INSTITUTS FRANÇAIS DE RECHERCHE EN INDE
FRENCH RESEARCH INSTITUTES IN INDIA

PONDY PAPERS IN ECOLOGY

ASSESSMENT AND CONSERVATION OF FOREST BIODIVERSITY IN THE WESTERN GHATS OF KARNATAKA, INDIA. 1. GENERAL INTRODUCTION AND FOREST LAND COVER AND LAND USE CHANGES (1977-1997)

B.R. Ramesh
Mohan Seetharam
M.C. Guero
R. Michon

UMIFRE 21 CNRS-MAEE

INSTITUT FRANÇAIS DE PONDICHÉRY
FRENCH INSTITUTE PONDICHERRY

6

PONDY PAPERS IN ECOLOGY No. 6

Assessment and Conservation of Forest Biodiversity in the Western Ghats of Karnataka, India.
1. General Introduction and Forest Land Cover and Land Use Changes (1977-1997)

B. R. Ramesh
Mohan Seetharam
M. C. Guero
R. Michon

INSTITUT FRANÇAIS DE PONDICHÉRY

The Institut français de Pondichéry (IFP) or French Institute of Pondicherry, is a financially autonomous research institution under the dual tutelage of the French Ministry of Foreign and European Affairs (MAEE) and the French National Centre for Scientific Research (CNRS). It was established in 1955 under the terms agreed to in the Treaty of Cession between the Indian and French governments. It has three basic missions: research, expertise and training in human and social sciences and ecology in South and South-East Asia. More specifically, its domains of interest include Indian cultural knowledge and heritage (Sanskrit language and literature, history of religions, Tamil studies, ..), contemporary social dynamics (in the areas of health, economics and environment) and the natural ecosystems of South India (sustainable management of biodiversity).

French Institute of Pondicherry, UMIFRE 21 CNRS-MAEE, 11, St. Louis Street, P.B. 33, Pondicherry 605001, INDIA

Tel: 91-413-2334168; Fax: 91-413-2339534

Email: ifpdir@ifpindia.org

Website: http://www.ifpindia.org

Authors

B. R. Ramesh, Mohan Seetharam, M. C. Guero and R. Michon are from the French Institute of Pondicherry.

This volume is part of a report published in collaboration with the Karnataka Forest Department under reference: Ramesh, B. R. and Swaminath, M. H., 1999. Assessment and conservation of forest biodiversity in the Western Ghats of Karnataka, India. Final report of a project funded by the Fonds Français de l'Environnement Mondial, convention n° 12-645-01-501-0. 126 pp.

Typeset by Mr. G. Jayapalan

Summary

PPE volumes 6 and 7 are parts of a project report published in 1999 in collaboration with the Karnataka Forest Department on the assessment and conservation of forest biodiversity in the Western Ghats of Karnataka. After introducing the project objectives and the study area, this volume deals more specifically with forest land-cover and land-use changes over a 20-year period (1977-1997), assessed from vegetation maps and satellite images. The study revealed that forest areas were converted to anthropogenic cover types at an annual rate of 0.63%. Forest loss was mitigated in areas under state protection (reserve forest), while degraded or fragmented forests lost more area than dense, undisturbed ones. Conservation priorities and recommendations for forest management are discussed in the second volume (PPE 7).

Keywords: Karnataka, India, land-cover, land-use, tropical forests, vegetation maps, Western Ghats.

TABLE OF CONTENTS

Chapter

1

General Introduction

The WGFP program and the French Institute's contribution

The Global context and the CBD

Tropical forests are being lost worldwide at alarming rates. Myers (1994) estimated that 132,000 km² of forest were lost in 1991. Apart from jeopardising vital ecosystem functions such as climate control, nutrient cycling, and pollution filtration, tropical deforestation is eroding the biological diversity of the planet. Species are being wiped out as their habitat is fragmented, degraded and destroyed. The International Convention on Biological Diversity (CBD) recognises the importance of ecosystems and habitats, and aims to promote their conservation *in situ*. As a signatory to the convention, India is committed to institute measures for *in situ* conservation, and to involve indigenous people and local communities as partners in these efforts.

Uniqueness and importance of WG

The Western Ghats constitute an escarpment running roughly parallel to the western coast of the Indian peninsula. The Ghats are not confined to Karnataka alone; they extend over nearly 1,500 km from Kanyakumari to northern Maharashtra, crossing five states.

The region of the Ghats (*see section on bioclimate and vegetation*) is the domain of dense low-elevation evergreen forests, of high-altitude shola-and-savanna grasslands, and of deciduous woodlands. The very diverse bioclimatic conditions experienced along the forest continuum have produced high levels of endemicity as well as vicariance of species.

Forest areas have shrunk considerably over the centuries, largely due to human activity. Commercial pressures, and the biomass needs of a rapidly growing population (*see section on history)* have degraded or destroyed vast stretches of the original forest. Consequently, there has been a loss of biological diversity of these ecosystems and a decline in the quality of the environment. The loss of forest cover in sensitive regions such as steep slopes and watershed areas can be expected to exacerbate crises such as soil erosion and flooding. Some endemic species have disappeared entirely, and others are on the verge of extinction. Due to its richness and its precariousness, the Western Ghats region is considered among the "hot spots" of the world.

Ineffective, obsolete forest management

The management of forest areas, legislated as being separate to private lands agricultural areas, and wastelands, is the responsibility of the Government and its State arm, the Karnataka Forest Department (KFD). Management policies have largely been a legacy of the colonial era and its industrial / commercial bias. The existing system has been incapable of limiting the disappearance of forests. There is a need for an integrated, comprehensive resource management approach. Efforts have been made to develop new management regimes to protect and conserve these valuable forests through policy changes.

WGFP: towards a concerted management of forests

The KFD, anxious to preserve the remaining areas of forest, is in the process of breaking its traditions with the past. In collaboration with the British Government's ODA (now the Department for International Development, DFID), the KFD has launched an ambitious program known as the Western Ghats Forestry Project (WGFP). The project is for the global management of the Western Ghats of Karnataka, a vast stretch of about 2 million hectares. It aims to reconcile three major concerns: economic development, equitable access to forest resources by local populations, and environmental conservation.

Objectives

The immediate objectives of the program include;

- Developing new systems of management by improving the organisation and capacity of the KFD by decentralising the decision-making process.
- Involving local populations with forest planning and management, and benefit sharing arrangements, i.e., Joint Forest Planning and Management (JFPM) in administered areas.
- Conserving the diversity and sustainability of the forests through sustainable forest management principles.

Management methodology / approaches

The WGFP's methodology is built around a concept of zoning. The project proposes to partition the forest into 4 zones for different management priorities, although end uses may overlap. For example, conservation of biodiversity is an important consideration in zones 1 to 3, but it is the *priority* in zone 1.

Zones are to be delineated on the basis of existing information on the distribution and status of forests, and from data generated by ecological surveys during the course of the project. This ecological information will also be used for monitoring the status of forests over time.

For the purposes of this project and its objectives, we will concern ourselves exclusively with zone 1. The management objectives of Zone 1 include;

- Protection of biodiversity, rare, endangered, and threatened flora and fauna, and habitats
- Protection of natural habitats, integral ecological units, animal corridors, shola-grassland boundaries.
- Protection of watershed and erosion-prone areas
- Conserving genetic resources
- Eco-tourism

In keeping with the decentralised management and community participation objectives of the project, there was consensus that all zoning must be planned and agreed with local communities. Forest protection and conservation cannot take place without their consultation and involvement. KFD and representatives of local communities will jointly assess all forest areas, especially zone 4 (areas to be managed primarily to meet local requirements).

The planning and management of zone 1 may be integrated closely with the protected area (PA) system in Karnataka, which includes National Parks and Wildlife Sanctuaries within the state. Current PA management largely excludes the involvement of local communities. Some consistency of approach is required, however, and potential zone 1 areas may serve as corridors for the movement of fauna between the P.A.s. Therefore, one option is to adopt zone 1 as a new model for integrating conservation and community forestry.

In addition, emphasis was laid within the WGFP for zones 2 and 3. These are forests to be managed with the objective of meeting state and stakeholder needs of timber and non-timber forest product (NTFP) through sustainable forest management.

Social, economic, and ecological research must be “client-oriented”. The stakeholders must be identified and attention focused on how the research will be used by these. Implicit in the objective of conservation is a recognition of the multiple use values (ecological, environmental, socio-economic) of the WG forests.

Some conflicts and trade-offs are possible, and these require a sound information base and macro-planning perspective. To this end it was proposed that a geographical information system (GIS) be set up and built. This geographical database will allow the demarcation and mapping of the different zones, the planning of field operations, and the integration of different kinds of information. Coupled with the use of digital satellite imagery, it will also enable the regular updating of information and the monitoring of field operations.

FIP’s contribution

The French Institute was invited to participate in the project, particularly in the conception and preparation of a geographic database for the delineation of zone 1, and for the assessment and monitoring of forest ecosystems.

Since it would be most efficient to use existing information wherever possible, it was decided to use the Forest Map of South India at 1/250,000 scale as a basis for work (*for more details, see section on Methods*).

A geographical database was built by digitising the information contained in the forest map. Recent satellite imagery was used to update the maps. Temporal and spatial landscape analyses were carried out on this information.

Information on the distribution area and ecology of tree species was compiled by collecting observations from field data, and from herbaria. Methods for assessing biodiversity were developed, and tree biodiversity of habitat types and their respective degraded stages was comprehensively studied and recorded on a database.

Finally, the zones were delineated on the basis of information derived from the above methods; from the distribution of endemic species, from forest maps, and from information on anthropogenic pressures.

Micro-scale studies were carried out in a permanent monitoring plot to derive information on the floristic composition and spatial structure of a dense low-elevation evergreen climax forest, and to assess the impact of logging disturbance on the recovery of this forest.

The History of Forest Use and Management Policy

Humans have been living in the forests and modifying their environment for well over ten thousand years. But it is only since the neolithic period, five thousand years ago, that the transition of human societies from hunter-gatherer to food-growing caused large-scale changes in vegetation (Subash Chandran, 1997).

Early agriculturists practised shifting cultivation in the forested hills (Box 1). In Karnataka, these land-use patterns persisted until the early twentieth century when they were gradually discouraged and then almost entirely extinguished after 1927. The current state of the forests of the Western Ghats of Karnataka is the outcome of patterns of resource utilisation and use conflict that stretch back to over two hundred years at least.

Box 1 - Shifting Cultivation

Also known as swidden cultivation, slash-and-burn agriculture, and rotational bush fallow, it is the extensive form of agriculture that alternates short crop phases with natural vegetation fallow (Ramakrishnan, 1996). According to one estimate in 1956, over half a million families were dependent on shifting cultivation in India, concentrated mostly in hilly areas (Subash Chandran, 1998).

Kumri was a form of shifting cultivation practised in Uttara Kannada and surrounding hill regions. Under kumri, a field was prepared for cultivation by felling large trees, allowing the wood to dry, and then burning. When the rains arrived, seeds were sown in the soil which had been fertilised by ashes (Buchy, 1996). It appears that fallow periods were very long in some cases. According to Buchy (1996) a kumri was cultivated “for only one year and not again as long as the cultivation could be remembered by the community”. Nevertheless, in some areas, kumri had significantly changed the composition of the original evergreen forest into deciduous patches (Subash Chandran, 1998). It has also been conceded that there were cases where the method had to be discontinued, particularly in erosion-prone areas such as hillslopes at the headwaters of streams (Pouchepadass, 1993).

In his study of the swidden regimes of the Malabar, Freeman (1994) found very little concern for environmental degradation. Large trees were felled and burnt, surrounding smaller trees uprooted and used for fencing, and the area was cleared of animals that were potential competitors for the jungle crops. Fallow periods were shorter than the time required for larger trees to become established, as they would be difficult to clear once again.

The colonial authorities disapproved of kumri. Foresters, acknowledged its subsistence nature, but viewed the system as destructive. In their opinion it led to the loss of forests, to the degradation of teak stands, and to soil erosion. Freeman (1994) suggests that given its record, the colonial administration was perhaps more concerned with controlling the population and raising revenues than with issues of forest conservation. The practice was gradually restricted, then prohibited entirely in 1897 (Buchy, 1996).

The pre-colonial period – Before 1800 C.E.

This period was also described as “pre-commercial” by Nadkarni *et al.* (1989). The central Western Ghats during this time were difficult to access and cultivate. Population was kept to minimal levels by the prevalence of malaria in the region. From the point of view of settled agriculturists, the forests were simply as an extension of the cultivated space. Thus the forests were (and still continue to be) extensively used by peasants to graze livestock, to hunt, to collect fuel, timber, leaf litter, green manure, seeds, fruit, honey, waxes, and gums.

Low population densities may have mitigated the effects of use conflicts that were already in place prior to colonisation. Class divisions, exploitation, and inequitable resource use existed then, as they do today. Buchy (1996) shows that “the colonisation of land, development of agriculture, deforestation and burning of forests” has been recorded even before the arrival of the British. Deforestation also occurred as a result of fuel and timber extraction and from the grazing of livestock (Pouchepadass, 1993). There were however, some examples, which exist to this day, of community restrictions on rights of access to certain areas of the forest. These include the sacred groves, which can be found all over the Western Ghats (Box 2).

According to early British accounts there was no alienation of local people from the forest, despite the fact that the forest was legally State property. The villagers apparently enjoyed various forest "privileges", including the freedom to burn and clear tracts around village settlements, which were then used to graze cattle and as a buffer shielding the settlements (Nadkarni *et al.*, 1989). This situation was to change soon.

There was some commercial exploitation of forest product, although trade in valuable products such as sandalwood and ivory, and later in teak, was a monopoly of the state. Hyder Ali, one of the rulers of the period, had set up a shipbuilding dock in Honnavar, on the North Canara (now Uttara Kannada) coast, for which teak was needed. Elsewhere, sandalwood, teak, blackwood, and ebony was extracted and exported.

Box 2 - Sacred Groves of the Western Ghats

Sacred groves are examples of spaces that have been delimited from surrounding areas and set aside. These areas have generally carried some form of civil interdictions on use and access. They vary widely in size, ranging from less than a hectare up to a few square kilometres (Ramakrishnan, 1996). These spaces may consist of native vegetation, and in some cases serve as reservoirs of rare, endangered, or threatened plant and animal species (Gadgil & Vartak, 1974).

Freeman (1994) found that in Kerala, the Kavus have a variety of physical profiles and use patterns, and range from dense forests, to stands of a few trees, to scrub thickets. He asserts that it would be a distortion to single out the stand of virgin forest as the archetypal sacred grove. Groves are generally associated with a deity or deities who may reside within the grove or nearby. The practice of reserving areas as sacred is apparently a world-wide phenomenon, which has its origins in hunter-gatherer societies (Hughes & Chandran, 1998). In India, sacred groves are found throughout the country and known by a variety of names.

In the modern period, sacred groves have come under the pressures of a market economy and increasing population densities. Kalam (1996) studied selected Devara-Kadu in Kodagu district of Karnataka, and found that they had been subject to encroachment and in some cases, to plantation forestry by the Forest Department. Numerous other sacred groves across the country have disappeared altogether.

Opinion is divided over the issue of whether these spaces owe their existence to a conservationist ethic that may have characterised early society and folk belief systems. Writers such as Freeman (1994) have concluded that while it is imperative to preserve and restore forest resources, including the groves, it would be a mistake to appeal to some "well-spring of religious belief" or to attempt to reconstruct a "distinctively Indian eco-wisdom" for inspiration.

The Colonial Period – 1800 to 1947

The defeat of Tippu Sultan and the British take-over in the region saw the rise of commercialisation and the intensive working of forests. By this time, oak was almost entirely depleted in Britain, and the forests of Malabar and Canara were rich in teak, which was needed by the coloniser's navy. Initially, the East India Company presided over the reckless and often wasteful extraction of hardwood timber. More trees were felled than actually required, including those logs which could not be used (Nadkarni *et al.*, 1989).

Following the realisation that the valuable hardwoods may not be limitless, the colonial state moved quickly to establish monopoly control over teak. In 1806, the post of Conservator of Forests was established to control the extraction of timber for government purposes and to regulate private trade (Pouchepadass, 1993). All private extraction of wood became an offence under the law. These policies proved unpopular with peasants who were denied their rights of access, and with local timber merchants upset over the State monopoly (Buchy, 1996). The post of Conservator was abolished in 1823. This led to a renewed frenzy of exploitation. Entire forests were clearfelled and the more accessible areas left completely denuded. Various reports, including one from the Indian Navy board in 1830, urged the reintroduction of the conservation policy. The post was reintroduced in 1847.

Alienation, Overexploitation, and Conflicts

Railway construction, which began in 1853, required one million sleepers every year. The sleepers also had to be changed once every ten years, and sometimes more frequently. Timber for the sleepers was extracted from the teak forests of Canara.

Meanwhile, the first coffee plantations were started in Coorg (now Kodagu District) in 1854. Within ten years, 20,000 acres (8094 Hectares) of dense forest were cleared to plant coffee (Pouchepadass, 1993). This resulted in a terrible ecological disaster characterised by rapid soil erosion, “recurrent failures of drainage” and a drier climate. This situation was compounded by infestation of an insect pest described as the “borer” (possibly the stem borer). Brazil’s entry into the market, and the subsequent drop in world coffee prices ruined many planters. Abandoned estates were overrun by Lantana, a weedy shrub that rapidly dominated the region. The forests, vulnerable to the borer, were unable to recover quickly on the impoverished soil.

In 1855, the colonial state issued a memorandum restricting the free movement of forest dwellers (Ghosh, 1993). The idea of a management policy was gaining ground in administrative circles. Uncontrolled forest use by the growing peasantry was believed to be responsible for its gradual disappearance, and the need was perceived for a definition of usage and property rights based on strict legal categories (Pouchepadass, 1993).

Thus, a staff of forest personnel was recruited to assist the Conservator in enforcing the existing laws, and regulations defining the functions of the Forest Department were drawn up in 1859. This was followed by the Indian Forest Act of 1865 [“Government Forest Act” according to Nadkarni *et al.* (1989)] which empowered the colonial government to declare any forest as State property. Existing rights and privileges enjoyed by the local communities in the surrounding forest areas were not however, affected. This act extended the earlier concept of “reserved trees” to classify areas of forest as either Reserved or Protected.

The Act proved inadequate, however, and was replaced by the Indian Forest Act of 1878. The new act was far more comprehensive, further restricted the rights of locals, and was principally concerned with defining the powers of the State. In addition to Reserved and Protected forests, the Act introduced a third category known as Village forests. Reserved forests were invariably those that were rich in timber, and were strictly off-limits to the peasantry except where there were predefined thoroughfares. Locals’ rights and access was permitted in protected forests, but these were liable to be withdrawn, and timber extraction was prohibited. It was in the village forests that locals were allowed to exercise their rights of access and collection (Nadkarni *et al.*, 1989).

Forest Department officers were invested with almost absolute authority, which could not be contested by any judicial proceedings (Buchy, 1996). The Department was under pressure to raise revenue and to expand. The subsequent years saw increasing areas of timber-rich forest brought under reserve category. The forests allotted for local use were generally already in a degraded state, and these soon became overused. The natural resource depleted, it became increasingly difficult to gather biomass for daily fuel and fodder needs. Artisanal forest-based industries declined, rural employment declined. It was a recipe for disaster, and there followed a long history of forest grievances, of resistance to, and conflict with the Forest Department (Pouchepadass, 1993).

To be fair, there were voices within administrative circles that recognised the rights of tribals and villagers and spoke of the need for equity and balance. Notably, it was Dietrich Brandis, the first Inspector-General of Forests who advocated various progressive initiatives. In the 1870s he pleaded for the revival and strengthening of village communal institutions and their recognition by law. Unfortunately, his supervisors in the imperial government did not appreciate these efforts (Gadgil & Guha, 1992).

Scientific forestry

The 1880s also saw the beginning of the era of "scientific forestry", the study of flora, control of pests and diseases, and Working Plans. The forests were to be managed systematically in the interests of sustainable use. Trees in mixed forests were selectively felled, and managed such that the species mix favoured high-value timber trees. Teak was particularly in demand and many artificial, monocultural plantations were established. Vast areas of "inferior" forest were relieved of their usable timber, burnt, and seeded with teak (Nadkarni *et al.*, 1989). Teak was planted well outside its natural habitat, even in the evergreen forest areas (Pouchepadass, 1993). Reserves of nursery saplings were maintained, to be used in case seeding was unsuccessful.

The Forest Act of 1927 retained the classification of forests that were established in 1878. Nadkarni *et al.* (1989) contend that the Act emphasised the rights and privileges of individuals over those of communities, and that this was intended to appease local élites by legitimating traditional forest use privileges such as *betta* (Uttara Kannada), *kumaki* (Dakshina Kannada), and *bané* (Kodagu). This Act, although amended, has not yet been replaced.

The Colonial period therefore, saw a shift from an essentially usufruct society to one based on individual property ownership, and from mixed stands of relatively undisturbed forests to managed monocultural practices (Ghosh, 1993). It saw the disruption of links between agriculture and forest, and the increasing concentration and centralisation of power in the hands of the State and the Forest Department. Most importantly local and community needs were subordinated to the commercial interests of large-scale industry and the wider economy.

Karsenty *et al.* (1999) describe a similar colonial experience under the French in West Africa. There, the definition of forest as a specific area, separate from farmland and agrarian systems, contributed to the State monopoly on forest management. These ideas were an outcome of the European 19^{th} century agricultural revolution. Even in Europe, the imposition of monopoly rights, accompanied by a great deal of conflict, was to the advantage of a few "eminent landowners" who were anxious to limit encroachments and user rights in forested land which they regarded as exclusively their own.

The Post Colonial Period – 1947 to present

The Industrial imperative

Independent India's first National Forest Policy of 1952 recognised the need for "balanced and complementary" land uses; the protection of hill slopes, watershed areas, and the prevention of soil erosion; the need for separate village plots for biomass needs, and the supply of timber for industry (Ghosh, 1993).

According to Shyamsunder & Parameshwarappa (1987), "at the beginning of the first Five-Year Plan in 1951, resources were scarce and the country was faced with the problem of generating resources for industry and other development projects". In fact, industrial development and centralised planning were the order of the day.

Various influential groups benefited vastly from state subsidies on raw materials, water, power, and fertilisers. They maintained and strengthened the institutions of state control over forests. As before, the bulk of the rural population, including landless labour, marginal farmers, nomads and tribals, had their interests sacrificed (Gadgil & Guha, 1992). Manufacturing that used forest resources had in fact been established prior to independence. And Nadkarni *et al.* (1989) argue that the effect of industrialisation was to spur resource consumption through technical change such as mechanised sawmills.

India's industrial capital was drawn to the forest resources of the region, where plywood units, paper mills, and rayon manufacturing were set up. These industries had agreements with the Forest Department for the supply of raw material at pre-arranged prices. The prices were absurdly low, and "were not based on a proper perception of scarcity of *in situ* forest resources" (Nadkarni *et al.*, 1989). Neither was the user interested in regenerating the resources consumed. For example, the paper industry was provided bamboo at one rupee per tonne in the 1950s, when the prevailing market price was two thousand rupees per tonne. Commercial and industrial interests had replaced strategic imperial requirements as the cornerstone of forest policy (Gadgil & Guha, 1992).

During this time, forestry operations were based on the concept of sustained yield forestry, itself a hangover from the "scientific forestry" ideas of the 19^{th} century. The forests were worked in cycles to allow time for trees to regenerate. For a variety of reasons, including an inadequate existing knowledge base on tropical forests, the system failed to generate the sustained yields expected (Gadgil & Guha, 1992). Demand for forest produce was generated not only from industry, but also from the electrification projects, which required poles for power lines. Forests were cleared rapidly and replaced by mining projects, dams and reservoirs, roads and colonies, and cultivated areas.

The emphasis on agriculture during this time also impacted on forest resources. And the stress laid on balanced land use and maximising returns from forests led to the establishment of monoculture plantations.

Shifting priorities

The Forest (Conservation) Act of 1980 was a significant landmark, and an important step towards conservation in practice. It prohibited state governments from de-reserving forests. It prohibited the use of forest land for "non-forestry purposes". It prohibited the leasing out of forest land. Most significantly, it prohibited the clearfelling of trees. Nevertheless, use conflicts remained and grew worse throughout the 1980s. The National Forest Policy of 1988 acknowledged that "the tendency to look upon forests as a revenue raising resource" was responsible for serious depletion. The Policy went on to emphasise the importance of meeting the biomass needs of local populations. (Ghosh, 1993)

Since 1988, there has also been official recognition and encouragement of the practice of Joint Forest Management (JFM). It is envisaged that village forests, locally managed by decentralised *Vana Panchayat* (forest committees), will be developed and conserved. There have been a few cases of successful implementation, notably in West Bengal and Orissa (Raju, 1996). The programme is still being tested in Karnataka and other states.

The Plantation Forestry and Social Forestry experiments in the 1970s and '80s were failures because they failed to halt the degradation of India's natural forests. Saxena (1997) suggests that, contrary to generally accepted practice where market (or commercial-industrial) needs are met by the private sector, and welfare / infrastructural needs are met by government or the public sector, in Indian forestry the reverse was attempted. This was one of the main reasons for its failure, he asserts.

The 1988 Forest Policy and June 1990 guidelines on JFM put forth a complete reversal of the old policy, and also specified the rights of communities. The guidelines urged state Forest Departments to co-operate with voluntary and non-governmental organisations, to use their accumulated expertise, and to build up meaningful people's participation for the protection and development of degraded forest lands.

The concept of JFM is a hybrid property rights system, combining State property and common property. Members have rights to exclude people from other villages from forests under their management, and a right to share in the forest produce. The State reserves the right of ownership, the authority to exclude cultivation, and the rights to control the disposal of timber.

Saxena (1997) believes that is still too early to assess the impacts of the new Forest Policy and JFM on deforestation. Nevertheless, timber and fuelwood prices have stabilised since 1987, and this may have eased pressure on the forests.

While there are no universal prescriptions for efficient and equitable resource management, a number of important lessons have emerged from areas where the programme has been implemented. Communal tenure works best where the rules are simple and unchanging over long periods. A high level of tenure security increases resource conservation. For various reasons, people have a preference for trees that yield non-timber forest products (NTFPs). Market distortions (monopolies, withholding information) need to be cleared. Finally, communal institutions have to be strengthened, and people allowed to develop “countervailing forces” to remove exploitative middlemen, loggers, moneylenders, etc. (Saxena, 1997). Cohesive village communities are a necessary component of successful programmes.

It is now proposed that the concept of JFM be extended into the realm of Protected Area management (Box 3) which has suffered numerous problems in practice (Kothari *et al.*, 1995).

Box 3 - Wildlife Management and Protected Areas

The establishment of National Parks (NP) and Wildlife Sanctuaries (WS) gained impetus in the 1970s with the Wildlife Protection Act of 1972. This followed a long history of sport-hunting, overexploitation, habitat loss, extirpation and extinction. Today, a network of nearly 500 Protected Areas (PAs) exists across the country, including 26 in Karnataka. These have been quite successful in stabilising and even enhancing the populations of some endangered species (Gadgil & Guha, 1992).

However, their constitution and management have not been without problems. A major source of conflict is the concept of nature reserves as closed natural habitats “not materially altered by human exploitation and occupation”. This idea was borrowed wholesale from the west and imposed in a top-down fashion on Indian social and ecological conditions.

According to one survey carried out in the 1980s, 69% of PAs surveyed had human populations living inside, and 64% had community rights, leases or concessions inside them (cited by Kothari *et al.*, 1995). This has generated a great deal of conflict in the form of loss of land and forest rights, forced displacement of traditional communities, hostility and physical violence.

To add to these problems, there have also been numerous attempts by urban-industrial lobbies, some successful and backed by the State, to exploit PAs for activities such as mining, commercial forestry, dam-building, road-building, and privileged tourism. Kothari *et al.* (1995) allege that PAs have been, and continue to be set up and managed in an arbitrary manner, based more on administrative than on ecological considerations.

A number of examples of successful management do exist, however. Local communities and forest officials have co-operated in protecting wildlife, maintaining traditional rights, and keeping out urban-industrial pressures. A co-operative system of Joint Protected Area Management (JPAM) is now envisaged, through a partnership of the concerned parties, with the objective of ecosystem conservation and ensuring the livelihood security of local communities (Kothari *et al.*, 1995).

On March 4, 1997, the Supreme Court passed an order banning commercial activity and the felling of trees on State owned forest land. This decision has effectively put an end to all green felling. A draft Forest Bill to replace the Act of 1927 is now under review, and has generated a great deal of discussion on the need for an equitable and sustainable resource use.

Clearly, it is necessary to reconcile the imperatives of conservation and the fuelwood, timber, and NTFP requirements of the people. To do this requires a concerted management plan for the forests. Input from all the stakeholders is necessary, and must be considered. The WGFP (see earlier section) aims at such an objective, inviting participation and sharing responsibility from the grassroots through institutions such as VFCs and JFM. It also aims to subdivide the forest areas into zones, which would indicate their priority in conservation. If the problem of forest management is that of reconciling diverse needs with scarce means, then a rational planning system based on well organised and ready information from diverse sources may go some way towards addressing these issues.

Chapter

2

The Study Area

A brief description of the Karnataka Western Ghats

Revenue administration and Forest administration

Karnataka – Districts and geographical regions

For administrative purposes, the State is divided into 20 districts (Figure 1). Each of these districts is composed of a number of *taluks*. Some districts have recently been bifurcated. At the time of writing this report, spatial data on these changes were unavailable.

The State has a total area of 191,791 km^2. Total population in the state is 44,977,201 (Census of India, 1991). State-wide population density is therefore 235 persons per km^2. Density however, is highly variable, and ranges between 2,210 persons per km^2 in Bangalore District, to 119 persons per km^2 in Kodagu and Uttara Kannada Districts (Figure 2). Other lightly populated districts include Hassan and Chickmagalur. Heavily populated districts include Belgaum, Dharwad, and Mysore.

From Figures 2 and 3, the regions of greatest population increase over a twenty-year period between 1971 and 1991 include the coastal areas of Dakshina Kannada, parts of Shimoga, and Mysore Districts.

According to the *State Gazetteer*, the State may be broadly divided into two physiographic divisions *viz.* The Coastal regions and the Karnataka Plateau. These may be further subdivided as follows.

The State's coastline is 400 km long from the Konkan coast in the north to the Kerala coast in the south. The coastal regions lie between the Arabian Sea and the Western Ghats. The region covers Dakshina Kannada District and the southwestern part of Uttara Kannada District. The Western Ghats rise steeply from the coastal plains, and form a ridge that runs parallel to the coastline. The word "Ghat" derives from the step-like scarps of the western edge.

The Malnad, or humid hill zone, reaching an altitude of between 1500 and 1800 metres, overlaps into the crest of the Ghats. The elevation is slightly higher here than the plateau to the east. The region is rugged, with a number of hills, receives a high level of rainfall, and is densely forested. It includes the southwestern parts of Belgaum, northern and eastern parts of Uttara Kannada, the extreme western parts of Shimoga and Chickmagalur Districts, southwestern parts of Hassan District, most of Kodagu, and extreme southwestern parts of Mysore District.

The Maidan or eastern plain, is composed of open and gently undulating country to the east. It is relatively flat, and merges with the Karnataka Plateau. The Northern Maidan includes eastern parts of Dharwad and Belgaum Districts. The region is drained by the Krishna and Godavari river basins. The southern Maidan is a broad, undulating plateau. It includes many local hill ranges, and the districts of Chitradurga, Mysore, Mandya, and the eastern parts of Hassan, Chickmagalur, and Shimoga Districts that are not part of the Malnad.

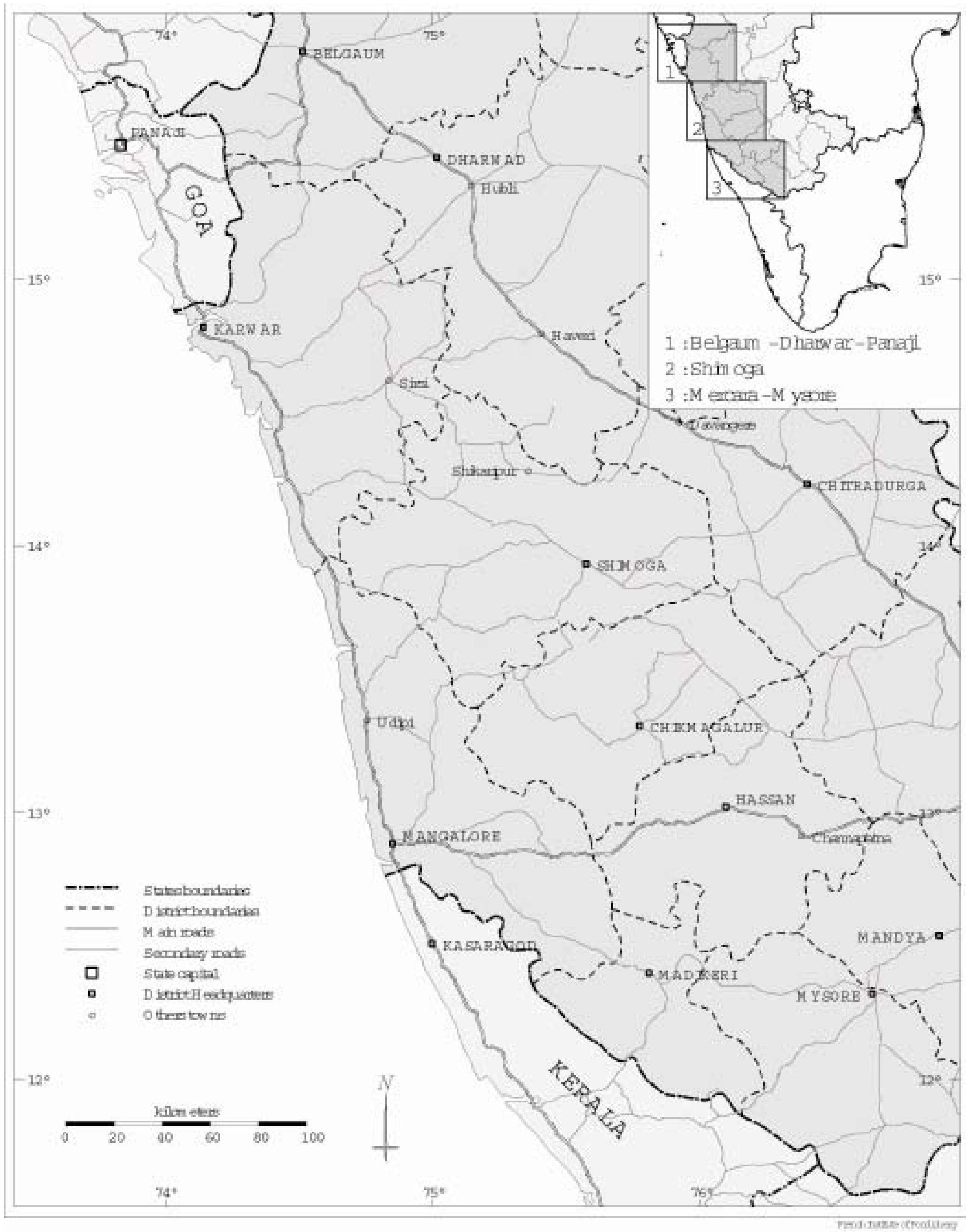


Figure 1: Political map of the study area. Inset shows the State of Karnataka in relation to southern India, and the study area of the project as covered by sheets 1 to 3 of the Forest Map.

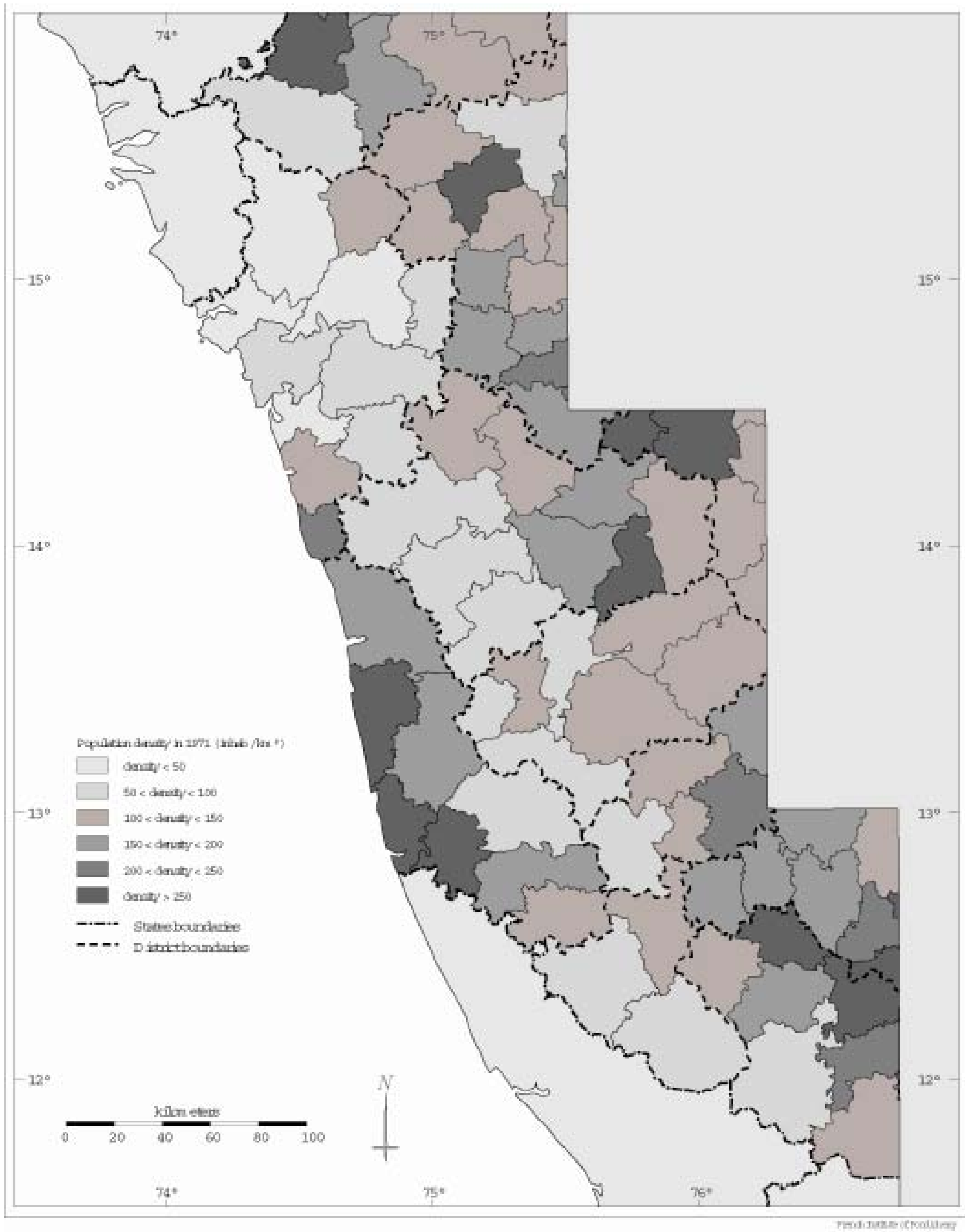


Figure 2: Population density in 1971

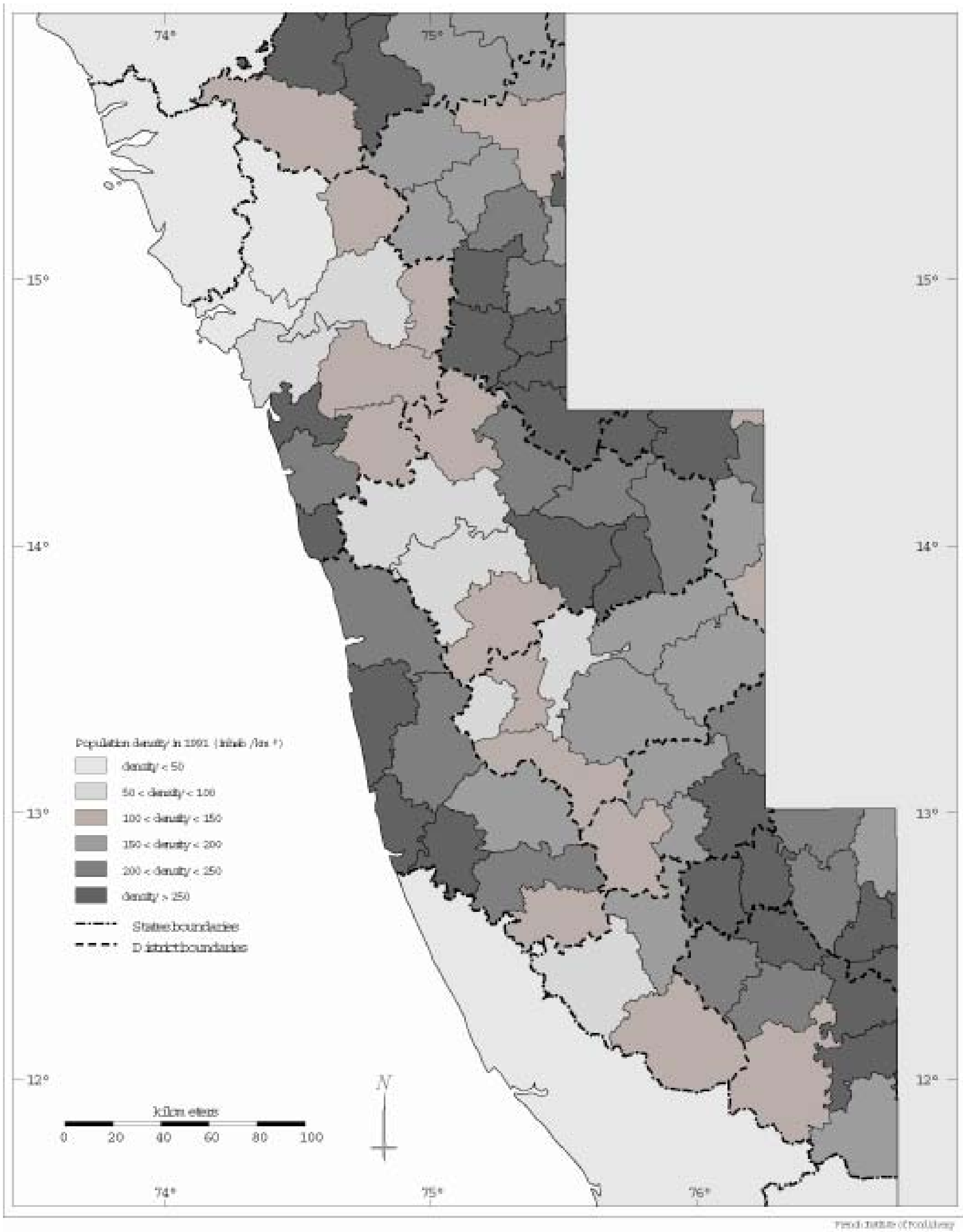


Figure 3: Population density in 1991

Karnataka - Forest administration

The Karnataka Forest Department has divided the State's area into 8 administrative circles. These are Kanara, Shimoga, Coorg, Mysore, Hassan, Belgaum, Bellary, and Bangalore. All but the last are either entirely or partially included in the study area of this project. These Circles in turn are divided into various 'forest divisions', of which there are 33. These 33 divisions are composed of 164 'ranges'.

Ranges are further sub-divided into 'forest blocks', which are defined as "a natural main division of a forest, generally bearing a local proper name or [assigned] number". Blocks are usually Reserve / State forests. Other forest categories include Protected / Minor forests, Village forests, and Revenue land.

Karnataka State contains 21 Wildlife Sanctuaries and 5 National Parks as Protected Areas (PAs) under the Indian Wildlife Act 1972 (Figure 4).

The study area however, is only part of the State. Table 1 shows the numbers and the total areas of forest administrative units located in the study area.

Table 1: Some details on the forest administrative areas within the study area

Number of circles	6
Number of divisions	23
Number of Reserve Forests	803
Total area of Reserve Forests	1,792,599 ha
Total area of the study area	7,165,090 ha
Number of Wildlife Sanctuaries	12
Total area of Wildlife Sanctuaries	178,724 ha
Number of National Parks	3
Total area of National Parks	285,497 ha

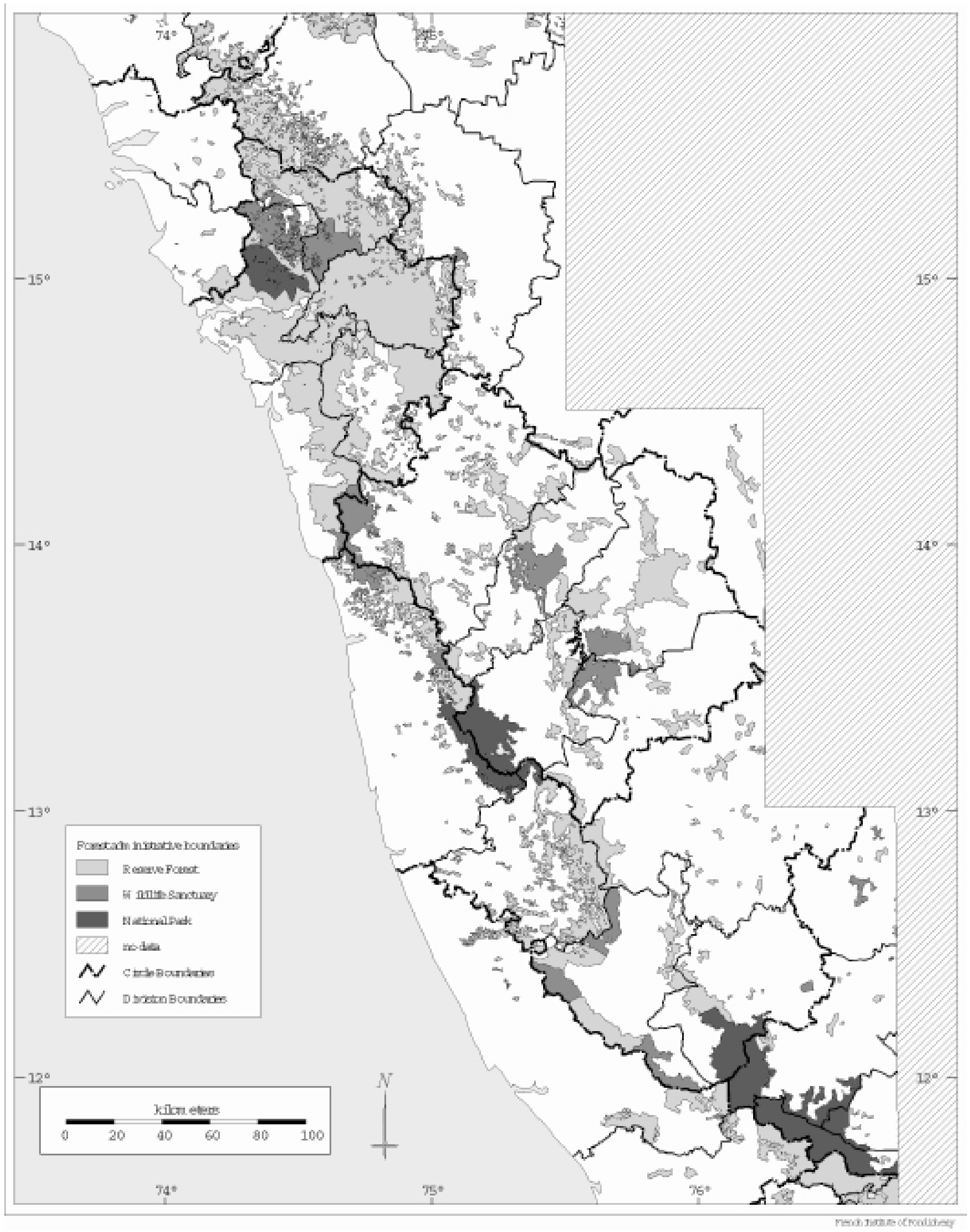


Figure 4: The protected areas of the study area, composed of Reserve Forest, Wildlife Sanctuaries, and National Parks.

A physical outline of the study area: relief and soil patterns

The Karnataka Plateau is limited to the west by the Western Ghats 'great escarpment', overlooking the coastal lowlands of Konkan and the Arabian Sea and drained by rivers flowing east to the Bay of Bengal. The general geometry of this major relief feature recalls the configuration of other high-elevation continental margins, such as eastern Brazil, eastern Australia, southern Africa or eastern Madagascar. At the western edge of the Karnataka plateau as a whole (Figure 5), the summer monsoon rains are orographically exacerbated by the Western Ghats relief barrier (Gunnell, 1997). The relative relief can reach 1,800 m and is responsible for a steep environmental cline from the edge of the plateau into the upland interior.

The uplands have evolved through a succession of regional denudational episodes, each tuned to the long-term tectonic activity of the Indian subcontinent (Gunnell, 1998a). And the Western Ghats escarpment shows signs of having receded, in post-Cretaceous times, by 40 to 70 km under the influence of headward erosion from west-flowing rivers (Gunnell & Fleitout, 1998, 1999; Widdowson & Gunnell 1999). Numerous signs of stream piracy by these rivers inland from the escarpment, point to the ongoing nature of the phenomenon. This process of scarp recession indicates that many palaeo-environmental clues to the evolution of the plateau have probably been obliterated. Nevertheless, the soils of the region are all strongly influenced by the present-day climate which, in all probability, was not fundamentally different in the geological past at timescales which are relevant to the study of vegetation patterns (Gunnell, 1998a). Indeed, the soil is predominantly lateritic from the coastline, up the escarpment and across the Karnataka plateau approximately as far as the 2000 mm isohyet. Beyond this, into the dry zone further east, the soil mosaic becomes more complex up to a point where forests dwindle into insignificance and escape the ambit of this study.

The humid hill zone, or *malnad*, is dominated by a landscape of rounded hills associated with interjacent flat, channelless valley floors. The annual soil water balance is consistently positive and the massive development of kaolinite as a product of rock weathering typifies the mode of soil development in this tropical climate (Gunnell & Bourgeon, 1997). The bedrock, whether fresh or even partly weathered, is rarely exposed, owing to the considerable depths of the soil profiles (10-40 m).

If greatly simplified, the lateritic soil geography (Bourgeon, 1989) in the *malnad* of Karnataka exhibits a strong positive correlation between the degree of desaturation (i.e., loss of nutrients: Ca, Na, K, Mg) or of rejuvenation by erosion of topsoil, and the local drainage and slope conditions under the influence of the competing drainage systems on either side of the Western Ghats escarpment. Two main categories of lateritic soil may be of some relevance to a better understanding of the biodiversity pattern:

'Reworked' lateritic soils exhibit a layer of slope colluvium over an in-situ weathering profile. They are therefore thickened by the overlying slope sediment and this testifies to some recent or ongoing phase of erosion in the upper slope region where the soil profiles have been 'rejuvenated', and, accordingly, thinned by erosion. Rejuvenation implies that soil-forming processes are hindered or retarded due to erosion which, a forested area, is a partial consequence of slope angle and intensity of dissection by rivers. As such, rejuvenated profiles (upslope) and reworked profiles (downslope) occur mainly on drainage basins, which are controlled by west-flowing rivers. These are particularly significant north of 14° of latitude, in the so-called region of the Ghats breaches (deep gorges and waterfalls). Lithology appears to be entirely subordinate at the macrolevel.

Desaturated, or "impoverished" ferrallitic soils. The impoverishment of soil horizons involves little or no physical erosion and truncation of the profile but will imply a varyingly intense level of chemical desaturation and a more or less accelerated evacuation of clay and iron particles from the profile. These impoverished soils dominate the humid upland region wherever the east-flowing rivers have not yet been captured by the west-flowing systems. Slopes are more gentle and relative relief only significant wherever greenstone belts made up of resistant quartzitic rocks steepen the relief.

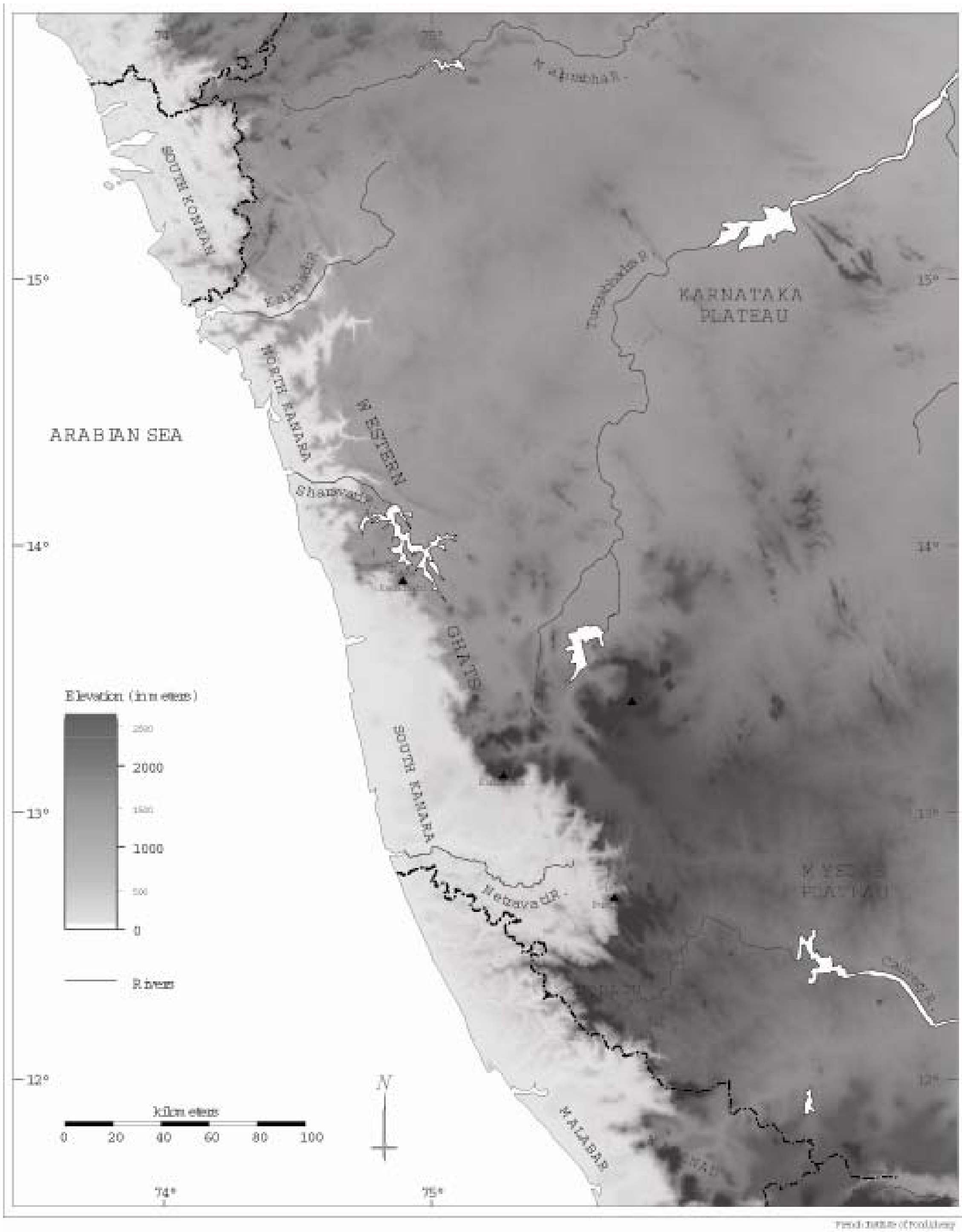


Figure 5: Physical map of the study area showing main rivers, peaks, and geographical regions.

The Bioclimate of the Study Area

Bioclimate is one of the most important factors in determining the types of vegetation of any region. The Western Ghats with its hilly terrain, is an escarpment parallel to the western coast, and harbours a wide array of bioclimates. The following are the bioclimatic characteristics of the study area, derived from the Bioclimatic map of the Western Ghats prepared by Pascal (1982b).

Rainfall

The southwest monsoon, linked to the arrival of moisture-laden southwesterly winds from the Arabian Sea, is a major phenomenon determining the rainfall of the Western Ghats between June and September. The differential timings in arrival and withdrawal of the south-west monsoon, and the orographic effects of the escarpment of the Ghats are the two major factors that are responsible for the south-north and west-east gradients in the rainfall regimes, respectively (Pascal, 1982b).

The south west monsoon which begins in the southern tip of the peninsula at the end of May or first week of June, arrives at the Kodagu region, and spreads to the remaining part of the study area within ten days. The withdrawal in the opposite direction begins in the month of September in Uttara Kannada and gradually reaches Kodagu two months later. This difference has resulted in a shortening of the rainy season from south to north and a corresponding decrease in dry season from north to south.

The progress of the monsoon from west to east brings heavy rains along the windward side of the Western Ghats. On a parallel stretch of 60 to 100 km, between the west coast and just over the escarpment of the Ghats, the rainfall varies between 2000 to 5000 mm. Within this zone, on either side of the crest of the Ghats, rainfall in isolated areas often reach more than 5000 mm. Agumbe, which is at 645 m altitude on the crest of the Ghats, receives an annual average rainfall of 7460 mm (Figure 4).

Towards the interior, the rainfall diminishes rapidly from 2000 to 900 mm within a distance of 10 to 50 km. In the transition zone (1500 – 2000 mm) the effect of the monsoon, although noticeable, is augmented by pre- and post-monsoon showers, which contribute considerably to the total rainfall per year. Further east, with the decrease in effect of south-west monsoon, the rainfall is more determined by thermic convection and sometimes due to cyclonic disturbance affecting the Bay of Bengal between October and December.

Temperature

The temperature gradient is mainly linked to elevation. Between 400 and 1500 m altitude, it has been estimated that decrease in temperature is almost 0.8 to 0.9° C for every increase in 100 m (Pascal,1982). Figure 5 shows isotherm lines of the mean temperature of the coldest month (t). Generally at low elevation (<800 m), between the coast line and over the crest of the Ghats, the 't' is more than 23° C. At medium elevations, especially over the hilly terrains of Kodagu, Chickmagalur and Hassan districts, the 't' varies between 16° to 23° C. However, the mean of the minima of the coldest month (M) is more than 15° C along the crest of the Ghats, and lower towards the interior. In high elevation (>1400 m) areas like Bababudangiri and Pushpagiri hill ranges, the 't' remains lower between 13.5° and 16° C.

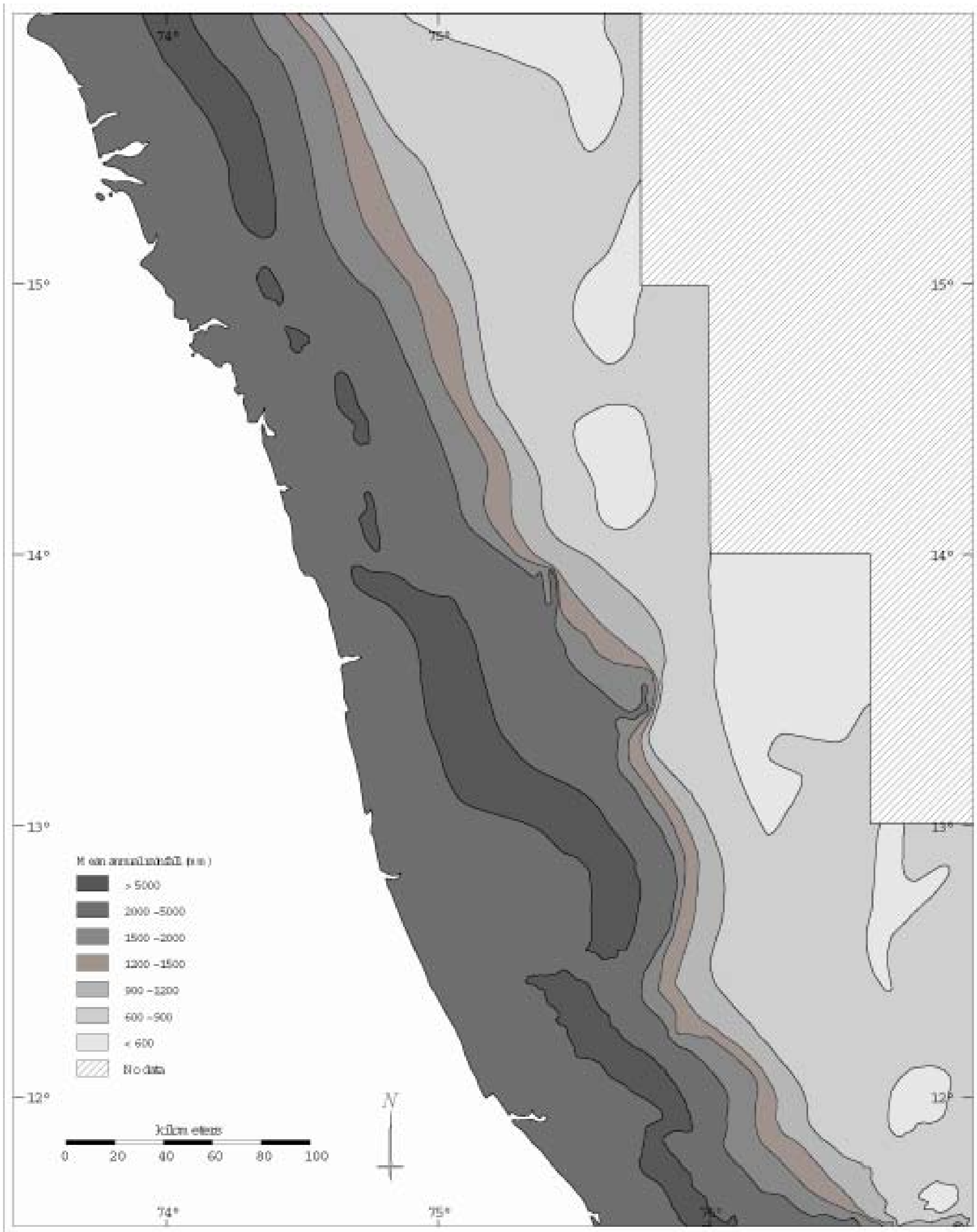


Figure 6: Rainfall in the study area

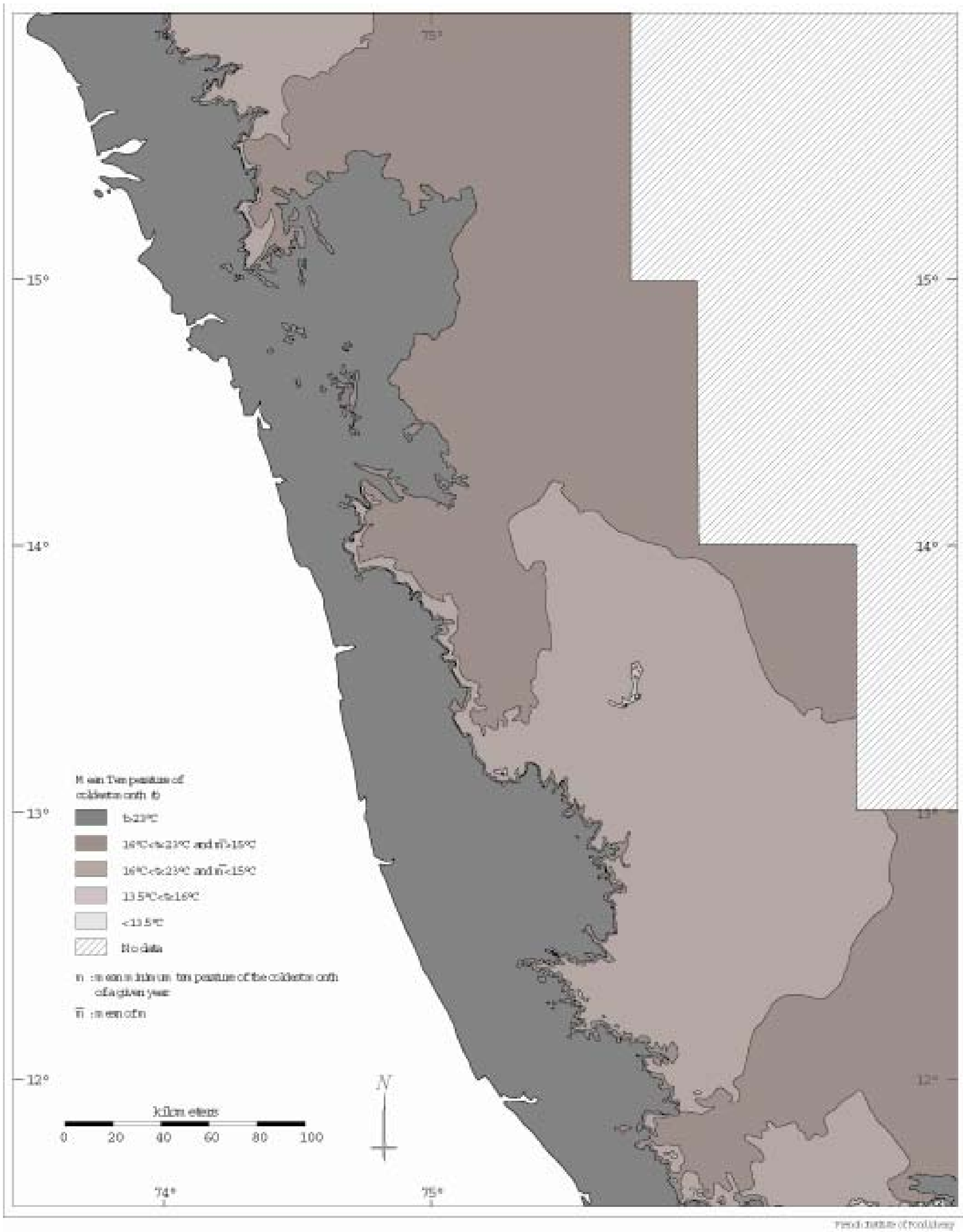


Figure 7: Temperature

Dry season

Length of the dry season is expressed in months. According to Bagnouls and Gaussen (1953) a month is considered as dry when the rainfall in mm is less than twice the value of the mean temperature (in °C). The number of dry months has been calculated for each year. Figure 6 shows the average number of dry months.

Along the south-north gradient, the increase in length of dry season from 4 to 7 months is related to the arrival and withdrawal of the monsoon. In the west-east direction, due to a sharp decrease in rainfall, especially in the southern region, the length of the dry season rapidly increases from 4 to 7 months within a distance of 55 km.

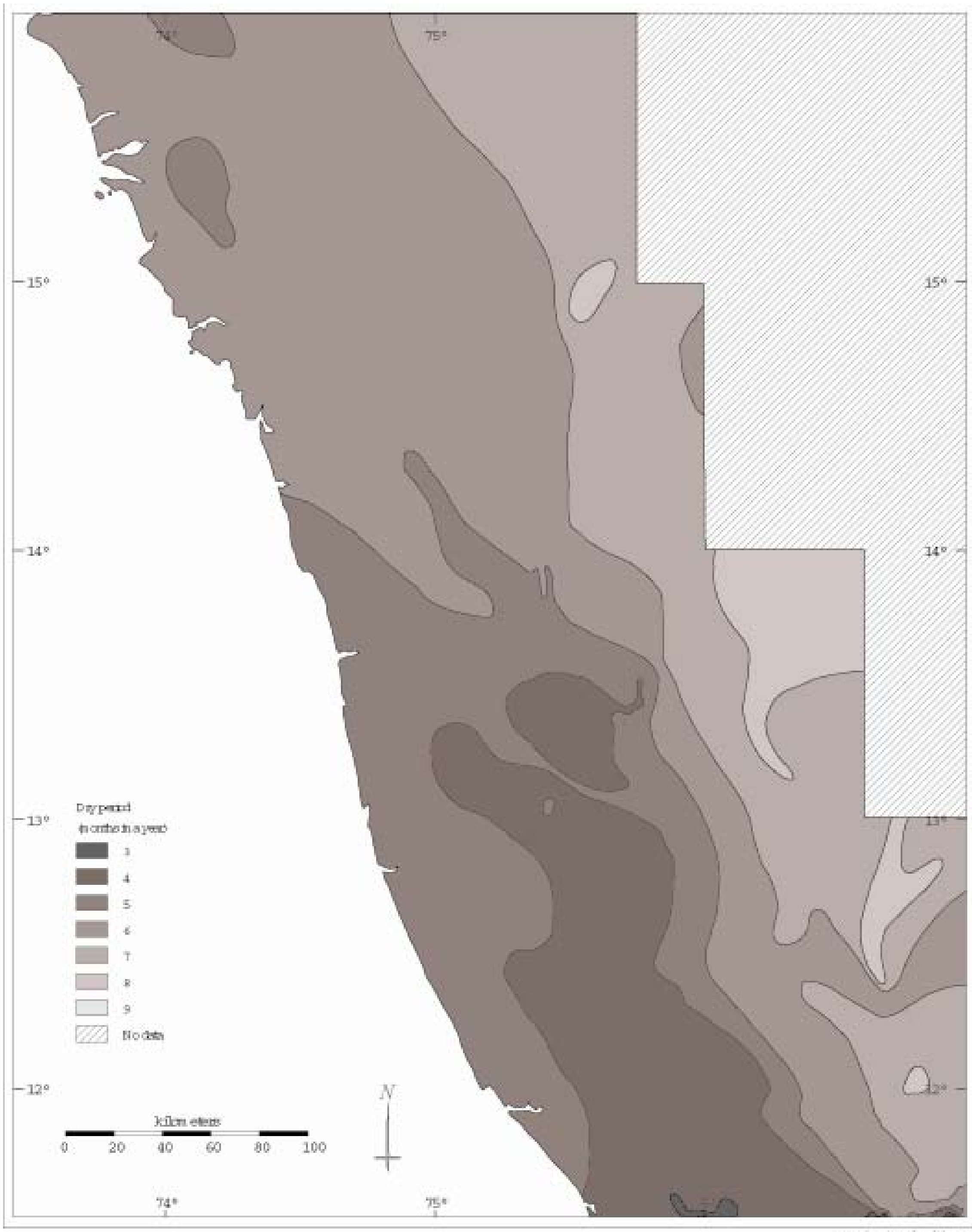


Figure 8: Length of dry season (in months) in the study area

Vegetation types

The diversity of vegetation in any region is mainly the result of abiotic factors such as the variety of bioclimate, soil, and topography. In addition, biotic interference especially of human activity has had a profound influence on vegetation, transforming it into varying degrees of degradation.

Criteria for classification

Concepts of climax and succession

Pascal (1986) while classifying the vegetation of the Western Ghats, followed the concept of 'climatic climax' in describing the floristic association and structure of the forests and, their successional stages.

Box 4 - Climatic climax

According to Clements (1916, 1936), a climax is the mature stable and optimal state of a phytocoenose, representing the final outcome of a progressive series of successive stages of vegetation. Under a given climate, all the successions converge towards a unique climax, which is the 'climatic climax'.

As far as the forest is concerned, the notion of climax has been further modified by recent authors (Hall *et al.*, 1978; Whitmore, 1978; Pascal, 1984, 1986) by considering the whole mosaic of a forest, which includes sylvegenetic dynamics, structure and floristic composition, when it is in equilibrium with the environmental conditions.

Succession of vegetation is either progressive towards the climax, or retrogressive (Figure 7). The former deals with events taking place over several decades or even a longer period. The latter is due to exploitation without suitable conservation measures. The degradation of climax formations may lead to two types of formations;

1. Formations with moderate exploitation, which could return to a climax if protected. They are called potentially climax-linked.

2. Highly degraded formations with different physiognomy are due to repeated logging and other biotic pressures like grazing and fire. These formations may no longer return to a climax under natural conditions.

Based on these concepts, the vegetation of the Western Ghats are classified using physiognomy, phenology and floristic composition (Pascal, 1982b & 1982c, 1984; Ramesh *et al.*, 1997).

Physiognomy

The physiognomy (external appearance of the vegetation which includes biological forms, structure and density) of the degraded formations may vary according to the mode of disturbance (Trochain, 1957; Legris, 1963). When fire is the destructive agent, the vegetation is savanna-woodland to tree savanna, characterised by tall grasses forming a more or less continuous ground cover. In the former, the trees are dense with distinct overlapping of crowns. In the latter, the trees are widely spaced. Shrub savanna (grassland) is a mixture of grasses, shrubs and herbs; trees are very scattered or absent and grass cover is continuous.

Table 2: Climax forest types in relation to bioclimate

		Forest types	Annual rainfall (mm)	Temperature (C°) t	Temperature (C°) $\bar{m}$	Temperature (C°) T	Dry season (month)
Evergreen and Semi evergreen climax forests	Low elevation types	Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonis	2000-6000	>20	>14	25-31	4 -5
		Dipterocarpus indicus-Humboldtia brunonis-Poeciloneuron indicum	5000-8000	>20	>12.5	25-27	4.5 slope 5-5.5 plateau
		Dipterocarpus indicus-Persea macrantha	>2000	20-23	13-16	25-29	5-6
		Dipterocarpus indicus-Diospyros candolleana-Diospyros oocarpa	3500-7000	>20	>15	25-30	5-6 slope 6-7 plateau
		Persea macrantha-Diospyros spp.-Holigarna spp.	2000-6000	>23	>15	28-31	6-7
		Diospyros spp.-Dysoxylum malabaricum-Persea macrantha=Kanforest	1500-2000	23-24.5	>18	26.5-28.5	6-7
	Medium elevation types	Mesua ferrea-Palaquium ellipticum-	2000-5000	17-22	<15	23-25	4-5
		Poeciloneuron indicum-Palaquium ellipticum-Hopea ponga	5000-7000	18-20	<15	23-25	4-5
		Memecylon umbellatum Syzygium cumini-Actinodaphne angustifolia	5000-6500	17-22.5	<15	25-30	5-7
	High elevation type	Schefflera spp.-Meliosma arnottiana-Gordonia obtusa	>2000	13.5-17	9-13	20-25	3-6
Deciduous climax forests	Moist type	Lagerstroemia microcarpa-Tectona grandis-Dillenia pentagyna	1500-2000	>20	13-20	25-31	4-7
	Dry types	Anogeissus latifolia-Tectona grandis-Terminalia alata	750-1500	>20	13-20	25-31	5-8
		Anogeissus latifolia-Chloroxylon swietenia-Albizia mamara	<800	>20	13-22	26-31	7-8

t = mean temperature of the coldest month; T = mean temperature of the hottest month; m = mean of the minimum of the coldest month of a year; $\bar{m}$ = mean of m

Scrub woodland and thickets are the result of cutting and grazing. Scrub woodland describes a thicket in which a few short-statured trees emerge in places. Thickets represent clumps of thorny shrubs and coppice shoots of unarmed trees. They are either closed or discontinuous, depending on the degree of disturbance (Figure 7).

Phenology

Forests are separated into 3 categories based on the relative percentage of evergreen and deciduous species;

1. Evergreen forests comprise pure patches of evergreen species, although a few deciduous ones may be found in the openings.

2. In deciduous forests, the majority of species shed their leaves in a particular season.

3. Semi-evergreen forests are a mixture of deciduous and evergreen species in varying proportions.

Floristic association

Floristic associations are derived based on certain species with characteristic distribution patterns that are mainly determined by the bioclimate and sometimes by edaphic conditions.

Relationship between climate and vegetation types

Using the above-mentioned criteria, Pascal (1986) has classified natural vegetation into evergreen and deciduous climax forests and their degradations. Totally 54 habitat types have been recognised (Annexe 1). These types are either a combination of floristic types and physiognomy or physiognomy alone.

The major floristic types (Table 2) are closely correlated to the temperature and rainfall regimes (Pascal, 1986). Evergreen, moist deciduous and dry deciduous climax types are clearly distinguished by the mean annual rainfall, whereas low elevation evergreen, medium elevation evergreen and high elevation evergreen floristic types are distinguished by the decrease in minimum temperature with the increase in altitude.

Evergreen and semi evergreen climax types

Excepting ‘Kan forests’, all the evergreen and semi-evergreen types are found in high rainfall zones (>2000 mm). In the low elevation forests, six major floristic types have been recognised. Along the evergreen belt northwards up to 14°25’N, these types are characterised by *Dipterocarpus indicus*. However, other associates like *Kingiodendron pinnatum* and *Humboldtia brunonis* lose their importance with the increase in dry period (>4.5 months) and, are gradually being replaced by *Diospyros* spp. Further north, beyond the Sharavati river valley, and with the increase in dry months (6-7), low elevation forests are characterised by species with higher ecological amplitude like *Holigarna* spp. and *Persea macrantha*.

The ‘Kan forests’ around the Soraba (14°10’N – 14°45’N) area are found in the rainfall zone between 1500 and 2000 mm. These are considered as edaphic facies maintained by the soil moisture regime (Pascal *et al.,* 1988).

Among the medium elevation types, *Mesua ferrea* - *Palaquium indicum* becomes the predominant type in the study area up to 13°30’N. *Poeciloneuron indicum,* which is generally common in very high rainfall areas (>5000mm) becomes a distinct type by its gregarious presence along with *Palaquium indicum* and *Hopea canarensis* especially in the Kudremukh area. However, north of the Kali river, with the increase in dry months (5-7), medium elevation forests are literally dominated by *Memecylon umbellatum* along with other characteristic species like *Actinodaphne angustifolia* and *Syzygium cumini*.

Forests at high elevation, above 1450 m and with relatively low temperature, are characterised by the *Schefflera* spp. - *Meliosma arnottiana* - *Gordonia obtusa* type.

Deciduous climax types

Within the study area, all the deciduous climax forests are confined to the Karnataka plateau and to the east of the evergreen formations, where the rainfall is <2000 mm. As a transition (between 1500 and 2000 mm rainfall) to dry deciduous types, moist deciduous climax forests are characterised by *Lagerstroemia microcarpa - Tectona grandis - Dillenia pentagyna.* With the further decrease in rainfall below 1500 mm and concomitant increase in dry period from 5 to 8 months, two dry deciduous types have been recognised, which are characterised by either of the following types: *Anogeisus latifolia - Tectona grandis - Terminalia alata* and *Anogeisus latifolia - Chloroxylon swietenia - Albizia amara*.

Secondary moist deciduous forests are to a certain extent similar to primary deciduous forests in floristic composition. However, its very presence in the potential area of the wet evergreen forest (rainfall > 2000 mm) suggests the secondary nature as one of the successional stages towards degradation.

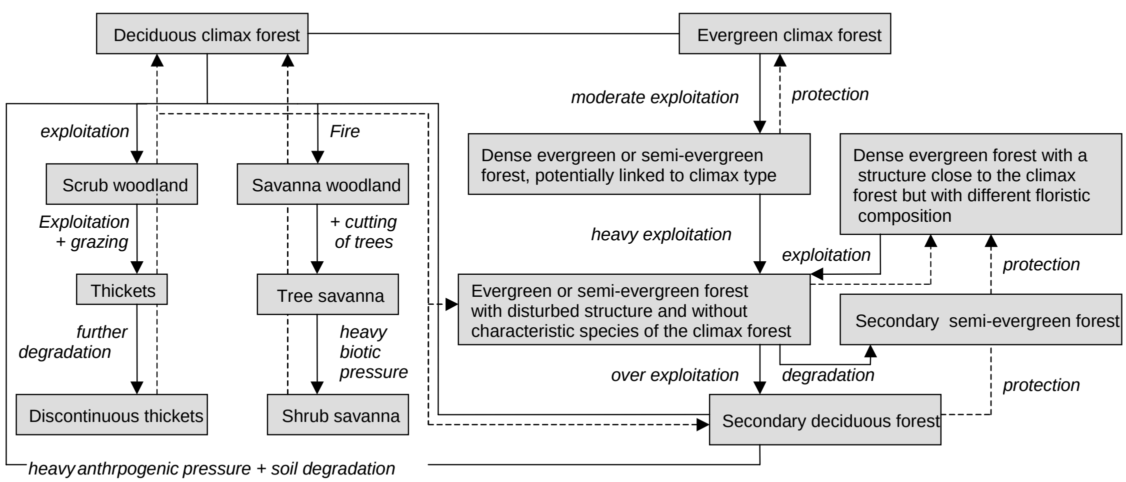


Fig. 9: Stages of successions derived from climax forest (adapted from Pascal, 1986; Ramesh, 1989)

Chapter
3

Updating the Forest Map: Part I

Building the geographical database: tools, methods, and theory

Materials and Methods

Building the Geographical Database: February 1997- August 1999

Vegetation maps of the French Institute (Pascal, 1982, 1984) at 1:250,000 scale formed the basis for the geographical database (Figure 10). They were based on 1972-1977 Landsat TM images as well as documents obtained from the Karnataka Forest Department and other sources such as Survey of India (SOI) topo-sheets and administrative maps. All information from the maps, considered as separate thematic layers, were redrawn on transparencies. The information layers were then scanned and vectorised, or directly digitised, depending on their complexity, and thus transferred to the database.

Box 5 - Materials

GIS software: Arc/Info (Environmental Systems Research Institute, release 7.0.4 for Unix), Kaleidos (Arc/Info macro commands library developed by the French research organisation, INRA)

GIS hardware: Sun Sparc-station 5 workstation, Calcomp drawing board III digitising table, Hewlett Packard “Designjet 750c Plus” plotter, Garmin geo-positioning system (GPS)

Satellite imagery: Indian Remote Sensing Satellite (IRS) 1B-LISS2 and 1C-LISS3, False Colour Composite photo prints, March 1997 (1:125,000 scale)

French Institute of Pondicherry Forest vegetation maps (1:250,000 scale). Sheet 1 (Belgaum-Dharwar-Panaji, 1984), Sheet 2 (Shimoga, 1982), Sheet 3 (Mercara-Mysore, 1982)

Current extent and content of the geographical database

The Karnataka Western Ghats lies within the extent of sheets 1 to 3 of the Forest Map of South India. The purpose of building the geographical database was both to update the vegetation maps, and to carry out spatial and temporal analysis on the study area.

The geographical database now consists of a number of digital spatial information layers (Table 3), which can be combined, overlaid and analysed, using Geographical Information Systems (GIS) technology. Each spatial information layer is documented; each feature is described by one or several semantic attributes. The two principal information layers are the land cover layers of 1977 and 1997. They were processed and overlaid in order to analyse the changes of land cover (extent and landscape) between 1977 and 1997 in a spatial and temporal way. The district boundary layer was built for specific geographic, administrative unit analysis. The layer of forest management units is useful as a means of assessing the efficacy of official protection status, and to allow identification of areas that may require special attention. The bioclimate is represented by a digital version of the 1:500,000 bioclimatic maps (Pascal, 1982) on the Western Ghats area. The bioclimatic maps display the temperature and rainfall regimes, and the lengths of the dry season (Figures 6 to 8). The positioning of sample plot locations on the database allows us to link descriptions of each of the plots to their spatial environment (bioclimatic zones, forest vegetation, and anthropogenic effects within a specific radius).

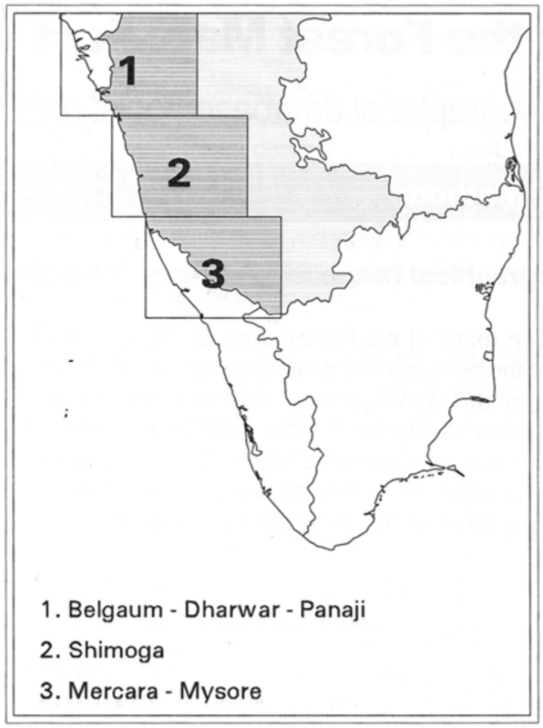


Figure 10: Location of the study area in relation to southern India. The study area within the state of Karnataka is shown dark grey. The three relevant sheets of the forest map are located on the figure.

Base land-cover layers: The 1977 vegetation layer

The existing forest maps 1 to 3 were used to copy vegetation limits, as polygons, onto transparencies. These were then scanned to produce raster image files. Raster files were converted to vector format on Arc/Info. This process invariably produces numerous errors, which have to be checked and corrected manually. Once this process of cleaning is complete, the layer is geo-referenced to locate the data in space. This allows the overlay and superimposition on other layers, and various other methods of data manipulation and analysis.

The information layer, or *coverage*, then required attribution, a process whereby the features (in this case they are vegetation polygons) have semantic attributes assigned to them. The ‘veg-code’ that was assigned to each of the polygons is also derived from the FIP maps, and describes the polygon’s vegetation type, elevation class, physiognomy, and other features.

Other layers were similarly derived, digitised, and attributed. For example, the “roads network” layer on the database contained semantic attributes for each of the arc features that made up the layer. These attributes specified whether the roads (arcs) were primary, secondary, or tracks.

The 1997 land cover layers:

Visual interpretation of 1997 IRS-1B and 1C satellite images, combined with field surveys, facilitated the update of 1977 vegetation coverages to 1997 vegetation coverages. This was done by digitising the changes of forest limits and forest physiognomic levels (Figure 9). Thus it is possible to determine changes from one physiognomic level to another (degradation) and from forest to non-forest cover (loss). At the same time, the changes in surface hydrology (new lakes) have also been recorded. The method of updating was defined and applied as follows.

Vegetation and Surface Water (lakes, reservoirs, and large rivers) information layers were combined (overlaid) and printed on transparency film together with the attribute code. The film was then overlaid on satellite imagery, changes were noted, and vegetation and surface water boundaries were redrawn (Box 6).

False colour composite satellite imagery from the Indian Remote-Sensing Satellites IRS-1B and 1C (1997) were used. These offer better accuracy, at 23m spatial resolution, than the images that were used to create the original maps. Firstly, using the imagery as background, the digital coverage was checked to identify and eliminate obvious errors of interpretation that may have occurred during the preparation of the original maps. Obvious types of error include, for example, areas that are shown as agricultural areas but are in fact covered by forest. These were also cross-checked in the field. And amendments were manually digitised out of corrected transparencies.

Next, the actual changes were noted, using the same procedure outlined above. Transparencies containing the new modifications were placed on a digitising Table, and all changes were digitised. A new information layer was thus created, and after cleaning and checking attribution, was used as the 1997 vegetation (forest cover) layer. At present, 21,941 polygons are now delineated and described in the 1977 land cover layer, and 23,136 in the 1997 land cover layer, distributed across 54 different vegetation types.

Box 6 - Manual photo-interpretation:

The process involved interpretation of the colours and the homogeneity (or otherwise) produced by the False Colour Composite (FCC) print. Colour is a result of the spectral reflectance of the vegetation. For example, dense evergreen forests appear bright red on these images and disturbed areas show a less vivid and more heterogeneous coloration. Deciduous forests (or areas with a majority of deciduous species such as teak plantations) were readily distinguished on dry season photographs when the trees had shed their leaves; moist deciduous areas appear red-brown. Dry deciduous vegetation ranges from a pale red-brown to beige, depending on the degree of disturbance or density. Coffee plantations are bright red-orange, and readily distinguished from surrounding evergreen or deciduous vegetation. Rubber cash-crop plantations are a vivid, light pink colour. It is important to emphasise here that while the phenology and physiognomy of vegetation stands may be ascertained from this method, information on the floristic composition cannot be derived.

A critically important component of this method is that of ground verification. “Ground truthing” was carried out for initial interpretation, and also for later confirmation. A hand-held geo-positioning system (GPS) was used wherever possible for accurate location fixing. Dense tree cover frequently hindered the use of a GPS however, and locations had to be extrapolated from known landmarks as found on SOI toposheets (1:50,000). The ground truthing followed a rapid assessment method that enabled large areas to be covered within a short time period. This method noted the physiognomic structure and composition of selected areas

Table 3: Information contained in the database

Information layer	Type of features	Semantic attributes	Number of features
Reference year : **1977,** Land cover (forests and wood plantations, non forested areas, lakes, reservoirs and surface water) in 1977	Polygons	Veg-code, Usage-code, Forest main group, Forest sub-group, Elevation-class, Physiognomy, Floristic type	21,941
Reference year: **1997,** Information layers, complementary to 1977 Land cover in 1997	Polygons	Veg-code, Usage-code, Forest main group, Forest sub-group, Elevation-class, Physiognomy, Floristic type	23,136
Rivers network and shoreline (1977)	Lines (Arcs)	Stream type	11,135
Roads network	Arcs	Road type	10,661
Railways network	Arcs		331
Towns more than 100,000 inhabitants (1971)	Points	Population –1971_class	3967
Taluk boundaries (1980)	Polygons	Taluk name District name District code State name State code Population 1971 Population 1991	197
Forest management units (ranges, circles, etc.)	Polygons	Division-code	81
Protected areas (reserved forests, wildlife sanctuaries, national parks) boundaries (1980)	Polygons	Unit number Unit type	2,313
Bioclimatic zonation (1980): - rainfall, - temperature, - dry season	 Polygons Polygons Polygons	 Rainfall class Temperature class Dry season class	 56 262 59
Biodiversity sampling plots	Points	Plot-number	96

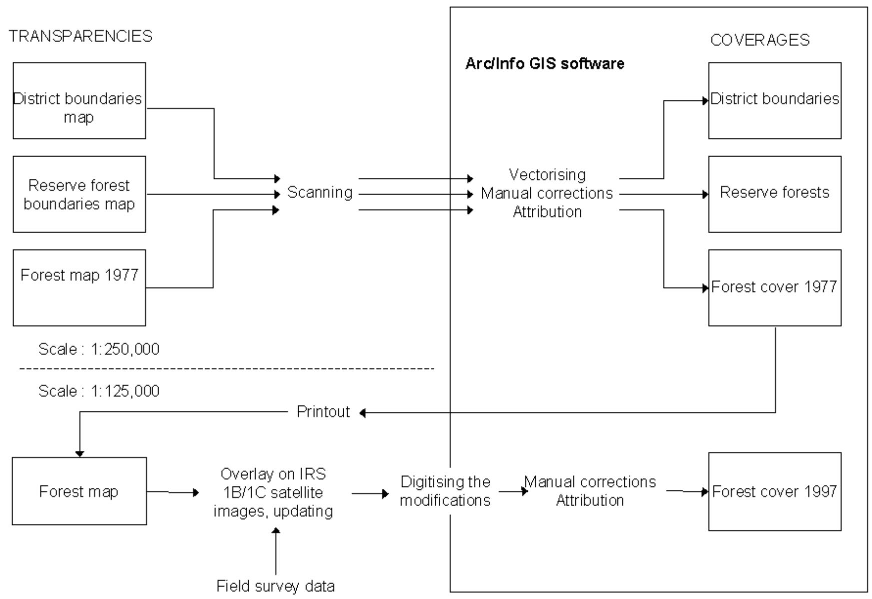


Figure 11: Steps in building the geographic database

Landscape analysis

Following the Convention on Biological Diversity, there has been a shift towards the ecosystem, community, or landscape level of study, and according to Barbault (1995) this together with landscape ecology should offer the best theoretical framework for analysing what he calls "biodiversity dynamics".

Landscape ecology aims to study patterns and processes, and focuses on landscape structure, function and change (Hobbs, 1995). Thus, with reference to our study, landscape structure in the form of vegetation composition and structure can be related to regional gradients in climatic variables, such as temperature and rainfall, and to changes in soil, landform and topography. At a finer scale, patterns may be the result of natural disturbances and human activity. Landscape *patches* are plant and animal communities surrounded by areas with dissimilar community structure or composition (Godron & Forman, 1983).

The Geographical Information System (GIS) developed under the project contains a spatially explicit database that allows us to carry out quantitative analysis of structure and change. Spatial structure can be described by patch origins, patch size, patch shape, and context. Furthermore, comparing structure from two time periods can assess landscape change. In our study, the time periods are roughly twenty years apart.

Landscape analysis was based on a generalised (reduced) typology comprising 15 land cover types, derived from physiognomic, floristic, elevation and forest groups characteristics. The revised typology included 11 forest types, 2 plantation types (coffee / tea plantations, and other forest or commercial plantations), and 2 non-forested types (agriculture, water tanks), as described in Table 4.

This typology was used in order to simplify the process of analysis, which would otherwise have become unmanageable with all 54 types that exist on the database and the forest maps.

Table 4: The reduced typology used in landscape analysis

No.	Type	Description
1	LEE Dense	Low elevation evergreen climax forests
2	MEE&HEE Dense	Medium and High elevation evergreen climax forests
3	LEE Dist & Sec	Low elevation evergreen and semi-evergreen, disturbed and secondary forests
4	MEE&HEE Dist	Medium and High elevation disturbed and secondary evergreen forests
5	SMD	Secondary Moist Deciduous, dense forest and woodlands
6	LEE Degraded	Low elevation evergreen, degraded forms (thickets, tree savannas)
7	MEE & HEE Degr.	Medium and High elevation evergreen, degraded forms
8	MD Dense-WL	Primary moist deciduous, dense forest and woodlands
9	MD Degraded	Primary moist deciduous, degraded forms
10	DD Dense-WL	Primary dry deciduous, dense forest and woodlands
11	DD Degraded	Primary dry deciduous, degraded forms
12	Coffee&Tea	Coffee and Tea plantations
13	Misc. Plantation	Miscellaneous forest plantations (teak, eucalyptus, acacia, rubber, casuarina)
14	Agri	Agricultural (cultivated) land, wasteland, barren land
15	Water	Surface water (reservoirs, lakes, tanks, large rivers)

Transitions

It is possible to quantify the total area occupied by any given vegetation type. It is also possible to overlay the two land-cover layers to perform spatio-temporal analyses. In our study, a transition matrix between 1977 and 1997 describes the changes, both in absolute area and in percentage terms, from one form of land-cover to another.

Patch size

Patch sizes and their variation within a given vegetation type were derived for the two time periods. This allows us to describe not only the frequency of various size classes of patches of any forest type at a particular time period, but also how this size distribution changed over time.

Patch shape

This is described by the ratio of its perimeter to area. Perimeter / Area ratios are of critical importance in landscape analysis in determining the impact of human activity on a landscape.

Both patch size and patch shape reflect the extent of habitat fragmentation of a landscape. According to Hobbs (1995), an important effect of human activity is the increasing fragmentation of natural ecosystems into small remnant patches. Habitat fragmentation has been studied in the light of two theories, that of island biogeography and of metapopulation dynamics (Collinge, 1996). Many species are adapted to large, rather than small patches of habitat. Therefore one effect of fragmentation may be to decrease species richness. Another effect is to increase habitat edges (illustrated by the perimeter/area ratio of patches) where different microclimatic conditions prevail, which selects against those species which require interior habitats (Vogelmann, 1995). Therefore, Menon & Bawa (1997) argue that habitat fragmentation accelerates species extinction due to factors such as demographic and environmental stochasticity, decrease in genetic heterozygosity, edge effects and human disturbance.

Patch context

This may be described as “the immediate mosaic-matrix in which a patch of a given type occurs” (Hobbs, 1995). One method for deriving this is to perform edge analysis. This gives us the length of the patch boundary or edge length that is shared with its neighbours, and what those neighbours are. When assessed against neighbouring anthropogenic patches, such as agricultural or settled areas, it can give an indication of the extent of existing or potential threat to a particular forest patch or patches from encroachment or other forms of disturbance.

Patch context can affect the present and potential future flows of materials and energy from one area to another. Constructing buffer areas around features of interest enables us to assess the comparative threat to forest areas or to reconstruct what may have already happened.

Population and deforestation

This small sub-study used an information layer of taluk (district sub-units) boundaries for all the districts in the study area and Census data from 1971 and 1991 to overlay on forest cover layers. Thus, we were able to derive population density (Figures 2 & 3), percent forest cover in the taluks at both time periods, and changes over time. These variables were plotted against one another to find out whether a direct linear relationship exists between population density, change in population density, and between forest cover and changes in forest cover.

Chapter
4

Updating the Forest Map: Part II

The landscape and its change over time

Results

Quantitative changes

Broad changes in the land cover

The overall loss of forest area was estimated at 11.88%. The annual rate of forest loss over twenty years was calculated at 0.63%.

After comparing the land cover distribution between 1977 and 1997, the results displayed in Table 5 were obtained:

Table 5: General changes in the land cover

	Forested areas		**Plantations**		**Non forest areas**		**Water bodies**		
Areas	M ha	*%*	M ha	*%*	M ha	*%*	M ha	*%*	***Total***
1977	3.2	*46.6*	0.27	*3.8*	3.54	*49.4*	0.16	*2.2*	*7.165*
1997	2.8	*39.4*	0.42	*5.9*	3.72	*52*	0.19	*2.7*	*7.165*

The proportion of total area covered by forest fell from 46.6 % to 39.4 % in twenty years. The loss of forested areas (380,000 ha) is mainly due to the extension of agriculture areas (237,000 ha), and to a lesser extent, to the increase in area of plantations (131,000 ha) and water bodies (13,000 ha) as shown in Table 6.

Table 6: Land use transition matrix 1977 – 1997 (millions of hectares)

77 -> 97	**Forest**	**Plantations**	**Agriculture**	**Water bodies**	**total 77**
Forest	2.8	0.130	0.237	0.013	**3.2**
Plantations		0.263	0.004	0.001	**0.27**
Agriculture		0.034	3.484	0.019	**3.54**
Water			0.001	0.159	**0.16**
total 97	**2.8**	**0.42**	**3.72**	**0.19**	**7.165**

Plantations

The total area under plantations increased from 267,000 ha in 1977 to 427,000 ha in 1997 (an increase of 60%).

Coffee and tea plantations

NB: The study area contains a negligible area under tea, and most of the land cover (98.78%) classified under the broader category of "coffee and tea" is in fact coffee. These areas increased from 141,495 ha in 1977 to 254,394 ha in 1997 (an increase of 79.8%).

Forest plantations

These include teak, rubber, acacia, and casuarina. Areas increased from 128,695 ha to 169,814 ha (+32%).

Agricultural and/or non-forest areas

The non-forest (wasteland, agricultural, or urban) areas increased by 180,000 ha (5%).

Area under water bodies (reservoirs, tanks, wide rivers)

This grew from 157,000 ha to 191,000 ha (21%). These new reservoirs appeared both in forest areas in the *Malnad* region, as well as in the drier, eastern areas (cf. land use transition matrix).

Forest Degradation and Disturbance

The extent of forest degradation and or disturbance was assessed by regrouping the forest types into three main physiognomic categories. These were dense, disturbed, and degraded.

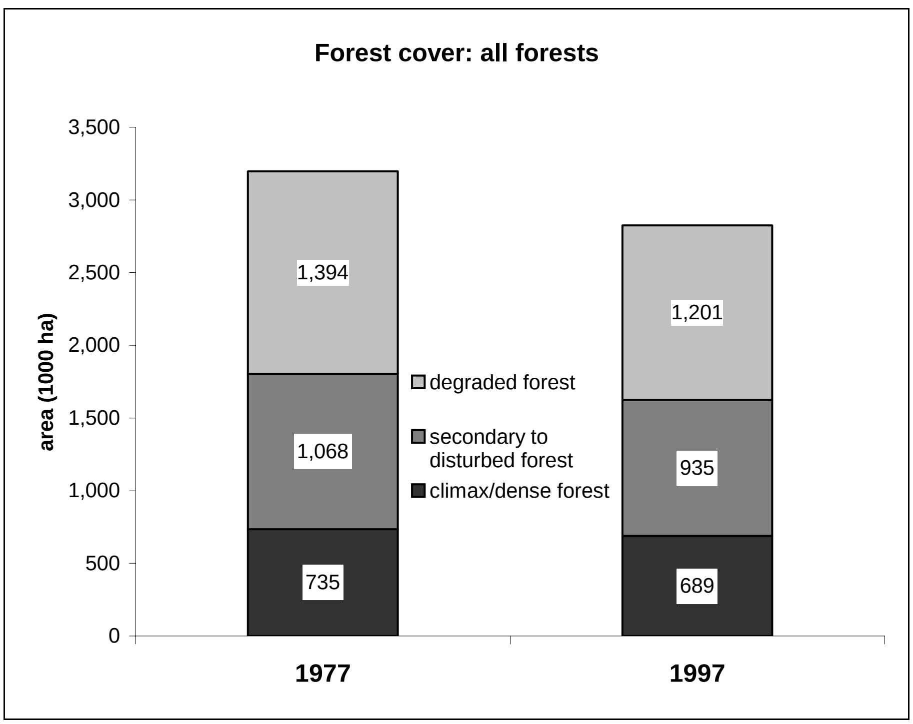


Figure 12: Changes in area of forest physiognomic types

In 1977, these 3 categories cover respectively 23%, 34 % and 43% of the total forest area. Almost 80% of the forest areas were thus already disturbed to degraded. In 1997, the proportions remained similar (24%, 33% and 44%), although forest loss i.e., forest areas converted to non-forest, was estimated at 380,000 ha. Inside the remaining forest, forest areas were considered to have degraded when they passed from dense to less dense or more degraded forms. Overall forest degradation between 1977 and 1997 was found to be 34,245 ha. This corresponds to 1.1% of the total forest areas in 1977. The figure is also one-tenth of total forest loss during this time period.

It is important to note that forest loss i.e., forest areas converted to non-forest, was highest in already degraded / disturbed forests (Figure 12).

Efficacy of the Reserve Forest (RF) classification

Areas under the Reserve Forest (RF) category represent 25.5% of the total study area. These include half of the total forest areas (1.56 million hectares), particularly 80 % of the total dense forest areas, 60% of the disturbed forests and 20% of the degraded forest areas. Within the RF, 81.8% of the area in 1997 was composed of forest.

From Figure 13, the *percentage* loss of forests outside RF areas (19%) is nearly five times greater than inside (4%). Forest loss for the study area overall is two and a half times greater than loss within RF areas.

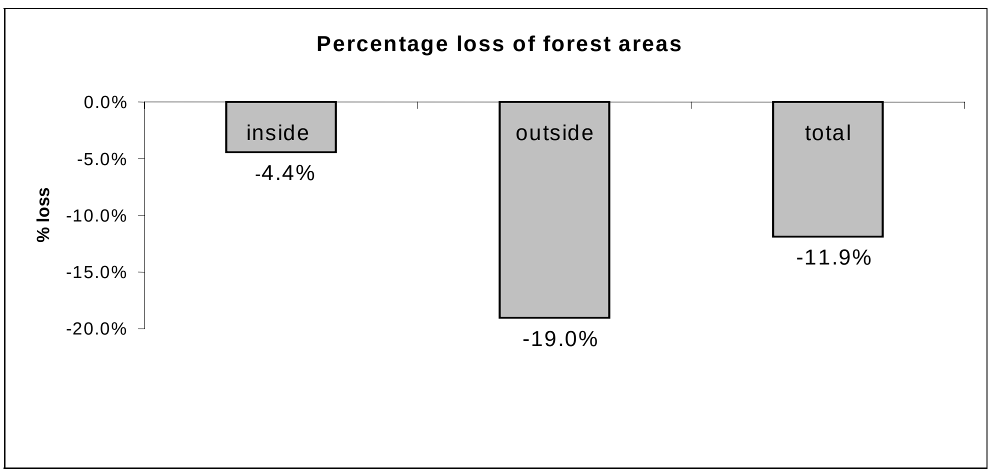


Figure 13: Overall percentage forest losses, inside RF, outside RF, and total

Percentage degradation outside RF areas (1.6%) was found to be nearly three times greater than inside (0.6%).

In absolute terms, 68,900 ha of forest area were converted to non-forest cover inside the RF, and 311,400 ha outside the RF.

Figure 14 suggests that forests under the RF category are less subject to degradation and loss than forests outside.

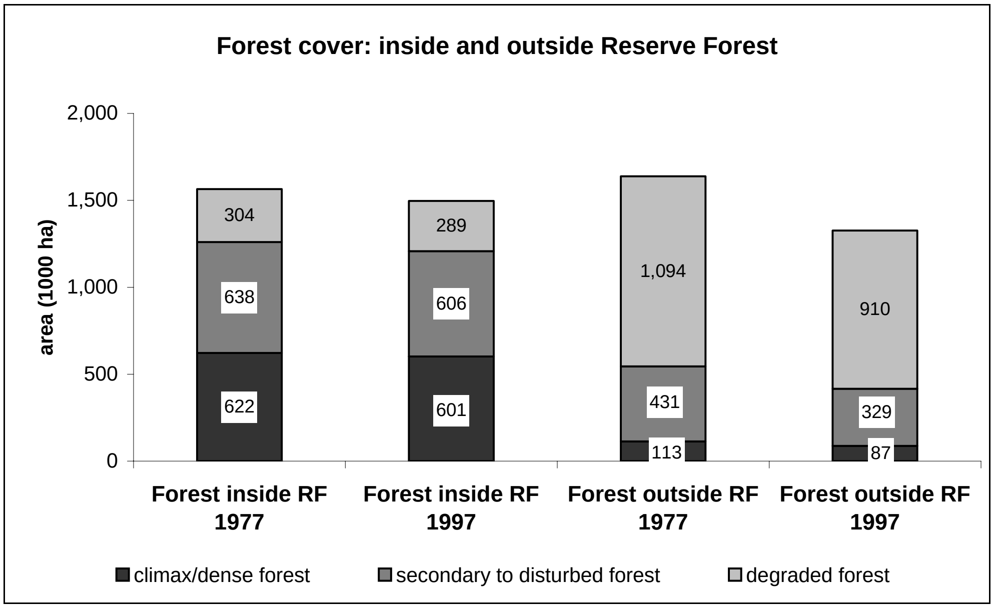


Figure 14: Comparing changes in forest physiognomy inside and outside the PA network

Transitions in detail

Changes according to the forest types

In absolute terms, we found that 380,270 ha of forest cover were lost. It is important to emphasise here that this is the aggregate of areas converted from forest types to non-forest types, and does not include areas that were degraded. From the overall changes by group, all forest land-cover types show decreases in area, compared to non-forest cover, which has increased in area. According to the typology defined in Table 4 (chapter 3, page 32), the most remarkable changes are the losses in area of SMD, LEE degraded, DD degraded, and MEE and HEE disturbed types. On the other hand, coffee and agricultural land made the biggest gains (Figure 16).

In terms of comparative loss in the grouped forest types, the dry deciduous forests and the secondary moist deciduous forests have been most affected. Evergreen climax forests were the least affected.

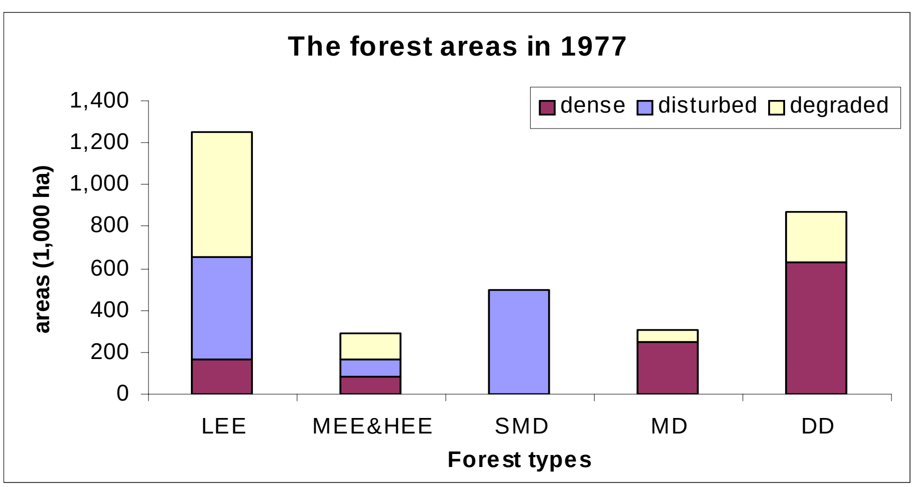


Figure 15 – The forest cover in 1977: areas / forest types

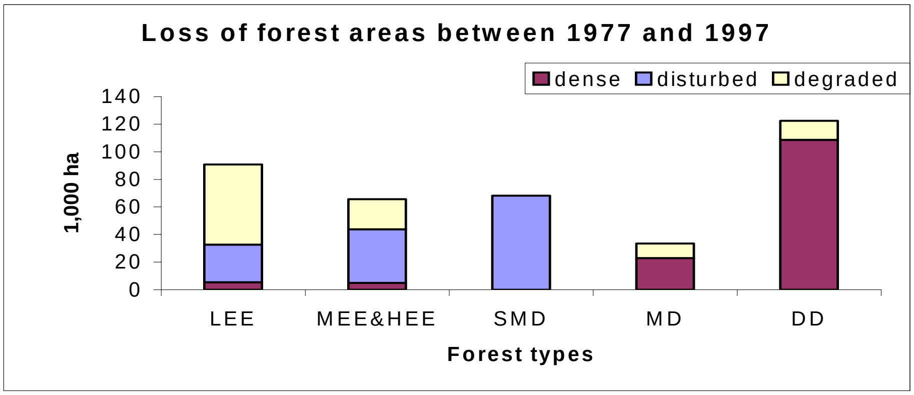


Figure 16 – The loss of forest areas between 1977 and 1997 / forest types

Figure 17 highlights the results of the areas loss for each forest type. In relative terms, the most affected forest type is MEE & HEE disturbed. More than 40% of these areas were converted into coffee plantations. The MEE & HEE and MD degraded types each lost nearly 20% of their areas into coffee (15%) and other plantations (5%). The SMD types lost nearly 10% of their area, equally distributed into coffee and other plantations. While 3% of these forests became more degraded (this forest type is the more affected by degradation). The DD degraded type lost 15% of the areas. The conversion was to agricultural use.

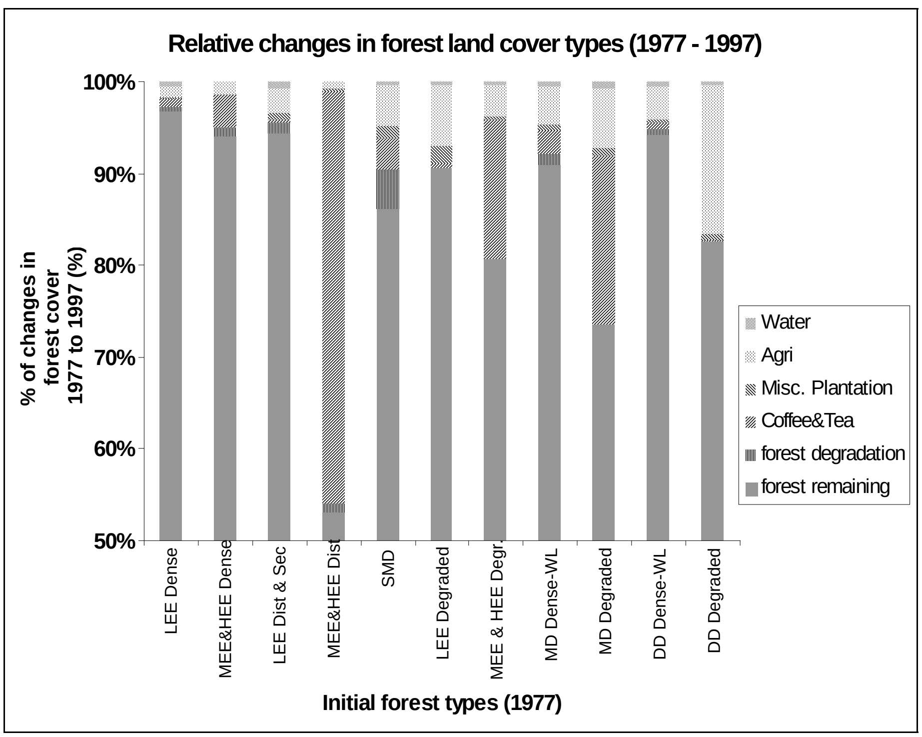


Figure 17: Where did the forest go?

Sources of non-forest land cover types.

It is apparent that no *new* forest areas have emerged. The pie charts (Figures 18 to 21) each show two pies. The pie on the right is an expansion of one portion of the pie on the left, in order to detail the sources of area increases. Large areas of forest plantations have been created largely from areas that were formerly agricultural, and also from secondary moist deciduous forests or degraded low elevation evergreen formations (Figure 18).

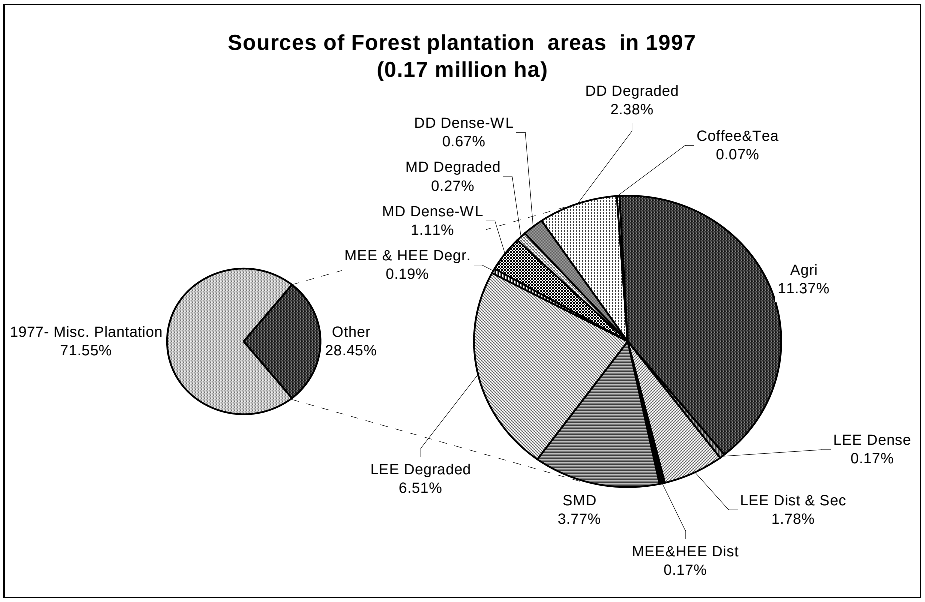


Figure 18: Land cover types converted to forest plantation areas between 1977 and 1997

Other major changes include the conversion of large areas of medium and high elevation evergreen forest, ranging from dense to degraded forms, into coffee. Also converted to coffee were secondary moist deciduous and dense primary moist deciduous forests as well as areas that were earlier under agriculture (Figure 19).

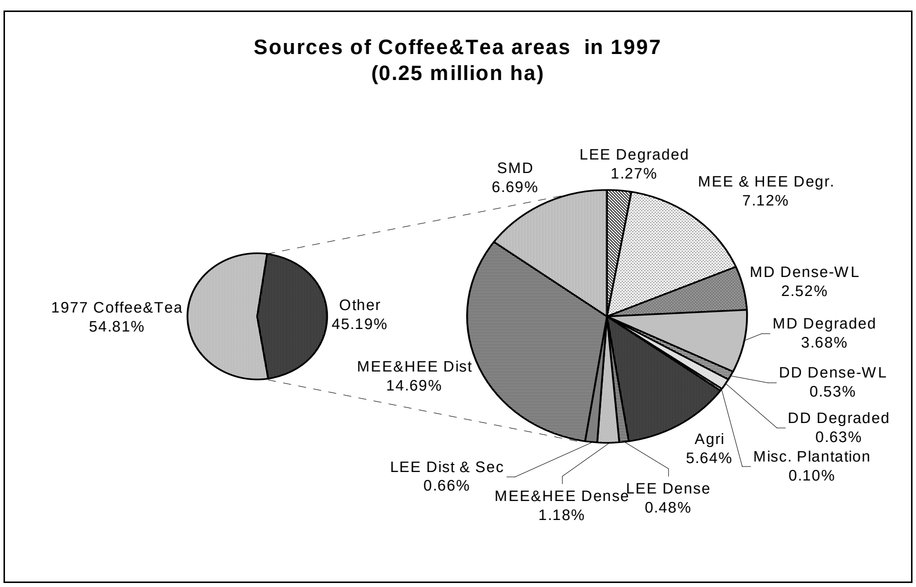


Figure 19: Land cover types converted to coffee and tea areas between 1977 and 1997

New agriculture areas were derived mainly from degraded dry and moist deciduous formations, and degraded low elevation evergreen formations, as well as secondary moist deciduous forests (Figure 20).

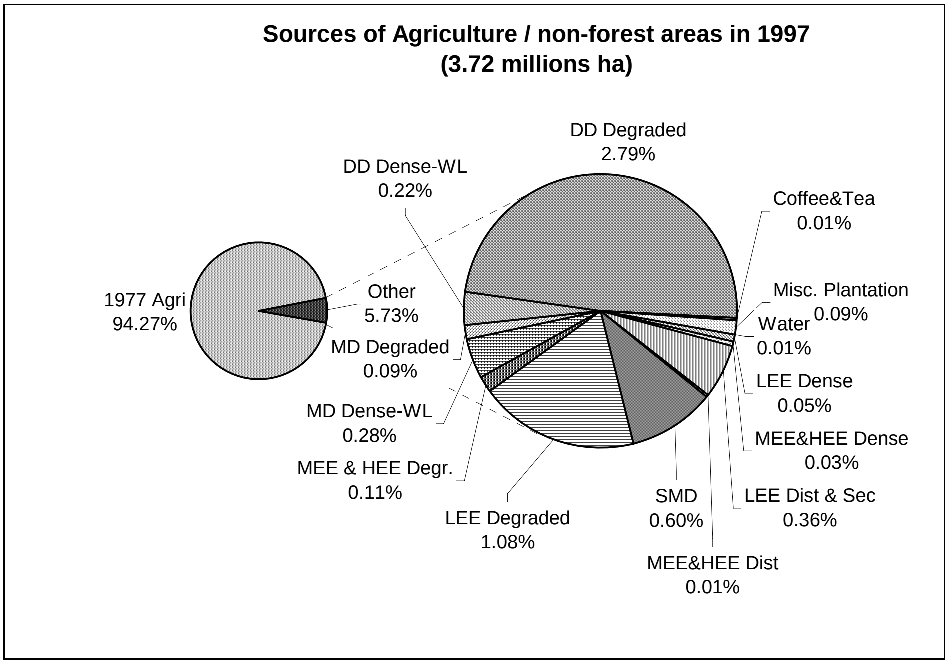


Figure 20: Land cover types converted to agricultural areas between 1977 and 1997

Finally, areas submerged by water included all forest types. Most affected were, however, the disturbed and secondary low elevation evergreen types. Two new reservoirs in Shimoga district were largely responsible for this increase in surface water (Figure 21).

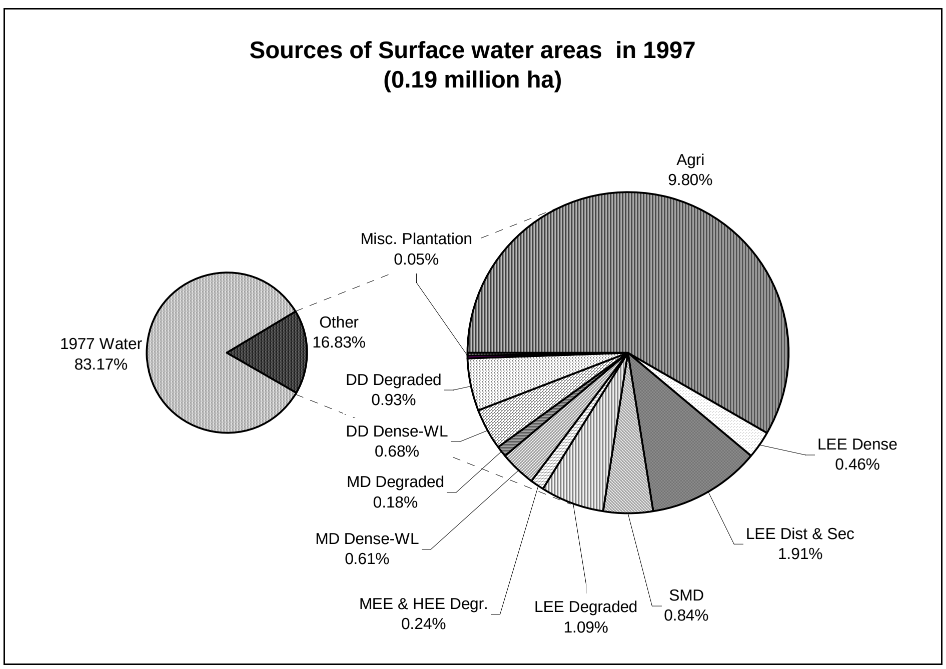


Figure 21: Land cover types converted to surface water areas between 1977 and 1997

About the forest landscape structure

Patch size distribution

A graph of cumulative frequencies of forest patches in 1977 (Figure 22) illustrates the structure of the landscape. Patches smaller than 150 ha in size make up more than 75% of the total number of forest patches, but less than 25% of the total area of forest. The forest landscape is therefore a mosaic of a small number of large patches, and far more numerous, small patches of forest. This distribution of area and size largely did not change between 1977 and 1997. In other words, the landscape overall continues to be composed of small but more numerous patches, interspersed with fewer large patches.

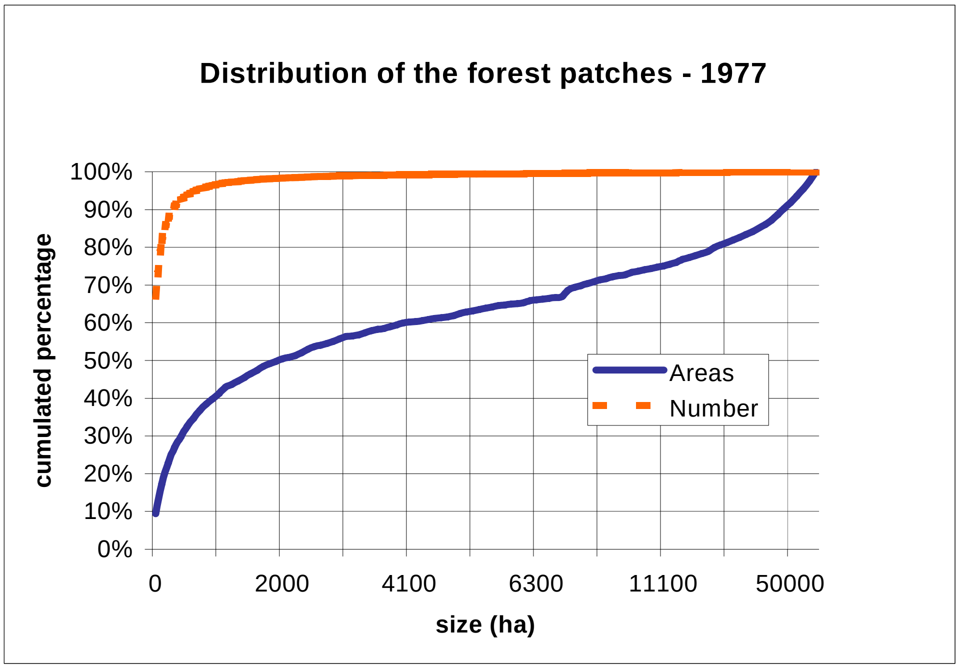


Figure 22: Cumulative frequency curves of area and number of patches of forest cover

Patchiness (patch size and number)

Forest types

Maximum patch sizes i.e., the size of the largest patch for any given group was determined (Figure 23). In all cases there was a decline except for dense LEE, which remained the same. Mean patch size was calculated for all forest patches in 1977 and 1997 (Figure 24). In almost all cases there were small decreases in mean areas.

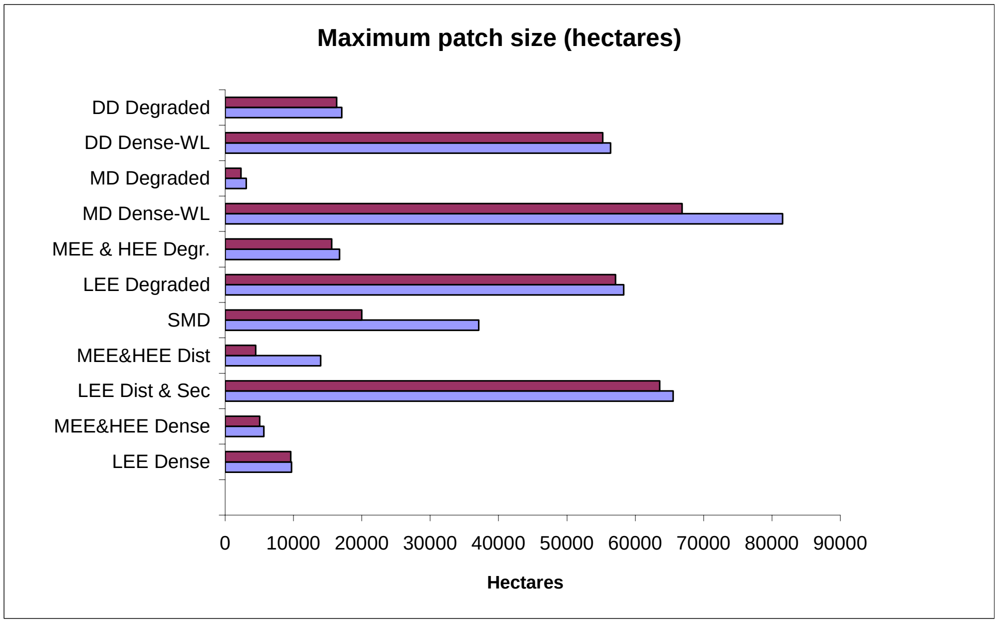


Figure 23: Size of largest patch of each forest type in hectares

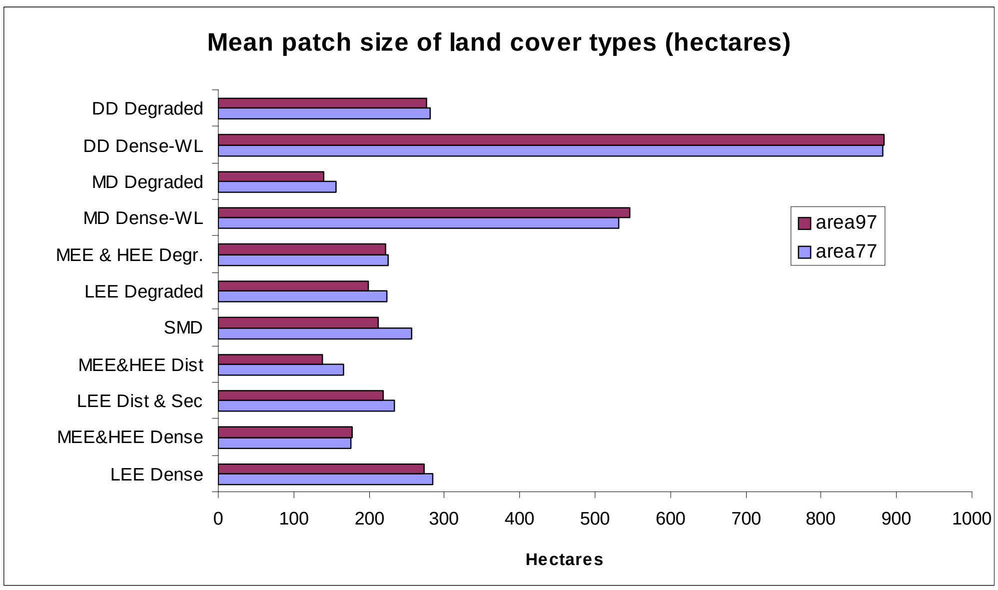


Figure 24: Mean patch size of forest types in hectares

Another indicator of patchiness is the number of patches per 100,000 ha according to the forest types. This showed that in almost all cases there was an increase in the number of patches in the area over time (Figure 25).

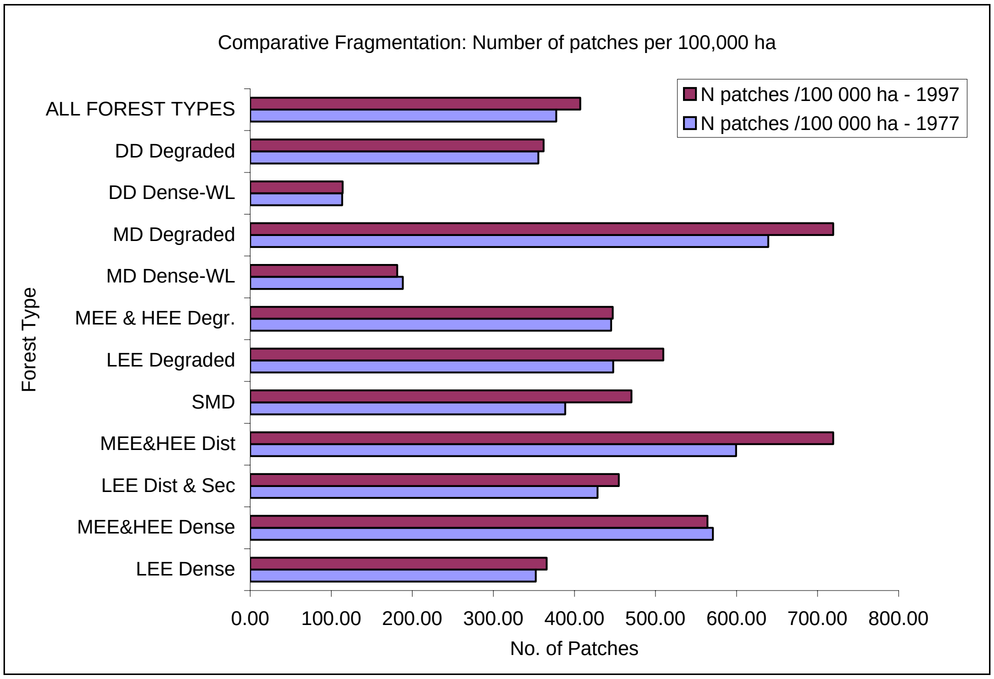


Figure 25: Changes in relative fragmentation over time

In sum, almost all forest types show decreases in their respective total areas (Figure 16).

However, not all these types show a decrease in the number of patches. In fact, many types show an increase in the number of patches, despite decreases in overall area. In all cases, the size of the largest patch has decreased. Of particular note are MEE & HEE disturbed forests, degraded forests, and Primary Moist Deciduous forests that have decreased in area and decreased in patch number. Secondary moist deciduous forests have declined in area, but increased in patch number.

Non-forest types

Conversely, the non-forest groups show increases in total area, and increases in maximum patch size. Coffee however shows a decrease in the number of patches despite a nearly 80% increase in total area. The small and medium size tea-coffee plantation areas (less than 1,000 ha) remained intact, and a very large, relatively homogeneous zone of coffee plantations appeared in the Kodagu District (refer to forest maps of 1977 and 1997).

Forest plantations also showed an increase in overall area as well as an increase in the total number of patches (85%). The number of small reservoirs has increased greatly, up from 925 in 1977 to 1,569 in 1997 (+69.6%).

Finally, there has been a 5 percent increase in the total cultivated area (which also includes wastelands, settlements and population centres). There has been a small (4%) increase in the overall number of patches and in the maximum patch size (Figure 25).

Patch size distribution and changes of area and number

All the forest patches were classified into two broad categories, those >800 ha and those ≤800 ha in size : patches ≤ 800 ha constitute 95% of the total number of forest patches, and 40% of the total areas. Changes in these two categories over time are revealing. In Figure 26, absolute areas lost of patches of each category for each forest type are displayed. These figures show that in almost all cases, greater areas were lost of patches > 800 ha. The single exception to this was degraded MD type, where the inverse is true. In the case of SMD forest type, there has been an increase in areas of patches ≤ 800 ha concurrent with a very large decrease in area of patches > 800 ha.

Changes in the number of patches in the ≤800 ha category (Figure 27) show either large numbers lost or large numbers created. In most cases, however, there has been an overall decline in the number of patches. Among the exceptions are dense LEE type and SMD types, which have seen an important increase in numbers of the ≤800 ha, category.

The figures show that in most cases large patches have eroded or fragmented into smaller, more numerous patches. And a large number of small patches have either disappeared entirely (mostly patches ≤800 ha) or have further broken up into even smaller remnant fragments.

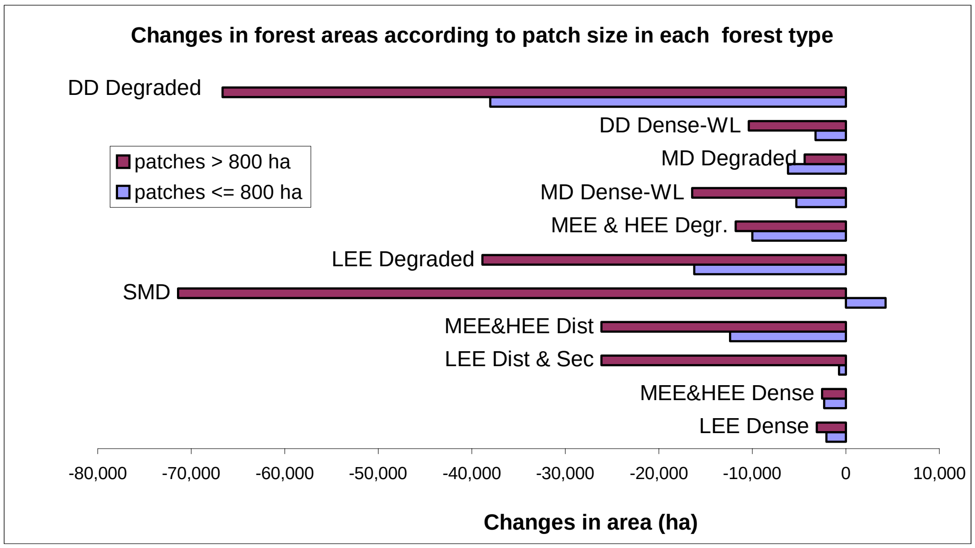


Figure 26: Absolute changes in area according to patch size category of forest types

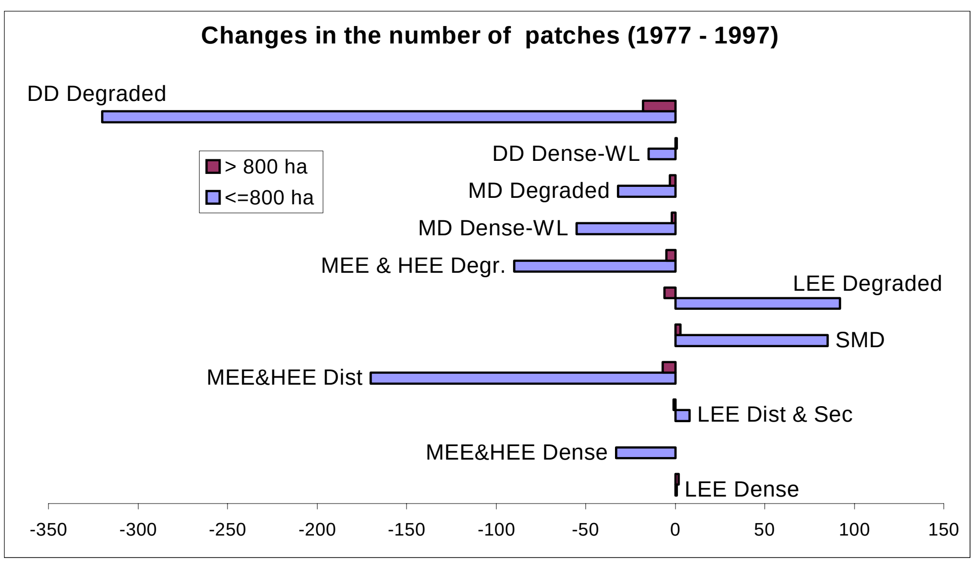


Figure 27: Absolute changes in number of patches according to patch size category of forest types

Perimeter / Area ratio (patch shape, changes in shape)

This is the simplest method of determining patch shape. Perimeter to Area (P/A) ratios (the ratio of a perimeter of a patch P in metres, to its area A in hectares) were determined for all forest patches, and then summed for each type. The results indicate that for many types there has been an increase in P/A ratio between 1977 and 1997, i.e., an increase in perimeter relative to area (Figure 28).

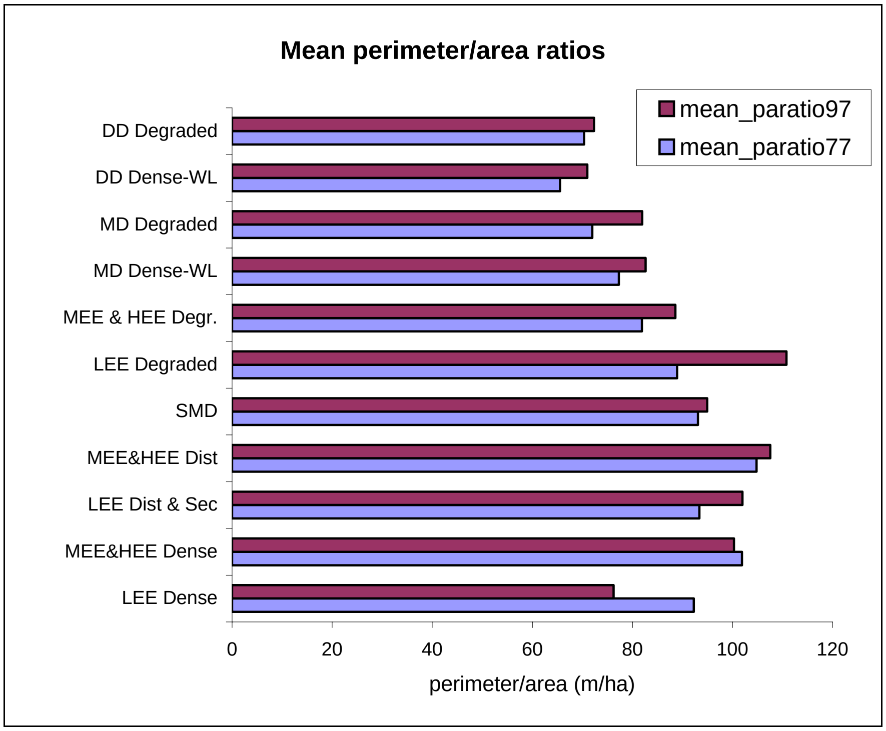


Figure 28: Mean of the Perimeter/Area ratios of all patches for each forest type

We then grouped all forest patches into perimeter/area classes, and plotted these against number of patches for each class (Figure 29). Figures for both years 1977 and 1997 were plotted on the same graph for the purposes of comparison. The general trends appear to be a bigger decrease in the number of patches with low to medium P/A ratios over time.

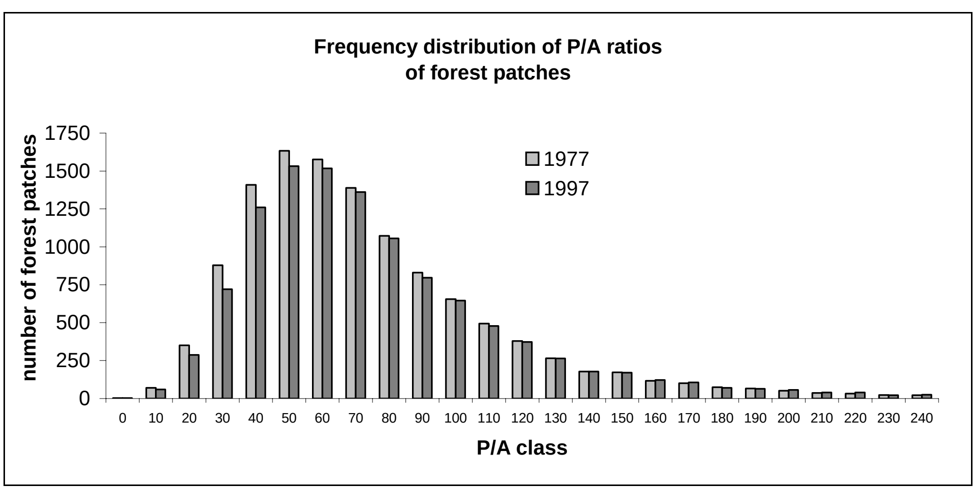


Figure 29: Number of patches in each P/A class for all forest patches considered together

Relationship between patch area and P/A ratio

The areas of all patches between 3 ha and 500 ha in size were plotted against their respective P/A ratios (Figure 30). The chart shows that as patch size falls below 100 ha and continues to fall, the P/A ratio relative to area rises exponentially. We can infer from this that as patches erode to less than 50 ha in size and further below this, the amount of edge or perimeter, relative to area increases sharply. This high perimeter to area ratio makes a forest patch highly vulnerable to degradation and loss in an anthropogenic context.

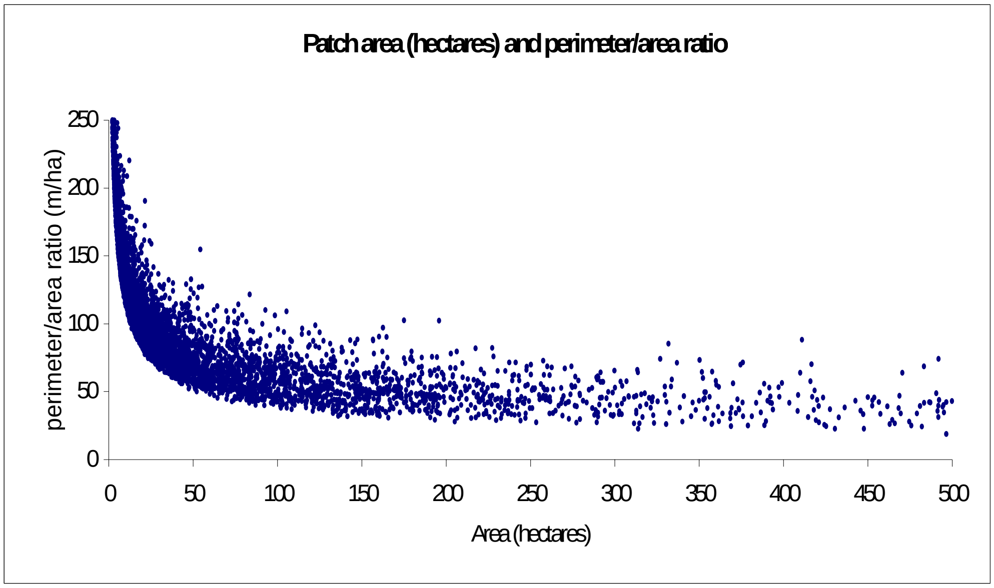


Figure 30: Typical relationship between P/A ratio and patch size.

Patch context: Edge Analyses

Edge analyses was performed as a predictive tool. Our assumption was that the proportion of boundaries shared with anthropogenic patches determines the extent of disturbance or deforestation. To test this assumption we performed a simple regression with percent forest loss as the dependent variable, and percentage edge length shared with anthropogenic patches as the independent variable. The results (Figure 31) were derived for each forest type as defined on the Forest Map (all 54 types). The distribution of points on the plot indicates that there is no strong correlation between the two variables.

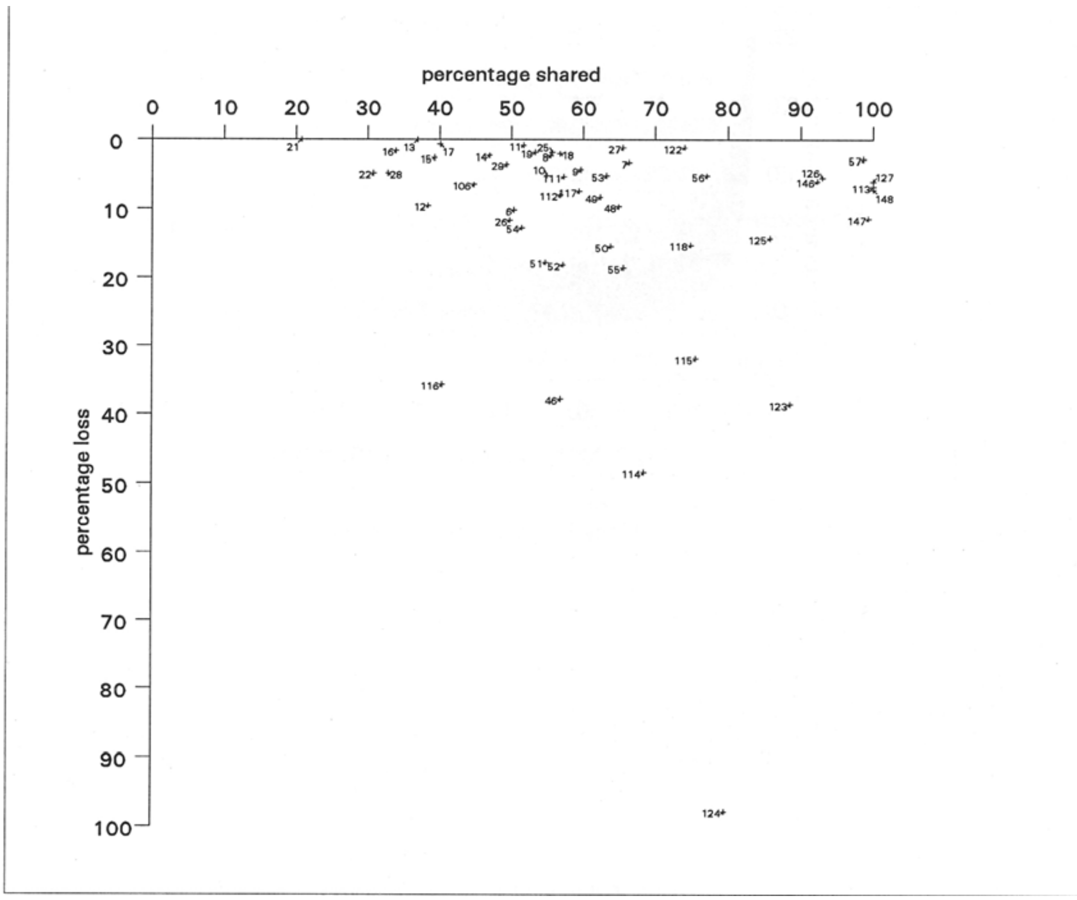


Figure 31: Scatter-plot showing percent edge shared with anthropogenic patches and percent area lost between 1977 and 1997 for detailed forest types

A bar graph of percent of total edge length shared with anthropogenic patches for each forest group (Figure 32) shows that in almost all cases the percent edge length has increased. This, taken together with other indicators such as increasing P/A ratios and increasing patchiness of the landscape, indicates that forest patches are in general becoming more dispersed or interspersed in anthropogenic types of land use. Therefore there is a considerable degree of degradation in terms of landscape characteristics and vulnerability to further degradation and / or loss is very high.

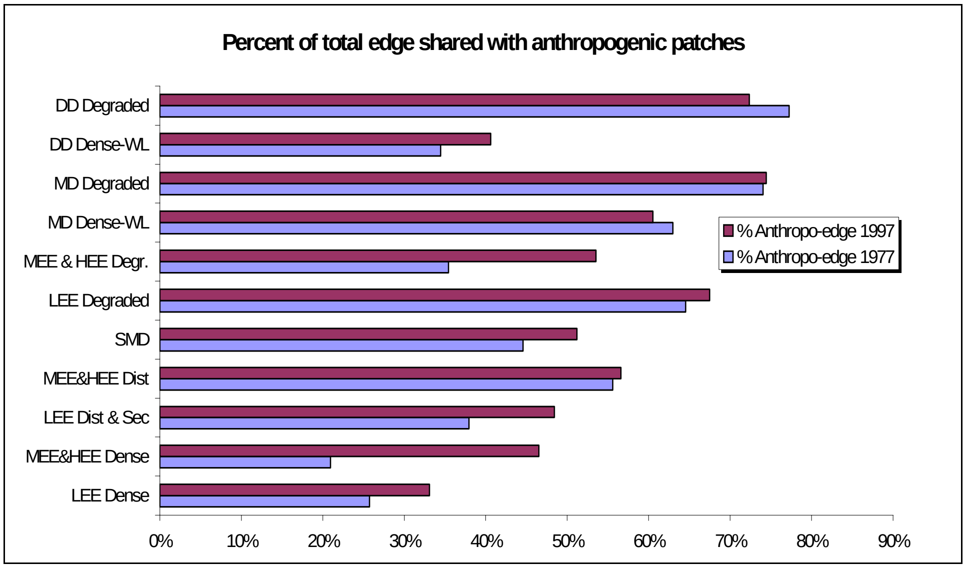


Figure 32: Proportion of total edge length of forest patches shared with anthropogenic patches.

Population and deforestation

Figures 33 and 34, each containing data at the taluk level, (population statistics were derived from the Census of India 1971 and 1991) are presented here. The selected taluks are all either partially or entirely within the study area.

From Figure 33, we see that there is only an extremely weak and non-significant correlation between percent forest cover in 1977 and population density in 1971. However, the interesting feature to note is that at the extremes of very high population density and very low population density, the inverse relationship with forest cover is clearer. There is however, a very broad range of values of percent forest cover that correspond to the middle range of population density values. This results in the low regression value. In Figure 34, the trend is even less significant, and barely detectable. There are also several outliers which reveal themselves to be taluks from Mysore and Kodagu Districts.

It is worth noting here that forest cover was considered as an aggregate measure comprising all forms of 'natural' vegetation, even including coastal open scrub and thickets.

After regrouping the taluk level data into districts, (Figure 35) we see that most of the districts have population densities within a relatively narrow range compared to more wide-ranging percent forest cover values. The districts of Uttara Kannada and Dakshina Kannada both experienced high levels of increase in population density and relatively low levels of forest loss (Figure 36). Conversely, Kodagu district saw a relatively low increase in population density but high levels of forest conversion. In terms of population density and forest area,

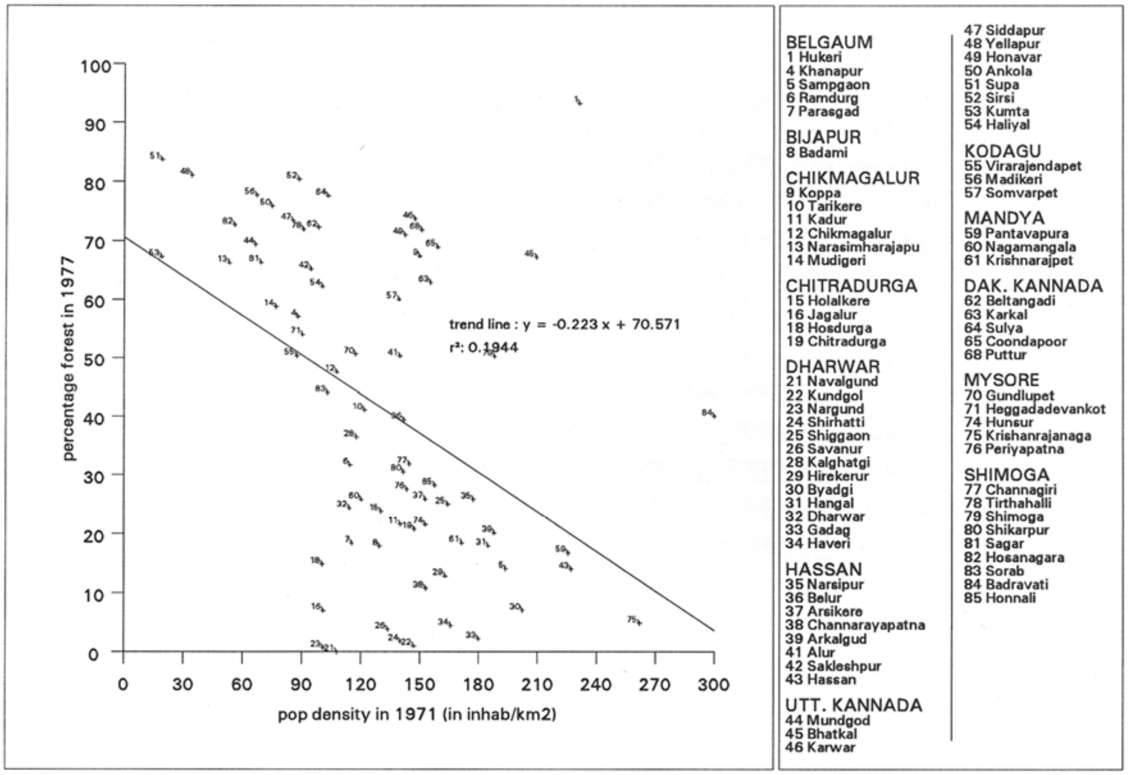


Figure 33: Scatter-plot of population density and percent forest cover for selected taluks

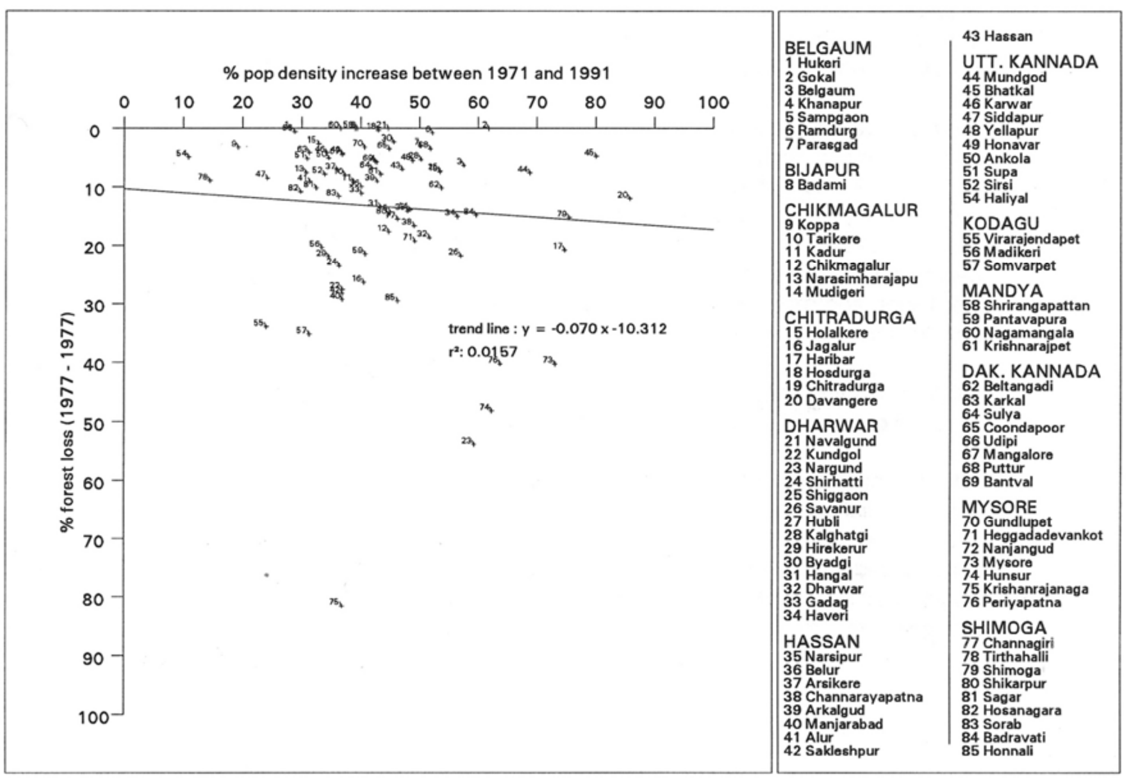


Figure 34: Scatter-plot of change in population density and change in percent forest cover for selected taluks

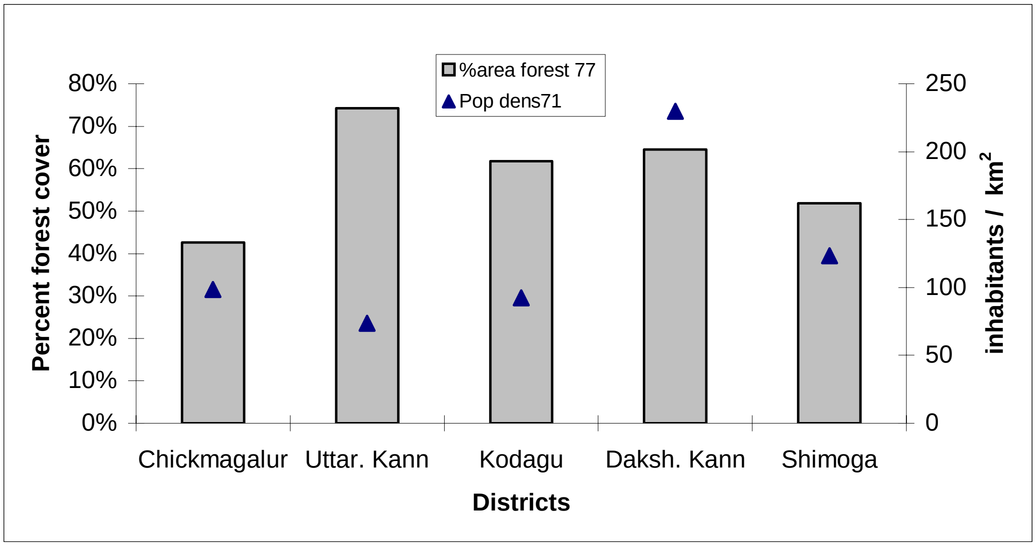


Figure 35: Population density (1971) and percent forest cover (1977) in selected districts

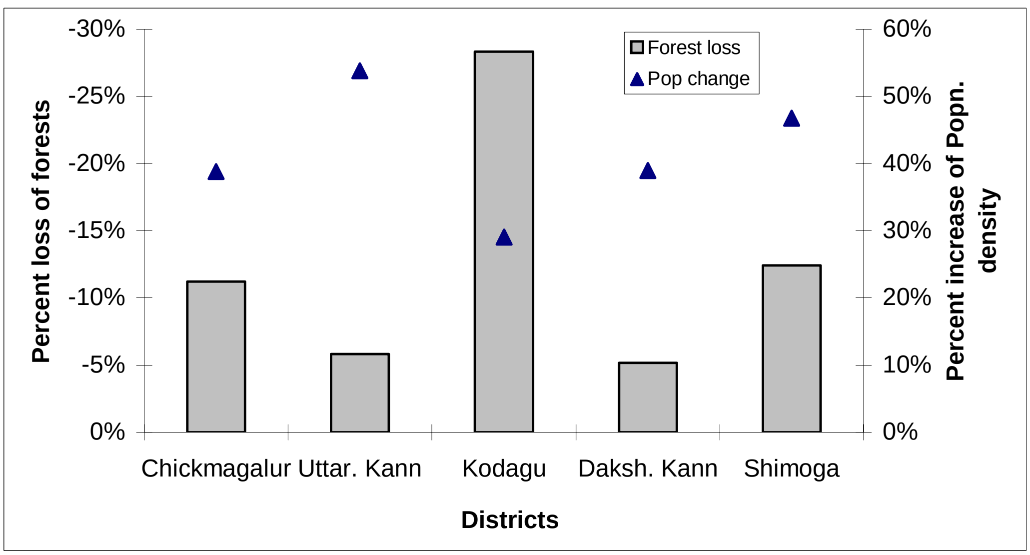


Figure 36: Percent change in population density (71 – 91) and percent loss of forest (77 – 97) for selected districts

In sum, there appears to be no direct linear relationship between percentage forest loss and percentage increase in population density. Neither is there any direct correlation between percent forest cover in 1977 and population density in 1971(Figures 33 & 34). Combined results for selected coastal and *Malnad* districts (Figures 35 & 36) similarly show no significant direct correlation between the variables of forest cover / loss of forest cover and population density / increase in population density.

Summarising the forest landscape structure and changes

Combining the different landscape indices allows us to have an assessment of the spatial organisation and the changes for each forest type between 1977 and 1997. It also gives some indications about the future.

The dense forest types (LEE, MEE&HEE, MD and DD), which together represent 23% of the total forest area, lost less than 10% of their area in twenty years. From Figure 14 we see that much of this forest type lies within the Reserve Forests (RF). However, LEE dense forest has to be examined closely. The mean P/A ratio decreased over twenty years, but conversely, the number of patches and the percentage of anthropogenic edges increased. This indicates a fragmentation tendency within a context of sustained human pressure.

Of the disturbed or secondary forests, 60% of the areas is within the RF. The relative loss of areas in the LEE disturbed or secondary forest is nearly 10%, and the patch density (number of patches / 100,000 ha) decreased, but the number of small patches (less than 800 ha) increased. The anthropogenic edge ratio and the mean P/A ratio also increased. This type is also expected to remain vulnerable.

The MEE&HEE disturbed or secondary types are most affected by relative area loss (45%), due to the extension of coffee plantation areas. The patch density, already high in 1977 (600 patches / 100,000 ha in this forest type), doubled, as the total number of patches decreased. The anthropogenic edge ratio remained high (57%). The remaining forests are in danger if the growth tendency of commercial plantations remains as in the 20 past years.

The SMD forests lost 14% of their areas. They are also the most affected by degradation. The patch density index increased over 20 years. This has to seen in the context of high increasing number of small patches. This effect is mainly due to the extension of agriculture and commercial plantation areas. The mean P/A ratio and anthropogenic edge percentage, already high in 1977, went on increasing. Therefore, human pressure on the remaining forests can be expected to continue to have an impact.

The degraded forests, composed 43% of the total forest areas in 1977, but only up to 20% of the area was protected under the RF category. These were the main types to be affected by agriculture area extension. At a lesser level they were also affected by the extension of commercial plantations.

The LEE degraded forests, are very extensive. These types lost 10% of their areas, converted into miscellaneous plantations and agriculture. The number of small patches (especially those less than 100 ha in size) has increased. The mean shape index (P/A) already high in 1977(90), increased even further in the intervening years to 112. As did the anthropogenic edge percentage. Further losses may be expected due to the high anthropogenic context.

The MEE & HEE degraded forests also lost large areas (-18%), due mainly to the extension of coffee plantations, as in the case of MEE&HEE disturbed forests. The anthropogenic edge percentage was at 40% in 1977. This increased to 60%. The total number of small patches declined as they were replaced by coffee. The future of these forests also depends on the tendencies of commercial plantations.

MD degraded forest, were also affected by a high loss of areas (-20%), due to coffee extension. Their fragmentation level, already high in 1977 (650 patches / 100,000 ha) increased even further in 20 years (750). The anthropogenic edge percentage remained very high (75%).

DD degraded forest, the single largest forest type in terms of areas, was affected by losses of area due to the extension of agriculture. Both small and large patches were affected by loss. The result of this was a higher fragmentation of previously large, homogeneous areas and a very major loss of smaller patches.

Thus, although the dense forests appear better preserved from human pressure, the degraded forests seem to be already condemned to an increasing land-use conversion. Human pressure on secondary and disturbed forests could be mitigated in order to avoid the loss of potential "biodiversity reservoirs".

Chapter

5

Updating the Forest Map III

An appraisal of the landscape status and of deforestation

Discussion

Overall changes in forest area

The three maps, figures 37 to 39, corresponding to the areas covered by the relevant sheets of the forest map, show areas of forest lost between 1977 and 1997. Loss of forests, in terms of area, is largely due to the expansion of agriculture in the eastern plains. In the *Malnad* area, however, it is mainly the increase in forest plantations and coffee areas since 1977 that are responsible for forest conversion.

The Reserve forest category

It appears that forest loss and degradation has been largely mitigated by the RF classification. It must be noted however, that in many cases the reserve forests and the dense tree cover that they contain are located in steep, inaccessible, and very sparsely settled terrain that is consequently less prone to encroachment and over-exploitation of forest product.

Forest degradation and loss

Forest loss figures are also interesting in terms of what types of forest were converted. It appears from our study that dense low elevation evergreen and dense moist deciduous forests were less affected than the other types. Those types most affected were disturbed and degraded MEE and HEE types, Secondary MD, and degraded DD types. The loss is explained when we consider that MEE and HEE types were the most prevalent form of vegetation replaced by the rapid expansion of coffee; SMD has been replaced by a range of land cover types including rubber plantations and reservoirs; and degraded DD forms by agriculture in the eastern table-lands.

It is worth noting that it is largely the degraded forests or forests that were already in a relatively degraded condition (with the possible exception of medium-elevation forests in the coffee-growing areas) that were lost to anthropogenic forms of land cover. Furthermore, it appears that forest disturbance or degradation to lower physiognomic levels was less prevalent than outright forest loss (from lower physiognomic levels)

There are a number of possible reasons for this. In many cases the forests that are already in a degraded condition are not covered by any protection status, and are therefore more prone to complete loss. Another factor to consider is that forest loss in the study area is characterised first by a deterioration, which is then followed by loss, rather than direct loss of dense forest. There are exceptions to this, however, as when reservoirs are built, and a certain amount of direct clear felling takes place.

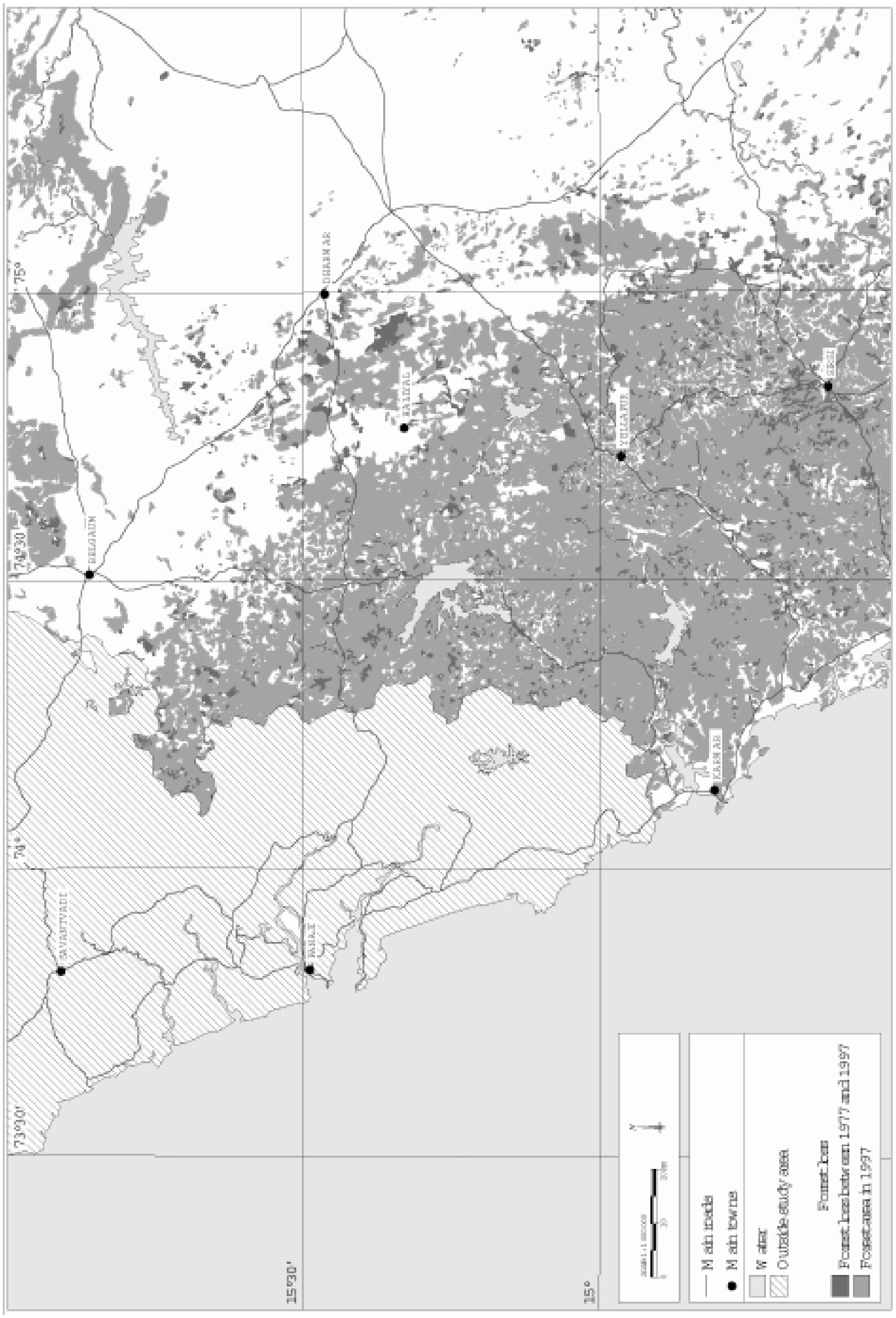


Figure 37: Loss of forest areas in sheet 1

One of the implications of this is that the areas that are presently in a degraded condition can be expected to further deteriorate and be lost shortly, unless protected. Forest degradation is also linked to fragmentation. This is detailed below. Finally, it is important to note that at the scale of the study, it is impossible to examine or to identify in detail the various small and dispersed encroachments and forest degradations (cut stumps, small fires, trails, lopping of foliage) that are apparent at ground level, and are an important form of forest loss in the study area. A more thorough picture of degradation would emerge from fine-scale studies of forest habitat. It would therefore be incorrect to assume that the low level of forest degradation observed at the 1/250,000 scale over time is indicative of low levels of deforestation.

Patchiness (patch size and number)

The measure of mean patch size can be misleading due to the very large spread in patch sizes, and should not be heavily relied upon. Nevertheless, although affected to different degrees; this does indicate that all groups have to some extent been subject to decreases in area and / or fragmentation. The decline in maximum patch size is certainly indicative of high patch erosion and increasing patchiness.

The state of the entire forest landscape is reflected in the graph of cumulated frequencies. Patches smaller than 800 ha form 95% of the total number of patches, and 40% of the area. The landscape is clearly already in a highly fragmented state. This is indicated in the fact that patches smaller that 800 ha have in many cases increased in number over time. In all cases, this is at the expense of larger patches within the same category, and patches larger than 800 ha. Absolute numbers of patches in the category of >800 ha may have increased in some cases, although this has been at the expense of very large patches.

Patch size effects on anthropogenic patches, in contrast to forest patches, are revealing. In most cases patch sizes have increased. Maximum patch size of coffee has increased by 238 percent! This was a result of the gradual coming together of more dispersed coffee patches into fewer, very large patches. This phenomenon, the opposite of the break-up of patches that we notice in the forest types, has also occurred in Hassan and Chickmagalur districts. The change process, in the case of forest patches, has been a combination of erosion and fragmentation, followed by further erosion.

Fragmentation has serious consequences for the forest habitat. Not only for the flora and woody tree species, but also for faunal biodiversity. Although faunal studies are outside the scope of this study, it is well known that some fauna require a minimum habitat size. Increasing fragmentation can therefore lead to extirpations of local populations, and in some cases to extinction. Small patches (and patches with high amounts of edge – see section below) contain less interior habitat, and consequently favour tree species that prefer the different microclimatic conditions that prevail in the edge. This has the effect of changing species composition towards increasing proportions of secondary species, weeds, and shrubs; flora that that have a wider ecological amplitude, and others whose presence is indicative of disturbance.

Perimeter / Area ratio (patch shape, changes in shape)

The near-universal increase in mean P/A ratio also points to a gradual deterioration of the forest habitat. Forest patches with high edge-to-area ratios are vulnerable to edge effects. When considered together with low patch sizes, the effects are exacerbated, and in many cases, an entire patch may consist entirely of edge habitat. Patch size and edge effect are related in the sense that decreasing patch size apparently also increases the relative P/A ratio.

Changes of frequencies of the P/A ratios of patches show that compact forest patches have become fissured and/or more porous, thus reducing the overall number of patches with low P/A ratios, and contributing to the numbers of forest patches with higher P/A ratios. However, we do not see this reflected in the graph to any great extent. There is no large overall increase in the number of patches with high P/A ratios.

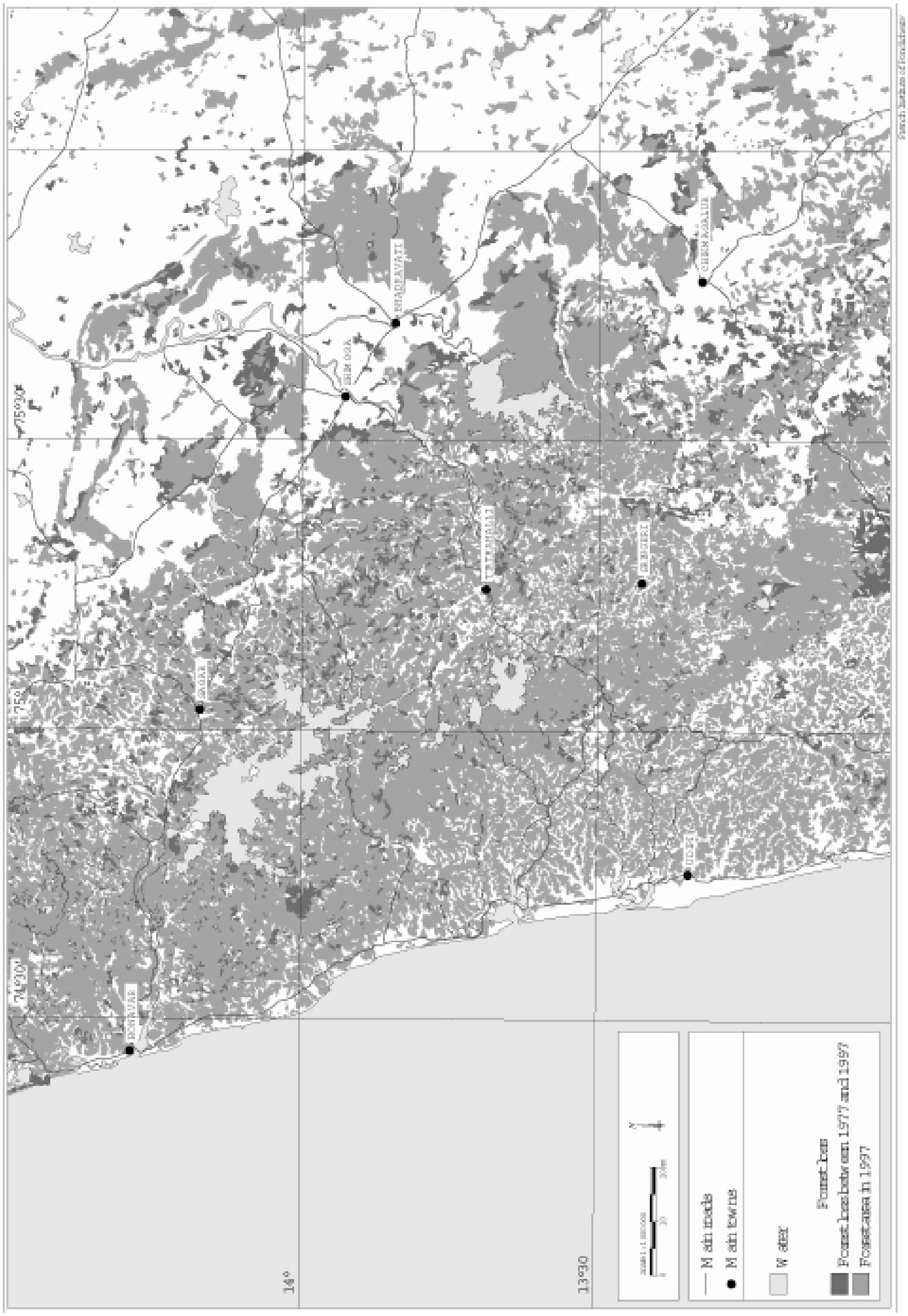


Figure 38: Loss of forest areas in sheet 2

One possibility is that previously existing patches with high P/A ratios have been lost entirely through conversion to non-forest types. We can see that on average, patches of already degraded forest types have higher P/A ratios. So that new entrants into the higher P/A classes merely substitute for this loss.

The effects of decreasing patch size and increasing P/A ratios therefore interact with each other to reduce the viability of small patches. Besides restricting the range of fauna that may be located there, the forest patch is qualitatively less consequential in terms of floral species composition. It is predisposed to edge effects that favour colonisers and wide fluxes of energy and nutrients. A remnant patch then loses viability, deteriorates, and is highly prone to be lost entirely.

Shared anthropogenic edge

Our analysis of edge length shared with anthropogenic patches was performed in order to test the idea that increases proportions of shared edge made patches more vulnerable to change. The basis for this is that neighbouring anthropogenic patches create a dynamic of large fluxes of energy and biomass that gradually erode or deteriorate the quality of a forest patch until it is lost entirely. It is apparent that in almost all cases the percent edge length shared has increased over time. This in itself may simply be indicative of the increased fragmentation of the forest patches, which structurally speaking, are generally dispersed in a medium of anthropogenic types that have been gaining area at the expense of forest types. But we wanted to test this analytical tool for its predictive value.

However, we found no relationship with forest loss when these two variables were plotted against one another. There may be a number of reasons for this. Forest has also been lost to reservoirs and forest plantations. In many cases, forest conversions to these types have occurred in interior habitats that have little or no edge shared with anthropogenic types. Another fact is that we do not know of the detailed process in the intervening twenty years – we only have two pictures of the area that are twenty years apart. For example, areas currently under coffee may have been in interior habitats with little or no shared edges in 1977, coffee establishment may have advanced gradually over this time. If we are to assume therefore that forest loss is a gradual, incremental process that is greatest at the interface, then the fact of increasing percent edge shared over time may be indicative of further, accelerated change.

Population and deforestation

Although studies of population levels and associated socio-economic variables are not within the purview of our study, it is useful to demonstrate the possibilities of a GIS and spatial approach in this context. Our analyses were of course, highly simplistic. A number of factors were not considered, such as seasonal migration, land distribution, and that much of the population is concentrated in towns. The fact that we found no direct linear relationship between the variables we used must not be taken to mean that no relationship exists. However, the question of deforestation and its causes is one that is heatedly debated. It is not our intention to delve too deeply into this area, which according to Taylor and García-Barrios (1995) is highly complex, involving detailed analyses of context-specific, socio-economic change. Therefore, just examining the size and rate of growth of the population may not adequately explain the causes of deforestation. Although we have largely confined this study to areas that we feel competent to analyse, studies of environmental change must be informed by detailed analyses of the political economy. We therefore recommend that finer scale studies are carried out, and the results considered in detail and assimilated into the formulation of long range planning. Lélé *et al.* (1998) suggest that “meso-scale” studies provide detail on both biophysical and socio-economic conditions, and the potential to extend these findings to a large region for policy formulation.

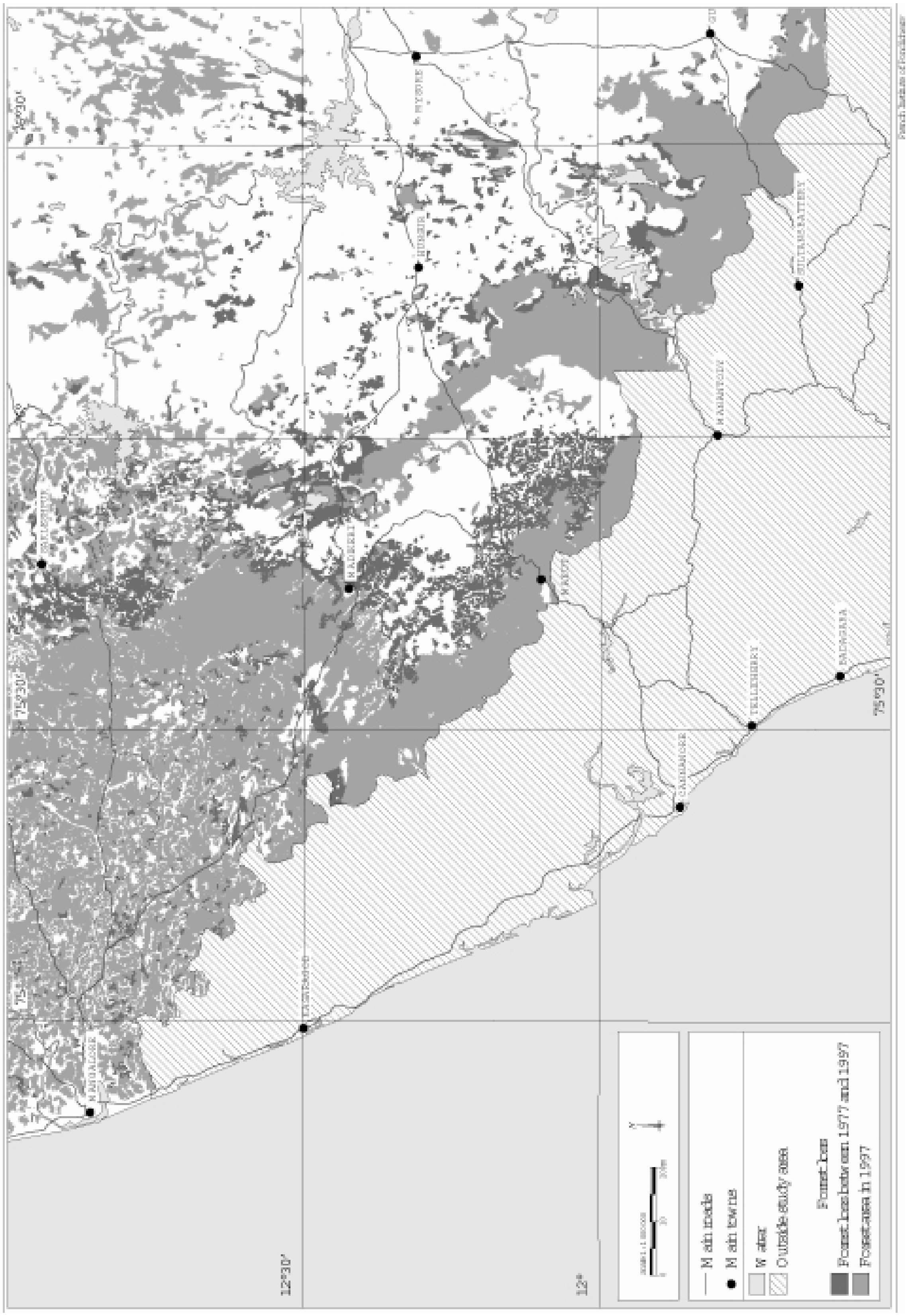


Figure 39: Loss of forest areas in sheet 3

Chapter
6

Case Studies

Specific examples of forest loss and their proximate causes

Kodagu District

Introduction

Kodagu district, in the middle of the Western Ghats is one of the richest centres of plant diversity (Keshava Murthy & Yoganarasimhan, 1990). Its hilly terrain with gentle slopes and wide climatic range provides ideal conditions for coffee cultivation. Coffee has become the main economic resource of the district, and a third of the coffee grown in India comes from Kodagu (Coffee Board, 1998). The spurt in coffee expansion in recent decades has had a profound effect on the vegetation cover of the region. It is therefore an immediate and primary concern to harmonise economic development and biodiversity conservation in a sustainable way.

Landscape analysis

Temporal landscape analysis indicates that in the past two decades, area under coffee has doubled, contributing to a loss of 28% of the forest area (Figure 40). The annual rate of loss is 1.4%. Medium elevation wet evergreen, and moist deciduous forests are the most affected types. Superimposition of the protected area network over the forest cover indicates that the loss is minimal inside the Reserved Forests and National Park compared to loss outside these areas.

Within the protected area (35% of the total area of the district) the forest loss is only 3%. The bulk of the loss, which is more than 50%, is outside the PA. The effectiveness of the PA in Kodagu may also be attributed to other factors apart from the protected status. Steep escarpment and very high rainfall (>5000 mm) along the west and increasing dryness (rainfall <1500 mm) towards the east of the district are the main limiting factors to the further expansion of coffee plantations (Figure 41).

Socio-economic factors

Moppert (in press) found that the Kodagu landscape has traditionally been characterised by scattered settlements at the bottom of slopes, and rice fields in the valleys. Uphill land was covered by forest and offered the ideal context for the introduction of coffee. Although the first plantations were large at over 1000 ha, the Coffee Board, after its inception in the 1940s, encouraged small planters and provided assistance with coffee cultivation and marketing.

The expansion of coffee areas beyond the “coffee belt” and towards the hilly western areas has been considerable over the last twenty years. The forests in these areas, initially used to procure secondary produce or to cultivate cardamom, were progressively cleared for coffee cultivation. Cardamom can be grown under dense forest canopy but with its cultivation there have been problems of disease and of fluctuating markets. This has favored a shift towards coffee cultivation, which requires a thinning of the tree cover. In addition, it is common practice to remove the diverse, native tree species, and to replace them with fast-growing exotics. The result of this is an inescapable loss of biodiversity.

Returns from coffee increased after the liberalisation of the coffee market. Large estates, more able to intensify and modernise their production, were disproportionately benefited. They have used this advantage to acquire increasing areas of land to the west, which in turn have been transformed for coffee. The sale of felled wood has also been profitable, and has offset the costs of clearing land.

Ultimately, Moppert asserts that the process of extending the large estates and transforming the landscape has in fact been slower due to the traditional land tenure systems in the district. Traditional systems have started to break down however, and land ownership is being concentrated. It seems inevitable therefore, that given the favourable markets and absence of a comprehensive state-level protection in place, the remaining accessible areas of forest will be transformed "as fast as the planter can afford its cost".

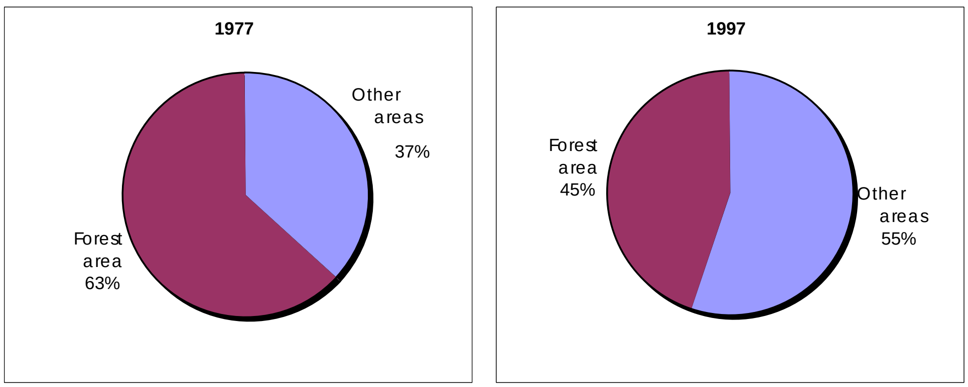


Figure 40: A comparison of percent forest area between 1977 and 1997

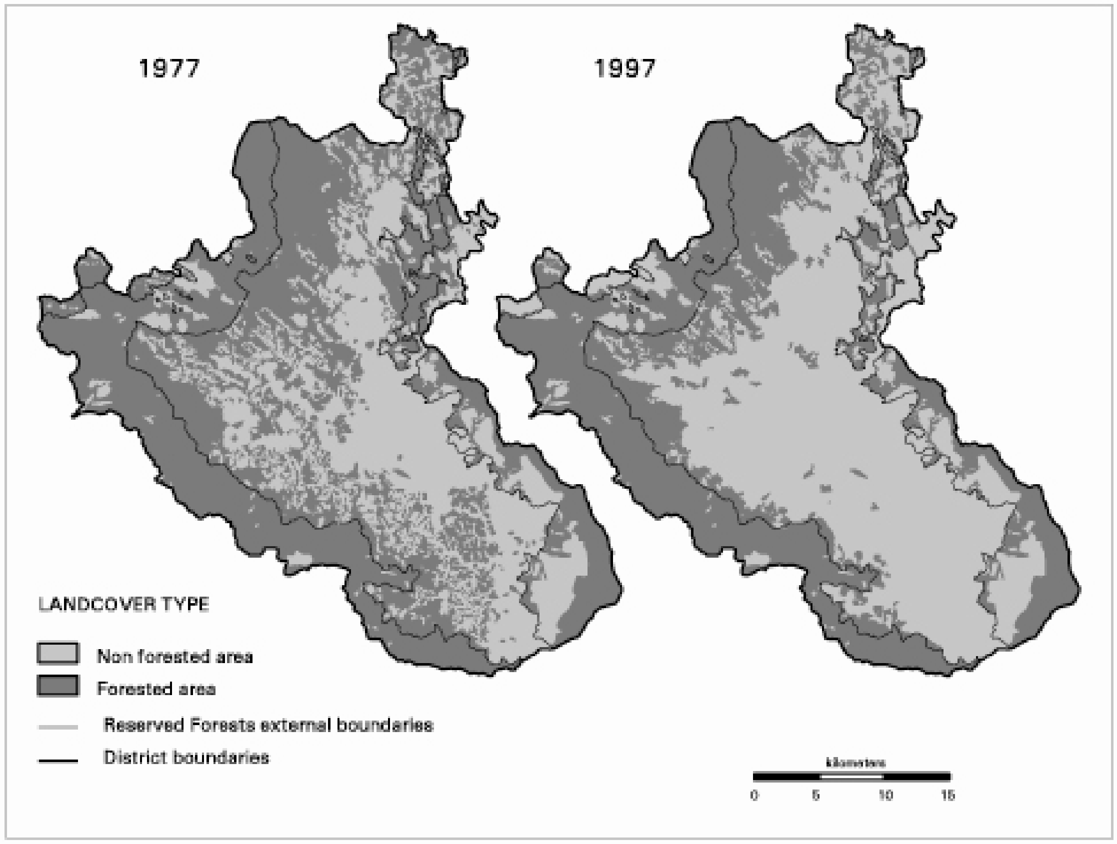


Figure 41: Loss of forest areas in Kodagu district between 1977 and 1997

Uttara Kannada

Introduction

The district of Uttara Kannada lies in the north-western sector of the state of Karnataka, between 13°55'N, 15°31'N and 74°03'E, 75°05E. It is divided into three topographic zones; (1) a coastal belt made up of estuarine plains and narrow coastal strips, (2) a central belt, consisting of hills and valleys of the Sahyadri range, and (3) the eastern table-land. The district is largely hilly in terrain and covered by thick vegetation and forests (just over 80% of the total geographical area of the district is officially classified as forest). It receives high rainfall, and annual precipitation can exceed 5000 mm near the crest-line of the Ghats. This decreases towards the north and east. Average annual precipitation for the district as a whole is 2741.7 mm.

Historically, the district has been a microcosm of the problems and limitations of the colonial and post-colonial state administration of forests. Large areas of forest were reserved, and intensively 'worked' to extract the most valuable timber. Local people were excluded from regeneration and management decisions. Far too much emphasis was placed on production forestry. Teak and softwood monocultures, were raised in the moist deciduous belt and also in some evergreen regions. Raw material was heavily subsidised for supply to industries. Prices did not reflect the scarcity of *in situ* natural resources, and consequently there was little interest in regeneration.

In addition, the district contains four large, west-flowing rivers that descend to the coastline. Since 1955, these have been dammed to generate hydroelectric power to meet the growing energy demands of the state. Large reservoirs have, and continue to be created in areas that were densely forested. Entire villages have been resettled, and land cleared for this. There has been an influx of migrant labour and attendant pressures on the forest. Mining activity has also contributed to deforestation in parts of the district.

The Arecanut-Spice garden

Our focus in this case study, however, is on the arecanut and spice gardens of the Sahyadri range. Arecanut (*Areca catechu*) cultivation in the deep narrow valleys around Sirsi (Figure 42) has been a traditional occupation for a number of generations. The farmers of Uttara Kannada have developed an intensive, multiple-cropping pattern in their spice gardens. Besides the areca palm, other crops such as pepper, cardamom, banana and coconut are grown simultaneously. This intensive cropping pattern is sustained by large quantities of leaf manure that is obtained by lopping the surrounding forested hillsides, known as betta lands or soppina-betta (Kamath, 1985)

Nadkarni *et al.* (1989) studied selected villages in the region. They grouped land under private control into the following major categories; (1) garden land, (2) paddy land (3) land under other food crops, (4) bena land or grassland, which provides fodder for livestock, (5) betta land, which provides leaf manure to the gardens. In the region, arecanut is the main commercialised crop. Its cultivation has transformed the entire physical and social landscape. Both betta and bena lands perform a supportive function in the supply of material and energy to the garden. They are generally on the upper reaches of the terrain, while gardens and paddy land lie in the valleys.

Betta lands are 'protected' forests assigned to garden lands at a ratio of 9:1, although this ratio varies widely. It has been noted that there are significant class differences in this aspect at the village level. The exclusive use of this resource has been privatised and concentrated into the hands of a few growers. The gardeners enjoy a range of privileges in these areas, including collection of leaf manure, grazing cattle, clearing and burning of weeds, and removal of earth, clay, and stone. The use of betta land is exclusive to their holders by title (Nadkarni *et al.*, 1989). There are certain conditions that must be met, however. Bettas are a government owned natural resource. Tree stands are the property of the State and may not be cut damaged or lopped without permission. The gardeners are expected to maintain 100 trees per hectare on this land.

In practice however, betta lands are generally in a highly degraded state. It is quite common to see entire hillsides that consist only of stunted, deformed trees. Even where the required number of trees do exist, they are often lopped excessively. Traditional leaf harvesting methods were cognisant of the need for sustainability. However, there was little or no artificial planting of trees, and natural regeneration was constrained by grazing (Nadkarni *et al.*, 1989).

The problem is exacerbated when betta lands become so degraded that gardeners can no longer obtain their needs from these areas and therefore encroach on the forests. There are a number of additional reasons for encroachments. Bettas were granted only for old gardens. Many of those who developed new gardens enclosed and attached forest lands to their gardens to harvest leaf manure.

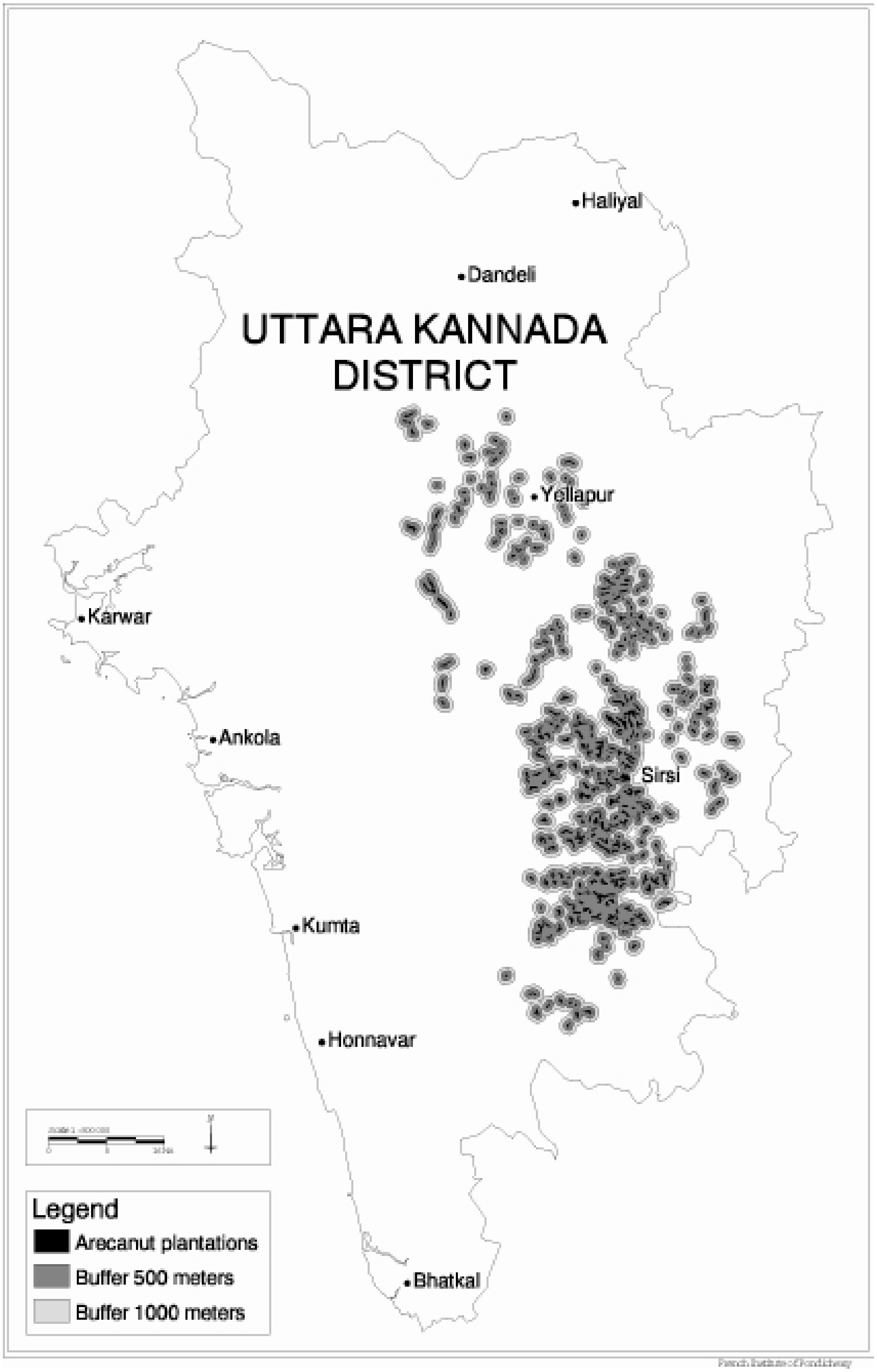


Figure 42: Arecanut valleys and buffers in Uttara Kannada

Spatial analysis

Selected arecanut areas were identified and delineated using satellite imagery at 1:125,000 scale. Using the spatial database, we performed a simple buffering around arecanut plantations to determine the effect of this land-use form on the surrounding vegetation.

First, results were compared according to different buffer radius values. Buffers of distance 500 metres and 1000 metres were used, based on field observations that estimated most of the impact of arecanut cultivation as occurring within a radius of 1000 kms. As shown in Figure 43, the arecanut patches are mostly surrounded with LEE degraded forest, agriculture areas, SMD and LEE disturbed and degraded forest in a 1,000 m radius context. Agriculture, LEE degraded and SMD forests are even more predominant within a shorter radius (500m).

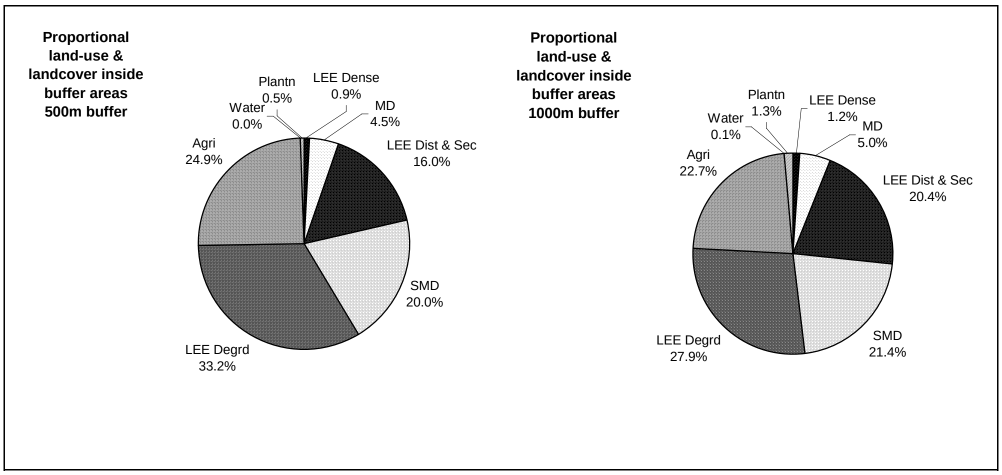


Figure 43: Land cover within buffer areas

Notably, within a 500 m buffer area, we found that the proportion of LEE degraded formations (comprising scrub woodland, tree savanna, and open thickets) was 33%, compared to 10% for the district as a whole. Also, secondary moist deciduous forests formed 20% of the total area inside buffers, compared to 16% of the area outside (Figures 44 and 45). This is consistent with field observations that reveal large areas of soppina-betta in a degraded condition; generally found as tree-savanna or dense to discontinuous thicket formations.

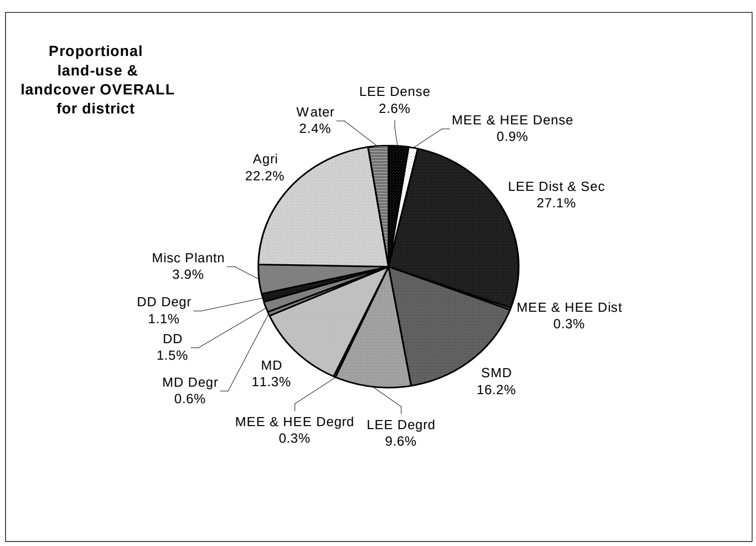


Figure 44: Land cover within the district as a whole

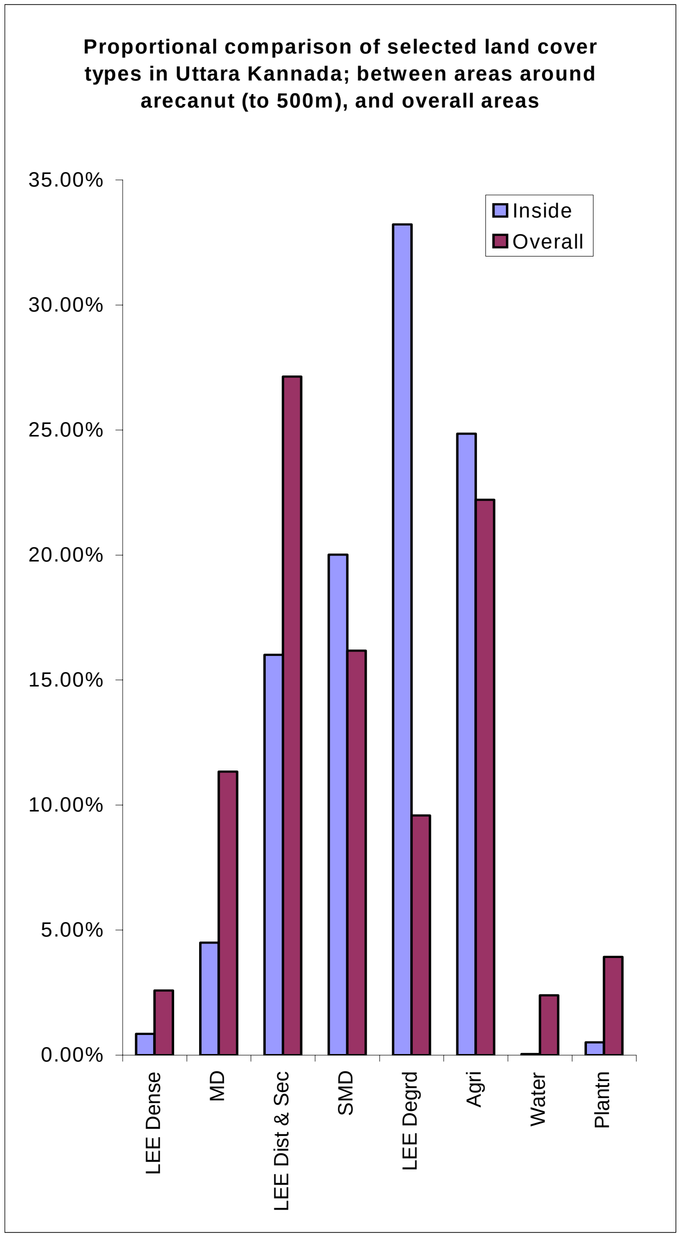


Figure 45: Direct comparison of percentage land cover

Bibliography

Bagnouls, F. & Gaussen, H. (1953) Saison sèche et régime xérothermique. *Documents pour les cartes des productions végétales*, Toulouse Tome III, Vol. 1, art. 8: p 47.

Barbault, R. (1995) Biodiversity dynamics: from population and community ecology approaches to a landscape ecology point of view*, Landscape and Urban Planning* 31: 89-98.

Bourgeon, G. (1989) Explanatory booklet on the reconnaissance soil map of forest area, Western Karnataka and Goa. - *Trav. sect. Sc. tech. Inst. Fr. Pond., h.sér. 20*: 203 pp.

Bourgeon, G. (1989) Reconnaissance soil map of forest area. Inst. fr. Pondichéry, *trav. sec. sci. tech.* Hors serie 20: P. 96 + 1 map.

Buchy, M. (1996) Teak and Arecanut, Colonial State, Forest and People in the Western Ghats (South India) 1800-1947, *publications du departement de sciences sociales* 2, French Institute, 10 St. Louis Street, P.B. 33, Pondicherry 605 001, INDIA: pp 255.

Clements, F. E. (1936) Nature and structure of the climax. *J. Ecol.* 24: 252-284.

Clements; F.E. (1916) Plant succession: an analysis of the development of vegetation. *Carnegie Inst. Washington Publ.,* 242: 1-512.

Collinge, S.K. (1996) Ecological consequences of habitat fragmentation: implications for landscape architecture and planning, *Landscape and Urban Planning* 36: 59-77.

Freeman, R. (1994) Forests and the Folk Perceptions of Nature in the Swidden Regimes of Highland Malabar, Pondy Papers in Social Sciences 15, Departement de Sciences Sociales, French Institute, 10 St. Louis Street, P.B. 33, Pondicherry 605 001, INDIA: pp 36.

Gadgil, M. & Guha, R. (1992) This Fissured Land – An Ecological History of India, Oxford University Press, Delhi: pp 274.

Gadgil, M. & Vartak, V.D. (1974) Sacred Groves of India-A plea for continued conservation, *J. Bombay Nat. Hist. Soc*. 72(2): 314-320.

Ghosh, A.K. (1993) *Forest Policy in India* In: Indian Foresty A Perspective (Edited by Rawat, A.S.) Indus Publishing Company, New Delhi: 69-84.

Godron, M. & Forman, R.T.T. (1983) Landscape modification and changing ecological characteristics. In: *Disturbance and Ecosystems: Components of Response*. (Ed. Money, H.A. and Godron, M). Springer-Verlag: pp12-28.

Gunnell, Y & Bourgeon, G. (1997) Soils and climatic geomorphology on the Karnataka Plateau, peninsular India. *Catena* 29: 239-262.

Gunnell, Y. & Fleitout, L. (1998) Shoulder uplift of the Western Ghats passive margin, India — a flexural model. *Earth Surface Processes and Landforms* 23: 391-404.

Gunnell, Y. & Fleitout, L. (1999) Morphotectonic evolution of the Western Ghats, India, in Summerfield, M. (Ed.): *Geomorphology and Global Tectonics.* John Wiley & Sons, Chichester, *sous presse.*

Gunnell, Y. (1997) Relief and climate in South Asia. The influence of the Western Ghats on the current climate pattern of peninsular India. *International Journal of Climatology* 17(9): 1169-1182.

Gunnell, Y. (1998a) The interaction between geological structure and global tectonics in multistoreyed landscape development : a denudation chronology of the South Indian shield. *Basin Research* 10: 281-310.

Halle, F., Oldeman, R.A.A. & Tomilinson, P.B. (1978) Tropical trees and forests. An architectural analysis. Springer-Verlag, New York: p 441.

Hobbs, R.J. (1995) Landscape Ecology In: *Encyclopedia of Environmental Biology* Vol. 2: 417-427.

Hughes, J.D. & Subash Chandran, M.D. (1998) Sacred Groves Around the Earth: An Overview In *Conserving the Sacred for Biodiversity Managemen*t (Editors: Ramakrishnan, P.S., Saxena, K.G. & Chandrashekara, U.M.), Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi: pp 69-86.

Kalam, M.A. (1996) Sacred Groves in Kodagu District of Karnataka (South India): A Socio-Historical Study In: *Pondy Papers In Social Sciences* 21, Departement de Sciences Sociales, French Institute, 10 St. Louis Street, P.B. 33, Pondicherry 605 001, INDIA: pp 53.

Kamath, S.U. (1985) *Gazetteer of India*, Karnataka State Gazetteer Part I, Government of India: 121-155.

Karsenty, A., Mebenga, L.M. & Penelon, A. (1999) Specialized Land use or Integrated Management of Forest areas, *Bois Et Forets Des Tropiques* special issue: 18-29.

Keshava Murthy, K.R. & Yoganarasimhan, S.N. (1990) *Flora of Coorg*, Vimsat Publishers, Bangalore: pp 711.

Kothari, A., Suri, S. & Singh, N. (1995) Conservation in India: A New Direction. *Economic and Political Weekly* October 28, 1995: 2755-2766.

Legris, P. (1963) *La végétation de l'Inde*. Inst. fr. Pondichéry, trav. sec.sci. tech. Tome 6.

Lélé, S., Rajashekhar, G. Hegde, V.R., Previshkumar, G. & Saravanakumar, P. (1998) Meso-scale analysis of forest condition and its determinants: A case study from the Western Ghats region, India. *Current Science* 75: 3: 256-263

Menon, S. & Bawa, K.S. (1997) Applications of geographic information systems, remote-sensing, and a landscape ecology approach to biodiversity conservation in the Western Ghats In: *Current Science* Vol.73(2): 134-144.

Moppert, B. (In press) Expansion of Coffee plantations and Landscape changes In: *Conservation of Biodiversity in the context of traditional knowledge and ecosystem rehabilitation* (Eds: Ramakrishnan, P.S., Elouard, C. and Guilmoto, C.Z.) Oxford and IBH, Delhi.

Myers, N. (1994).Tropical Deforestation: Rates and Patterns. In K. Brown and D.W. Pearce, eds., The Causes of Tropical Deforestation: 27-40. University College London Press, London, U.K.

Nadkarni, M.V., Pasha, S.A. & Prabhakar, L.S. (1989) *The Political Economy of Forest Use and Management,* Sage Publications, New Delhi: pp 182.

Pascal, J. P. (1984)(With the collaboration of Shyam Sunder, S. & Meher-Homji, V.M.) *Forest Map of South India: Belgaum-Dharwar-Panaji*. Published by the Karnataka and Goa Forest Departments and the French Institute of Pondicherry. Inst. fr. Pondichéry, trav. sec.sci. tech. Hors série 18c.

Pascal, J.P. (1982a) *Bioclimates of the Western Ghats at 1/250,000* (2 sheets). Inst. fr. Pondichéry, trav. sec.sci. tech. Hors série 17.

Pascal, J.P. (1982b)(With the collaboration of Shyam Sunder, S. & Meher-Homji, V.M.) *Forest map of South India. Mercara-Mysore.* Published by the Karnataka and the Kerala Forest Departments and the French Institute, Pondicherry.

Pascal, J.P. (1982c)(With the collaboration of Shyam Sunder, S. & Meher-Homji, V.M.) *Forest map of South India. Shimoga*. Published by the Karnataka and the Kerala Forest Departments and the French Institute*. Inst. fr. Pondichéry, trav. sec. sci. tech*. Hors série 18b

Pascal, J.P. (1986) *Explanatory booklet on the Forest Map of South India - Sheets: Belgaum-Dharwar-Panaji; Shimoga; Mercara-Mysore.* Published by the Karnataka Forest Department and the French Institute of Pondicherry*. Inst. fr. Pondichéry, trav. sec. sci. tech*. Hors série 18.

Pascal, J.P., Ramesh, B.R. & Bourgeon, G. (1988) The "Kan Forests" of the Karnataka plateau (India): Structure and Floristic composition, trends in the changes due to their exploitation, *Tropical Ecology* 29(2): 9-23.

Pouchepadass, J. (1993) The Ecological History of the Western Ghats in the Modern Period: A Preliminary Survey, In: *Aspects of ecological problems and Environmental Awareness in South Asia* (Ed. Wolfgang L. Werner) Manohar Publishers, New Delhi: 105-131.

Raju, G. (1996) From Joint Forest Management to Joint Protected Area Management: Can the Concept be Extended? In *People & Protected Areas Towards participatory conservation in India*, (Editors Kothari, A., Singh, N. & Suri, S.), Sage Publications, New Delhi: 93-113.

Ramakrishnan, P.S. (1996) Complex Agroecosystems, *in situ* Biodiversity Conservation and Global Change in the Indian Context In: *Conserving Biodiversity For Sustainable Development* (Edited by Ramakrishnan, P.S., Das, A.K., & Saxena, K.G.) Indian National Science Academy, Bahadurshah Zafar Marg, New Delhi: 11-26.

Ramesh, B.R. (1989). Evergreen forests of the Biligirirangan Hills, South India. Ecology, structure and floristic composition. Ph.D. Thesis, University of Madras, 171pp.

Ramesh, B.R. & Pascal, J.P. (Geomatics by Nouguier, C.) (1997) *Atlas of Endemics of the Western Ghats (India). Distribution of tree species in the evergreen and semi-evergreen forests*. Institut Francais de Pondicherry, Publications du departement d'ecologie 38.

Ramesh, B.R., De Franceschi, D. & Pascal, J.P. (1997) *Forest Map of South India - sheet: Tiruvananthapuram-Tirunelveli*, Hors série 22a, Published by the Kerala and Tamil Nadu Forest Departments and the French Institute of Pondicherry. Institut Français de Pondichéry, Publications du départment d'écologie.

Ramesh, B.R., Menon, S. & Bawa, K.S. (1997) A Vegetation Based Approach to Biodiversity Gap Analysis in the Agastyamalai Region, Western Ghats, India. *Ambio* Vol. 26(8): 529-536.

Saxena, N.C. (1997) *The Saga of Participatory Forest Management in India*, published by the Center for International Foresty Research, Jakarta 10065, Indonesia: pp 214.

Shyamsunder, S. & Parameswarappa, S. (1987) Forestry in India – The forester's view, *Ambio* Vol.16(6): 332-337.

Subash Chandran, M.D. (1997) On the ecological history of the Western Ghats. *Current Science* Vol. 73(2): 146-155.

Subash Chandran, M.D. (1998) Shifting Cultivation, Sacred Groves and Conflicts in Colonial Forest Policy in the Western Ghats In: *Nature & The Orient* (Eds. R.H. Grove, V. Damodaran, S. Sangma). OUP. pp 675-707.

Taylor, P.& Garcia-Barrios, R. (1995) The social analysis of ecological change: From systems to intersecting processes In: *Social Science Information* (SAGE, London, Thousand Oaks, CA and New Delhi), 34(1): 5-30.

Trochain, J.L. (1957) Accord interafricain sur la definition des types de vegetation de l'Afrique tropicale. *Bull. Inst. d'Etudes Centre-africaines (N.S.),* Brazaville 13-14: 55-63.

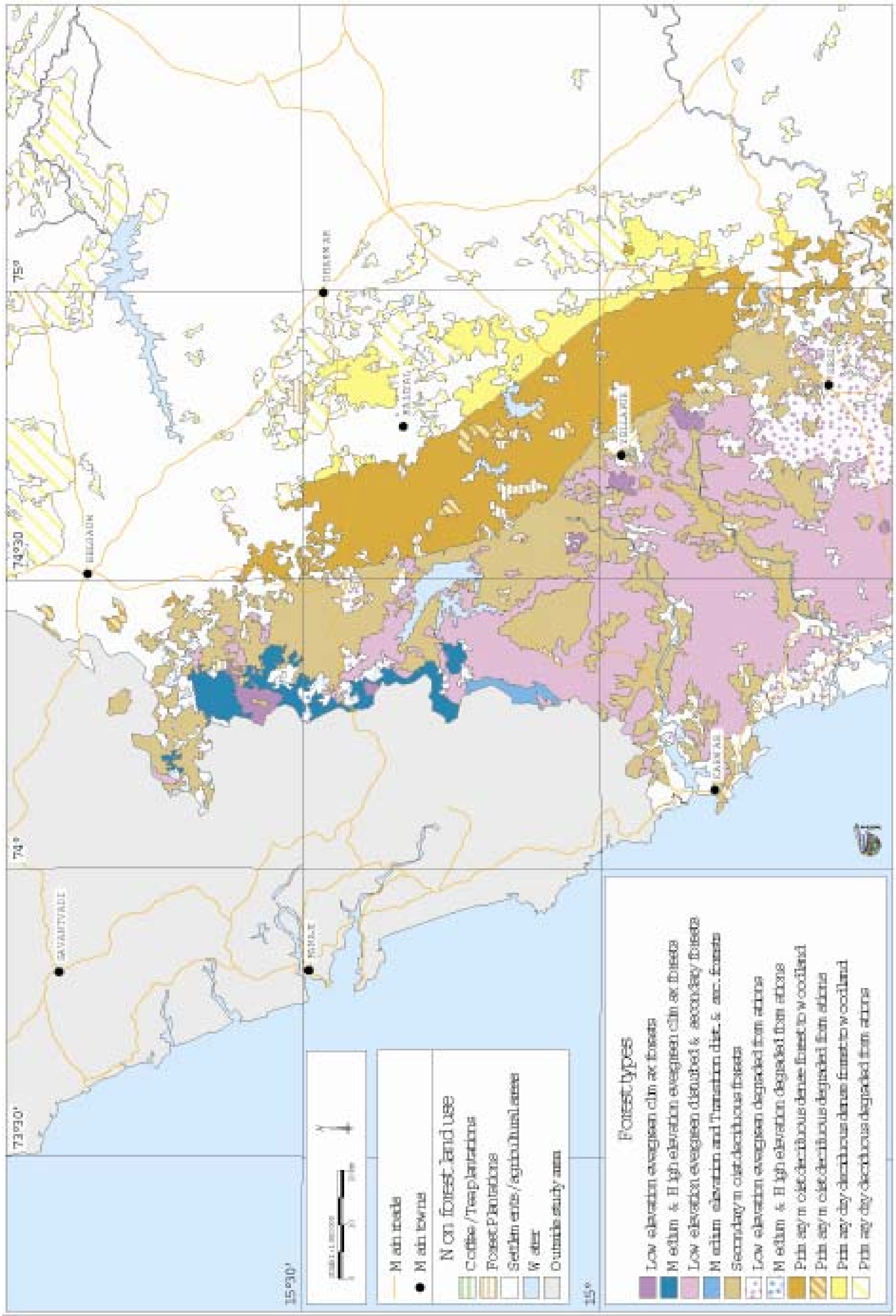
Vogelmann, J.E. (1995) Assessment of Forest Fragmentation in Southern New England using Remote Sensing and Geographic Information Systems Technology, *Conservation Biology* Vol. 9(2): 439-449.

Whitmore, T.C. (1978) Gaps in the forest canopy. In: *Tropical trees as living* systems. (Eds. P.B. Tomlinson and M.H. Zimmermann), Cambridge University Press: 639-655.

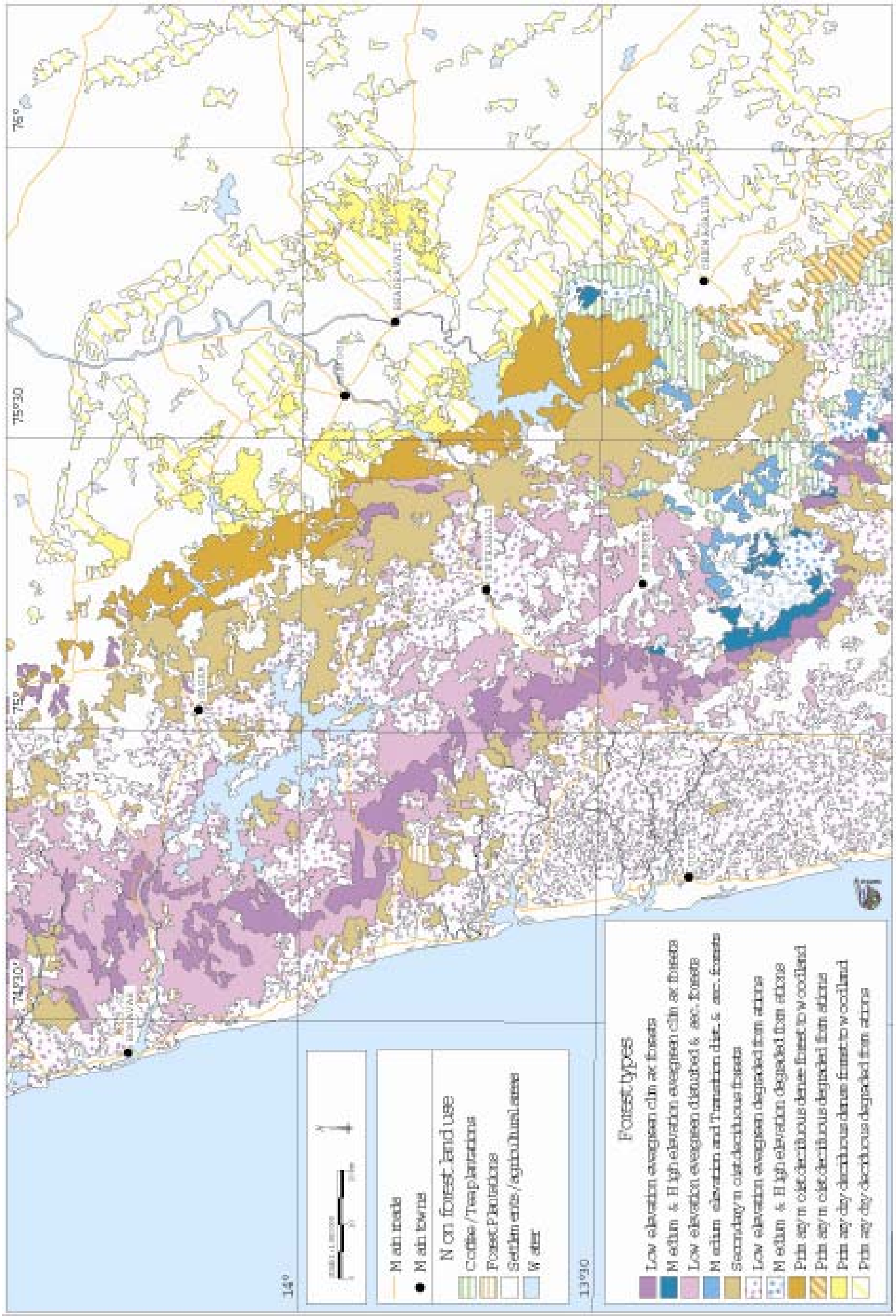
Widdowson, M. & Gunnell, Y. (1999) *Lateritization, geomorphology and geodynamics of a passive continental margin: the Konkan and Kanara coastal lowlands of western peninsular India.* In: Thiry, M. & Simon-Coinçon, R. (eds): Palaeoweathering, Palaeosurfaces and Related Continental Deposits, International Association of Sedimentologists, Special Publication 27: 245-274.

Map figures

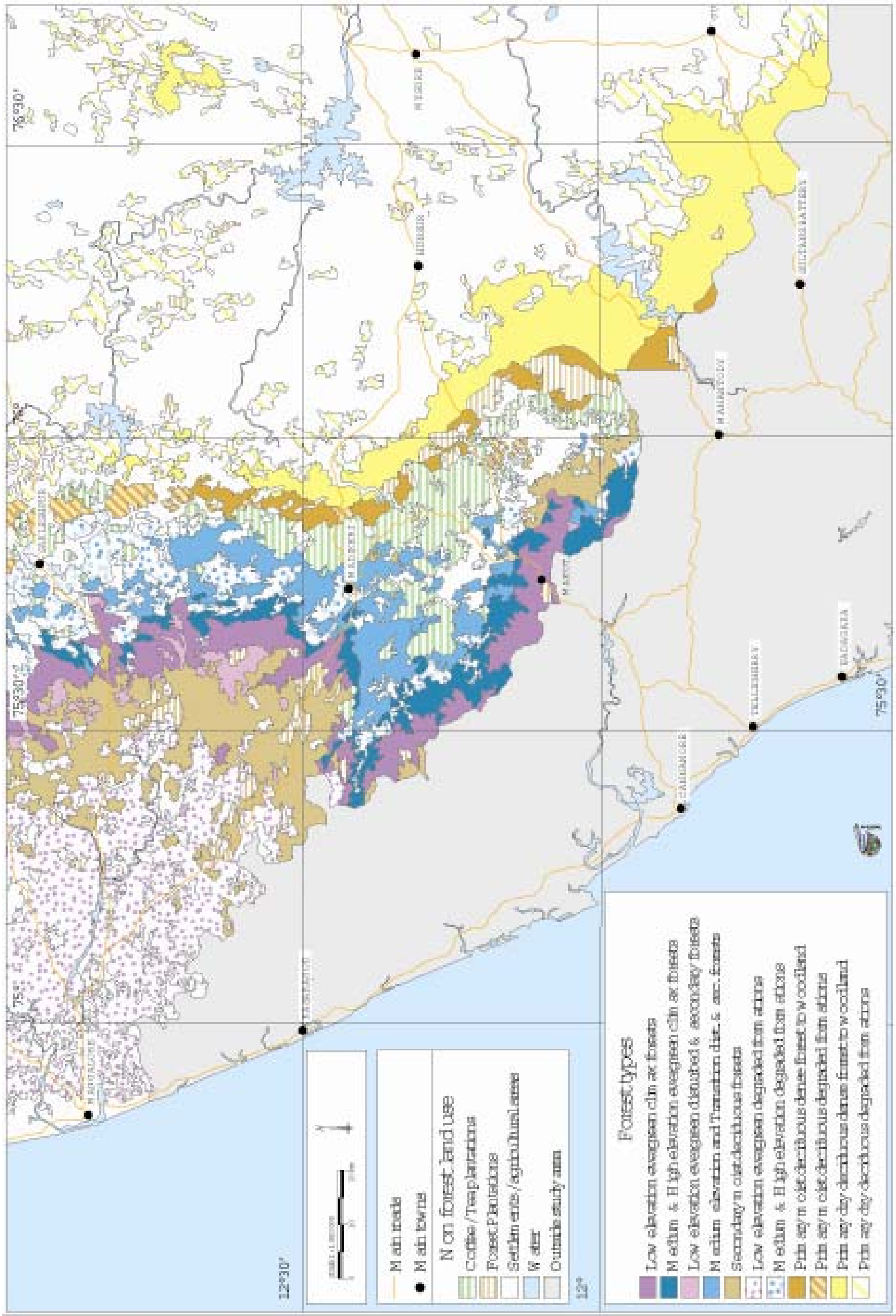
1. Sheet 1 of the Forest Map (Belgaum-Dharwar-Panaji) – Vegetation polygons simplified – 1977 status
2. Sheet 2 of the Forest Map (Shimoga) – Vegetation polygons simplified – 1977 status
3. Sheet 3 of the Forest Map (Mercara-Mysore) – Vegetation polygons simplified – 1977 status
4. Sheet 1 of the Forest Map (Belgaum-Dharwar-Panaji) – Vegetation polygons simplified – 1997 status & BSP locations
5. Sheet 2 of the Forest Map (Shimoga) – Vegetation polygons simplified – 1997 status & BSP locations
6. Sheet 3 of the Forest Map (Mercara-Mysore) – Vegetation polygons simplified – 1997 status
7. Distribution of basal area ranges on Sheet 1 (Belgaum-Dharwar-Panaji)
8. Distribution of endemic tree species ranges on Sheet 1 (Belgaum-Dharwar-Panaji)
9. Distribution of tree species richness ranges on Sheet 1 (Belgaum-Dharwar-Panaji)
10. Distribution of tree species diversity (Shannon) ranges on Sheet 1 (Belgaum-Dharwar-Panaji)
11. Distribution of basal area ranges on Sheet 2 (Shimoga)
12. Distribution of endemic tree species ranges on Sheet 2 (Shimoga)
13. Distribution of tree species richness ranges on Sheet 2 (Shimoga)
14. Distribution of tree species diversity (Shannon) ranges on Sheet 2 (Shimoga)
15. Conservation value map of forest areas on sheet 1 (Belgaum-Dharwar-Panaji)
16. Conservation value map of forest areas on sheet 2 (Shimoga)



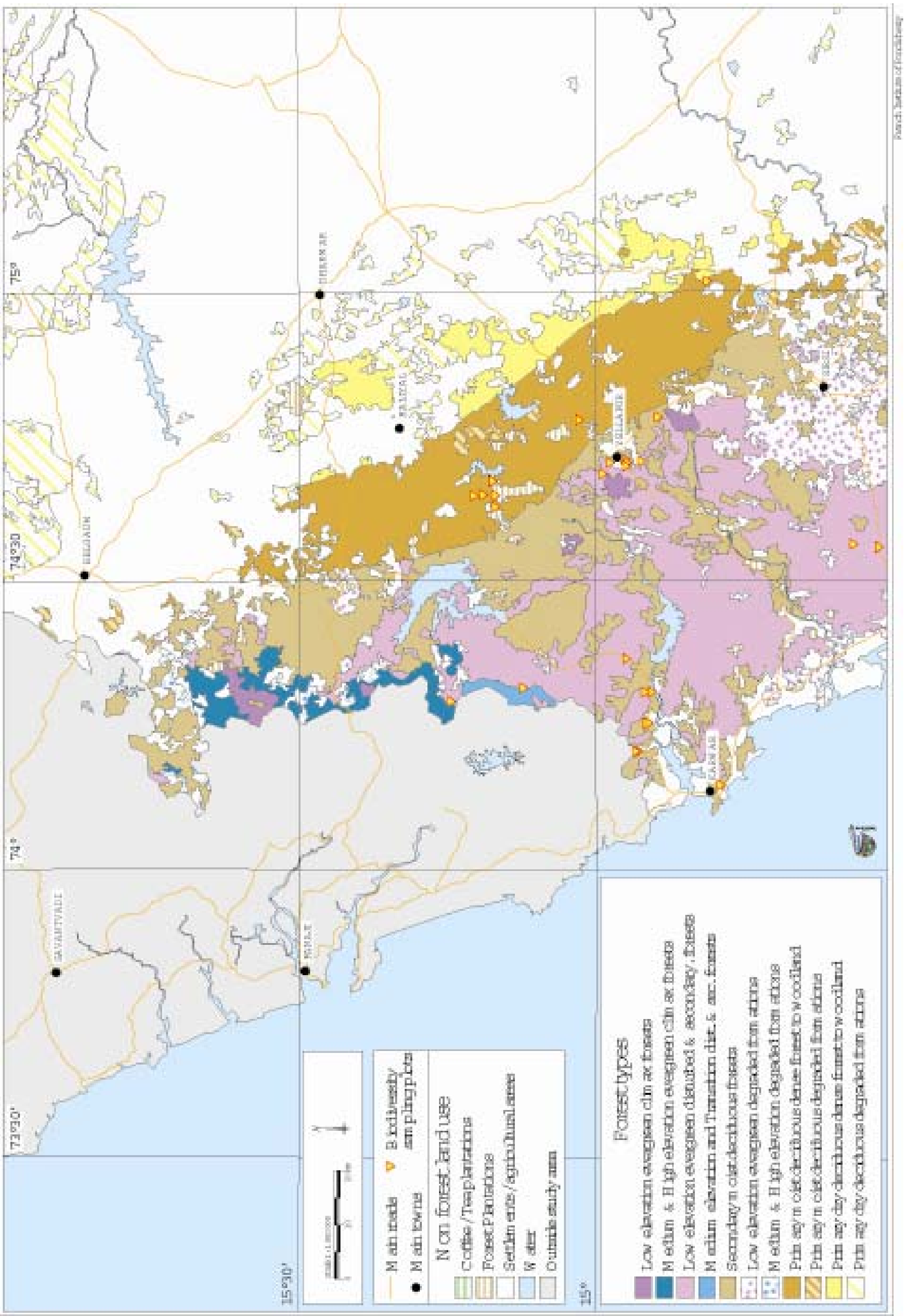
Map Figure 1: Sheet 1 of the Forest Map (Belgaum-Dharwar-Panaji) – Vegetation polygons simplified – 1977 status.



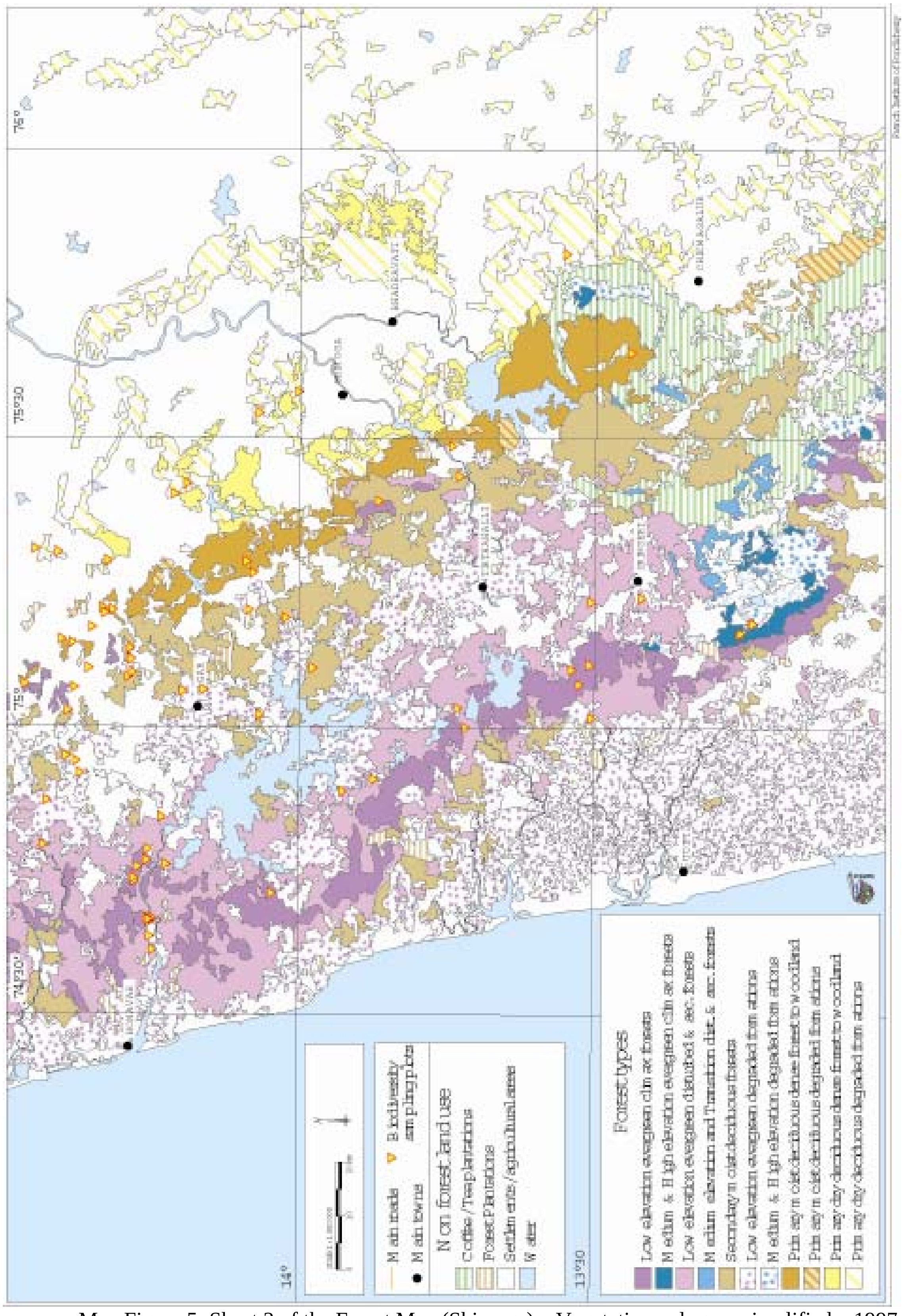
Map Figure 2: Sheet 2 of the Forest Map (Shimoga) – Vegetation polygons simplified – 1977 status.



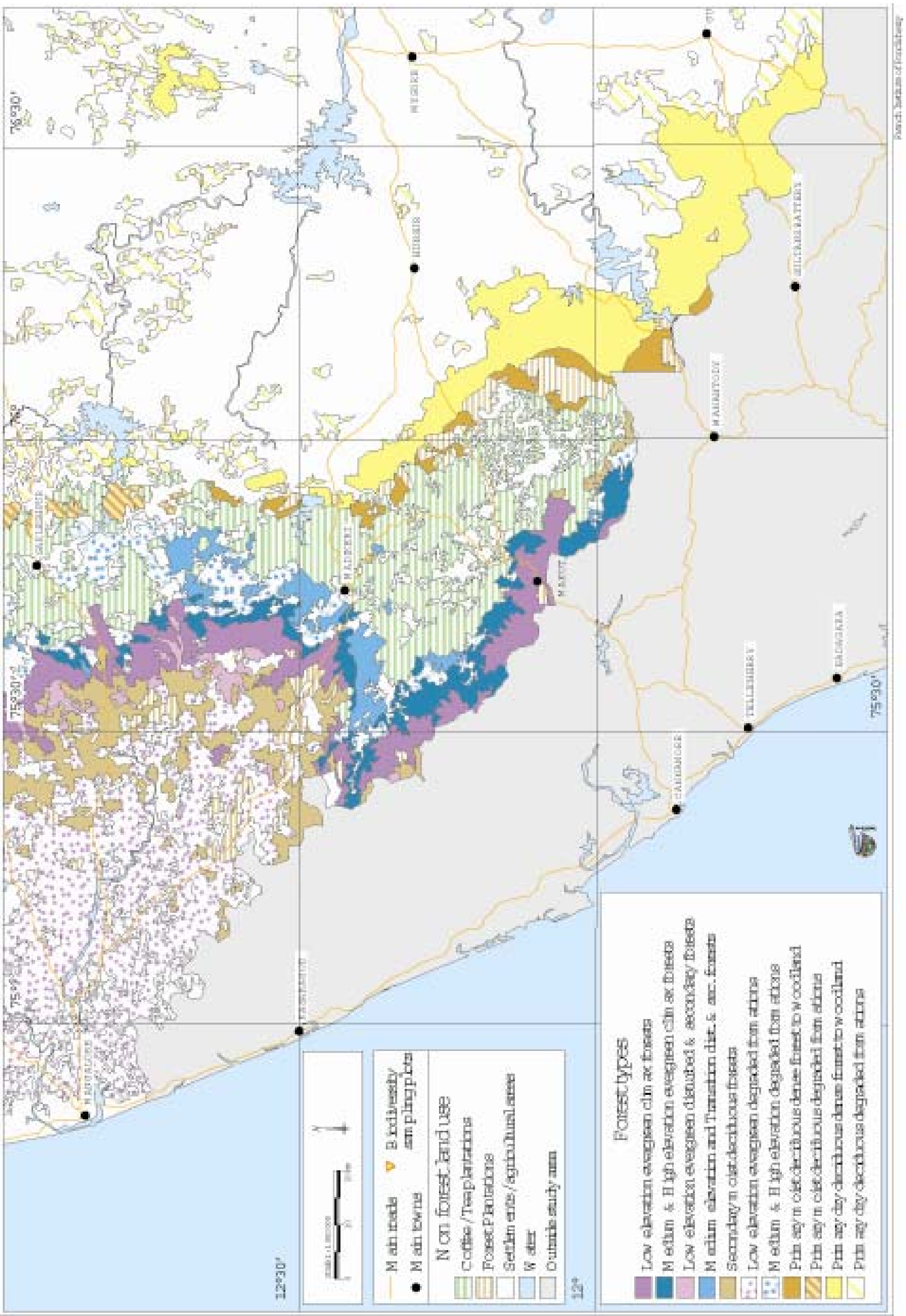
Map Figure 3: Sheet 3 of the Forest Map (Mercara-Mysore) – Vegetation polygons simplified – 1977 status.



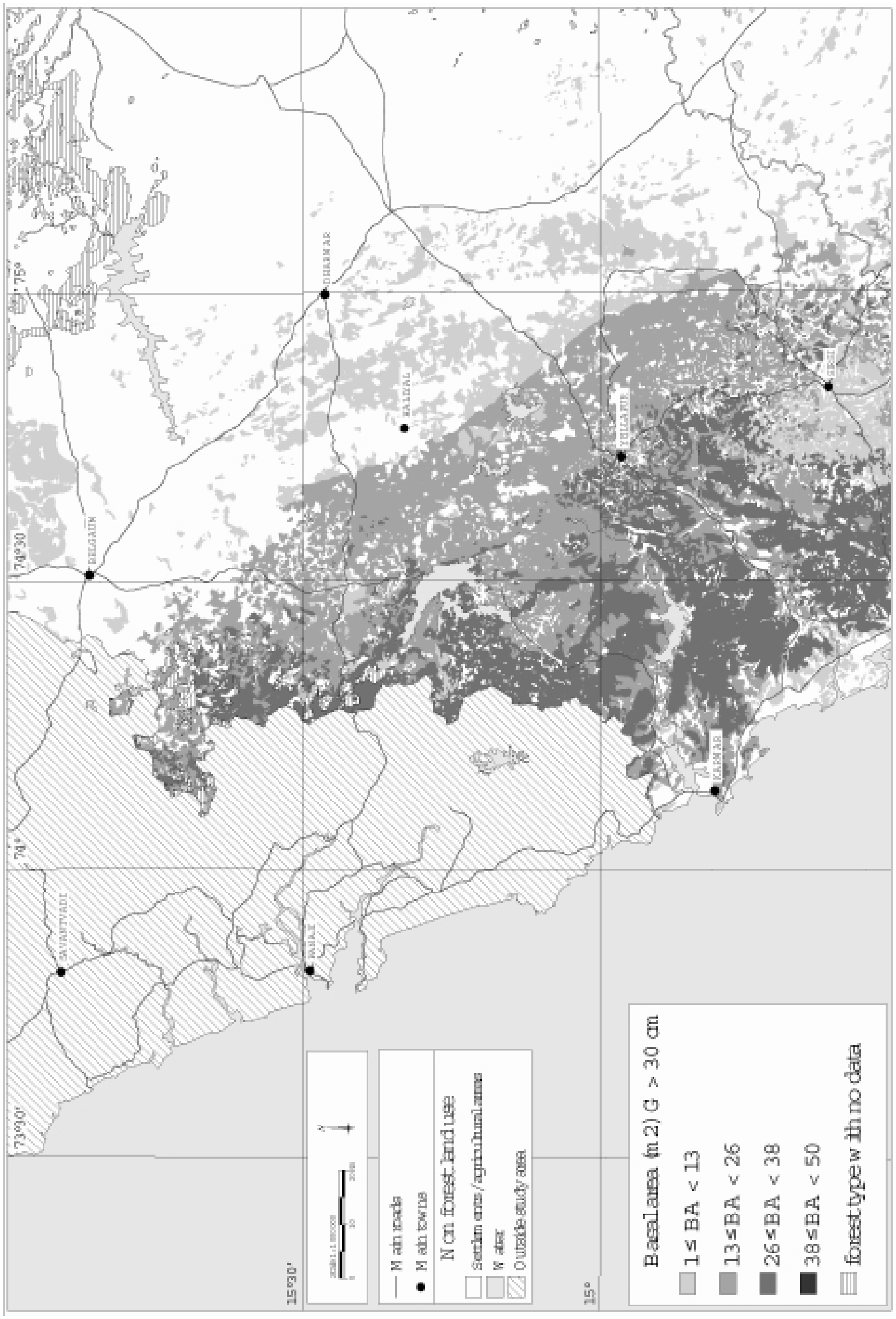
Map Figure 4: Sheet 1 of the Forest Map (Belgaum-Dharwar-Panaji) – Vegetation polygons simplified – 1997 status & Biodiversity Sampling Plot locations



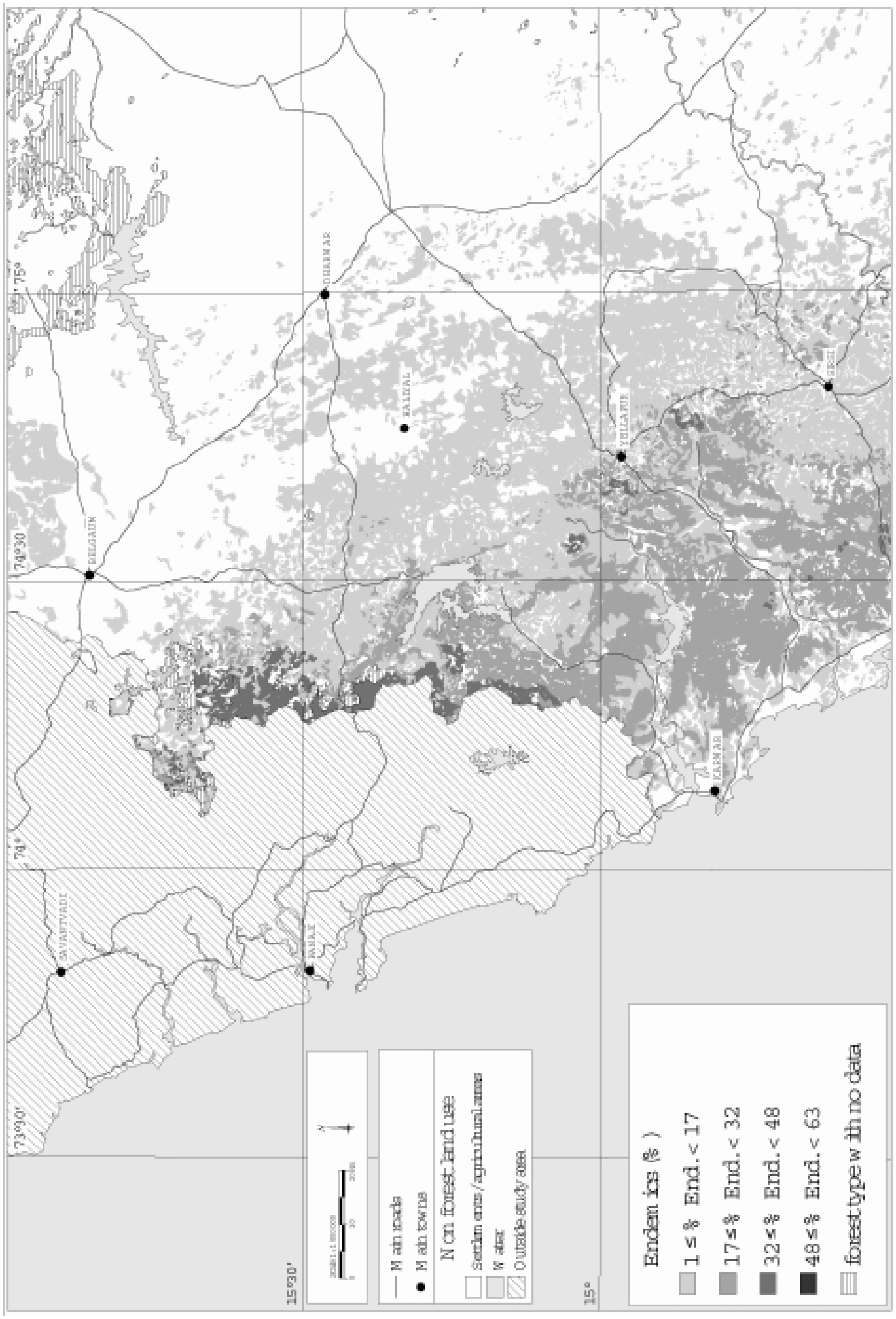
Map Figure 5: Sheet 2 of the Forest Map (Shimoga) – Vegetation polygons simplified – 1997 status & Biodiversity Sampling Plot locations



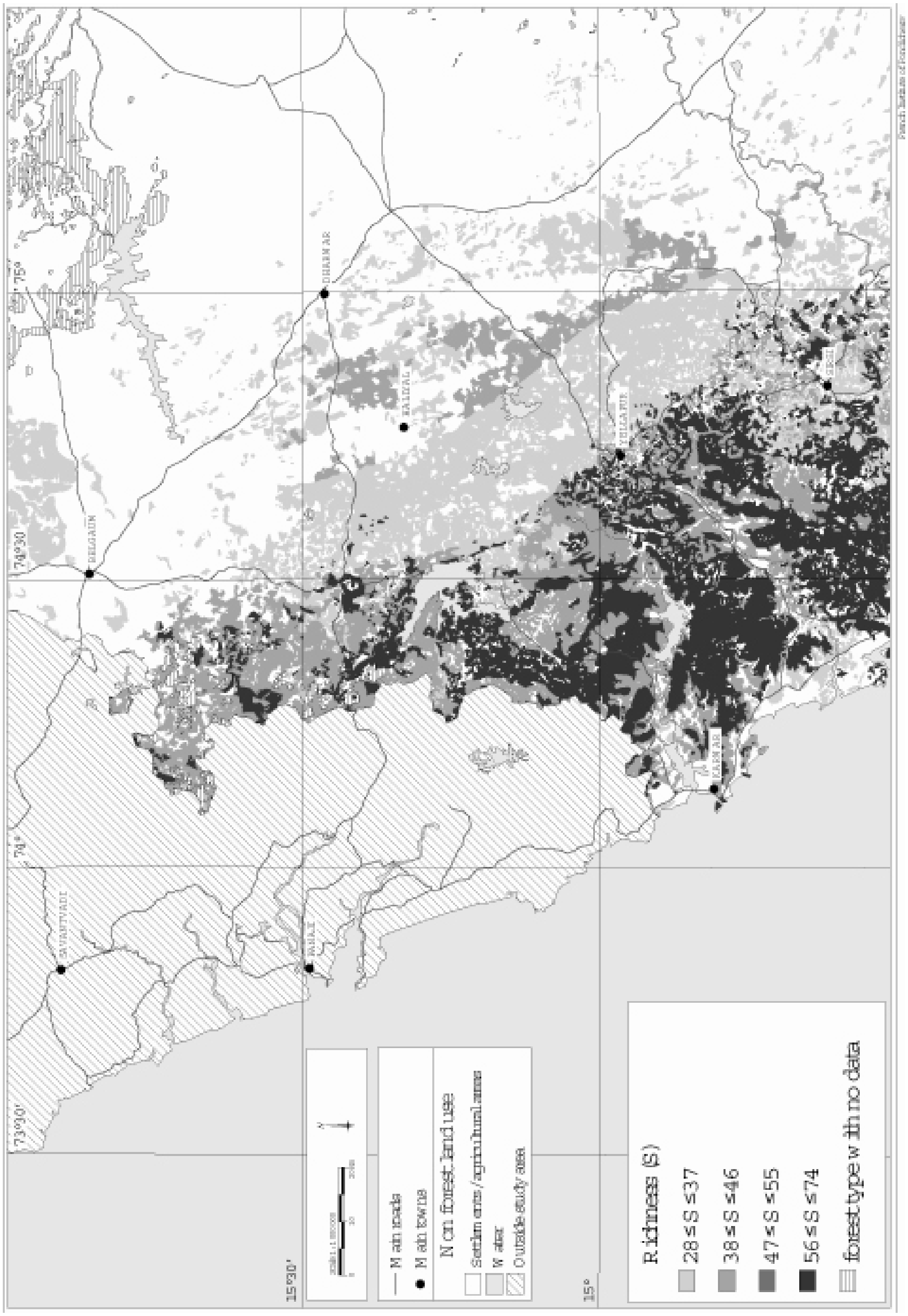
Map Figure 6: Sheet 3 of the Forest Map (Mercara-Mysore) – Vegetation polygons simplified – 1997 status



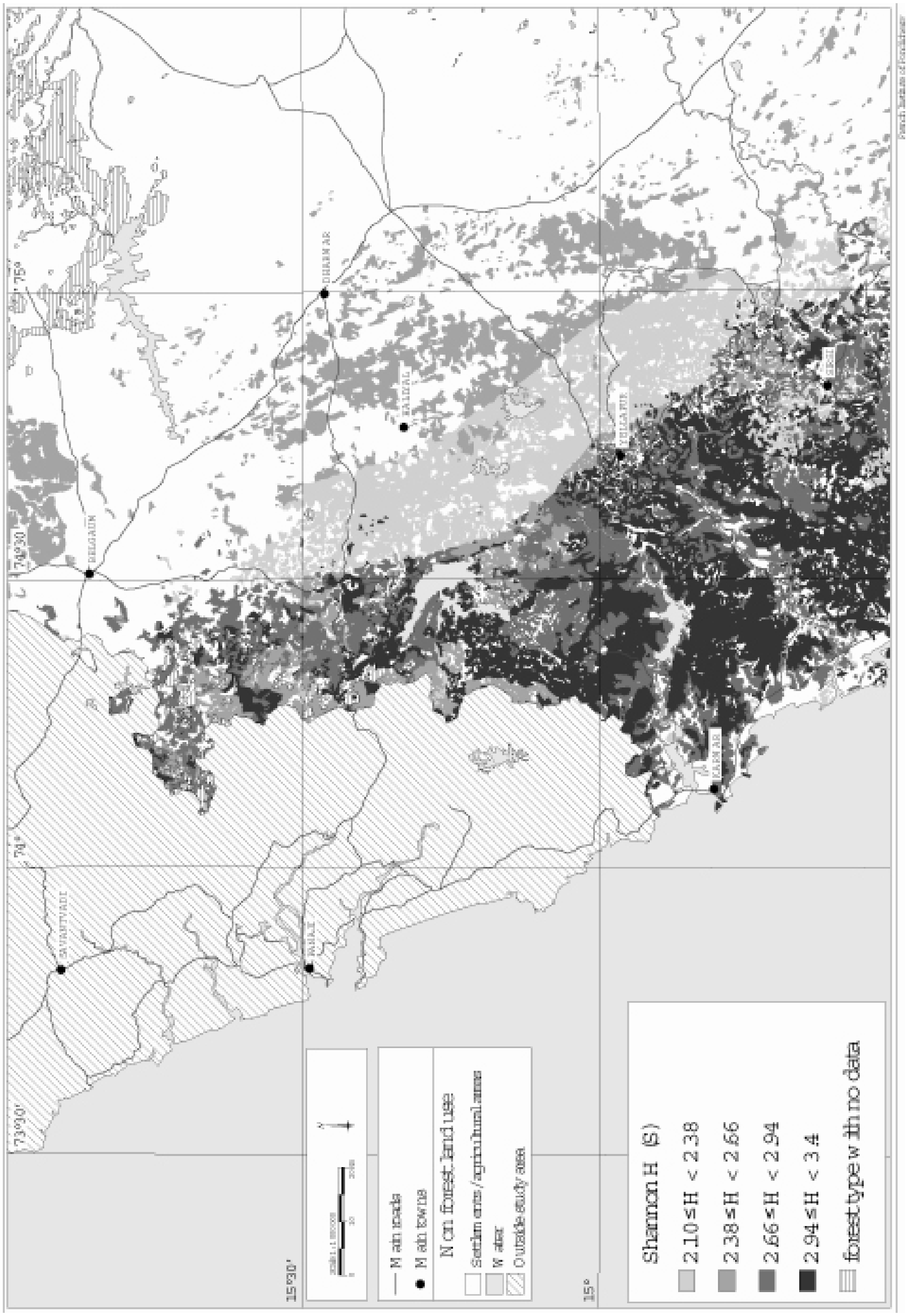
Map Figure 7: Distribution of basal area ranges on Sheet 1 (Belgaum-Dharwar-Panaji)



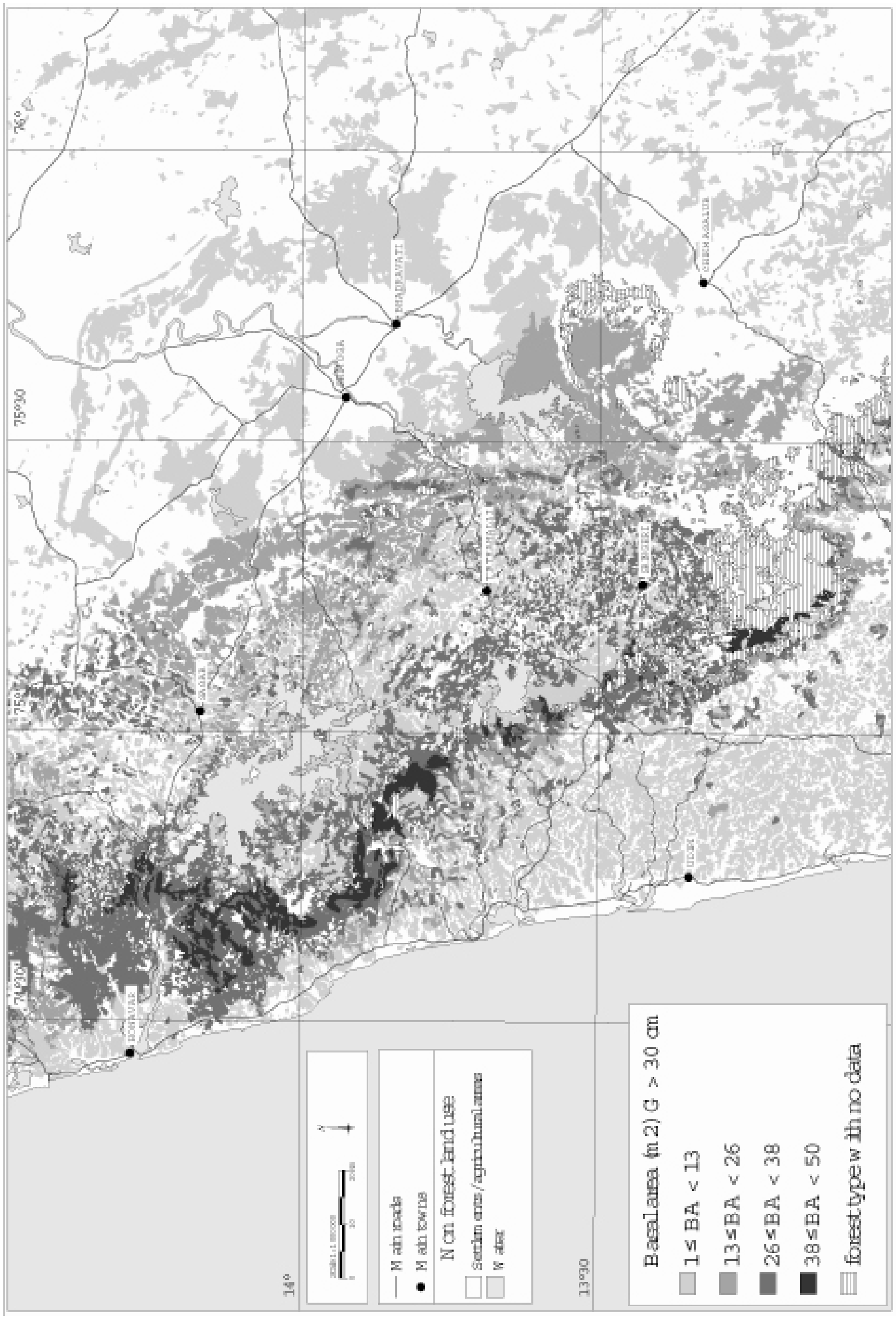
Map Figure 8: Distribution of endemic tree species ranges on Sheet 1 (Belgaum-Dharwar-Panaji)



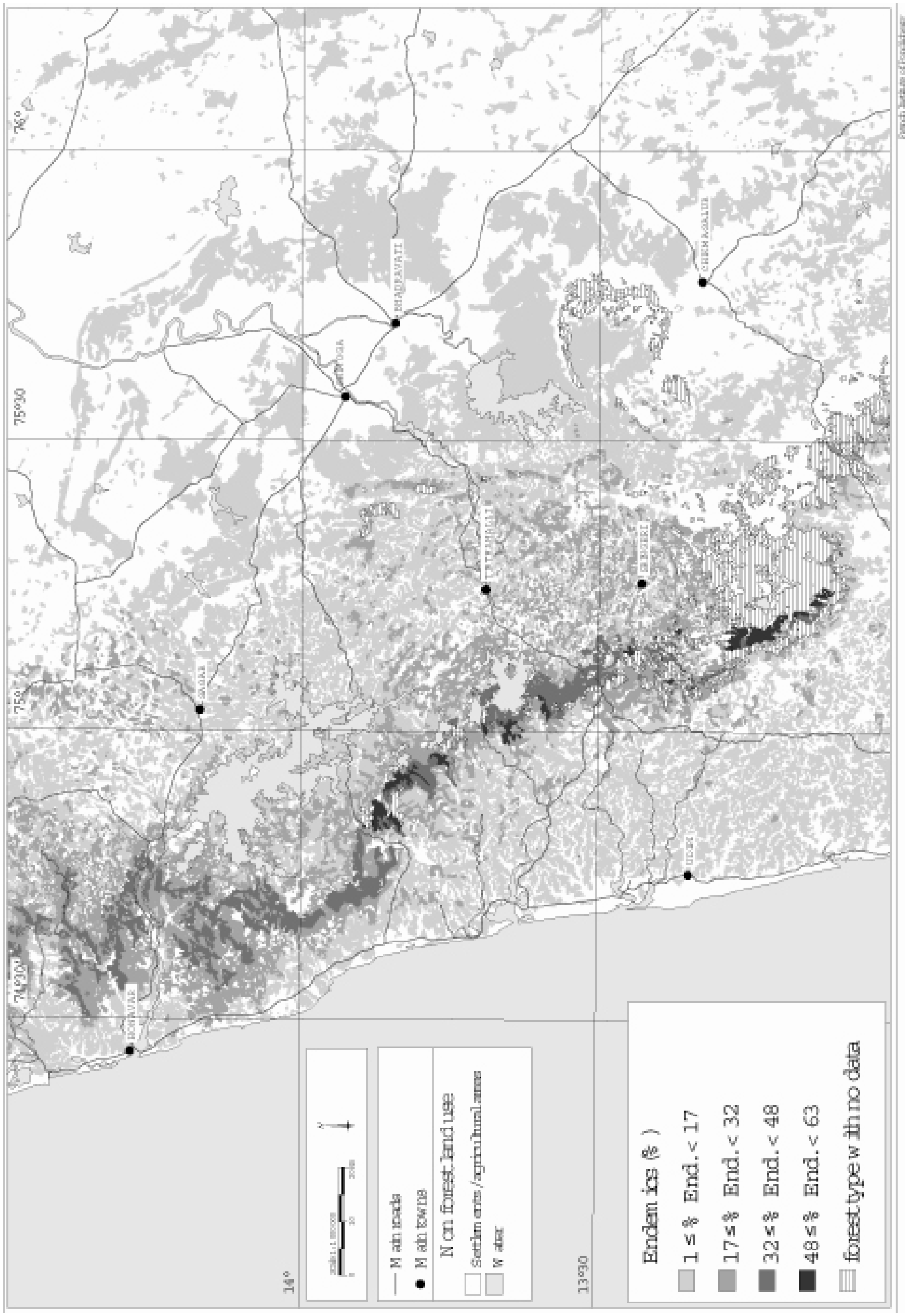
Map Figure 9: Distribution of tree species richness ranges on Sheet 1 (Belgaum-Dharwar-Panaji)



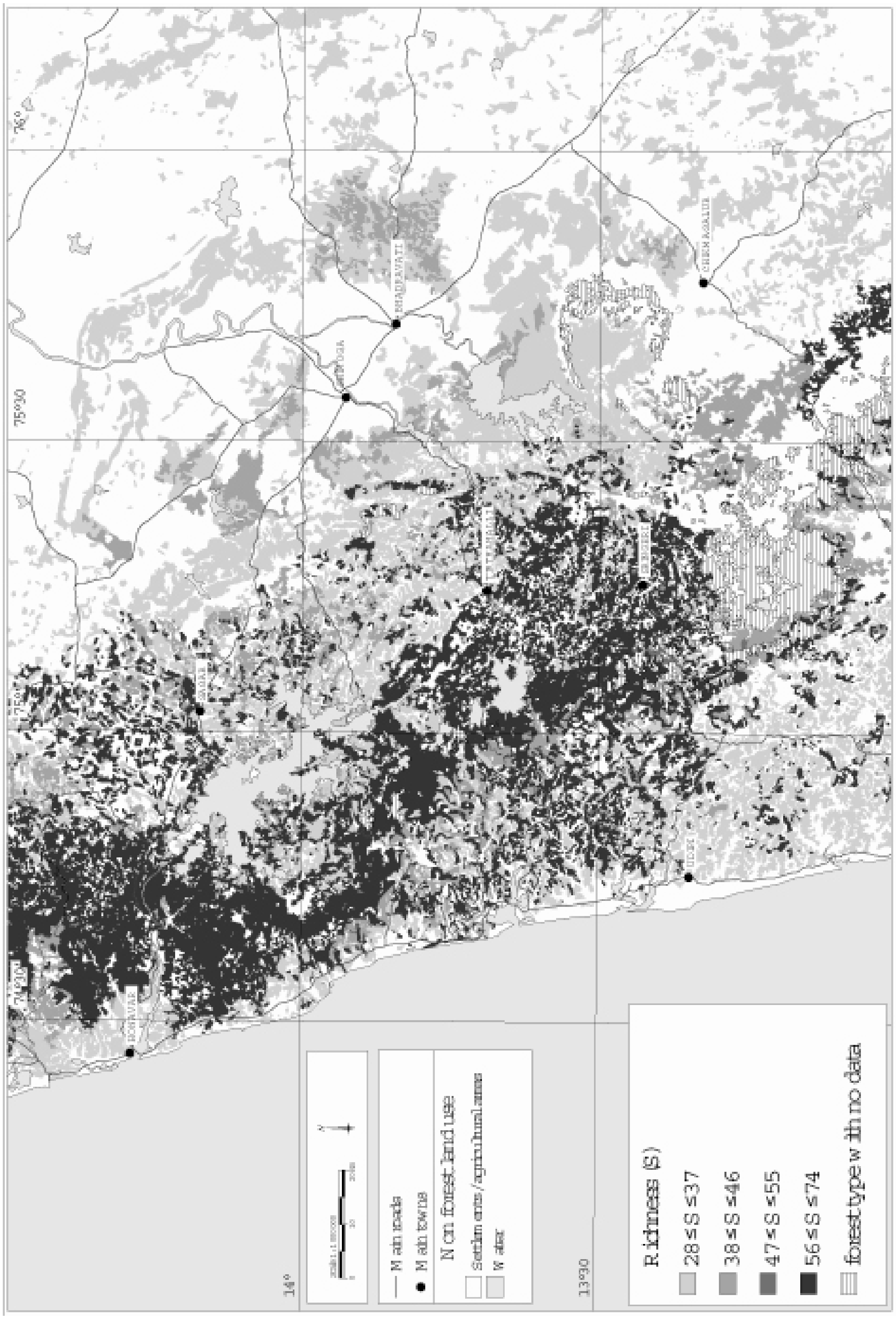
Map Figure 10: Distribution of tree species diversity (Shannon) ranges on Sheet 1 (Belgaum-Dharwar-Panaji)



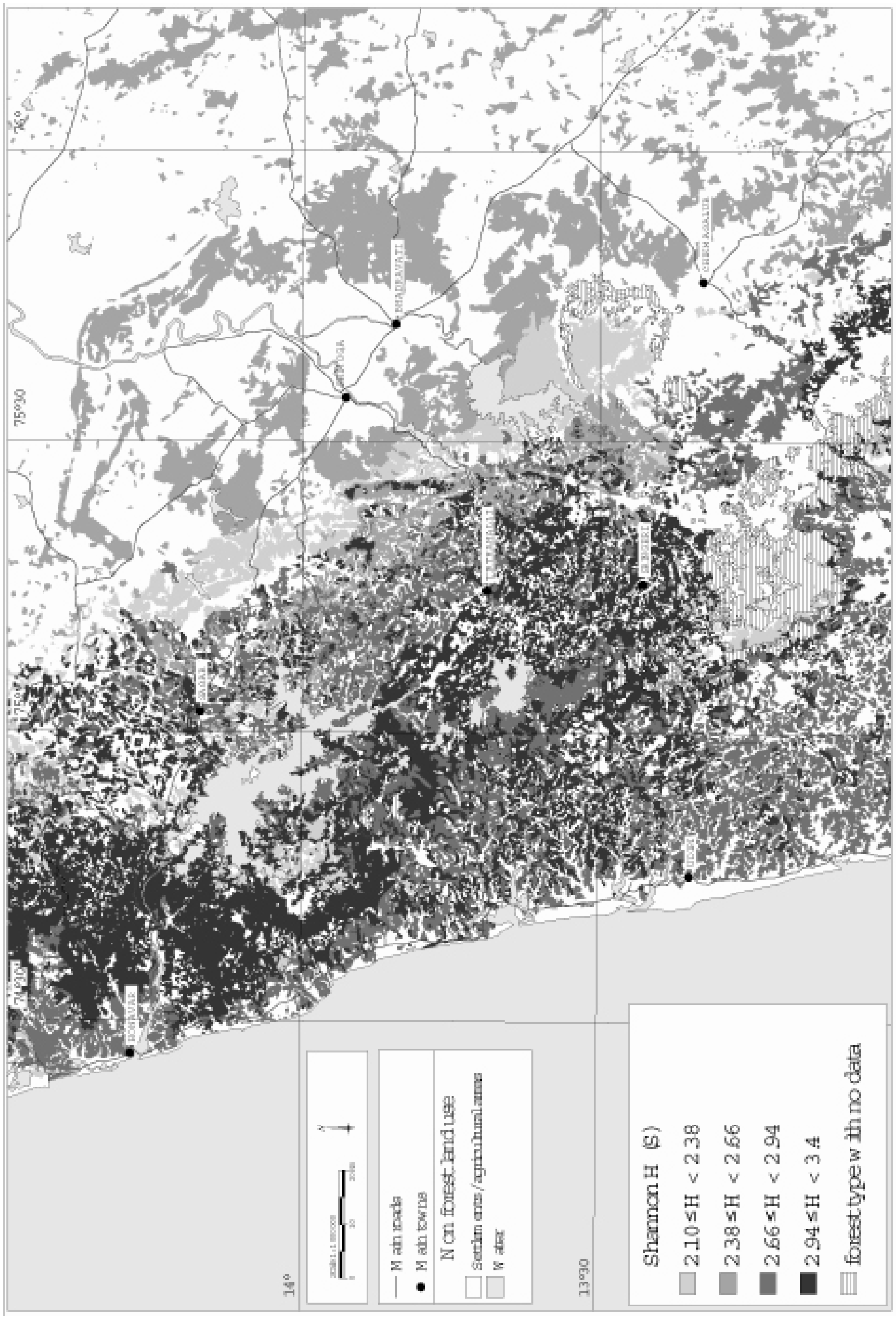
Map Figure 11: Distribution of basal area ranges on Sheet 2 (Shimoga)



Map Figure 12: Distribution of endemic tree species ranges on Sheet 2 (Shimoga)



Map Figure 13: Distribution of tree species richness ranges on Sheet 2 (Shimoga)



Map Figure 14: Distribution of tree species diversity (Shannon) ranges on Sheet 2 (Shimoga)

Colour plates

Clockwise from top-left: Evergreen forest near Agumbe; Evergreen forest in Kodagu district; *Ficus virens*; Seedling of *Dipterocarpus indicus*; Flowering *Ardisia solanaceae*; Medium elevation grassland, and evergreen forest in Kudremukh National Park.

Clockwise from top-left: Rocky outcrops near Yana, Uttara Kannada; Base of *Poeciloneuron indicum*; Moss and creepers in an evergreen forest; Fruit of *Globa* spp.; Aerial roots of *Myristica fatua*

Clockwise from top-left: Teak plantation in Uttara Kannada; Grazing on a bare hilltop; Area flooded by reservoir; Rubber plantation in Dakshina Kannada; Coffee grown on slopes in foreground; Paddy in the valleys.

Clockwise from top-left: Leaf litter collection; Green-manure collection from roadside; Logs from dam clearing; Arecanut orchard in valley and denuded hillsides; "Skeletal" overpruned trees on betta-land; Dam-site clearing in the Sharavati valley.

Annexe 1

A table describing forest classification on sheets 1 to 3 of the Forest Map

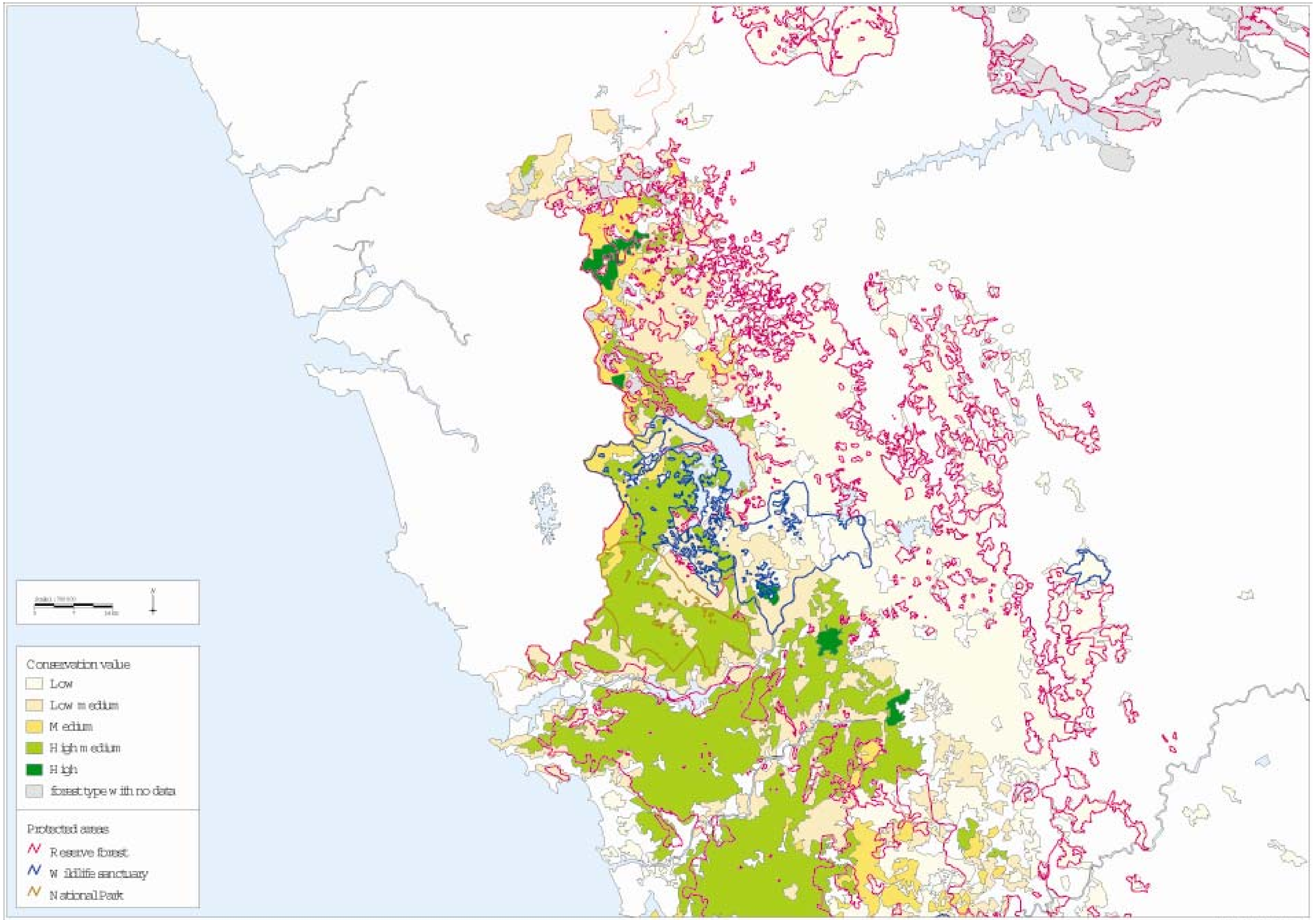
(Forest habitat types not represented by BSPs are shaded grey)

group1	mainGroup	SubGroup	Physiognomy	elevation	Type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Dipterocarpus indicus - Humboldtia brunonis - Poeciloneuron indicum* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Low elevation	*Dipterocarpus indicus - Humboldtia brunonis - Poeciloneuron indicum* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Poeciloneuron indicum* facies of *Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Low elevation	*Poeciloneuron indicum* facies of *Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Low elevation	*Dipterocarpus indicus - Kingiodendron pinnatum - Humboldtia brunonis* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Kan	Low elevation	*Diospyros spp. - Dysoxylum malabaricum - Persea macrantha* "kan" forest type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Poeciloneuron indicum* facies of *Dipterocarpus indicus - Persea macrantha* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Dipterocarpus indicus - persea macrantha* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Persea macrantha - Diospyros spp. - Holigarna spp.* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Low elevation	*Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Low elevation	*Poeciloneuron indicum* facies of *Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa* type

wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Low elevation	*Poeciloneuron indicum* facies of *Dipterocarpus indicus - Diospyros candolleana - Diospyros oocarpa* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Medium elevation	*Cullenia exarillata - Mesua ferrea - palaquium ellipticum*
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Medium elevation	*Memecylon umbellatum - Syzygium cumini - Actinodaphne anguistifolia* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	High elevation	*Schefflera spp. - Gordonia obtusa - Meliosma arnottiana* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Medium elevation	*Mesua ferrea - Palaquium ellipticum* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Medium elevation	*Mesua ferrea - Palaquium ellipticum* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	Medium elevation	*Palaquium ellipticum - poeciloneuron indicum - Hopea canalensis* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Dense evergreen	High elevation	*Schefflera spp. - Gordonia obtusa - Meliosma arnottiana* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed to semi-evergreen	Medium elevation	*Palaquium ellipticum - poeciloneuron indicum - Hopea ponga* type
moist deciduous forests	Deciduous climax forests and degradations	Moist deciduous forests	Scrub woodland to thicket		*Lagestroemia microcarpa - Tectona grandis - Dillenia pentagyna* type
moist deciduous forests	Deciduous climax forests and degradations	Moist deciduous forests	Woodland to savanna woodland		*Lagestroemia microcarpa - Tectona grandis - Dillenia pentagyna* type
moist deciduous forests	Deciduous climax forests and degradations	Moist deciduous forests	Dense		*Lagestroemia microcarpa - Tectona grandis - Dillenia pentagyna* type
moist deciduous forests	Deciduous climax forests and degradations	Moist deciduous forests	Discontinuous thicket to low scattered shrubs		*Lagestroemia microcarpa - Tectona grandis - Dillenia pentagyna* type
dry deciduous forests	Deciduous climax forests and degradations	Dry deciduous forests	Scrub woodland to thicket		*Anogeissus latifolia - Tectona grandis - Terminalia tomentosa* type
dry deciduous forests	Deciduous climax forests and degradations	Dry deciduous forests	Tree savanna		*Anogeissus latifolia - Tectona grandis - Terminalia tomentosa* type
dry deciduous forests	Deciduous climax forests and degradations	Dry deciduous forests	Woodland to savanna woodland		*Anogeissus latifolia - Tectona grandis - Terminalia tomentosa* type
dry deciduous forests	Deciduous climax forests and degradations	Dry deciduous forests	Dense		*Anogeissus latifolia - Tectona grandis - Terminalia tomentosa* type

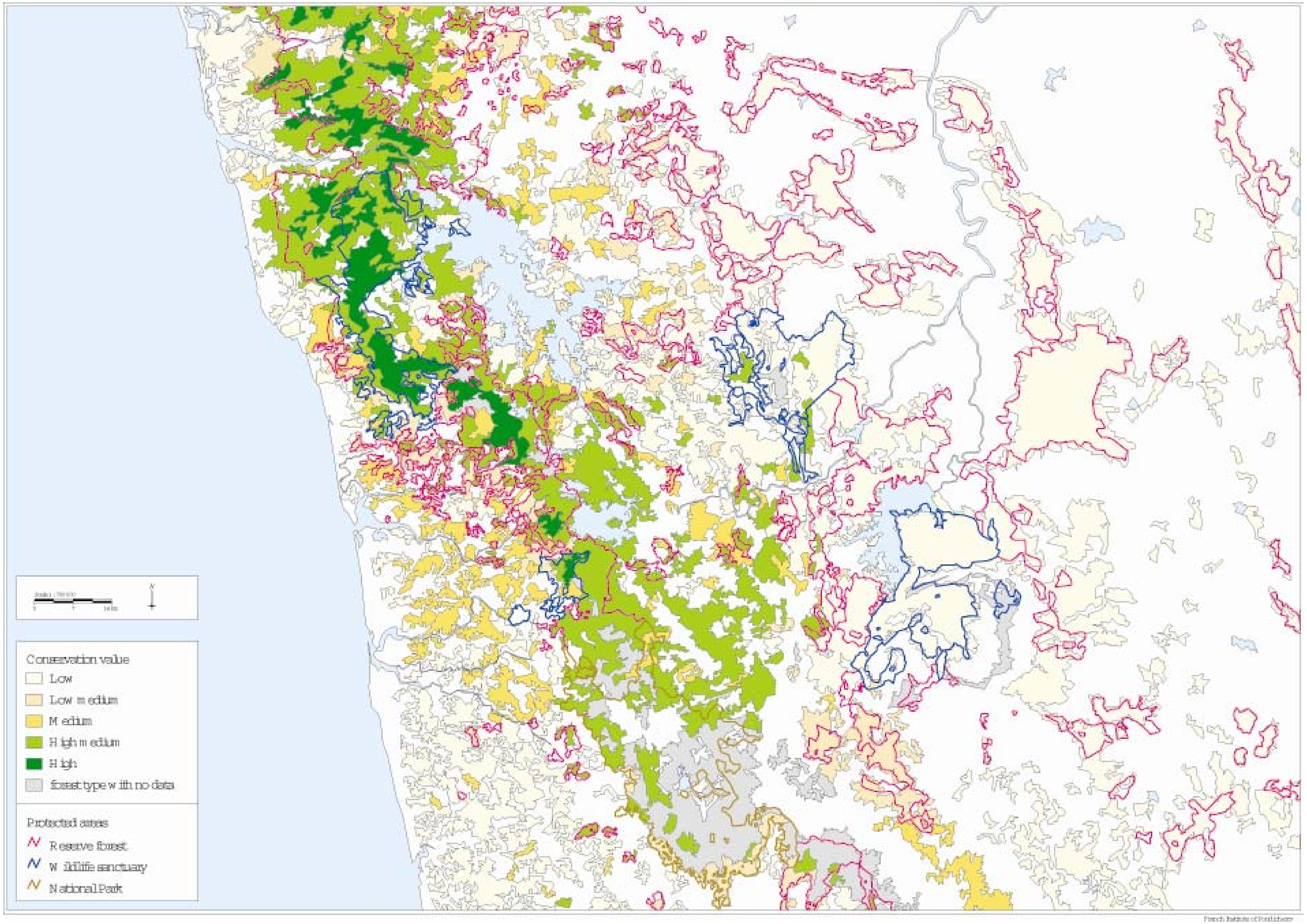
dry deciduous forests	Deciduous climax forests and degradations	Dry deciduous forests	Discontinuous thicket to low scattered shrubs		*Anogeissus latifolia - Tectona grandis - Terminalia tomentosa* type
dry deciduous forests	Deciduous climax forests and degradations	Dry deciduous forests	Scrub woodland to thicket		*Anogeissus latifolia - Chloroxylon swietenia - Albizia amara* type
dry deciduous forests	Deciduous climax forests and degradations	Dry deciduous forests	Discontinuous thicket to low scattered shrubs		*Anogeissus latifolia - Chloroxylon swietenia - Albizia amara* type
wet evergreen climax and related forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Wet evergreen or semi - evergreen climax and potentially related forests	Disturbed	Transition type	Transition type
wet evergreen secondary semi-evergreen forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; evergreen and semi -evergreen forests	Disturbed	Low elevation	
wet evergreen secondary semi-evergreen forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; evergreen and semi -evergreen forests	Secondary	Low elevation	
wet evergreen secondary semi-evergreen forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; evergreen and semi -evergreen forests	Disturbed	Transition type	
wet evergreen secondary semi-evergreen forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; evergreen and semi -evergreen forests	Disturbed	Medium elevation	
wet evergreen secondary semi-evergreen forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; evergreen and semi -evergreen forests	Secondary	Medium elevation	
wet evergreen secondary semi-evergreen forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; evergreen and semi -evergreen forests	Disturbed	High elevation	
wet evergreen secondary moist deciduous forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; secondary moist deciduous forests	Dense		
wet evergreen secondary moist deciduous forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Secondary or degraded stages; secondary moist deciduous forests	Woodland to savanna woodland		
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Dense thicket	Low elevation	
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Dense thicket	Medium elevation	

wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Dense thicket	High elevation	
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Tree savanna to grass savanna	Low elevation	
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Tree savanna to grass savanna	Medium elevation	
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Tree savanna to grass savanna	High elevation	
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Scattered shrubs	High elevation	
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Scattered shrubs	Low elevation	
wet evergreen other degraded forests	Wet evergreen and semi - evergreen climax forests and degradation stages	Other degraded stages	Scattered shrubs	Medium elevation	
moist deciduous forests	Deciduous climax forests and degradations	Moist deciduous forests	Tree savanna		
plantation	Plantations	Coffee	Commercial Plantations		
plantation	Plantations	Tea	Commercial Plantations		
non forest	Non Forest	Agricultural	(Non-physiognomy)		
water bodies	Water bodies	Water Tanks	(Non-physiognomy)		
plantation	Plantations	Miscellaneous	Commercial Plantations		



French Institute of Pondicherry

Map Figure 15:Conservation value map of forest areas on sheet 1 (Belgaum-Dharwar-Panaji)



Map Figure 16: Conservation value map of forest areas on sheet 2 (Shimoga)

Pondy Papers in Ecology

1. CLAIRE ELOUARD, FRANÇOIS HOULLIER, JEAN-PIERRE PASCAL, RAPHAEL PÉLISSIER, B.R. RAMESH. Dynamics of the dense moist evergreen forests. Long Term Monitoring of an Experimental Station in Kodagu District (Karnataka, India), 1997, n°1, 23 p.
http://hal.archives-ouvertes.fr/hal-00373536/fr/

2. FRANÇOIS HOULLIER, YVES CARAGLIO, MURIEL DURAND. Modelling Tree Architecture and Forest Dynamics. A Research Project in the dense moist evergreen forests of the Western Ghats (South India), 1997, n°2, 37 p.
http://hal.archives-ouvertes.fr/hal-00373538/fr/

3. MURIEL DURAND. Architecture and growth strategy of two evergreen species of the Western Ghats (South India), *Knema attenuata (J. Hk. & Thw.) Warb. (Myristicacece) and Vateria indica L. (Dipterocarpacece)* 1997, n° 3, 39 p.
http://hal.archives-ouvertes.fr/hal-00373540/fr/

4. FRANÇOIS HOULLIER, RANI M. KRISHNAN, CLAIRE ELOUARD. Assessment of Forest Biological Diversity. A FAO training course. 1. Lecture Notes 1998, n° 4, 102 p.
http://hal.archives-ouvertes.fr/hal-00373545/fr/

5. CLAIRE ELOUARD, RANI M. KRISHNAN. Assessment of Forest Biological Diversity. A FAO training course. 2. Case study in India, 1999, n° 5, 75 p.
http://hal.archives-ouvertes.fr/hal-00373548/fr/

6. B. R. RAMESH, MOHAN SEETHARAM, M. C. GUERO, R. MICHON. Assessment and Conservation of Forest Biodiversity in the Western Ghats of Karnataka, India. 1. General Introduction and Forest Land Cover and Land Use Changes (1977-1997), 2009, n° 6, pp. 1-64 p.

7. B. R. RAMESH, M. H. SWAMINATH, SANTHOSHAGOUDA PATIL, S. ARAVAJY, CLAIRE ELOUARD. Assessment and Conservation of Forest Biodiversity in the Western Ghats of Karnataka, India. 2. Assessment of Tree Biodiversity, Logging Impact and General Discussion. 2009, n° 7, pp. 65-121.