	0.77
30.	Hessige-4	Honavar	6.44	3.11	0.06	0.94	0.91
31.	Kadnir	Honavar	5.03	2.39	0.18	0.82	0.75
32.	Karikan-lower slope	Honavar	5.49	2.56	0.13	0.87	0.77
33.	Karikan-semievergreen	Honavar	4.48	2.57	0.13	0.87	0.82
34.	Karikan-temple side-diptero patch	Honavar	4.40	2.24	0.18	0.82	0.74
35.	Mahime	Honavar	4.09	2.41	0.13	0.87	0.83
36.	Sharavathy-viewpoint	Honavar	5.84	2.75	0.10	0.90	0.82
37.	Tulsani-1	Honavar	5.58	2.78	0.09	0.91	0.84
38.	Tulsani-2	Honavar	4.63	1.87	0.35	0.65	0.59
39.	Castlerock IB	Joida	5.50	3.00	0.06	0.94	0.90
40.	Castlerock-moist-dec.	Joida	4.44	2.32	0.16	0.84	0.75
41.	Castlerock-semi everg	Joida	4.97	2.55	0.14	0.86	0.80
42.	Desaivada-Nandgadde	Joida	2.21	1.50	0.30	0.70	0.60
43.	Gavni-Kangihole-Joida	Joida	6.79	2.94	0.08	0.92	0.83

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Table 1.4–*Contd...*

Sl.No.	Locality Name	Taluk	Sps. Richness	Shannon	Simpson Dominance	Simpson Diversity	Pielou Evenness
44.	Ivolli-Castlerock	Joida	3.70	1.94	0.26	0.74	0.66
45.	Joida-deciduous	Joida	4.77	2.66	0.09	0.91	0.88
46.	Kushavali	Joida	6.28	2.63	0.14	0.86	0.77
47.	Shivpura	Joida	2.52	1.89	0.19	0.81	0.76
48.	Gopishetta	Karwar	4.73	2.32	0.15	0.85	0.74
49.	Goyar-moist dec	Karwar	3.74	2.22	0.17	0.83	0.77
50.	Kalni-goyar	Karwar	6.73	2.97	0.08	0.92	0.86
51.	Karwar-moist dec	Karwar	4.23	2.58	0.10	0.90	0.91
52.	Devimane-Campsite	Kumta	7.02	3.01	0.08	0.92	0.84
53.	Devimane-Sirsi side	Kumta	6.04	2.73	0.10	0.90	0.80
54.	Devimane-temple	Kumta	5.52	2.69	0.11	0.89	0.80
55.	Devimane-with myristicas	Kumta	5.96	2.76	0.10	0.90	0.81
56.	Hulidevarakodlu	Kumta	6.97	2.87	0.10	0.90	0.81
57.	Kalve	Kumta	6.05	2.76	0.12	0.88	0.83
58.	Kalve-moist dec.	Kumta	4.64	2.53	0.12	0.88	0.82
59.	Kandalli-Devimane	Kumta	5.55	2.31	0.23	0.77	0.69
60.	Mastihalla-Devimane arch	Kumta	5.28	2.61	0.13	0.87	0.80
61.	Mathali-Kandalli-Devimane	Kumta	5.74	2.62	0.14	0.86	0.78
62.	Soppinahosalli	Kumta	3.34	2.34	0.13	0.87	0.87
63.	Surjaddi	Kumta	5.60	2.87	0.07	0.93	0.86
64.	Surjaddi-Morse	Kumta	6.05	2.79	0.09	0.91	0.82

Contd...

Table 1.4–*Contd...*

Sl.No.	*Locality Name*	*Taluk*	*Sps. Richness*	*Shannon*	*Simpson Dominance*	*Simpson Diversity*	*Pielou Evenness*
65.	Attiveri-teakmixed-drydec	Mundgod	4.18	2.31	0.16	0.84	0.77
66.	Godnal	Mundgod	2.74	1.84	0.23	0.77	0.72
67.	Gunjavathi	Mundgod	2.08	1.51	0.32	0.68	0.69
68.	Karekoppa-Gunjavathi	Mundgod	2.32	1.94	0.19	0.81	0.81
69.	Katur	Mundgod	3.35	1.70	0.36	0.64	0.63
70.	Katur to Gunjavati	Mundgod	3.67	2.43	0.12	0.88	0.86
71.	G1-Kathalekan-nonswamp	Siddapur	7.91	3.39	0.04	0.96	0.91
72.	G2-Kathalekan-nonswamp	Siddapur	7.37	3.18	0.06	0.94	0.87
73.	G3-Kathalekan-nonswamp	Siddapur	7.75	3.42	0.04	0.96	0.95
74.	G4-Kathalekan -nonswamp	Siddapur	7.58	3.12	0.07	0.93	0.86
75.	G5-Kathalekan-nonswamp	Siddapur	7.51	3.16	0.06	0.94	0.86
76.	Kathalekan-savanna	Siddapur	1.82	1.52	0.23	0.77	0.95
77.	G6-Kathalekan-nonswamp	Siddapur	4.31	2.39	0.14	0.86	0.76
78.	G7-Kathalekan-nonswamp	Siddapur	8.69	3.36	0.05	0.95	0.89
79.	G8-Kathalekan- nonswamp	Siddapur	6.98	2.91	0.10	0.90	0.82
80.	G9-Kathalekan-nonswamp	Siddapur	3.25	1.77	0.32	0.68	0.61
81.	Hartebailu-soppinabetta	Siddapur	4.38	2.24	0.18	0.82	0.71
82.	Hutgar	Siddapur	5.22	2.53	0.13	0.87	0.79
83.	Joginmath-1	Siddapur	7.11	3.05	0.07	0.93	0.86
84.	Joginmath_2-semievergreen	Siddapur	5.42	2.84	0.08	0.92	0.88
85.	Kathalekan-1	Siddapur	8.69	3.36	0.05	0.95	0.89

Contd...

Table 1.4–*Contd...*

Sl.No.	Locality Name	Taluk	Sps. Richness	Shannon	Simpson Dominance	Simpson Diversity	Pielou Evenness
86.	Kathalekan-2	Siddapur	7.56	3.31	0.05	0.95	0.90
87.	Kathalekan –swamp-1	Siddapur	7.53	2.92	0.09	0.91	0.81
88.	Kathalekan –swamp-2	Siddapur	5.58	2.67	0.11	0.89	0.81
89.	Kathalekan –swamp-3	Siddapur	6.51	2.74	0.11	0.89	0.79
90.	Kathalekan –swamp-4	Siddapur	5.89	2.52	0.15	0.85	0.75
91.	Kathalekan –swamp-5	Siddapur	4.43	2.55	0.11	0.89	0.84
92.	Kathalekan –swamp-6	Siddapur	6.01	2.76	0.13	0.87	0.81
93.	Kathalekan –swamp-7	Siddapur	7.74	3.08	0.08	0.92	0.85
94.	Kathalekan –swamp-8	Siddapur	5.79	2.69	0.10	0.90	0.80
95.	Kathalekan –swamp-9	Siddapur	6.67	3.04	0.07	0.93	0.87
96.	Kathalekan-3	Siddapur	8.59	3.38	0.05	0.95	0.89
97.	Malemane-1	Siddapur	6.42	3.16	0.05	0.95	0.90
98.	Malemane-2	Siddapur	6.40	3.08	0.07	0.93	0.88
99.	Malemane-3	Siddapur	5.69	2.82	0.08	0.92	0.85
100.	Siddapur evergreen	Siddapur	5.72	2.81	0.08	0.92	0.86
101.	Talekere	Siddapur	2.98	1.47	0.43	0.57	0.56
102.	Bugadi-Bennehole	Sirsi	7.17	3.00	0.08	0.92	0.84
103.	Gondsor-sampekattu	Sirsi	2.67	2.01	0.16	0.84	0.87
104.	Hulekal-Sampegadde-Hebre	Sirsi	7.92	3.14	0.07	0.93	0.85
105.	Kanmaski-Vanalli	Sirsi	4.76	2.80	0.08	0.92	0.86
106.	Khurse	Sirsi	4.99	2.44	0.14	0.86	0.75
107.	Masrukuli	Sirsi	3.39	2.04	0.21	0.79	0.75

Contd...

Table 1.4–*Contd...*

Sl.No.	Locality Name	Taluk	Sps. Richness	Shannon	Simpson Dominance	Simpson Diversity	Pielou Evenness
108.	Hiresara-bettaland	Yellapur	2.85	1.90	0.24	0.76	0.72
109.	S5-Gidgar-Yemmalli	Yellapur	7.94	3.09	0.08	0.92	0.84
110.	S6-Tarukunte-Birgadde	Yellapur	8.36	3.36	0.05	0.95	0.90
111.	S7-Arlihonda-Nandvalli	Yellapur	9.83	3.47	0.05	0.95	0.90
112.	S8-Yellapur-Mavalli	Yellapur	7.94	3.12	0.08	0.92	0.85
113.	S9-Kiruvatti	Yellapur	3.13	1.83	0.25	0.75	0.66
114.	Hasrapal-evergreen	Yellapur	5.16	2.91	0.07	0.93	0.91
115.	Hulimundgi-semievergreen	Yellapur	5.84	2.85	0.08	0.92	0.87
116.	Lalguli-moist-dec	Yellapur	3.53	2.27	0.14	0.86	0.84

trees are towards the Ghat areas of Bhatkal, Honavar, Siddapur and Kumta coinciding with higher occurrence of evergreen forests (Figure 1.13)

Table 1.5: Percentage of Western Ghat Endemism and Evergreenness in the Forest Samples

Sl.No.	Locality Name	Taluk	Per cent W Ghats (Endemism)	Per cent Evergreeness
1.	Asolli-1	Ankola	55.70	100.00
2.	Asolli-2	Ankola	73.28	96.95
3.	Hosakere	Ankola	55.30	93.18
4.	S1-Katangadde-Agasur	Ankola	22.22	68.38
5.	S2-Balikoppa-Badgon	Ankola	2.52	10.08
6.	S3-Hegdekoppa-Kasinmakki	Ankola	15.00	40.83
7.	S4-Vajralli-Ramanguli	Ankola	12.61	27.73
8.	Kachinabatti	Ankola	8.62	15.52
9.	Maabagi	Ankola	22.68	73.20
10.	Dakshinakoppa	Bhatkal	7.69	82.69
11.	Gujmavu (semi evergreen)	Bhatkal	63.72	100.00
12.	Hudil (evergreen)	Bhatkal	80.65	98.92
13.	Hudil (semi evergreen)	Bhatkal	30.37	93.33
14.	Golehalli	Haliyal	0	0
15.	Kudalgi-Tatigeri	Haliyal	0	0
16.	Magvad	Haliyal	0.00	1.75
17.	Sambrani	Haliyal	0	0.0
18.	Yadoga	Haliyal	0.00	10.64
19.	Ambepal-1	Honavar	48.91	95.65
20.	Ambepal-2	Honavar	62.14	100.00
21.	Chaturmukhabasti	Honavar	32.76	70.69
22.	Gersoppa	Honavar	50.00	95.45
23.	Gundabala	Honavar	32.94	100.00
24.	Hadageri-1	Honavar	54.55	98.86
25.	Hadageri-2	Honavar	53.57	98.81
26.	Halsolli	Honavar	79.07	100.00
27.	Hessige-1	Honavar	49.02	99.02
28.	Hessige-2	Honavar	44.30	99.33
29.	Hessige-3	Honavar	24.79	90.60
30.	Hessige-4	Honavar	37.78	95.56
31.	Kadnir	Honavar	67.01	95.88
32.	Karikan-lower slope	Honavar	62.04	95.62

Contd...

Table 1.5–*Contd...*

Sl.No.	*Locality Name*	*Taluk*	*Per cent W Ghats (Endemism)*	*Per cent Evergreeness*
33.	Karikan-semievergreen	Honavar	62.96	96.30
34.	Karikan-temple side-diptero patch	Honavar	75.53	96.81
35.	Mahime	Honavar	25.00	90.63
36.	Sharavathy-viewpoint	Honavar	65.69	98.04
37.	Tulsani-1	Honavar	64.15	89.62
38.	Tulsani-2	Honavar	83.62	97.41
39.	Castlerock IB	Joida	71.85	100.00
40.	Castlerock-moist-dec.	Joida	5.31	18.58
41.	Castlerock-semi everg	Joida	24.51	84.31
42.	Desaivada-Nandgadde	Joida	0	0
43.	Gavni-Kangihole-Joida	Joida	50.00	90.67
44.	Ivolli-Castlerock	Joida	65.12	92.25
45.	Joida-deciduous	Joida	10.61	40.91
46.	Kushavali	Joida	38.61	98.02
47.	Shivpura	Joida	0	0
48.	Gopishetta	Karwar	4.76	25.71
49.	Goyar-moist dec	Karwar	0.00	1.06
50.	Kalni-goyar	Karwar	61.00	86.00
51.	Karwar-moist dec	Karwar	0.00	2.27
52.	Devimane-Campsite	Kumta	60.27	91.10
53.	Devimane-Sirsi side	Kumta	51.64	90.16
54.	Devimane-temple	Kumta	58.49	97.48
55.	Devimane-with myristicas	Kumta	74.62	95.38
56.	Hulidevarakodlu	Kumta	53.51	88.60
57.	Kalve	Kumta	62.07	93.10
58.	Kalve-moist dec.	Kumta	3.26	46.74
59.	Kandalli-Devimane	Kumta	69.23	98.46
60.	Mastihalla-Devimane arch	Kumta	62.28	96.49
61.	Mathali-Kandalli-Devimane	Kumta	67.18	99.24
62.	Soppinahosalli	Kumta	4.55	4.55
63.	Surjaddi	Kumta	65.32	89.52
64.	Surjaddi-Morse	Kumta	65.29	98.35
65.	Attiveri-teakmixed-drydec	Mundgod	0.00	4.26
66.	Godnal	Mundgod	1.25	2.50
67.	Gunjavathi	Mundgod	0.00	2.13
68.	Karekoppa-Gunjavathi	Mundgod	0.00	0.00

Contd...

Table 1.5–*Contd...*

Sl.No.	*Locality Name*	*Taluk*	*Per cent W Ghats (Endemism)*	*Per cent Evergreeness*
69.	Katur	Mundgod	1	1.54
70.	Katur to Gunjavati	Mundgod	0	0
71.	G1-Kathalekan-nonswamp	Siddapur	54.61	98.58
72.	G2-Kathalekan-nonswamp	Siddapur	61.85	99.42
73.	G3-Kathalekan-nonswamp	Siddapur	60.58	91.35
74.	G4-Kathalekan -nonswamp	Siddapur	58.91	98.45
75.	G5-Kathalekan-nonswamp	Siddapur	55.70	97.47
76.	Kathalekan-savanna	Siddapur	0.00	0.00
77.	G6-Kathalekan-nonswamp	Siddapur	50.91	98.79
78.	G7-Kathalekan-nonswamp	Siddapur	52.48	95.74
79.	G8-Kathalekan- nonswamp	Siddapur	60.18	97.35
80.	G9-Kathalekan-nonswamp	Siddapur	77.96	98.92
81.	Hartebailu-soppinabetta	Siddapur	44.74	75.00
82.	Hutgar	Siddapur	60.61	92.93
83.	Joginmath-1	Siddapur	26.89	97.48
84.	Joginmath_2-semievergreen	Siddapur	20.24	83.33
85.	Kathalekan-1	Siddapur	52.48	95.74
86.	Kathalekan-2	Siddapur	44.08	91.45
87.	Kathalekan –swamp-1	Siddapur	71.43	99.16
88.	Kathalekan –swamp-2	Siddapur	71.70	99.06
89.	Kathalekan –swamp-3	Siddapur	72.65	97.44
90.	Kathalekan –swamp-4	Siddapur	80.17	99.14
91.	Kathalekan –swamp-5	Siddapur	76.92	98.90
92.	Kathalekan –swamp-6	Siddapur	70.40	99.20
93.	Kathalekan –swamp-7	Siddapur	56.19	99.05
94.	Kathalekan –swamp-8	Siddapur	81.75	100.00
95.	Kathalekan –swamp-9	Siddapur	60.33	99.17
96.	Kathalekan-3	Siddapur	33.93	83.93
97.	Malemane-1	Siddapur	48.63	99.32
98.	Malemane-2	Siddapur	63.51	95.95
99.	Malemane-3	Siddapur	60.00	98.26
100.	Siddapur evergreen	Siddapur	48.10	96.20
101.	Talekere	Siddapur	73.42	93.67
102.	Bugadi-Bennehole	Sirsi	46.21	75.76
103.	Gondsor-sampekattu	Sirsi	0.00	3.45
104.	Hulekal-Sampegadde-Hebre	Sirsi	57.25	96.38

Contd...

Table 1.5–*Contd...*

Sl.No.	Locality Name	Taluk	Per cent W Ghats (Endemism)	Per cent Evergreeness
105.	Kanmaski-Vanalli	Sirsi	58.12	94.24
106.	Khurse	Sirsi	9.33	39.33
107.	Masrukuli	Sirsi	9.68	11.29
108.	Hiresara-bettaland	Yellapur	2.11	18.95
109.	S5-Gidgar-Yemmalli	Yellapur	9.17	27.50
110.	S6-Tarukunte-Birgadde	Yellapur	42.50	86.67
111.	S7-Arlihonda-Nandvalli	Yellapur	21.85	60.50
112.	S8-Yellapur-Mavalli	Yellapur	33.33	42.50
113.	S9-Kiruvatti	Yellapur	0.00	0.00
114.	Hasrapal-evergreen	Yellapur	52.33	96.51
115.	Hulimundgi-semievergreen	Yellapur	22.09	60.47
116.	Lalguli-moist-dec	Yellapur	0.00	1.89

A total of 76 Western Ghat endemic tree species were found in the study areas. Altogether 127 endemic trees were endemic to Western Ghat-Sri Lanka biodiversity hot spot (45.6 per cent endemism). Western Ghat endemic shrub species numbered to 39 and together with Sri Lanka the shrub species were 82. Herb layer had 76 Western Ghat endemics and together with Sri Lanka endemics rise to 137 species. Highest evergreen forests (100 per cent) were found in Dipterocarpus forests of Asolli 1 (Ankola), Ambepal-2 (Honnavar), Kathalekan Swamp grid 8-T3 (Siddapur)and non-Dipterocarpus forests of Gujmaav of Bhatkal, Gundabala (Honnavar), Halsolli (Honnavar) and Castlerock IB (Joida). These were either Kans or less disturbed areas in areas with difficult access. Most of the Kathlekan, Karikan, Malemane, Gersoppa and Devimane area forests were higher evergreen forests as fire was absent and protected due to reserved status. All Mundgod taluk transects along with Goyar (Karwar), Magvad (Haliyal), etc., which were moist to dry deciduous had very negligible to zero endemism. Endemism is seen as a factor closely correlated to forest evergreenness. Nearly 50 per cent of total transects were having 50 per cent and above tree endemism; such forests had evergreenness of 90 per cent and above. The deciduous forests had hardly any Western Ghat endemics. Endemism is the first casualty even in high rainfall areas under heavy human disturbances. The endemics tend to decline in the wake of fire, logging, grazing and such disturbances leading to endemic poor secondary evergreen forests and finally into deciduous ones devoid of any endemics. Even in endemic rich forests the more sensitive ones such as *Syzygium travancoricum, Dipterocarpus indicus, Palaquium ellipticum, Madhuca bourdilloni, Myristica* spp., vanish early with disturbances. The habitats of these species are rich watershed areas giving rise to perennial streams.

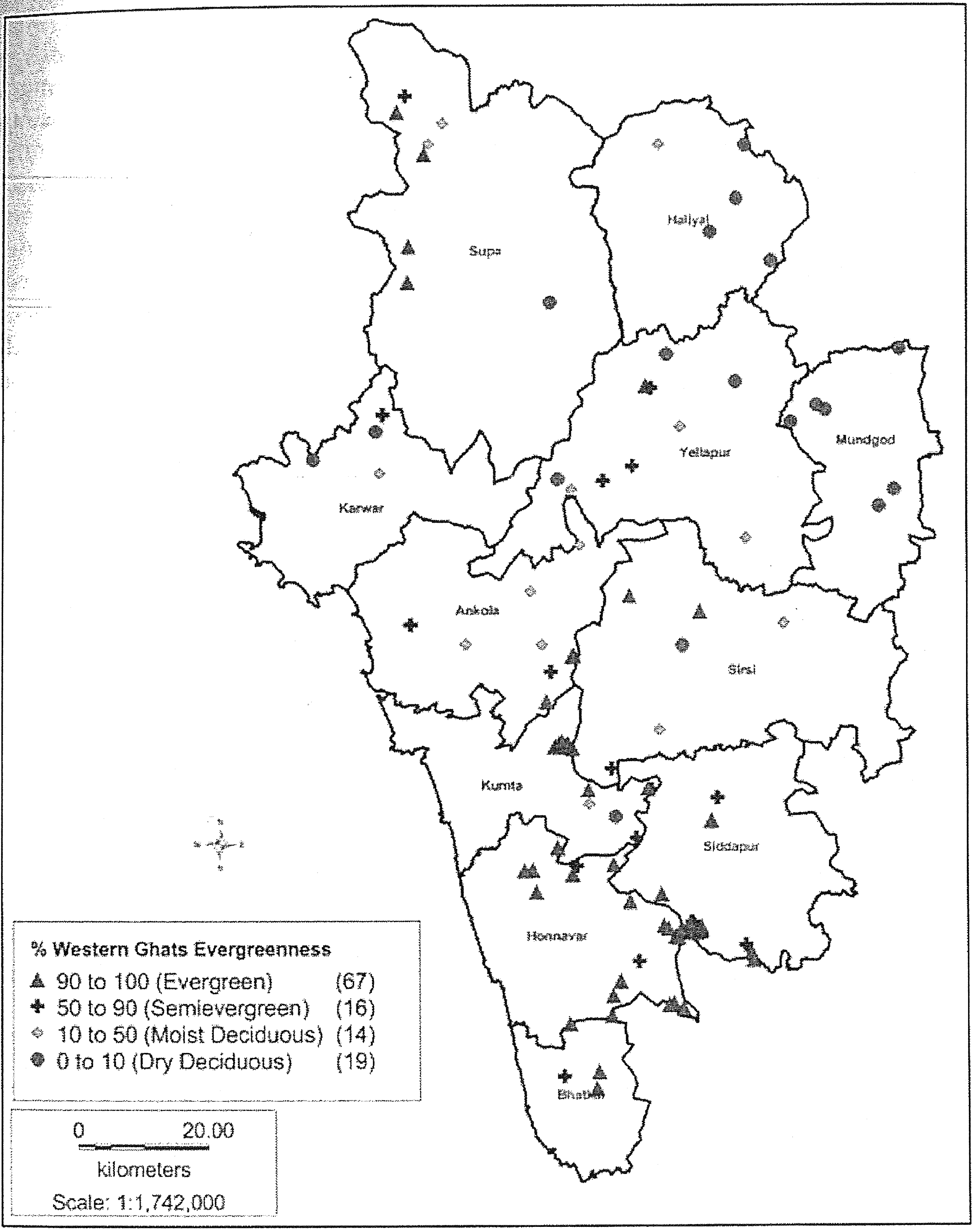

Figure 1.12: Uttara Kannada Map Showing Percentage of Tree Community Evergreeness in the Samples Studied.

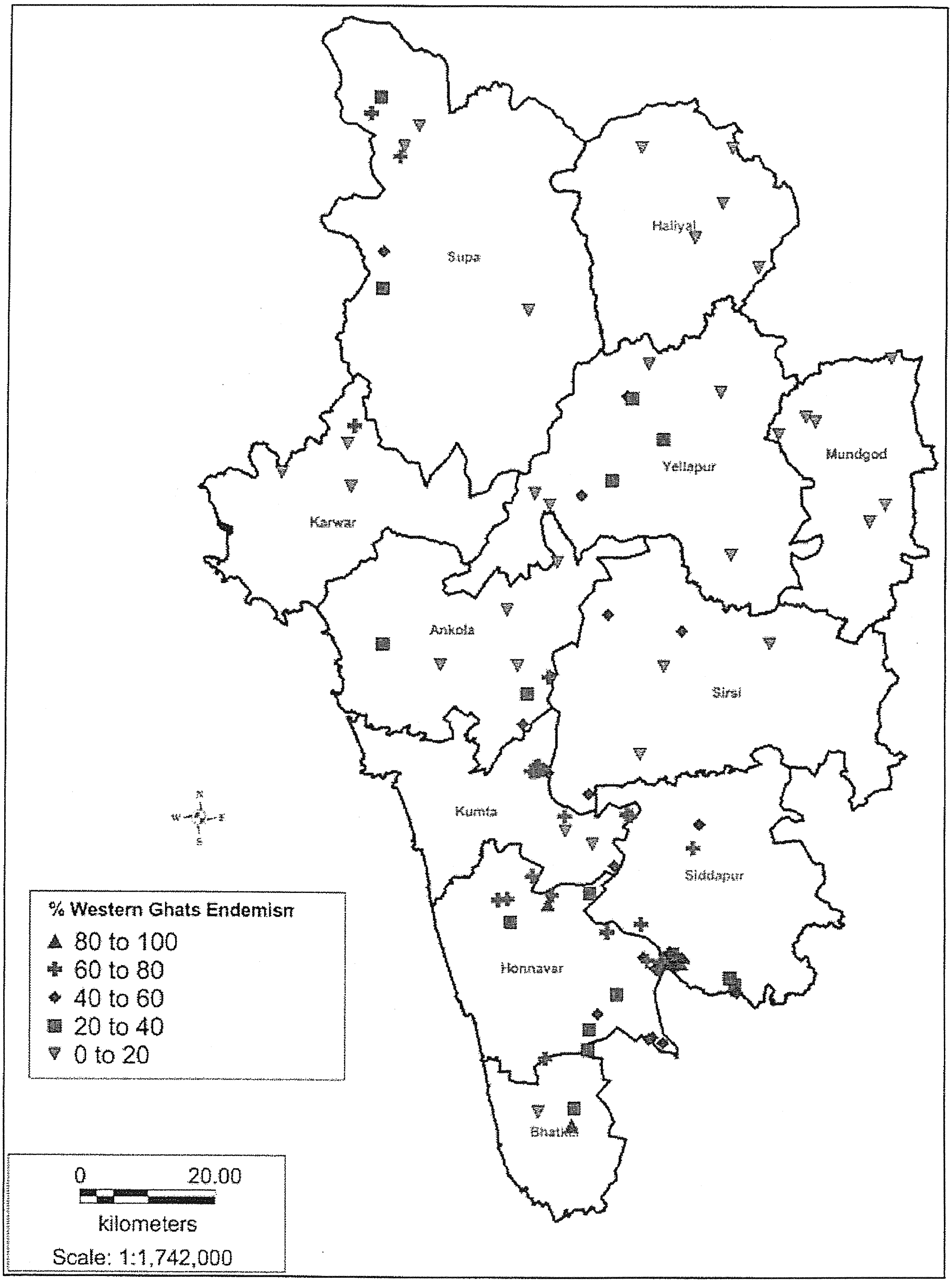

Figure 1.13: Uttara Kannada Map Showing Forest Samples with Tree Endemism (of Western Ghats).

Important Value Index (IVI)

Important value index is an important parameter to estimate the dominant species in an area taking into account its basal area, density and frequency. Higher the IVI greater is the dominance of that species. Asolli-1 of Ankola has higher IVI for *Dipterocarpus indicus* (50.15) followed by *Knema attenuata* (30.77) and *Holigarna grahamii* (26.25); all of these are Western Ghat endemics. *Dipterocarpus indicus* is red-listed by IUCN as Endangered. The dominance of evergreen tree species like *Olea dioca, Aporosa lindleyana Holigarna arnottiana* in a forest indicates secondary nature of the forest. Greater human pressures in such forests, especially in the form of forest burning, such as at Maabgi of Ankola, might have increased deciduous species like *Terminalia alata, Vitex altissima* and *Dillenia pentagyna* etc. Higher values of biomass/ C-stocks are associated with less human or natural disturbances or better site qualities (Lugo and Brown,1992; Brown, 1997). Whereas the undisturbed parts of Kathalekan had high biomass, within the forest interior some hills were savannized in the past, a sample there having least biomass and carbon storage of 10.06 t/ha and 5.03 t/ha respectively). In Gondsor-Sampekattu savanna of Joida the values were higher; with low biomass of 28.37 t/ha and carbon sequestration of 14.19 t/ha this site was only next higher in hierarchy among the 116 transects (Figure 1.14).

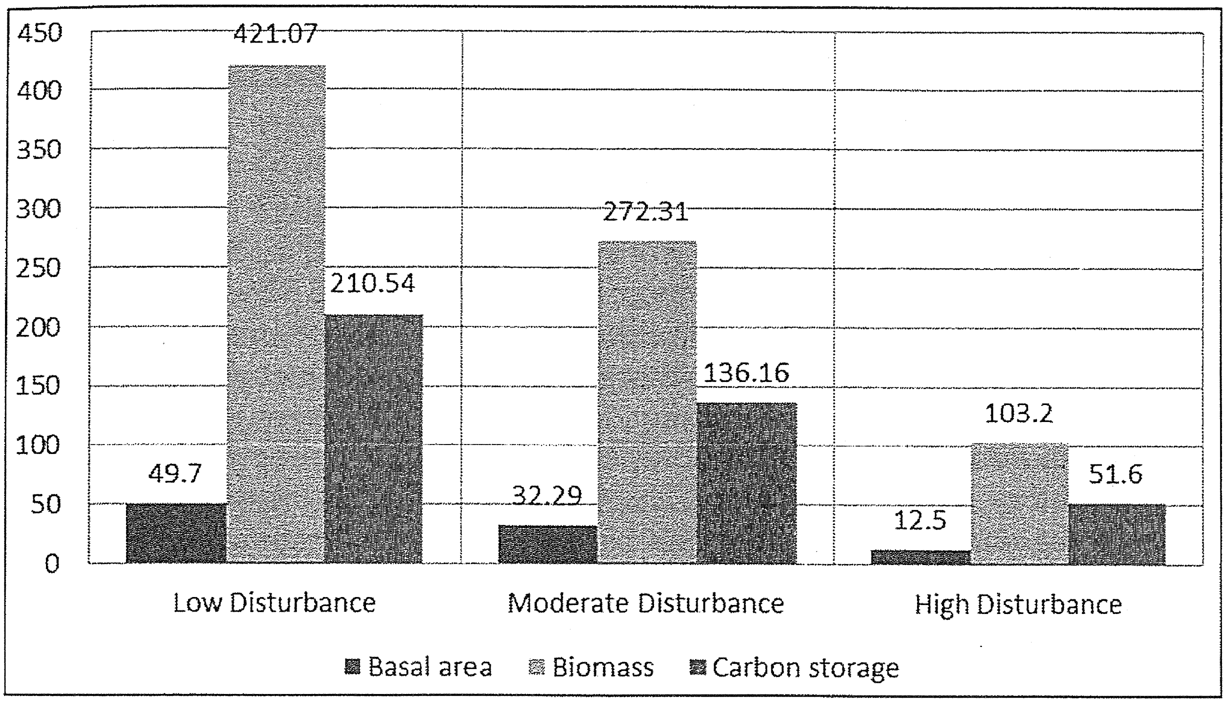

Figure 1.14: Average Basal Area, Biomass and Carbon Storage in Samples of different Disturbance Gradients.

Prioritisation of Forests for Biodiversity Conservation

Role of Endemism in Conservation Priorities

Species richness and endemism are two key attributes of biodiversity that reflect the complexity and uniqueness of natural ecosystems (Caldecott *et al.*, 1996). Myers *et al.* (2000) strongly favour identification and prioritisation of 'hotspots', or areas featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat. Their focus is more on species, rather than populations or other taxa, as the most prominent and readily recognizable form of biodiversity. Concentrating a large proportion of conservation support on these areas would go far to stem the mass extinction of species that is now underway. Nelson *et al.* (1990), based on forest studies in Brazilian Amazonia, realized the importance of locating true concentrations of plant endemism for selecting priority conservation areas to guarantee preservation of unique species. A study on 19 species of endemic mammals and birds in Mexico made Peterson *et al.* (2000) favour setting of regional conservation priorities based on combinations of modeling individual endemic species' distributions, evaluating regional concentrations of species richness, and using complementarity of areas by maximizing inclusion of species in the overall system. The optimized reserve system identified by this approach is stated to have performed 33–58 per cent better than existing protected areas in inclusion of the endemic species. Therefore they favoured making necessary adjustments in the existing systems through incorporation of endemic areas. Strengthening such observations Stattersfield *et al.* (1998) conclude that the 218 endemic bird areas identified by Birdlife International provide a reasonable overlap with the biodiversity hotspots identified by other conservation organisations, and are a focus for conservation action. Burlakova *et al.* (2011) advocated the need for adopting species rarity and endemism in aquatic domains also for the conservation of regionally rare and endemic fresh water molluscs in Texas.

Reviewing the role of endemism, Meadows (2008) stated that ecoregions rich in endemics are also rich in overall species. For example, the 10 percent of the world's land area with the most endemics also has more than 60 percent of all terrestrial vertebrate species. Likewise10 percent of land with the greatest number of endemic amphibians and reptiles also contains more than 70 percent of all terrestrial vertebrate species. In addition, ecoregions rich in endemics of any one vertebrate class are also rich in endemics of the other three classes. At the same time many researchers on vertebrate conservation also content that their findings may not apply to nonvertebrates and that endemism is only one criterion for planning. However, using endemism along with other factors to identify global priorities focuses conservation in critical regions, where on-the-ground efforts will yield the greatest payoffs for biodiversity.

Humid tropical forests, like the rain forests, are richest systems in biodiversity. Regions of high rainfall also have large volumes of water in the river flow (World Water Assessment Programme, 2012). The confluence of rainforests and hydropower potential have prompted many nations with large areas of tropical rainforest - including Brazil, Peru, Colombia, the Democratic Republic of the Congo, Vietnam, and Malaysia - plan to expand their hydropower energy capacity. It is generally assumed that deforestation will have a positive effect on river discharge and energy generation resulting from declines in evapotranspiration (ET) associated with forest conversion. Study in the Xingu River basin of Amazonian Brazil using hydrological and climate models showed that simulated deforestation of 20 per cent and 40 per cent within this basin increased discharge by 4–8 per cent and 10–12 per cent, which could make similar increases in energy generation from a very large hydropower station planned in the river. When indirect effects were considered, simulated deforestation inhibited rainfall in the Xingu basin by 6 to 36 per cent, thus offsetting the likely gains (Stickler *et al.*, 2013). Moreover the loss of top soil and landslides and sedimentation in the downstream areas following deforestation are also to be considered. Forest decline can as well upset microclimate conditions and cause disappearance of scores of sensitive species.

The Western Ghats together with Sri Lanka constitute one of the 34 Biodiversity Hotspots of the world in view of exceptionally rich biodiversity, high degree of endemism and at the same time undergoing tremendous threat from human activities. The original extent of this combined Hotspot was 189,611 km^2. Of the hotspot vegetation what remains today is merely 43,611 km^2 area. Tremendous population pressure and biomass needs have created heavy fragmentation of Western Ghat forests. Both these regions in this hotspot together continue to shelter still 3,049 endemic plant species, 10 endemic threatened birds, 14 endemic threatened mammals, 87 threatened amphibians and so on (Conservation International, 2013).

Protected Areas in Uttara Kannada

Karnataka has five National Parks and 21 Wildlife Sanctuaries. Uttara Kannada district has mainly two important protected areas namely **Anshi National Park** and **Dandeli Wildlife Sanctuary**. These two PAs are brought together under **Dandeli-Anshi Tiger Reserve** with focus on tiger conservation. The DATR presently covers an area of 1365 sq.km. in the taluks of Joida, Haliyal and Karwar. Admittedly, we were not given permission to carry out forest ecological studies within this Tiger Reserve. Hence we have relatively lesser sampling areas within these taluks. Recently (in 2011) **Attivery Bird Sanctuary** was declared in Mundgod taluk covering 2.23 sq.km area, mainly composed of a reservoir and its peripheral areas.

Conservation Reserves are a new concept under the framework of Protected Areas under the Wildlife (Protection) Amendment Act of 2002. These reserves they seek to protect habitats that are under private ownership also, through active stakeholder participation. They are typically buffer zones or connectors and migration corridors between National Parks, Wildlife Sanctuaries and reserved protected forests in India. They are designated as conservation reserves if they are uninhabited and completely owned by the government but used for subsistence by communities, and community reserves if part of the lands are privately owned. Administration of such reserves would be through joint participation of forest officials and local bodies like gram sabhas and gram panchayats. They do not involve any displacement and protect user rights of communities. In Uttara Kannada, some such Conservation Reserves were set up by the Government of Karnataka, under the initiative of the Mr Anant Hedge Ashishar of Western Ghat Task Force, the Karnataka Forest Department, ATREE and SACON with technical inputs from Mr. Balachandra Hegde. Presence of endangered and endemic species, critical corridors connecting larger Western Ghats landscape and potential threats for the region etc., were considered for identifying conservation priority areas (Dandekar- http://sandrp.in/rivers/Novel_Conservation_reserves). Four such reserves were set out to protect Lion tailed macaque habitats, rare and endangered Myristica Swamps, Hornbill habitats and a riverain ecosystem (details are given in Table 1.6 and Figure 1.15).

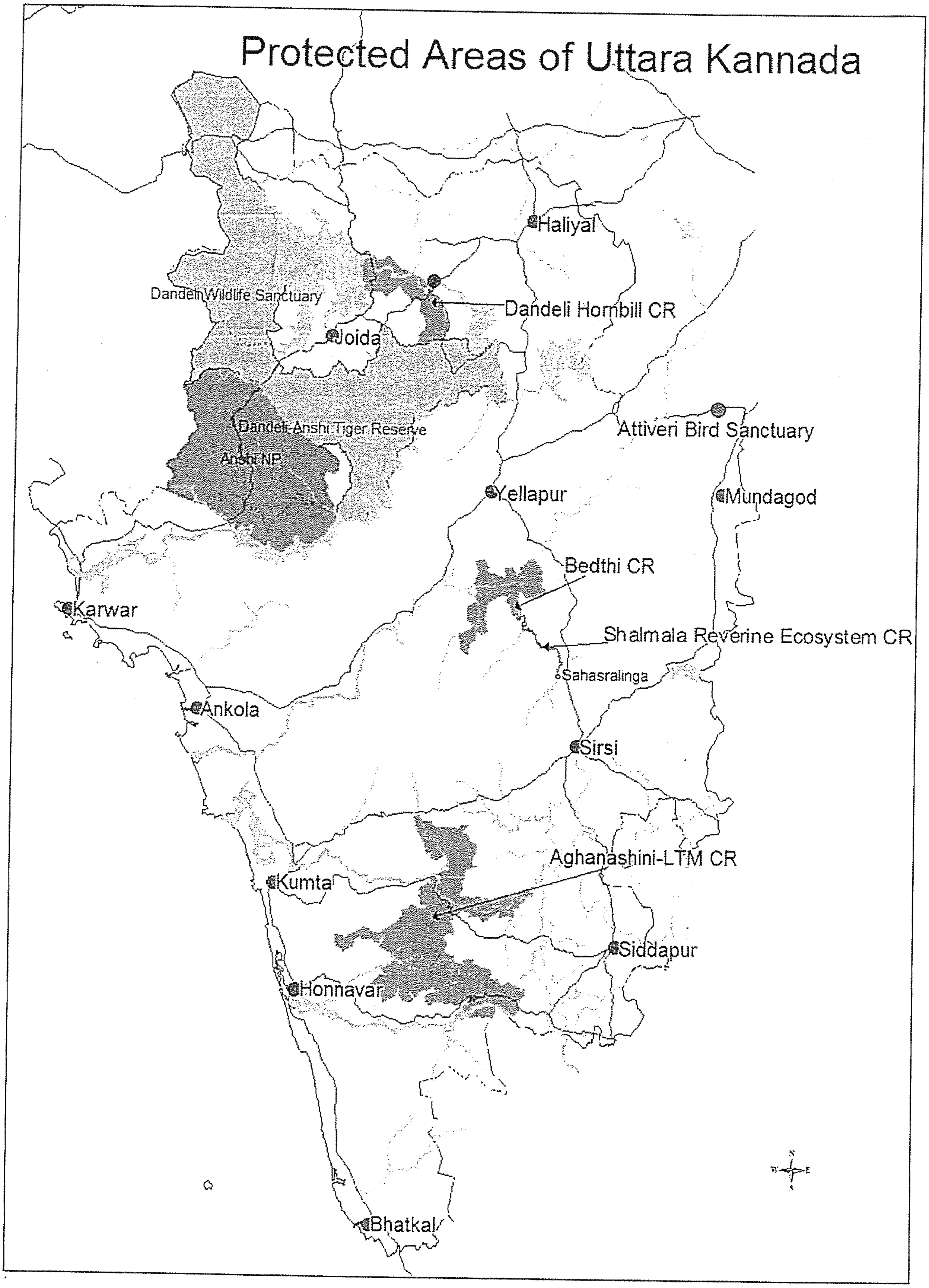

Figure 1.15: Protected Areas of Uttara Kannada.

Table 1.6: Details of Conservation Reserves in Uttara Kannada

Name	Area (sq.km)	Coservation Priority Species	Priority Locations
Aghanashini LTM Conservation Reserve	299.52	Lion tailed macaque, Myristica swamps	Unchalli Falls, Kathalekan, Muktihole
Bedthi Conservation Reserve	57.07	Hornbills *Coscinium fenestratum* (medicinal plant)	Magod Falls, Jenukallugudda, Bilihalla Valley, Konkikote
Shalmala Riparian Eco-system Conservation Reserve	4.89	Flora and fauna and as an important corridor in Western Ghats of Karnataka	
Hornbill Conservation Reserve	52.50	Hornbills	Kali River

Assigning Conservation Values through Correlation between Five Notable Parameters of Tree Communities in Uttara Kannada

To be helpful in preparing a composite conservation index for forest patches studied through 116 transects and covering the entire district we considered five important variables (per cent evergreenness, per cent endemism, basal area, tree height and Shannon diversity index) that were studied about these samples. The relative importance of these variables in assigning conservation values, based on the 116 sample studies is depicted in Figure 1.16. Some notable points on these variables are given below:

Evergreenness

Evergreen forests of the Western Ghats, due to various reasons, such as seats of high endemic diversity and high hydrological value is an important factor for assigning convservation values. We have considered here percentage of evergreen trees in the total tree population of the sample as evergreenness.

Endemism

Tree endemism is of overall importance in for assigining conservation values. Through an earlier study in the Western Ghats it was established that forest evergreenness in a stand, is a strong positive determinant of tree endemism in the same stand (Chandran, 1997). The find was carried forth beyond into the domain of endemism among fresh water fishes in the streams of Sharavathi River catchment (Sreekantha *et al.*, 2007) establishing that the number and percentage of endemic fishes among total fish fauna in a stream was directly correlated to the percentage of evergreenness and tree endemism in the catchment area forests of that particular stream. In Uttara Kannada amphibian studies highest species diversity (35 species), with high percentage of Western Ghat endemism (26 species, 74 per cent endemism) occurred in a mere 2.25 sq.km area of high evergreen forests (almost 100 per cent) characterised by Myristic swamps in Kathalekan of Siddapur taluk (Chandran *et al.*, 2010).

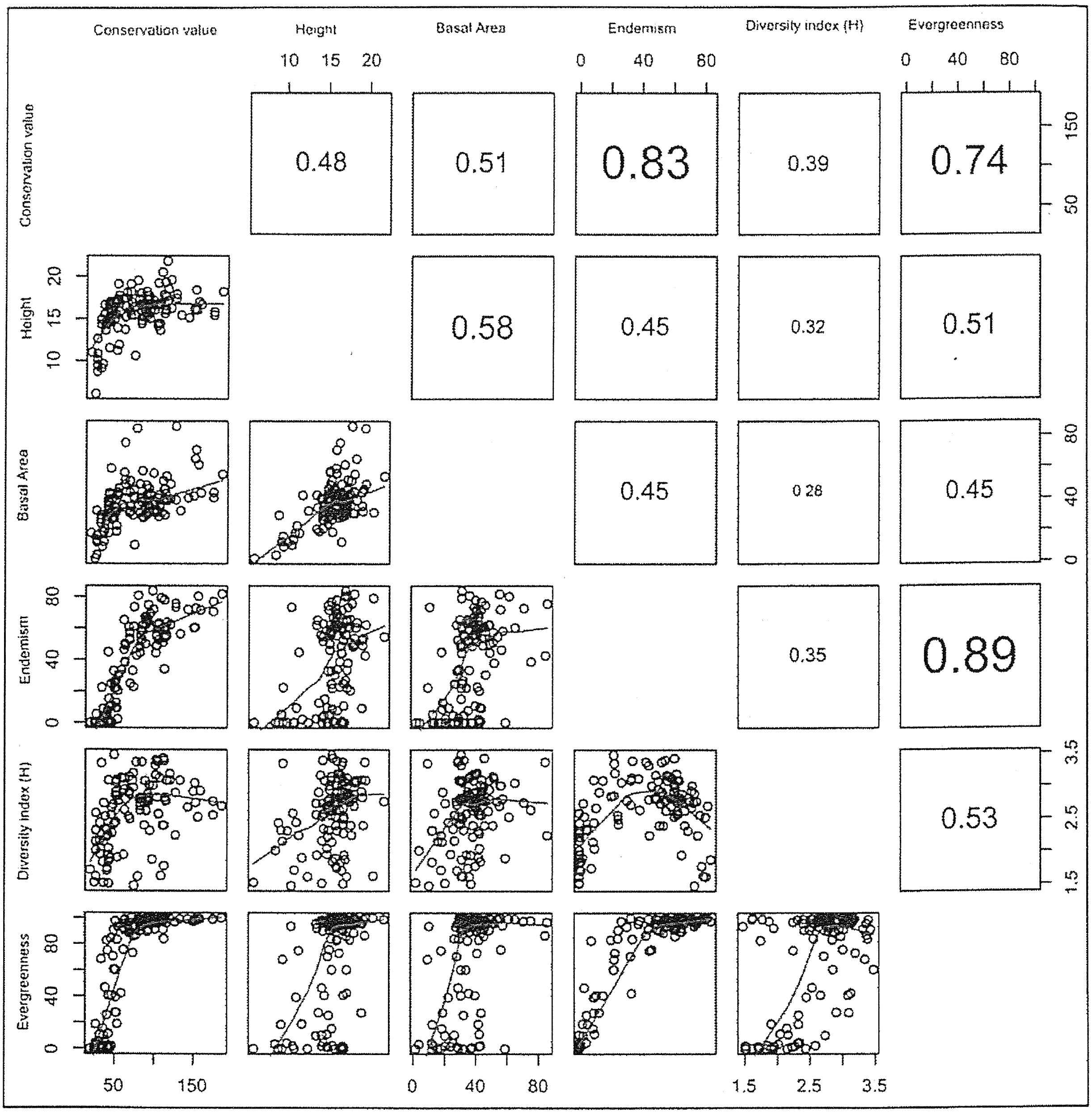

Figure 1.16: Relative Importance of Tree Community Parameters for Assigning Conservation Values (n=116, P< 0.0001).

Tree Heights

World over tallness of forest stands is considered indicative of the old growth nature and merits high conservation value. Human impacts on tall forests through logging, either clear felling or selection felling would result in regenerated trees of lesser heights, as the competition for light is minimised.

Basal Area

Basal area of trees per hectare expressed sq.m is a standard expression in forest ecological studies worldwide about the relative growth of forests. It is a major factor for estimating forest stand biomass and therefore also for estimation of carbon sequestration.

Diversity Value

It is generally accepted that higher diversity in general goes hand in hand with conservation importance.

It is evident from the analysis that the highest correlation (0.89) was between ' per cent endemism' and ' per cent evergreenness'. This can be also justified from the fact that those transects which have 50 per cent or more endemism have evergreenness values as high as 90 per cent and more (Table 1.5). This was followed by the parameters basal area, tree height and Shannon diversity with which it had correlation in descending order of 0.51, 0.48 and 0.39 respectively. The percentage endemism is the most decisive factor in conferring higher conservation value to any ecosystem as endemics lost in their respective regions are irreplaceable. Higher endemism in a particular area indicates the presence of high sensitive species in that area, implying that there should be greater prioritisation in the conservation of endemic areas in any conservation programmes, not sidelining in any way the importance in conservation of any widely distributed but threatened species like elephant or tiger. The tree height and basal area can also be considered as factors contributing to the overall conservation value of the forest areas.

Principal Component Analysis

A PCA of the sample sites was carried out considering the observed and quantified characters of tree communities *viz.*, evergreenness, endemism (of Western Ghats), height and basal area. The PCA (Figure 1.17) shows that the first two axes accounted for 86.57 per cent of the cumulative variance explained by the four gradients extracted in the PCA analysis and the direction and length of each arrow indicated the direction and rate of maximum changes in each variable. The Eigen value for the first axis was 2.53, whereas for the second axis it was 0.92. The loading scores obtained in PCA also indicated that the prime factors influencing the forest vegetation are evergreenness and endemism than the height and basal area in first axis (Table 1.3). The high evergreen/endemism rich areas also host many rare and threatened species and essentially need to be prioritised for biodiversity conservation.

In a scheme of ranking sites representative of forest patches, areas of high tree endemism- which are essentially high evergreen areas, degree of endemism needs to be conferred higher value than height or basal area/ha. The latter two are, in the conditions of Uttara Kannada, much dependent on the degree of protection that a forest patch enjoys. Even moist deciduous forests, can attain much height and high basal area, but tree endemism (of Western Ghats) is scanty here even in the absence of human disturbances. At the same time height factor cannot be ignored in evergreen forests as we hardly get threatened tree species like *Dipterocarpus indicus, Myristica magnifica, Syzygium travancoricum* etc. in any dwarfish evergreen forest. Being on the positive side of conservation both height and basal area are to be given a proportionate score or rank points while preparing a composite index for conservation. Most of the areas which are negatively correlated with evergreen and endemism axis are mostly degraded areas or deciduous forests with hardly any Western Ghat tree endemism. The presence in the Western Ghats of a variety of life forms such as very sensitive fauna like endemic amphibians, fishes, birds or butterflies etc. and endemic primate

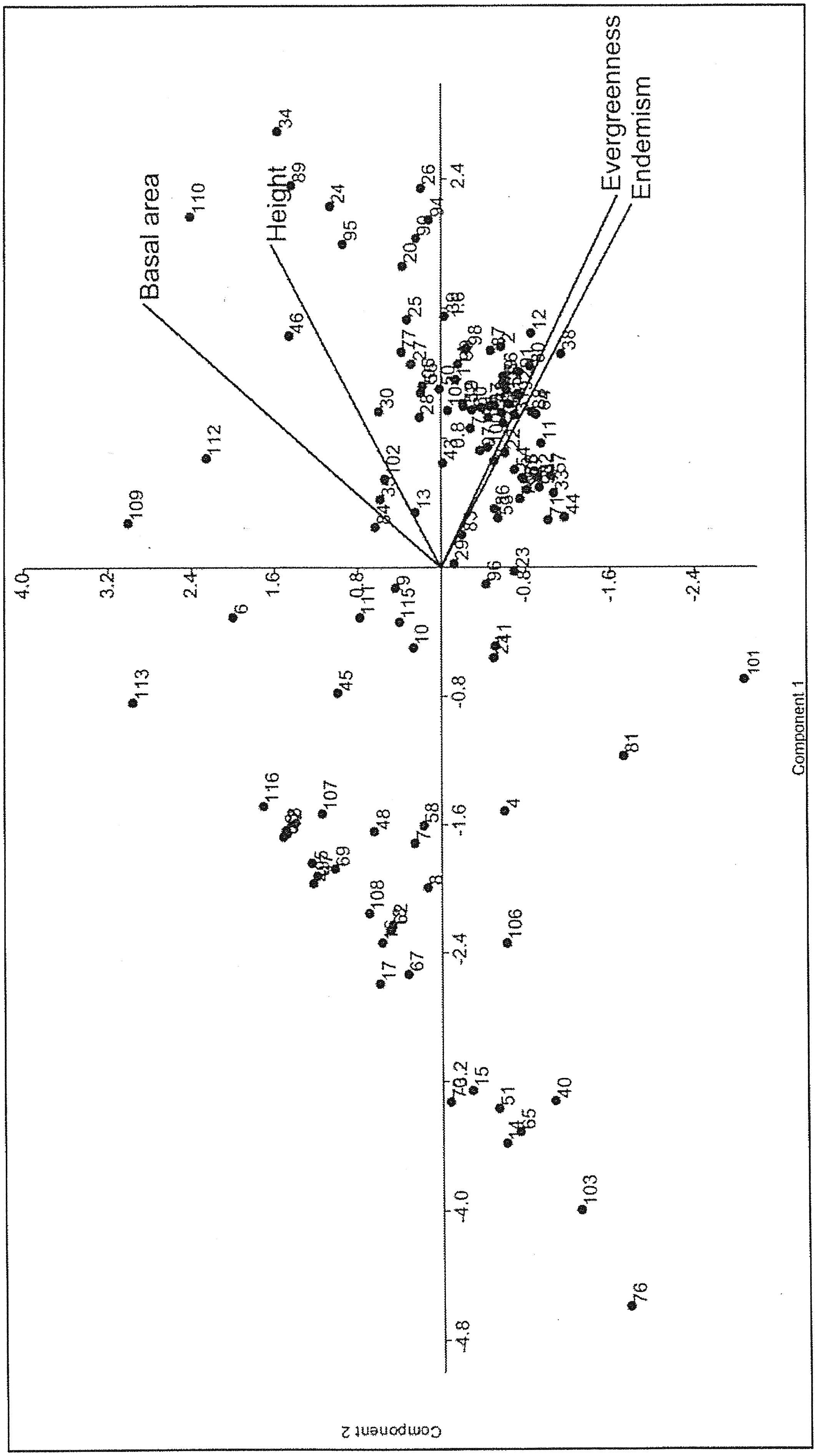

Figure 1.17: PCA Scatter Diagram Represents Four Variables with 116 Sampling Sites.

like Lion-tailed macaque is dependent on forest evergreenness and tree endemism. Recognizing the relative importance of high tree endemism (reflecting degree of evergreenness of the forests), forest canopy heights and basal areas/ha, on the basis of PCA carried out, we have formulated a conservation prioritisation scheme. The rationale for ranking is based on a cumulative score based on the relatively higher importance of endemism, followed by height and basal areas. In assigning conservation scores for each transect sample we have added the loading scores from Table 1.7 for each of the three parameters considered *viz.*, endemism, height and basal area. These scores are in addition to a value assigned to threatened tree species (highest for Critically Endangered, followed in importance by Endangered and Vulnerable species). Also taken into consideration is the value for diversity index (Shannon-Weiner) of each transect?

Table 1.7: Summary of PCA Analysis:
Eigen Value, Per cent of Variance and Loading Score

	Axis 1	*Axis 2*	*Axis 3*	*Axis 4*
Eigen value	2.53963	0.9233	0.4315	0.1054
Per cent variance	63.491	23.084	10.79	2.6355
		PCA view – loading score		
Endemism	0.8678	–0.4236	0.1347	0.2219
Evergreenness	0.8894	–0.3915	0.0305	–0.2342
Basal area	0.6321	0.6678	0.3928	–0.0153
Height	0.772	0.3805	–0.5081	0.0329

Evolving Criteria for a Composite Index for Forest Biodiversity Conservation Assessment in Uttara Kannada

For major mammals like tigers, elephants and such flagship species the Dandeli-Anshi Tiger Reserve, composed of Anshi National Park and Dandeli Wildlife Sanctuary, together cover 1365 sq.km or 13.3 per cent of the district itself. The DATR already covers good parts of Joida and western parts of Haliyal taluks and interior parts of Karwar taluk towards the Anshi Ghat. The forests covered under its domain include evergreen to semi-evergreen, moist and dry deciduous and savannah and scrub as well. We were not successful in getting necessary permission to make studies in this wildlife rich protected area. Such restrictions were not faced in Conservation Reserves and other administrative categories of forests. Now that we have already made 116 sample transects in the district and gathered data on the plant species diversity for each sample area, basal area, biomass, estimates of carbon sequestration, percentage of evergreenness and Western Ghat endemism and about the distribution of threatened species etc. we have attempted here to formulate a scientific basis for ranking of each representative sample site, through value assignments given to the key parameters *viz.*, 1. Endemism (reflects evergreenness of the forest stand); 2. Basal area of trees (indicator of biomass and carbon sequestered), 3. Canopy height; 4. Diversity index and 5. Presence of threatened tree species (based on IUCN Red List)

Criteria for Selection and Assignment of Scores for Evolving Composite Conservation Ranking of Forest Patches (Table 1.8 for details)

Tree Endemism

One of the prime reasons for Western Ghats constituting a Global Biodiversity Hotspot along with Sri Lanka is the high degree of endemism in the flora and fauna. As per cent of tree endemism is strongly linked to per cent of evergreenness, considering both the parameters for assigining scores would amount to bias against other parameters for evolving composite conservation index. We have assigned a score for tree endemism starting with a minimum of 5 for 20-30 per cent endemism for a sample adding additional 5 points for every 10 per cent interval.

Table 1.8: Criteria for Composite Index for Biodiversity Conservation Importance Ranking in Uttara Kannada

Parameter		*Score*	*Parameter*		*Score*
Average height (m)	14-15	5	**Basal area (m^2)**	20-30	5
	15-16	7		30-40	7
	16-17	9		40-50	9
	17-18	11		50-60	11
	18-19	13		60-70	13
	19-20	15		70-80	15
	20-21	17		80-90	17
Endemism per cent	20-30	5	**Threatened species**	Vulnerable	10
	30-40	10		Endangered	20
	40-50	15		Critically Endangered	30
	50-60	20		New species	30
	60-70	25			
	70-80	30			
	80-90	35			
Diversity index(Shannon)	1-2	5			
	2-3	7			
	3-4	9			
Add value for all transects		20			

Basal Area

From a starting minimum score of 5 points for 20-30 sq.m basal area/ha 2 additional points are given for every 10 sq.m addition in basal area (30-40 sq.m, 40-50 sq.m and so on). The assignment is made bearing in mind the fact that selective logging of trees and other forms of extraction of biomass can reduce the basal area even for a high diversity forest rich in endemism.

Average Height of Trees

Most of Uttara Kannada falling in the high rainfall zone, except Mundgod and eastern parts of Haliyal and Yellapur, would support high statured trees, the tallest emergent exceeding 30 m and the lesser ones attaining anything from few meters to over 20 m. We have estimated the height of each tree within transect cum quadrat samples and arrived at the average height per sample. Undisturbed forests tend to have more heights than disturbed and secondary forests or savannas. As tall statured forests have greater conservation importance than dwarfer ones we have assigned a score ranging from a minmum of 5 for average tree height of 14-15 m with addition of 2 points for every 1 meter increment.

Diversity

A minimum score of 5 points has been given for Shannon-Weiner diversity index of 1-2, 7 points for 2-3 and 9 points for 3-4.

Threatened Species

Presence of any IUCN Red Listed tree species in any forest sample, notwithstanding any other parameter considered here automatically raises the conservation importance of that forest. This is despite the fact that many tree species are yet to be evaluated for their rarity by the IUCN. We have assigned 30 points for each Critically Endangered tree species, 20 points for an Endangered species and 10 points for a Vulnerable species. Any new tree species described from the forest in particular will gain for the hosting site yet another 30 points.

Additional Value

As it is difficult to rank an ecosystem sample holistically as many features go undervalued or unconsidered for ranking all sites have been uniformly given an add value of 20 points (Table 1.8 for ranking criteria). Results of application of the composite ranking system for forest conservation adopted here is presented in Table 1.9.

Significant Results

IUCN Red Listed Plants

The forest studies revealed the presence of six threatened tree species in the transect areas. Kathalekan Myristica swamps and other swamps in Siddapur and Honavar are extremely threatened habitats with threatened species like *Myristica magnifica, Gymnacranthera canarica, Syzygium travancoricum* and the new tree species *Semecarpus kathalekanensis* exclusive to the swamps. *Dipterocarpus indicus* is present in the relic kan forests of Siddapur, Honavar and very rarely in Ankola (Table 1.10).

Endemism

Details of tree endemism were given in Tables 1.5 and Figure 1.13. Endemics are exclusive trees to the Western Ghats. Concentration of endemic trees, expressed as percentage of endemism in the sample stands, is more in the southern evergreen forests of Siddapur and Honavar, followed by Kumta and Sirsi. Endemism tends to decline in the northern forests, as most of them are secondary in nature. The Myristica swamps, themselves highly threatened areas, are remarkable for the congregation of Western Ghat endemic trees: *e.g.*, Sample areas from Kathalekan swamps T1 (76.92 per cent), T2 (80.17), T3 (81.75 per cent), T4 (71.7 per cent), T6 (71.43 per cent), T8 (70.4

Table 1.9: Composite Conservation Index, Based on Total Site Ranking Score, for 116 Forest Samples

Sl.No.	Asolli-1 Asolli-2	Taluk	Score for Parameters					Add Value	Total
			Height	Basal Area	Endemism	Threatened sp.	Diversity		
1.	Hosakere	Ankola	11	7	20	50	7	20	115
2.	S1-Katangadde-Agasur	Ankola	13	7	30	50	7	20	127
3.	S2-Balikoppa-Badgon	Ankola	9	7	20	20	7	20	83
4.	S3-Hegdekoppa-Kasinmakki	Ankola			5		9	20	34
5.	S4-Vajralli-Ramanguli	Ankola	5	5			7	20	37
6.	Kachinabatti	Ankola	7	7			9	20	43
7.	Maabagi	Ankola	5			20	7	20	52
8.	Dakshinakoppa	Ankola	9				7	20	36
9.	Gujmavu (semi evergreen)	Ankola	11	9	5	20	9	20	74
10.	Hudil (evergreen)	Bhatkal	9	7			5	20	41
11.	Hudil (semi evergreen)	Bhatkal	9	7	25	25	7	20	93
12.	Golehalli	Bhatkal	13	7	35		5	20	80
13.	Kudalgi-Tatigeri	Bhatkal	9	9	10		7	20	55
14.	Magvad	Haliyal				7		20	27
15.	Sambrani	Haliyal						20	20
16.	Yadoga	Haliyal	7	5				20	32
17.	Ambepal-1	Haliyal		7				20	27
18.	Ambepal-2	Haliyal	7	5				20	32
19.	Chaturmukhabasti	Honavar	15	7	15	40	7	20	104
20.	Gersoppa	Honavar	17	9	25	40	9	20	120
21.	Gundabala	Honavar	7	5	10		7	20	49

Contd...

Table 1.9–*Contd...*

Sl.No.	Asolli-1 Asolli-2	Taluk	Score for Parameters					Add Value	Total
			Height	Basal Area	Endemism	Threatened sp.	Diversity		
22.	Hadageri-1	Honavar	13	7	20	20	9	20	89
23.	Hadageri-2	Honavar	9	5	10	20	9	20	73
24.	Halsolli	Honavar	17	11	20	40	7	20	115
25.	Hessige-1	Honavar	17	9	20	40	7	20	113
26.	Hessige-2	Honavar	17	7	30	30	5	20	109
27.	Hessige-3	Honavar	13	9	15		7	20	64
28.	Hessige-4	Honavar	11	9	15	20	7	20	82
29.	Kadnir	Honavar	11	7	5	20	7	20	70
30.	Karikan-lower slope	Honavar	13	11	10		9	20	63
31.	Karikan-semievergreen	Honavar	9	7	25	20	7	20	88
32.	Karikan-temple side-diptero patch	Honavar	5	9	25	40	7	20	106
33.	Mahime	Honavar	7	7	25	40	7	20	106
34.	Sharavathy-viewpoint	Honavar	13	17	30	40	7	20	127
35.	Tulsani-1	Honavar	11	7	5		7	20	50
36.	Tulsani-2	Honavar	13	7	25	20	7	20	92
37.	Castlerock IB	Honavar	13	7	25	20	7	20	92
38.	Castlerock-moist-dec.	Honavar	11	7	35	20	5	20	98
39.	Castlerock-semi everg	Joida	9	11	30	20	9	20	99
40.	Desaivada-Nandgadde	Joida					7	20	27
41.	Gavni-Kangihole-Joida	Joida	9	5	5		7	20	46

Contd...

Table 1.9–*Contd...*

Sl.No.	*Asolli-1 Asolli-2*	*Taluk*	*Score for Parameters*					*Add Value*	*Total*
			Height	*Basal Area*	*Endemism*	*Threatened sp.*	*Diversity*		
42.	Ivolli-Castlerock	Joida	11	7			5	20	43
43.	Joida-deciduous	Joida	7	9	20		7	20	63
44.	Kushavali	Joida	5	7	25		5	20	62
45.	Shivpura	Joida	11	9			7	20	47
46.	Gopishetta	Joida	11	15	10		7	20	63
47.	Goyar-moist dec	Joida	9	11			5	20	45
48.	Kalni-goyar	Karwar	7	7			7	20	41
49.	Karwar-moist dec	Karwar	7	7			7	20	41
50.	Devimane-Campsite	Karwar	13	9	25		7	20	74
51.	Devimane-Sirsi side	Karwar					7	20	27
52.	Devimane-temple	Kumta	11	9	25	20	9	20	94
53.	Devimane-with myristicas	Kumta	7	9	20	20	7	20	83
54.	Hulidevarakodlu	Kumta	7	9	20	20	7	20	83
55.	Kalve	Kumta	7	9	30	20	7	20	93
56.	Kalve-moist dec.	Kumta	13	9	20		7	20	69
57.	Kandalli-Devimane	Kumta	9	5	25	20	7	20	86
58.	Mastihalla-Devimane arch	Kumta	7	5			7	20	39
59.	Mathali-Kandalli-Devimane	Kumta	9	9	30	20	7	20	95
60.	Soppinahosalli	Kumta	9	9	25	20	7	20	90
61.	Surjaddi	Kumta	9	9	25	20	7	20	90
62.	Surjaddi-Morse	Kumta	7	5			7	20	39

Contd...

Table 1.9–*Contd...*

Sl.No.	Asolli-1 Asolli-2	Taluk	Score for Parameters					Add Value	Total
			Height	Basal Area	Endemism	Threatened sp.	Diversity		
63.	Attiveri-teakmixed-dry dec	Kumta	13	7	25	20	7	20	92
64.	Godnal	Kumta	11	7	25	20	7	20	90
65.	Gunjavathi	Mundgod					7	20	27
66.	Karekoppa-Gunjavathi	Mundgod	9	9			5	20	43
67.	Katur	Mundgod	7	5			5	20	37
68.	Katur to Gunjavati	Mundgod	11	7			5	20	43
69.	G1-Kathalekan-nonswamp	Mundgod	11	5			5	20	41
70.	G2-Kathalekan-nonswamp	Mundgod		5			7	20	32
71.	G3-Kathalekan-nonswamp	Siddapur	7	7	20	40	9	20	103
72.	G4-Kathalekan -nonswamp	Siddapur	9	7	25	50	9	20	120
73.	G5-Kathalekan-nonswamp	Siddapur	9	9	25	40	9	20	112
74.	Kathalekan-savanna	Siddapur	11	7	20	40	9	20	107
75.	G6-Kathalekan-nonswamp	Siddapur	5	9	20	40	9	20	103
76.	G7-Kathalekan-nonswamp	Siddapur					5	20	25
77.	G8-Kathalekan- nonswamp	Siddapur	13	11	20	40	7	20	111
78.	G9-Kathalekan-nonswamp	Siddapur	11	5	20	40	9	20	105
79.	Hartebailu-soppinabetta	Siddapur	9	9	25	80	7	20	150
80.	Hutgar	Siddapur	9	9	30	40	5	20	113
81.	Joginmath-1	Siddapur			15		7	20	42
82.	Joginmath_2-semievergreen	Siddapur	9	7	25		7	20	68
83.	Kathalekan-1	Siddapur	11	7	5		9	20	52

Contd...

Table 1.9–*Contd...*

Sl.No.	Asolli-1 Asolli-2	Taluk	Score for Parameters					Add Value	Total
			Height	Basal Area	Endemism	Threatened sp.	Diversity		
84.	Kathalekan-2	Siddapur	13	9	5		7	20	54
85.	Kathalekan –swamp-1	Siddapur	11	5	20	20	9	20	85
86.	Kathalekan –swamp-2	Siddapur	11	7	15	40	9	20	102
87.	Kathalekan –swamp-3	Siddapur	11	9	30	80	9	20	159
88.	Kathalekan –swamp-4	Siddapur	7	9	30	70	7	20	143
89.	Kathalekan –swamp-5	Siddapur	9	15	30	70	9	20	153
90.	Kathalekan –swamp-6	Siddapur	11	13	35	70	7	20	156
91.	Kathalekan –swamp-7	Siddapur	9	9	30	100	7	20	175
92.	Kathalekan –swamp-8	Siddapur	9	9	30	100	7	20	175
93.	Kathalekan –swamp-9	Siddapur	9	7	20	70	7	20	133
94.	Kathalekan-3	Siddapur	13	11	35	100	7	20	186
95.	Malemane-1	Siddapur	15	13	25	70	9	20	152
96.	Malemane-2	Siddapur	9	5	10	60	9	20	113
97.	Malemane-3	Siddapur	11	7	15	40	9	20	102
98.	Siddapur evergreen	Siddapur	15	7	25	40	9	20	116
99.	Talekere	Siddapur	13	9	25	40	7	20	114
100.	Bugadi-Bennehole	Siddapur	13	7	15	20	7	20	82
101.	Gondsor-sampekattu	Siddapur			30	20	5	20	75
102.	Hulekal-Sampegadde-Hebre	Sirsi	7	11	15		9	20	62
103.	Kanmaski-Vanalli	Sirsi					7	20	27
104.	Khurse	Sirsi	9	11	20		9	20	69

Contd...

Table 1.9–*Contd...*

Sl.No.	Asolli-1 Asolli-2	Taluk	Score for Parameters					Add Value	Total
			Height	Basal Area	Endemism	Threatened sp.	Diversity		
105.	Masrukuli	Sirsi	7	11	20	20	7	20	85
106.	Hiresara-bettaland	Sirsi		5		20	7	20	52
107.	S5-Gidgar-Yemmalli	Sirsi	7	9			7	20	43
108.	S6-Tarukunte-Birgadde	Yellapur		9		20	5	20	54
109.	S7-Arlihonda-Nandvalli	Yellapur	15	9			9	20	53
110.	S8-Yellapur-Mavalli	Yellapur	17	17	15		9	20	78
111.	S9-Kiruvatti	Yellapur	9	7	5		9	20	50
112.	Hasrapal-evergreen	Yellapur	13	7	10		9	20	59
113.	Hulimundgi-semievergreen	Yellapur	11				5	20	36
114.	Lalguli-moist-dec	Yellapur	15	7	20		7	20	69
115.	Asolli-1	Yellapur	13	7	5		7	20	52
116.	Asolli-2	Yellapur	11	9			7	20	47

Table 1.10: The IUCN Red Listed Tree Species found in Various Transects

Red Listed Species	*Family*	*Category*	*Locations*	*Taluk*	*Remarks*
Gymnacranthera canarica	Myristicaceae	Vulnerable	Alsolli 1, Alsolli 2 Halsolli, Kathalekan G1, G2 Kathalekan swamp T1, T2, T3, T4, T5, T6	Ankola Honavar Siddapur Siddapur	Confined to Myristica swamps only
Myristica fatua	Myristicaceae	Endangered	Halsolli Kathalekan swamps T1,T2, T5, T9	Honavar Siddapur	Confined to Myristica swamps only. In relics of primary forests
Dipterocarpus indicus	Dipterocarpaceae	Endangered	Alsolli 1, Alsolli 2 Ambepal 1, Ambepal 2 Hadageri 1, Hadageri 2 Karikan lower slope Karikan s.evergreen Karikan templeside Kathalekan non-swamp grids G1, G2, G3, G4, G5, G6, G7, G8 Kathalekan swamp grids T1, T2, T3, T4, T5, T6, T7, T8, T9	Ankola Honavar Honavar Siddapur	New reports for Ankola in relics of primary forests. Northward range extention in Western Ghats
Hopea ponga	Dipterocarpaceae	Endangered	Widespread in evergreen forests Honavar, Kumta, Siddapur, Sirsi and Ankola and sparingly in Karwar and Yellapur	Honavar, Kumta, Siddapur, Sirsi, Ankola, Yellapur Karwar	
Vateria indica	Dipterocarpaceae	Endangered	Kathalekan 3	Siddapur	Planted widespread in the district; natural in Mattigar kan, Siddapur
Syzygium travancoricum	Myrtaceae	Critically Endangered	Kathalekan G8, Kathalekan swamp T3, T6, T8, T5	Siddapur	Also found very sparingly in Ankola Ghats. Range extention in Uttara Kannada reported for first time
Semecarpus kathalekanensis	Anacardiaceae	New tree species	Kathalekan swamps T1, T2	Siddapur	New tree species reported

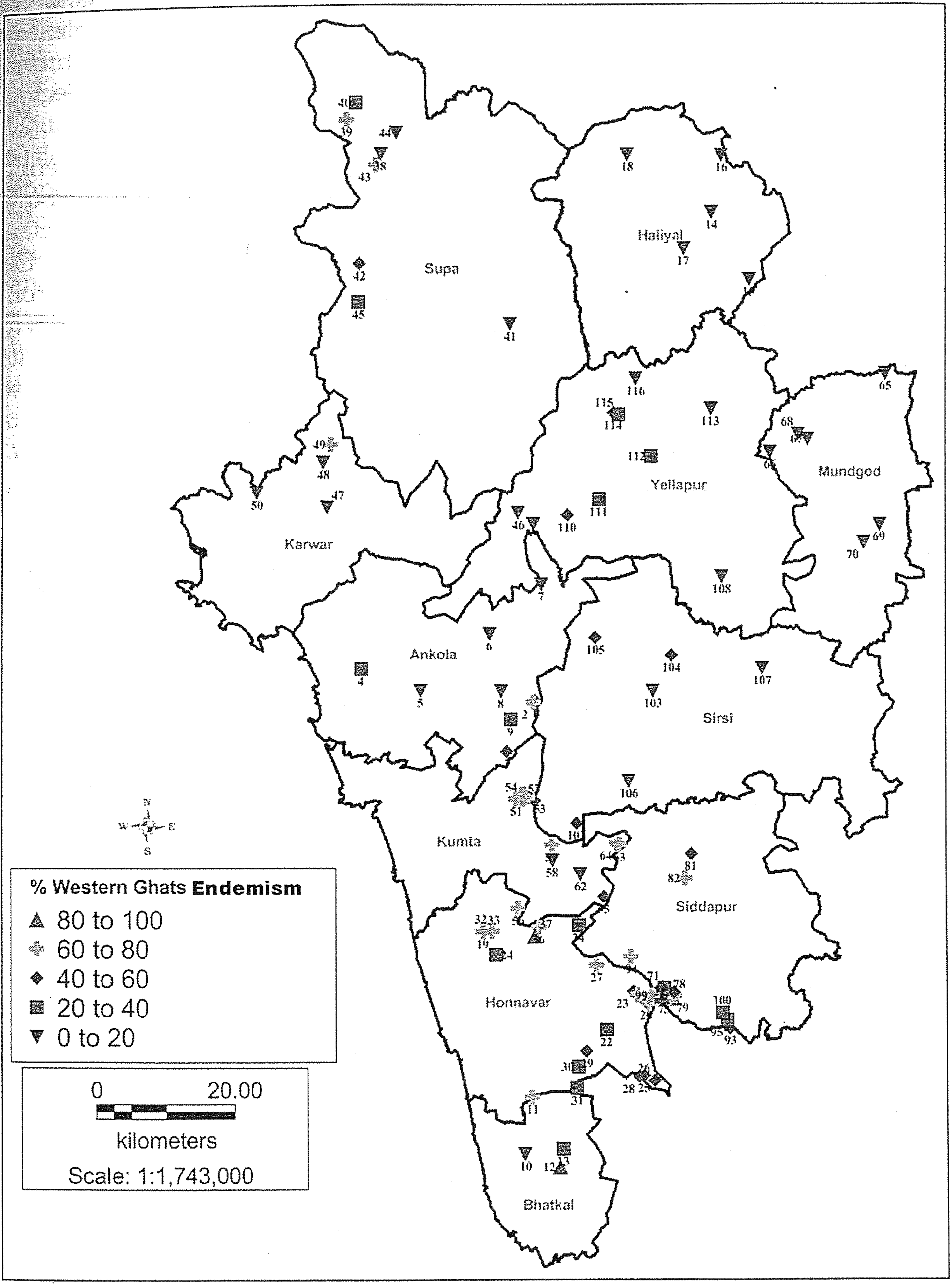

Figure 1.18: Tree Endemism Levels in different Transects of Uttara Kannada.

per cent) and T9 (72.65 per cent). Non-swamp samples from Kathalekan are also rich in tree endemism: *e.g.*, T8 (77.96 per cent). Some other high endemic areas are in Tulsani-2 of Honavar (83.2 per cent), Hudil in Bhatkal (80.65), Karikan temple side sample in Honavar (75 per cent), Halsolli in Honavar (79.07 per cent) and from Devimane Ghat in Kumta (74.62 per cent). The northern forests show drastic decline in endemism (Figure 1.18 for distribution of tree endemism).

High endemism concentration areas in the Siddapur and Honavar ghats covering the drainage areas of Sharavathi and Aghanashini rivers constituting the backbone of the Aghanashini Conservation Reserve, the main habitat for the Endangered primate Lion tailed macaque and for the presence of maximum Myristica swamps in the district (Figure 1.18). In a recent study 35 amphibian species were reported from Kathalekan, most of them in and around the Myristica swamps. Of these 74 per cent are endmics to the Western Ghats. *Philautus ponmudi* is Critically Endagered and its northernmost distribution range in Western Ghats ends in Kathalekan. Five of these species are Endangered and yet another 5 are Vulnerable. Several of them being data deficient also might figure in the threat categories of the Red List (Chandran *et al.*, 2010).

Tree Height Criteria

In Uttara Kannada forests make a mosaic of secondary ones, due to anthropogenic effects through centuries, in different stages of succession here and their enmeshing relics of primary forests like the kans. Several tall growing emergent, evergreen, endemic and non-endemic trees like *Artocarpus hirsuta, Dipterocarpus indicus, Syzygium travancroicum, S. gardneri, Dysoxylum malabaricum, Calophyllum tomentosum, Ficus nervosa, Lophopetalum wightianum* etc. are instrumental in maintaining tiered structure of the forests and in providing habitats for several birds (*e.g.*, Imperial pigeon, hornbills), bats and Lion-tailed macaque. Vertical compression of forests can adversely affect primary forest arboreal fauna.

Conservation Value and Basal Area

Old growth and primary forests tend to accumulate more biomass, as reflected in the girth of tree trunks. Naturally, long periods of undisturbed growth will increase tree dimensions as could be seen from the basal areas/ha. Several endemic tree species are associated with high basal area forests and increase their conservation importance. High basal area is index of high biomass and high levels of carbon sequestration. Human impacts in the form of logging can reduce stand basal areas. Selective cutting may not eliminate tree species as such in a mixed stand. Therefore the conservation value of the stand may not suffer seriously through some degree of forest exploitation. But forest exploitation through tree cutting and mutilation can severely alter the faunal composition by upsetting their habitat qualities. Forest stands of exceptional conservation values should have at least over 40 m^2/ha of tree basal area in Uttara Kannada conditions.

Significance of Diversity

Biodiveristy, in terms of genetic, species and ecosystem diversity, is paramount in considerations of conservation. Biodiversity on the earth is getting seriously impacted due to various human activities, directly (through exploitation and alterations in habitats for human wants) and indirectly (through pollution of land and water and air and climatic changes). Protecting of biological diversity has economic and ethical grounds. The species have their own intrinsic values unrelated to human needs. In the complexity of biological communities loss of one species may have far reaching consequences affecting even the humans. As far as forest tree diversity in Uttara Kannada forests (expressed in Shannon diversity index of sample areas) is considered it is found that conservation values of tree community expressed as a composite value are not necessarily dependent on high diversity index, though there is tendency towards increase in conservation value with rising diversity index. Stand should not be however too poor (diversity value of 1-2 in our study areas). Several stands of climax vegetation are too specialised to their habitats (*e.g.*, Myristica swamps), so that they are not that rich in tree species but are seats of high Western Ghats endemism. The Myristica swamps and their immediate surroundings abound in endemic individuals of similar nature so much so the stand diversity as expressed in Shannon index ranges between 2-3 only, unlike many secondary disturbed forests which have diversities of 3-4.

Prioritsation of Forest Areas for Conservation

On the basis of the composite conservation index prepared for assessing the plant diversity (mainly trees) conservation value of stands in forests, based on 116 transects, each covering 2000 m^2 of forest, a map has been prepared and presented here (Figure 1.19). High and very high conservation ranking areas (conservation values of ≥ p 80) are along the Western Ghat regions in the south of the district, mainly in the taluks of Honavar, southern Siddapur (Kathalekan-Malemane area), a zone of high percentage evergreen forests with high degree of forest endemism. If faunal endemism is added to these areas the conservation values will continue to increase as compared to the northern taluks. Conservation values of moderate importance are found in sites throughout the district, scantily so in Mundgod, Joida and Haliyal taluks- despite the fact that these are of high conservation value for non-endemic mammals and flagship species like elephant and tiger. As bulk of the Dandeli-Anshi Tiger Reserve is in Joida, Karwar and Haliyal taluks (as we had no permission to work in such areas, our reliance is more on few samples studied earlier to the new regulations imposed on scientific studies in the Tiger Reserves within the State). As savannah, deciduous forests and more of open grassy areas exist especially in Joida taluk, as telltale marks of its shifting cultivation history, the grazing ecosystem fares better here ideally promoting tiger and panther and other carnivores through promotion of herbivorus prey animals. Not belittling in any way the importance of major mammal conservation in National Parks and Sanctuaries of Western Ghats, as far as Uttara Kannada is concerned scanty efforts were ever made to conserve pockets of high endemism, which is the major consideration for conferring Biodiversity Hot Spot status for the Ghats as a whole. Our studies on forest vegetation clearly reveal that high evergreen forest areas, with negligible timber values, unlike the deciduous forest zone of the district of north-eastern taluks, have greater endemic biodiverisity as reflected in the forest stands.

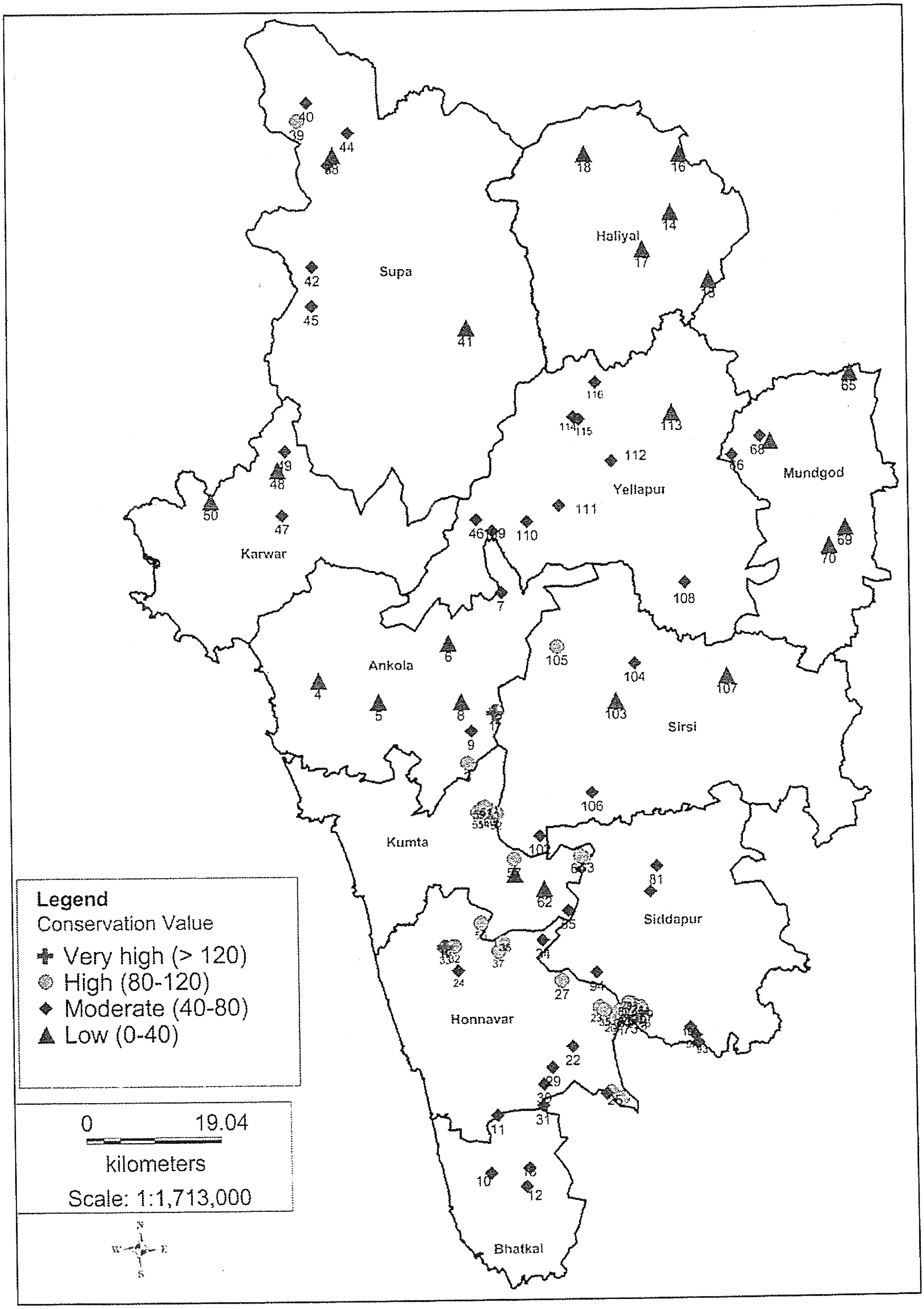

Figure 1.19: Tree Diversity Conservation Values of Forest Stands in Uttara Kannada (for non-economic parameters).

Moreover, in studies related to fresh water fishes of Sharavathi River tributaries in Shimoga taluk it was found earlier that the landscape elements in the catchment of the tributary plays a decisive role in especially fish endemism. A tributary, for instance like Yennehole, had 18 species of fishes of which 8 were Western Ghat endemics. The catchment area forests in Yennehole basin had 86 to 100 per cent evergreen trees where endemism varied between 46-58 per cent. Yet another tributary Nagodi with 19 fish species had also 8 endemic fishes, including a new species *Schistura nagodiensis*, and 68-99 per cent evergreen forests with 36-71 per cent tree endemism in the drainage basin. In contrast Nandihole tributary flowing through a degraded landscape of highly human affected forests, agricultural areas and monoculture tree plantations, with merely 0-16 per cent evergreenness and low endemism of 0-11 per cent in the catchment forests. Although there were 14 fish species in the river only 2 were endemics. The message is that the evergreenness of forests, which goes in harmony with endemism, plays a very crucial role for the entire forest and linked ecosystems in the Western Ghats, as landscape elements play decisive role in distribution of aquatic organisms like fishes making untrammelled nature a holistic system (Sreekantha *et al.*, 2007). High tree endemism areas of Kathalekan, especially the Myristica swamps and adjoining damp areas, had at least 35 species of amphibians. Already we have referred to the amphibian richness of the swampy Kathalekan evergreen forests with high percentage of tree endemism. Conservation values assigned for forest areas for prioritisation of conservation, using the composite index is given in Figure 1.19.

Nelson *et al.* (1990), Peterson *et al.* (2000) and Myers *et al.* (2000) strongly favour identification and prioritisation of 'hotspots', or areas featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat. Their focus is more on endemic species, rather than populations or other taxa, as the most prominent and readily recognizable form of biodiversity.

Using a grid system (preferably 1x1 km) of forest surveying we need to have a proper stock of the distribution of endemic tree species, and demarcate areas of high tree endemism for prioritization of conservation as such areas are also good for endemic faunal elements and for their hydrological importance. Centres of high floristic endemism (of especially trees) are also the centres of endemic fishes in the streams draining them, in addition to amphibians and birds.

The role of man-made plantations needs a re-evaluation, in the light of high soil erosion, weed infestation, poor hydrology and poor associated faunal diversity as compared to natural forests (Murthy *et al.*, 2002, 2005). The teak plantation areas in general, despite the high value of teak timber, were found to have lower biomass and needs enrichment planting by NTFP species, nectar species for honey bee promotion, Soil erosion from forests and forest plantations is a matter of grave concern. As rains are often very high (upwards of 3000 mm/per annum) in most places, and so much of rainfall within a short period of mostly four months a dense forest cover is required to check soil erosion and increase infiltration into the ground water. Here we recommend eventual conversion of deciduous forests and their degradation stages (except grasslands or grassy blanks, critical resources for grazing ecosystems) in heavy rainfall zone into evergreen forests. Poor grade tree plantations with eroded soils need to be restored with natural forest species through planting of saplings and dibbling of seeds.

Forest restoration in the catchment areas of rivers will improve perennial nature of streams ensuring perpetual inflow of clear water into the storage dams of hydroelectric projects in Sharavathi and Kali rivers than bringing into them an onrush of water turbid with soils down the poorly vegetated terrain. The active monsoon period being of four months it is necessary to increase residency of water within the watershed soils than releasing it en mass into the reservoirs or other downstream areas as surface water, which eventually get lost through faster evaporation in the prevailing climatic conditions.

The species chosen for forest enrichment/afforestation should have strong bearing on a. increase in endemism; b. more of ecologically site specific NTFP species; c. benefit to birds and bats and other frugivorous animals and d. favour populations of wild bees and create employment opportunities through bee-keeping and enhance pollination services of both cultivated crops and forest plants.

A system for assigning conservation values to the forest patches based on characteristics of tree communities has been adopted here. **Assignment of conservation priorities is based mainly on five variables of forests namely: a). per cent evergreenness, b). per cent endemism, c). basal area, d). tree height and e). Shannon diversity index.** Principal component analysis based on the first four variables revealed that evergreenness of the forests is strongly linked to the presence of endemic trees. Higher the evergreen components more endemics congregate in such areas. Basal area and tree heights are linked to other two factors – but not so strongly as these two are subjected to rapid fluctuations depending on human impacts. Relative correlation between these five factors was obtained through application of Pearson correlation matrix. A composite conservation index is prepared for the 116 forest samples using scores allotted to the factors per cent endemism, mean canopy height, basal area and diversity index. Additionally the presence of IUCN Red Listed trees, if any, were given high conservation score- the actual score depending on the category of threat.

Highest conservation values are more for forests towards the south from Sharavathi Valley (Kathalekan-Malemane-Gersopppa stretch to the Aghanashini valley in Siddapur and to a small extent in Sirsi). Incidentally this stretch of forests, having the northernmost populations in the Western Ghats of the Endangered primate Lion-tailed macaque, of Myristica swamps and *Dipterocarpus* trees, has been already declared by the Government of Karnataka as Aghanashini LTM Conservation Reserve.

The study reveals that there is only a thin line difference between rain forests and deserts. Whereas the heavy rainfall of coast and malnadu taluks can potentially promote loftiest evergreen forests of Western Ghats many locations are characterized by poorer vegetation- poorer in biomass and in conservation ranking. The poorest savanna site exists on a hill top ironically in the Kathalekan forests of highest conservation value, dotted with Myristica swamps, by presence of lofty *Dipterocarpus* threatened and endemic plant and animal species (especially amphibians and LTM). Whereas the swamp forest samples of Kathalekan have average carbon sequestration of 225.506 t/ha the savanna patch has merely 5.06 t/ha. The land was savannized at least over 100 years ago by the shifting cultivators. Though today uninhabited the forest recovery has not taken place. Similar paradoxes exist between adjoining forest patches everywhere in the district.

Whereas in the earlier efforts towards conservation it was often the flagship species like elephant, tiger etc. and their habitats that captured major attention in the conservation priorities of the Government. Today, the Western Ghats, along with Sri Lanka constitute a hotspot of high endemism and significant threat of imminent extinctions. Therefore it has become necessary to evaluate and rank areas of high endemism, which we have attempted in this study through the application an objective method. Suggestions based on our sustained ecological research in Uttara Kannada district are:

- ☆ In the specter of climatic change that the planet is facing with its widespread implications especially on farming and biodiversity, the need has arisen to increase carbon sequestration in the forest areas. There are considerable areas of degraded forests in Uttara Kannada, the biomass of which has to be increased substantially through protection, enrichment and co-management.
- ☆ Inviolate forests should be identified range-wise for increased conservation efforts.
- ☆ Myristica swamps are among the oldest and original forest types of the Western Ghats. They have some of the highest degrees of floral and faunal endemism. Efforts should be made to make all out search for such swamps, record their locations and areas and conserve them along with their catchment area forests
- ☆ The *kan* forests and 'devarabanas' were **unique cultural identities** of bygone days. They still have portions harbouring deities and are seats of high endemism. As most of them got merged with state reserved forests they lost their pre-colonial identities as sacred groves from safety forests (except the smaller banas close to or in the middle of villages). Efforts should be made to trace them out and map and protect them.
- ☆ Conservation of Western Ghat endemism is important. High percentage of forest tree endemism even influences endemism among fishes in the streams that drain such forests.
- ☆ Biomass upgradation is an urgent necessity especially in the deciduous forest areas everywhere, especially in the maidan taluks of the district.
- ☆ Biomass and diversity are lower in the coastal minor forest tracts. Through consistent efforts involving local VFCs multiple species forests should be raised in such areas.
- ☆ Coastal lateritic hills were paid least attention so far; except for raising Acacia plantations no major activities were undertaken in them. Laterite plateaus also have great richness of monsoon herbs which flower gregariously and offer nectar for the survival of honey bees during the

rainy season. Some ideal plateaus need to be conserved for their characteristic endemic flora.

☆ Regarding **scope for forestry based alternative development plan for enhancing the economic productivity of the region** we wish to state that **since** bulk of the lands in the district (over 70 per cent area) being under the control of the Forest Department there is very little scope for economic advancement of bulk of the local population beyond subsistence level. There is also not much scope for major developmental interventions due to the fragility of the terrain and the ecosystems. As economic growth gets stunted people, especially younger generation tend to migrate into the cities for better prospects. Such mass migrations from rural areas will strain the cities as well beyond their carrying capacities too- as it is happening in Bangalore. To reverse the trend as far as Uttara Kannada is concerned the following recommendations are made for creation of more of forestry based livelihoods without any major interventions into the ecosystems as such:

a. NTFP species should be widely raised.

b. Bee keeping to be promoted as an important enterprise to benefit the people and forests (through pollination). Village peripheral forests and roadsides should be planted with numerous types of nectar plants used for foraging by honey bees (separate submitted on bee keeping).

c. There is laxity among the arecanut garden owners as regards management of soppinbetta forests for fear of not getting the fruits of such improvement as the bettas are under Government ownership. It is recommended the betta owners be allowed certain tree rights if they adhere to certain norms like maintenance of the bettas to certain biomass levels, say like 30-35 sq.m of basal area/ha for trees.

d. The farmers require a helping hand from the Government in growing and marketing of medicinal plants and their primary products. Medicinal plants grown in VFC forests in home gardens or in fields, which also grow wild in the forest areas, should be procured by the Forest Department. This is to stop smuggling of medicinal plants from the forests, unauthorized exploitation by outside agencies and for betterment of local livelihoods.

e. Preparation of bio-pesticides, harmless to humans and domestic animals, may be promoted as a cottage industry using local plant resources, especially from village peripheral forests/VFC managed areas.

f. Vegetable dyes/or textiles coloured using such dyes, or for use as food colours are in increasing demand. Numerous plants in forests, mangroves and beaches are potential sources of such dyes. Village peripheral forests may be enriched using such plants to generate rural employment. Technology transfer is necessary.

g. Enormous scope for exploration of production and trade of plant based cosmetics and nutraceuticals (*e.g.*, from *Garcinias* and *Phyllanthus emblica* -amla) should be explored.

h. VFC managed sandalwood farms are recommended for the taluks of Haliyal, and Mundgod and for the eastern zone of Yellapur, Sirsi and Siddapur.

i. Being well forested district of hills and valleys, waterfalls, sea beaches and mangroves and for its cultural diversity Uttara Kannada has good scope for generating eco-friendly livelihoods through tourism promotion at grassroots level. This facet of development with the vision of upgrading livelihoods of grass root level people while also enriching forests, mangroves, sea beaches and coastal laterite plateaus has been successfully worked out by the Honavar Forest Division, at Apsarakonda, Om Beach (Gokarna), Kasarkod, Bellangi etc. The State Government should liberalise the licensing policy on home stays and community managed cottages (through VFCs) to benefit growth of decentralized ecotourism in the district, to benefit both village communities and local ecology.

j. Decentralised systems of forest nurseries for generating women's employment and providing scope for application of indigenous farming techniques for forestry purposes.

☆ Village level biodiversity hotspots should be identified and protected through the involvement VFCs/local Biodiversity Management Committees. Eventually these, through succession and vegetational enrichment will turn out to be local hotspots of biodiversity.

☆ Realizing the fact that depletion of forests of food resources and human induced vegetational changes in forests have adverse consequences on wildlife while increasing crop raids by animals enrichment of secondary forests and poor grade tree plantations with food resources for forest herbivores is highly desirable.

☆ NTFP collection, that yields only minor revenue to the state, is being carried out in many forests with gay abandon causing destruction of the resource itself. We recommend that the VFCs and other forest dwellers in respective villages be organized and trained in scientific harvesting of NTFP which also serves as medicinal plants.

☆ Rampant collection of poles, cane, fuel wood etc., has been taking a heavy toll on forest resources particularly in the village vicinities. Most of the easily accessible areas with many medicinal plants are more prone to exploitation and get converted into scrub and thickets. Even the semi-evergreen and evergreen forests higher up in more inaccessible areas are also being exploited for fuel wood, timber etc., due to which many of these forests have thorny thickets as under-growths. We recommend conduct of sustained programmes on biodiversity awareness. Also bamboo considered as 'poor man's timber' the villagers may be allowed to harvest it from designated areas for their own bonafide use, so that they will desist from pole cutting and stake removal from the forests which destroys lakhs of tree saplings and pole sized juveniles.

Recommendations

1. Forests towards Carbon Mitigation

Carbon sequestration in any given forest is related to forest biomass. Basal area/ha is an index of the forest biomass. Higher carbon sequestration in stream course/swamp forests was a significant find of this study. In Kathalekan forests 9 forest samples along the water course-swamp parts had average carbon storage of 211.87 t/ha. In the nine samples from forest away from water course areas, carbon sequestration was less at 165.54 t/ha. On a hilltop savannized part, obviously due to shifting cultivation practice in the past, the carbon sequestration was very poor at 5.03 t/ha only. Numerous hill tops and wind exposed slopes of the district are in savannized state with poor biomass, demonstrating the fact clear felling of a rain forest can bring in desertified conditions. Nevertheless, these grassy patches considering forest as a place of tree growth, often also with undergrowth, the savannised forests and several secondary forest samples subjected to ongoing human impacts, or sytems recovering from past human impacts, had some of the least basal areas, irrespective of whether they fall in high, moderate or low rainfall areas. All the taluks have such forests, which are low in biomass. Altogether 3 out of 116 samples, as studied by transect cum quadrat method, had basal areas of < 10 sq.m, 10 transects had basal areas between 10-20 sq.m/ha and 17 had between 20-30 sq.m. To such degraded forest areas also belongs bulk of the Soppinbetta or leaf manure forests allotted to arecanut garden owners of mainly the malnadu areas, for exercising the traditional privileges, importantly leaf manure collection. Thus a betta inTalekere of Siddapur had only 10.12 sq.m basal area ha and Hartebailu betta in same taluk had only 17.80 sq.m/ha basal area. Gondsur-Sampekattu betta in Sirsi taluk had just 3.74 sq.m as the basal area. Hiresara bettaland in Yellapur was exceptional in having 41.73 sq.m basal area.

2. Riparian Forest Protection

River and stream bank forests, including inland swamp area forests are to be considered as endangered ecosystems for various reasons, including for their high accumulation of biomass and higher levels of carbon sequestration. Forest rangewise river-stream-swamp protection action plans, incorporating adequate amount of inviolate vegetation growth for protection of ecology of these vital water courses along with their rare and endemic species is critical. The maps and action plans prepared for special protection of such areas should be included in the forest working plans of every forest division. If such working plans are already prepared these should be still prepared as supplements. Timber extraction, conversion into monoculture plantations, or encroachments or any developmental activities should not be allowed affecting these inviolate forests.

3. Protection of Myristica Swamps

These are remnants of the original primeval forests of the Western Ghats. The lineage of such forests could be traced to the supercontinent of Gondwanaland. The swamps, repositories of ancient and highly threatened rare biodiversity, are under various kinds of threats. They would have perished in large scale in early agricultural history of Western Ghats, being reclaimed for rice fields and betelnut gardens. Many of the last remaining fragments of swamps are also under threat from agricultural expansion. The swamps should be demarcated in the forest working plans for the relevant areas and recommended for protection through preferably co-management with the VFCs. The catchment areas for the swamps are to be protected from any kind of human disturbances being very important sources of hydrology. Kathalekan swamps in Siddapur taluk, being the most precious genepool of threatened plants and amphibains, among others, beng situated alongside the Honavar-Bangalore highway might get wiped out in case of road widening. The widening should not be permitted through any of the Myristica swamps or primary forest remnants.

4. Conservation of Unique Forest Related Cultural Identities

The district abounds in forest related unique cultural identities like sacred groves and sacred trees. Sacred groves are known by various names like kans or devarabanas (often the presiding deities' names are added to respective banas-kans- such as Jatakabana, Choudibana, Kari-kanamman-bana, Hulidevarukan, Naagarabana etc.). Numerous ancient trees, especially of genus *Ficus*, or several others like *Mimusops elengi, Mesua ferrea, Mangifera indica, Mammea suriga, Aegle marmelos* etc. are present dotting the landscapes of villages and towns signifying sacred locations of cultural value. Whereas the *kans* were traditionally large groves, of several hectares or even few sq.km in area (Kathalekan for *e.g.*), the *banas* are smaller ones, mostly within an acre in area. While the former is associated often with other forests or wilderness the latter is often found closer to or within human settlements. The *kans* were places where tree cutting was not permitted under traditional management, but NTFPs could be taken care of and harvested (*e.g.*, Wild pepper, cinnamon, toddy and starch from *Caryota urens* etc.). The *kans* while protecting wild genepool amidst secondary, human impacted landscapes, also acted as safety forests, being fireproof systems due to their evergreenness and high humidity, as sources of perennial streams and springs and as sources of NTFP. The smaller groves the *banas*, were not traditionally violated for any form of bioresources. In short both *kans* and *banas* were unique cultural identitites of the region while they preserved the region's climax vegetation. With the process of forest settlement during the British period, most of the *kans* lost their original identity as village sacred groves from safety forests, and were treated not much different from other forests. The smaller sacred groves are under shrinkage too due to erosion of conservation ethics due to changing cultural worldviews of the local communities (Chandran, 1998; Chandran and Gadgil, 1993). A detailed survey of 86 villages gave details about the presence of 241 sacred groves. We strongly recommend that the Government through the Forest Department take immediate steps to revive the system of preservation of these ancient sacred groves however small they are.

5. Identification and Recouperation Old *Kan* Forests

Kan forests were sacred forests of local rural communities of central Western Ghats. They are known as *devarakadus* in Coorg district. Devarakadus of Coorg have official recognition as sacred forests to this day. The kans of Shimoga district were demarcated in maps and their areas were already listed from early British period. But the British did not recognize the sacredness of the *kans*. In Uttara Kannada many *kans* of Sirsi and Siddapur were demarcated villagewise in forest settlement reports. At the same time many other *kans* got merged with rest of the reserved forests without any special status conferred on them and subsequently it became difficult even to locate their boundaries. Such is the case of Kathalekan in Siddapur, Karikan in Honavar and Halsollikan in Ankola which we studied in detail. All these three *kans*, despite being reserved forest areas, are associated with sacred locations within them or in their vicinity, where local people continued the worship of deities. Interestingly all these places continued to maintain their distinctness as relics of primary evergreen forests embedded in a vast matrix of secondary forests. All these forests have *Dipterocarpus indicus*, a primary evergreen forest tree of South Indian Western Ghats. This species, though commoner in more southern forests, have isolated occurrences in Uttara Kannada mostly associated with *kan* forests. The presence of this Endangered evergreen tree has enhanced the conservation value of all these forests. Asollikan is a locality where we observed also the Critically Endangered tree *Madhuca bourdillonnii*. The discovery of this rarest species in Ankola taluk, once thought to be extinct and rediscovered in southern Kerala Ghats in its original home range, is an instance of traditional, community based conservation practice. Presence of species like *Myristica magnifica* (Endangered), *Syzygium travancoricum* (Critically Endangered), *Gymnacranthera canarica* (Vulnerable) and *Semecarpus kathalekanensis* (newly described tree species from the Myristica swamps of Karikan), underscores the importance of surveying, demarcating and protecting the lost *kans* (sacred forests) of pre-colonial times, and demarcating them for more careful protection and restoration through natural regeneration. The *kan* forest areas, were considered during British period as hydrologically important areas, being associated with perennial streams and springs (Chandran and Gadgil, 1993). Even a small *kan* of just one ha, in the Mattigar village of Siddapur taluk has *Syzygium travancoricum* (Critically Endangered) and *Vateria indica* (Endangered). The *kans*, many of them in ruins, due to various reasons, should be salvaged and brought under a system of co-management involving the local VFCs, if they are closer to villages.

6. Conservation and Promotion of Forest Endemism

High rainfall areas have high biodiversity values and higher conservation values. High rainfall areas of malnadu and coastal taluks are major seats of endemic biodiversity of both plants and animals. Kathalekan studies in Siddapur taluk (by various investigators) reveal how the high endemism is associated with Myristica swamps, at least 35 species of amphibians, endemic hornbills and Imperial pigeon, Endangered primate Lion –tailed macaque etc. The very distribution of fresh water fishes is highly correlated to terrestrial landscape elements, of which quantity and quality of evergreen forests are more important. Of the 64 species of fresh water fishes reported from Sharavathi River, including in its catchment areas of Shimoga, 18 species were endemics to Western Ghats, including three new species *Batasio sharavathiensis*, *Schistura nagodiensis* and *S. sharavathiensis* and 24 species confined to Peninsular India (Bhat and Jayaram, 2004; Sreekantha *et al.*, 2007).

7. Upgrading Biomass in Deciduous Forests and Secondary Deciduous Forests

The quality and quantity of a deciduous forest stand is very much reflected in its total biomass of which basal area is an index. Eleven forests surveyed in the deciduous forest zone of Haliyal and Mundgod taluks reveal unsatisfactory biomass, estimated basal areas/ha being in ranges of 10-20 sq.m for three samples, 20-30 sq.m for five samples, 30-40 sq.m for just two samples and only one falls in 40-50 sq.m category (43.09 sq.m at Godnol in Mundgod). Forest fragmentation of high order, shifting cultivation practices in the past, massive conversions into monoculture plantations, clear felling and selection felling rampantly practiced in the past are some of the major causes for low basal areas. Compact stretches of forests especially in areas thinly populated by humans may be prioritised for developing ideal forests of high stature through special protection and periodical monitoring of the progress of natural succession and tree growth. The forest management should aim at developing in the deciduous forest zone of Mundgod, Haliyal, in the drier eastern parts of especially Joida, Yellapur and Sirsi compact stands with basal areas exceeding 35 sq.m/ha.

8. Increasing Biomass and Diversity in Secondary Deciduous Forests of Coastal Taluks

The secondary moist deciduous forests along the coastal taluks have been in impoverished state due to high density human impacts. Bulk of such forests constituted the 'minor forests' meant for meeting the biomass needs of coastal people, including cattle grazing. Through special protection of promising forest patches using barbed wire fencing, and closing any kind of exploitation in such protected areas, natural regeneration can be promoted, for at least five year period. Thereafter these forests can be open for free movement of wildlife and more such selected blocks can be protected, using the mode of forest working plans.

9. Demarcation of Potential Areas for Conservation of Congregation of Endemic Trees

Our survey reveals there are special areas in the forests where species like *Myristica fatua, Dipterocarpus indicus, Syzygium travancoricum* etc. congregate. More such areas should be traced out through the involvement of forest guards and village people and earmarked for special conservation efforts.

10. Importance of Conservation of the Native Flora of Coastal Laterite Hills and Plateaus

From ancient times the coastal hills and plateaus of Uttara Kannada, from Ankola to Bhatkal, presented a picture of a barren and desolate terrain with sparse growth of woody vegetation. As such these were demarcated as minor forests for meeting the biomass needs of the local population and for cattle grazing. Many have been used in the recent decades for raising monocultures of *Acacia auriculiformis*. Our studies reveal that during the rainy season, open lateritic areas get carpeted with tiny herbs, where billions of flowers bloom providing crucial off-season nectar resources for honey bees, which, especially the domesticated ones, are otherwise to be fed artificially using sugar/jaggery solutions.

11. Forest Resources for Improving Economic Conditions of Local Citizens

Regarding scope for forestry based alternative development plan for enhancing the economic productivity of the region we wish to state that since bulk of the lands in the district (over 70 per cent area) being under the control of the Forest Department there is very little scope for economic advancement of bulk of the local population beyond subsistence level unless suitable small scale enterprenureship complementary to forests and nature are nurtured in the district. This recommendation is made considering the least scope in the district for major developmental interventions due to the fragility of the terrain and the ecosystems. As economic growth gets stunted people, especially younger generation tend to migrate into the cities for better prospects. Such mass migrations from rural areas will be too exacting on the carrying capacities of cities- Bangalore, for instance is burgeoning with population and developmental activities with heavy toll on ecology the impacts far reaching even on ecology of Western Ghats. To reverse the trend as far as Uttara Kannada is concerned the following recommendations are made for creation of more of forestry based livelihoods without any major interventions into the ecosystems as such:

i. Sustainable Use of Soppinbettas

Soppinbettas are forests allotted to arecanut garden owners of mainly the malnadu areas, for exercising the traditional privileges, importantly leaf manure collection. The farmers do not have tree rights in these bettas although in most bettas we observed trees are constantly lopped for leaf manure collection, apart from collection of leaf litter from the ground. Bettas sampled were understocked in tree biomass (a betta in Talekere of Siddapur had only 10.12 sq.m basal area ha, in Hartebailu of same taluk a betta had only 17.80 sq.m/ha basal area and in Gondsur-Sampekattu betta in Sirsi taluk it was abysmally low 3.72 sq. m). Some farmers maintain bettalands in better conditions *e.g.*, Hiresara bettaland in Yellapur (basal area 41.73 sq.m/ha). One of the reasons for understocking and low biomass is that many farmers also use the bettas as tree savannas interspersed with grassy areas; as a result they are able to maintain improved cattle unlike the coastal farmers who are hard pressed for fodder grasses even to feed their diminutive indigenous cattle. The laxity in betta management is partly due to the general fear among the farmers that any improvement in the betta forests at their expenses will not be repaying for them as they do not enjoy absolute ownership over the betta lands or the trees. It is recommended here that the farmers be allowed to have rights on the trees (for timber and fuel) in the betta if they upgrade the tree biomass from present basal area indicator of less than <20 sq.m/ha to minimum of 30-35 sq.m/ha, which minimum limit the Forest Department may fix after examination of the condition of the betta on a case to case basis.

ii. Promotion of Beekeeping

Uttara Kannada has ideal district for promotion of bee keeping. Bee keeping is complementary to forestry and farming because of pollination benefits. Uttara Kannada can reap enormous benefits through especially production of forest and farming based organic honey. Even roadsides and wastelands can be planted with nectar producing plant species. Although about 7000 sq.km area is under forest cover the district has achieved only very little progress in bee keeping. One of the key reasons is the inadequacy of bee forage plant species in the village peripheral forests which are often in degraded state, with scanty attention paid to enriching them with bee forage plants. Particularly nectar producing species, groups of them flowering in different times of the year, composed of a community of site specific flowering herbs, shrubs, climbers and trees are to be promoted to support apiculture in villages. Even the landless and marginal farmers can involve in bee keeping depending on bee forage plants in forests, roadsides, mangroves and beaches. Through proper planning and implementation of 'forests for bee keeping' project, hypothetically, at the density of two bee colonies per ha of forest (not necessarily by placing bee boxes in every ha of forest, as the bees travel few km in search of forage plants; for *e.g.*, *Apis dorsata* has a foraging range of 3 km radius -Batra, 2001), at a modest estimate honey production based on 700,000 ha of forests at 40 kg/ha using native bees *Apis cerana*, and Rs.200/-kg rate at prevailing minimum rate, can yield 28,000 tons of honey worth Rs.560 crore. Honey is a good health food in demand nationally and internationally. Proper marketing as organic forest honey can fetch much more income (for *e.g.*, Soapnut tree based honey fetches upwards of Rs.700/- kg). Surplus honey can be used in the mid-day meal programmes for school students. To achieve such ambitious target we recommend that even a wing of Forest Department be made to promote apiculture related activities.

The bettaland farmers should be assisted in bee keeping activities aiming at a minimum of one bee box for every acre of betta. They are to be guided in enriching the bettalands with bee forage plants so that the vegetation of impoverished bettas are also improved. Improved vegetation and better ground cover can also improve local hydrological conditions. A single bee colony (in a bee box) can earn for the farmer Rs.4000/- extra money, through better management and vegetational enrichment. The farmers also stand to gain from increased farm productivity due to the pollination services from bees, and NTFPs from bee forage plants. The farmers need training in bee keeping related activities. Sirsi-Siddapur taluks, which have some of the highest forest fragmentation in the district, can also substantially improve the forest wealth through betta rehabilitation.

iii. Promotion of Marketable Medicinal Plants

The farmers require a helping hand in growing and marketing of medicinal plants and their products. The farmers would look forward to the Government/ Forest Department, for acting as a purchasing agency for medicinal plants or their products. In this regard by undertaking the role of a facilitator between the producer and the purchaser (pharmaceutical companies) the Government/Forest Department would play a vital role in biodiversity conservation and enhancing the value of bettalands, minor forests, and even those who grow medicinal plants in their household gardens or private lands. The role of Forest Department as a purchasing agency while bettering local livelihoods can also stop smuggling of medicinal plants from the forests and other unauthorized exploitation by outside agencies.

iv. Biopesticides from Forest Plants

Various plant species of the district *viz.*, neem, *Pongamia*, *Vitex negundo* etc. are sources of biopesticides. Promotion of such plants in VFC managed forests and bettalands can further the cause of organic farming in the district while also earning extra income to the locals from production of marketable, homemade biopesticide formulations, under an assited programme from the Government. Neem based pesticide formulations are widely popular in the world. Azadirachtin, the main active principle of neem is also found in *Melia azedarach* (Hebbevu) of same family. However, use of such pesticides in India is making tardy progress, despite the fact that knowledge base for neem pesticidal properties is from India. Bark extract of *Acacia nilotica* has been found to provide complete protection to oranges from the blue mold fungus (Varma and Dubey, 1999). Leaf extract of *Clerodendron inerme*, a hedge plant and coastal shrub, is found effective against red spider mite. Use of *Lantana camara* extract to control cotton pests is a good example of a grass root level practice (Varshney, 2006). Strychnine from *Strychnos nux-vomica* is used as a rat poison. Pongamia leaves and bark are sources of traditional biopesticides, especially having insect deterrant properties (Kiruba *et al.*, 2006). Seeds of the giant forest liana *Entada pursaetha* are used to control rats in the Garo Hills of North-East India.

v. Vegetable Dyes from Forest Plants

World over, especially from developed countries, there is growing demand for textiles dyed using vegetable dyes. Total market for herbal dyes was estimated to be worth US$ one billion and growing annually at the rate of 12 per cent (Gokhale *et al.*, 2004). India has a wealth of traditional knowledge on production of plant based textile (for cotton, wool and silk) and leather dyes. The market demand for such dyes is yet unrealized in the absence of surveys. It is right time for Uttara Kannada district to capture this market using the enormous potential for growing plant sources of vegetable dyes in the VFC managed areas, including sea beaches and mangroves, under a sustained programme including training programmes for transfer of appropriate technology. Numerous plant species can be promoted for dye production in cottage industry level:

a) *Acacia catechu* (Khair): Catechin red from wood for dyeing silk, cotton and calico printing
b) *Acacia nilotica* (Jali): Catechin from wood for dyeing light yellow, dark grey, reddish brown
c) *Aegle marmelos* (Bilpatri): Marmalosin from fruit rind for yellow and gray
d) *Bauhinia purpurea* (Mandara): Chalcone and butein for dyeing and tanning purple
e) *Butea monosperma* (Muttaga): Dried flowers with several components for dyeing of silk brilliant yellow
f) *Caesalpinia sappan*: Brazilin from wood and pods for red and black
g) *Cassia fistula* (Kakkemara): Bark and sapwood for red
h) *Cassia tora* (Tagati): Rubrofusarin from seeds for tannin and dyeing blue
i) *Chukrasia tabularis* (Gnadhagarige): Leaves for red
j) *Dipterocarpus* spp. : Bark for brown and gray
k) *Madhuca indica* (Mahua): Bark for reddish yellow

l) *Mallotus phillippensis* (Kumkum): Fruits for dyeing silk red
m) *Mangifera indica* (Mango): Bark and leaves for dyeing silk yellow
n) *Morinda citrifolia* (Noni): Morindin from root and bark for dyeing silk dull red
o) *Pterocarpus marsupium* (Bet-honne): Epicatechin from bark for dyeing silk brownish red
p) *Rubia cordifolia* (Manishta): Manjistin and purpurin from stem and bark for reddish brown, light pink, light brown, gray
q) *Terminalia arjuna* (Holematti): Arjunic acid from bark for light brown
r) *Terminalia chebula* (Haritagi): Chebulinic acid from fruits for yellow and dark gray
s) *Tectona grandis* (Teak): For dyeing silk yellow
t) *Ventilago maderaspatana*: Ventilagin from root and bark for colouring cotton and tassar silk chocolate
u) *Woodfordia fruticosa:* Lawsone from leaves and flower for dyeing pink or red
v) *Zizyphus jujuba* (Bora): Fruit as modant in dyeing silk

There are many more such plant sources of dyes. The important needs before implementation are:

☆ Documentation of traditional practices, study of local and global demands
☆ Improvisation of traditional techniques
☆ Commercial cultivation of wild sources
☆ Standardisation in dyeing practices

vi. Cosmetics and Nutraceuticals from the Wild

As such lot of authorised and unauthorised extraction of NTFP used for cosmetics and nutraceuticals are happening in the district, for instance from plants like *Garcinia* spp. Kokam fat from *Garcinia* seeds has global demand as is most sought after for preparing skin creams. Following in importance is seed fat from *Madhuca indica* (mahua tree). *Garcinia cambogea* and *Phyllanthus emblica* are few among several nutraceutical plants, the multiplication and sustainable harvests of which can generate considerable rural employment. The traditional Indian cosmetic products of India came from a variety of plants like Amla, Shikakai (*Acacia concinna*), neem, soapnut (*Sapindus laurifolius*).

vii. VFC Managed Sandal Farms

Sandalwood (*Santalum album*) is perhaps the costliest of tree species in the world, Karnataka being its greatest production centre. The high cost of the wood has become baneful to the species, as the tree faces highest smuggling risks. Individual householders and farmers seldom dare to grow this valuable species due to their inability to safeguard it. Collective responsibility by village community seems to be the only course for the future of sandal. We therefore recommend the adoption of the species by VFCs in their respective jurisdiction especially in the taluks of Mundgod and Haliyal and eastern parts of Sirsi, Yellapur and Siddapur.

viii. VFC Managed Medicinal Plant Areas

Medicinal plant gardens of fast depleting and highly traded species may be promoted through VFCs for growing *Salacia chinensis, Nothopodytes foetida, Embelia* spp., *Coscinium fenestratum, Costus speciosus, Rauwolfia serpentina, Asparagus racemosus* etc. Many highly degraded forests, scrubs and thickets contain numerous medicinal plants particularly near coastal areas. These are to be mapped and brought under strict in situ conservation measures, so as to preserve the native medicinal gene pool.

ix. Forests for Ecotourism

Natural and cultural heritage are primary attractants for tourism world over. Uttara Kannada is an idyllic district of valley villages of lush greenery merging with wooded hillsides and grasslands offering tremendous scope for development of eco-tourism and study tourism. Tourism flourishes especially in areas with more than two landscape elements meet – such as sandy seashore and beach forest (*e.g.*, Kasarkod), sea shore and hillscape (*e.g.*, Apsarakonda), waterfall and forest (*e.g.*, Jog, Unchalli and Magod waterfalls), pilgrimage and picnic trail through forest to cathedral rocks (*e.g.*, Yana, or to hilltop shrine of Karikanamma in the vicinity of *Dipterocarpus* sacred grove) and so on. In all these places and in many more areas, apart from National park and sanctuary, the Forest Department has demonstrated that tourism can be conducted successfully to benefit the local communities organized into VFCs. This facet of development with the vision of upgrading livelihoods of grass root level people while also enriching forests, mangroves, sea beaches and coastal laterite plateaus has been successfully worked out by the Honavar Forest Division, at Apsarakonda, Om Beach (Gokarna), Kasarkod, Bellangi etc. The potential should be developed so as to generate income to the locals through preservation of their local environment and local cultures without the need for migration into cities in search of employment. Key elements for successful development of eco-tourism are limiting growth within sustainable limits (Jog Falls, unfortunately, is a location where ecological norms are not adhered to creating considerable negative impact on environment), generating benefits to the local community (and not to major enterprises from outside), monitoring and mitigating ecological impacts (mostly not happening in our ecotourism areas, except in PAs). Partnership with local community/VFC is of great importance of success of ecotourism. We recommend that in all areas with ongoing, potential ecotourism training be imparted to especially local youth in successful management of tourism, in running forest trails, in bird watching, familiarisation with local flora and fauna etc. Liberal issuance of licenses for home stays and community/VFC managed cottages is necessary for ecotourism to benefit grassroot level people and environment.

x. NTFP Species Raising and Utilisation

For betterment of livelihoods at local level NTFP yielding species should be raised on a larger scale in VFC areas. Auctioning of NTFP to contractors is found to be injurious to forests due to overharvests, unscientific harvesting methods and for the poor returns of revenue to the State. The local VFCs, tribal societies, self-help groups of women etc should be prioritised for NTFP harvests.

xi. Decentralised Systems of Forest Nurseries

For generating women's employment in village areas and also providing scope for application of indigenous farming techniques for forestry purposes sets of local species may be raised in household nurseries.

12. Village Level Biodiversity Hotspots

Our studies show that biodiversity conservation values are correlated to forest endemism. Although Western Ghats itself is part of a global biodiversity hotspot, the concept of village level biodiversity hotspots should be promoted through community participation. Such hotspots, which are especially centres of local level biodiversity, should be identified and special attention given to their protection through Biodiversity Management Committees/Village Forest Committees. Eventually these special patches should serve as local climax natural ecosystems also strengthening local hydrology.

13. Decentralised Systems of Forest Nurseries

Villagers in close vicinity of forest areas may be commissioned to raise small scale nurseries of selected species flowering plants for replanting in forest areas, roadsides etc. to reduce the load on the understaffed Forest Department which is required to spend considerable time and resources on large scale nurseries. This will increase rural employment, especially for women while also giving scope for application of indigenous planting techniques.

14. Promoting Food Plants for Wild Animals

Bulk of Uttara Kannada forests are of secondary nature, either old growth forests or forests, scrub and savannah in different stages of succession. As such these massive vegetational changes that have happened through centuries of human impacts, have adverse consequences on native fauna thinning the populations of many or causing their local extinctions. Leaving aside old growth forests, which should not be subjected to any kinds of tampering, the rest should be enriched with food plants for various faunal elements, particularly birds and frugivorous bats, primates and other mammals. This enrichment is also necessary to reduce crop raiding by wild animals. Care should be taken to preserve grassy blanks within forest areas, critical resources necessary for grazing wild animals. Such grassy blanks should not be subjected to afforestation.

15. VFC Based Resource Monitoring

As villages are dispersed in Uttara Kannada all over forest areas it would make much sense to adopt a system of participatory resource estimation and monitoring within their respective areas- such as estimates of *Myristica*, cinnamon, gooseberry, *Garcinias* and other NTFP plants, key medicinal plants like *Nothapodytes, Cosicinim, Salacia, Embelia* and so on as well as of honey bee colonies within forests. This will strengthen bonds between the Forest Department and village communities while also getting a fair idea of the worth of forests at local level for the provisional goods they contain.

16. Meeting the Fuel Needs

Fuel extraction, both legal (especially removal of dead and fallen from interior forests) and illegal by local population is instrumental in degradation of many forests. Energy efficienct stoves, biogas, solar devices, use of agricultural wastes etc. are to be promoted as fuel in rural areas. At the same time adequate fuelwood/or other alternative fuels should be granted to cottage industries run by potters, lime makers etc.

17. Selecting Appropriate Areas for Tree Plantations

Raising monocultural/mixed tree plantations has to be site specific. Planting of *Acacia auriculiformis* has to be restricted to rocky or otherwise impoverished terrain and not in lands with good soil resources where native species are to be preferred.

18. Dispensing with the Practice of Climber Cutting

Climber cutting is an archaic practice in forestry to promote tree growth. The Western Ghats harbour good diversity of climbers including endemic ones. The climber cutting practice has to be disbanded or restricted to tree plantations only as it would otherwise cause destruction of biodiversity including medicinal plants and entail adverse impacts on wildlife.

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