MASTER

Climate Change and Forests: Impacts and Adaptation

A Regional Assessment for the Western Ghats, India

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EXECUTIVE SUMMARY

Potential climate change over the next 50 to 100 years could have major impacts on tropical forests. Forests, particularly in the tropics, are subjected to anthropogenic pressures leading to degradation and loss of forest ecosystems. Impacts of climate change will be additional to anthropogenic pressures, possibly compounding the impacts. Given the significant dependence of local people and economies on forests in tropical and temperate countries, there is a need to assess the possible impacts of climate change and to develop adaptation measures. In view of the importance of assessing the impacts of climate change at regional scale, Sida initiated two studies in India; the first study focused on the subtropical forests in the northern state of Himachal Pradesh, while the second study focused on the biodiversity rich tropical forests of the Western Ghats in southern India. The findings and implications of the study in the Western Ghats are presented in this report.

The diversity of forest types in the Western Ghats ranges from wet evergreen and deciduous forest to dry thorn and montane forests with a wide range of annual rainfall regimes (from less than 65 cm to over 300 cms). The study was conducted in two regions of the Western Ghats; the Uttara Kannada district (13.55' and 15.31'N lat. and 74°05' to 75°05'E long.) and the Nilgiris (10.45' N to 12°N lat. and 76°15' to 77°E long.). Climate change projections for 2020 and 2050 based on Kelly (1996) were used in assessing the possible impacts on forests. In general, the "most likely" projections of climate change were an increase in mean temperature in the range of 0.3-1.0° C and an increase in precipitation of 3-8% over the study regions by the year 2050. The "worst case" scenario was an increase in temperature of 1° C and a decrease in precipitation by 8% by 2050.

To assess the vegetational responses to climate change, a simple model based on present-day correlations between climatic (mean annual temperature and precipitation) and vegetation types for these regions was developed. Likely changes in the areas under different forest types were assessed for "moderate climate" sensitivity and central scaling factor (referred to as the "most likely scenario") for the years 2020 and 2050, and "high climate" sensitivity and a lower scaling factor (the "worst case scenario") for 2050.

Some of the major conclusions and implications are listed here.

1. Projected climate change impacts on vegetation

For the Nilgiris, the projected changes under the "most likely" scenario were an increase in the area under evergreen forests due to increased precipitation as well as an increase in dry thorn forest due to increased temperature. In addition there was a noticeable decline in dry deciduous forest and modest decrease in montane forest/grassland. In Uttara Kannada the projections indicate a corresponding shift from the drier vegetation types towards moister types. Under the "worst case" scenario, there were no changes in the area under evergreen forest but substantial decrease in the area under dry deciduous forest and an increase in dry thorn forest in the Nilgiris (which means 'blue mountains'). For Uttara Kannada no clear trends could be discerned although a transition towards dry forest could be expected. The projected climate change could be at a rate higher than the capacity of the ecosystems and plant species to adapt.

2. People's dependence on forests

In the Nilgiris as well as Uttara Kannada, between 50% and 75% of rural households gather a large diversity of forest products for household as well as

commercial use. The diversity of non-timber forest products (NTFPs) gathered and their financial value varied among different forest types. The financial value of NTFPs gathered is in the region of Rs. 1233/household/year in semi-evergreen forests and Rs. 3445/household/year in the evergreen forest zone in Uttara Kannada. In the Nilgiris the range is Rs. 687/household/year in dry deciduous forests and Rs. 4955/household/year in the moist deciduous forests. This income level is significant given the current agricultural wage rate of Rs. 35 to 50/person day in the Western Ghats region (1 US$ = Rs. 35)

3. Social, gender and employment aspects of dependence

Households belonging to all socio-economic categories depend significantly on forests. Women contributed 30% to 50% of the total human labour used in gathering NTFPs. The employment generated in gathering NTFPs is in the range of 150 to 200 person days/household/year.

4. Impact of climate change on NTFP flows:

Given the significant projected changes in area under different forest types, particularly the increase in the area under evergreen and moist deciduous forests which provide high NTFP flows/ha, the quantity and value of potentially extractable NTFPs is likely to increase by 2050, assuming an equilibrium vegetation response. Given the uncertainties regarding the regional projections of climate change and vegetation response, as well as the sustainability of harvest practices, the findings should only be considered as an indicator of the direction of change.

5. Forest land use changes:

In the Western Ghats region, analysis of forest land-use change in the post 1980 period suggests that the area under forests has stabilised and no large scale deforestation has been recorded. The area under annual crops is 3.9% in Nilgiris district and 9.3% in Uttara Kannada district. Further, in the districts of Western Ghats, the area under crops seems to have stabilised during the past 10 to 15 years, even though the population is growing at over 2% per annum. Conversion of forest land for infrastructure is likely to continue but will be strictly regulated. This indicates that forest lands are not being converted for crop production in any significant manner. Forest conservation policies (regulations and development programmes such as large reforestation) have contributed significantly to reduce threats to forest land use.

6. Climate change impacts versus land use pressure on forests

The Second Assessment Report of the IPCC (1996) concluded that in tropical countries, until the middle of the next century, land-use change (deforestation) will be more significant in determining forest area and status than changes in climate and atmospheric chemistry. In regions such as Western Ghats, where the area under forests has nearly stabilised during the past 10 to 15 years, climate change could be an important factor affecting forest area and status. Forest conservation policies and large scale reforestation programmes along with increasing productivity of croplands have reduced the pressure on existing forests.

However, the projected expansion of evergreen forest vegetation into the current moist deciduous forest regions as well as expansion of moist deciduous vegetation into the dry deciduous vegetation, under the projected climate change scenario, is likely to occur only under conditions of minimal human induced barriers such as crop fields, grazing lands, settlement and water bodies. Forest boundary shifts and species migration could be significantly hampered by fragmentation of forests, conversion of forests to croplands, settlement or infrastructure, overgrazing and fire.

7. Measures to enhance forest resilience and adaptation:

The main goal should be to minimise the adverse impacts on forest ecosystems and human societies depending on them.

Three types of measures are suggested;

i.) technological and silvicultural measures
ii.) forest land use policies
iii.) forest conservation and development programmes and institutional arrangements.

A set of 'no regrets' strategies that aim at reducing current and future pressures on forests could contribute significantly to forest conservation as well as enhancing forest resilience.

8. Technological and silvicultural measures:

Anticipatory planting, inclusion of multiple species and multiple clones of a given species, promotion of natural regeneration in degraded lands, *ex situ* and *in situ* conservation of biodiversity, sustainable extraction of wood and NTFPs, are some of the technical options for enhancing and forest resilience. The reforestation programme in degraded forest and village common lands in the Western Ghats region provides an opportunity for anticipatory planting. The large reforestation programme of the post-1980 period is dominated by short rotation plantations. Even these lands will also become available for anticipatory planting at the end of the rotation period.

9. Forest land and product use policies:

The policies that are required to promote forest resilience and enable implementation of adaptation measures include:

- Strengthening and stricter implementation of the 1980 Forest Conservation Act.
- Expansion of the Protected Area concept both for large reserves and small dispersed (village scale) refuges as stepping stone reservoirs of biodiversity.
- Banning the extraction of industrial wood from forests and shifting the source of extraction from forests to plantations on farm lands.
- Promotion of NTFP based forest management to create long-term involvement and interest of local communities.
- Promotion of participatory approaches to forest management with more effective devolution of decision making and management powers to local communities than is now provided under some Joint Forest Management programmes.
- Community participation would enable promotion of regeneration of naturally migrating plant species due to the protection offered.

10. Forest conservation and development programmes:

Forest policies must be supported by appropriate programmes and institutions to implement and manage conservation and adaptation measures.

- Promotion of natural regeneration in degraded forest as well as village commons through community management systems to promote regeneration of migrating species.
- Conversion of the current large reforestation programme into an opportunity to implement many adaptation practices such as anticipatory planting, multi-species and multi-clonal plantations, broader deployment of species, seed sources and families.
- More effective implementation of fuelwood conservation programmes such as biogas and efficient stoves to reduce pressure on forests.
- A shift from timber based forest management practices to sustainable forestry practices focussed more on NTFPs to conserve biodiversity and enhance flow of forest products and incomes to local communities and the economy.

11. Institutions for implementing adaptation measures:

Appropriate institutional mechanisms are necessary to plan, implement and monitor forest conservation, development and adaptation measures.

Forest Department: A formidable structure and manpower exists in the Western Ghats region but needs retraining and motivation to change practices, including a move away from the rigid 'working plan' approach and also support to participatory forest management.

NGOs: In the Western Ghats region, there is a significant presence of NGO movements. There is a need for involvement of NGOs more effectively as a bridge between the Forest Department and village communities, in forest conservation and regeneration programmes.

Village Forest Committees (VFC): A reasonably representative local institution in the form of a VFC has evolved. But for the VFCs to be effective, they must be vested with adequate decision making and managerial powers to protect, sustainably manage and benefit from the management of forests, village commons and degraded lands. Traditional forest conservation and sustainable forest management practices could contribute significantly to enhancing forest resilience and adaptation.

12. Barriers to implementation of adaptation measures:

Some technological, institutional, policy and financial barriers and measures to overcome them are identified.

13. Networking of South and South-East Asian institutions for research, monitoring and information sharing:

- Impacts of climate change on forest ecosystems and flow of forest products and services need to be assessed over a long-term to enable formulation of adaptation and mitigation strategies.
- There is a need for capacity building and information sharing by networking existing institutions in the Asian region.

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1. INTRODUCTION

Climate change, loss of biodiversity, land degradation, pollution and stratospheric ozone depletion are dominant global environmental problems today. Climate change has reached centre stage due to its potential adverse impacts on natural and human-made ecosystems. Forests dominate much of the land surface of the earth and nearly 3 billion people depend on forests directly or indirectly. Thus, there is great interest in understanding the impacts of climate change on forests and in developing forestry adaptation strategies, not only on a global or continental scale, but also on a regional scale. This report attempts to assess the possible impacts of climate change on forests, the secondary impacts on human communities and their economy, and finally to suggest adaptation strategies for the forests of the Western Ghats region in southern India.

The consensus of the world's scientific community, as reflected in the second scientific assessment of the Intergovernmental Panel on Climate Change (IPCC 1996) document, is that significant climate change is likely to occur over the next century. Global temperatures could increase by 1.0-3.5^{o} C by the year 2100. This projected global average temperature change which will be greater than recent natural fluctuations and which will also occur at a rate significantly faster than the observed changes during the past 10,000 years. Climate models also project enhanced evaporation from climate warming resulting in changes in mean precipitation, seasonal shifts in precipitation, changes in soil moisture, and changes or enhanced occurrence of extreme climatic events. The projected climate change is expected to have significant impacts, often adverse, on natural ecosystems (forests, grasslands, wetlands, etc.), agricultural production, aquatic ecosystems, and human health. It is necessary to understand the impacts of climate change in order to see how the resilience of natural systems can be enhanced, and adaptation and mitigation strategies developed to minimise the adverse impacts on natural ecosystems as well as human societies.

1.1 Climate change and tropical forests

In 1990, forests covered about one-fourth of the earth's land surface (FAO, 1993). Forests dominate the terrestrial ecosystems covering about 40% of the earth's area. The total area under tropical forests (including plantations and other wooded areas) is estimated to be 3.44 x 10^9 ha (52% of global total forest area) with a forest biomass roughly equal to 297 x 10^9 t (67.5% of global total biomass) (FAO 1995).

Tropical forests are home to nearly four-fifths of global plant diversity. In tropical countries, rural and indigenous communities accounting for nearly 70% of the total population (of about 3 billion) depend directly or indirectly on forests for food, medicines, construction material, fuelwood and raw material for handicrafts and household articles. In the past the extraction of forest products by local communities was largely for subsistence, but increasingly this caters to the market economy. Forests also provide timber and non-timber raw materials for a range of industrial products. Given the close dependence of rural and indigenous populations (forest dwellers) on forests for food, medicines and livelihood, any adverse impact of climate change will affect the lives of a great number of people, apart from irreversible changes in natural ecosystems.

Sustained increases in temperature of as little as 1^{0}C could be sufficient to cause changes in the growth and regeneration capacity of many tree species. Under a supposed doubling of atmospheric CO_2 (a "2 X CO_2 climate"), current global models project that a substantial fraction of existing forests will experience climatic conditions under which they do not currently exist, possibly leading to new vegetation types (IPCC, 1996). According to another review, even under the least dramatic climate change scenarios, ecological impacts on forests can be anticipated (Markham and Malcolm, 1996).

The response of forests to climate change will be influenced by a set of climatic and regional non-climatic factors such as land use change and other anthropogenic factors. Forests are currently being subjected to anthropogenic pressures, particularly deforestation, forest fragmentation and forest degradation. The annual tropical deforestation rate for the 1980s was estimated to be around 15 Mha (FAO, 1993a). In tropical regions, forests will continue to be subject to human pressures in the coming decades for meeting the needs for land and biomass. Thus, forest diversity, standing stock, growth rates and ultimately the area under forests are going to be affected by these anthropogenic factors. There is a need to understand the impacts on forest vegetation at the local or regional level, since socio-economic impacts will manifest themselves at this scale.

1.2 Climate change, forest ecology and economics

Human-induced climate change represents an important additional stress on many natural ecosystems and socio-economic systems which are already affected by pollution, increasing resource demands and un-sustainable management practices (IPCC 1996). Currently there is little information on the impacts of projected climate change on forest biodiversity, biomass production, and ultimately forest product flows, particularly at the regional and local levels. The secondary impacts on local communities, the local or regional economy are even less understood. Although the Second Assessment Report of IPCC, (1996) attempted to assess the socio-economic impacts of climate change on forests, it did not generate any new useful information. This was largely due to the absence of studies at local, regional and even at the global level. Currently some studies are being initiated under the US Country Studies Programme, Sida's Africa initiative and many nationally supported research programmes. The approach and methodology for assessing the impacts of projected climate change on forests at the regional level and, further, the resulting impacts on socio-economic aspects are still evolving. There is much interest among researchers as well as policy makers in such studies. Policy makers as well as forest managers need information, so that they can develop short and long-term strategies to adapt to and to mitigate the adverse effects of climate change.

The present study is an attempt in that direction; to develop an approach and methodology to assess the impacts of climate change on forest ecology and economics. We make a preliminary assessment of the impacts in an ecologically important region (Western Ghats) of a major tropical country (India), and suggest tentative strategies to local communities and policy makers for adapting to and mitigating the adverse effects of the projected impacts of climate change.

1.3 Climate changes studies in India

India, the most populous tropical country (884 million in 1991), has about 64 million ha under forest. Anthropogenic pressures on forests are among the highest in the world with only 75 ha of forest/1000 human population and 7 livestock/ha of forest land. India has recently implemented some of the most innovative forest conservation programmes and the tropical world's largest reforestation programme (Ravindranath and Hall 1994). India has a large rural (627 million) and indigenous (50 million) population, which depends on forests directly or indirectly. Any impacts on forest vegetation will have significant economic implications for these large populations. Thus, India provides an interesting case study to make preliminary assessments of impacts of climate change on forests and local economies.

1.3.1 SIDA initiative on climate change and forests in Himachal Pradesh

Our present study in the Western Ghats region (during 1995-96) is the second regional study in India supported by the Swedish International Cooperation Development Agency. An earlier study supported by Sida was conducted in the mountainous state of Himachal Pradesh in northern India during 1994-1995 (Deshingkar *et. al*, 1997) with the objectives of:

- asessing the possible impacts of changes in climate on the area under different forest types
- assessing the impacts of climate-induced changes on forests on dependent local communities and the economy and,
- identifying sustainable adaptation strategies which will simultaneously meet immediate development needs and satisfy long-term conservation goals.

The study concluded that climate change should be viewed as one amongst many agents of change which will shape forests in the future. Sustainable adaptation strategies should aim to minimize the negative impacts of anthropogenic pressures and also safeguard the ecological functions of forests in the longer term. In the land-scarce context of Himachal Pradesh suggested adaptation strategies focus on participatory management of forests and the selection of tree species for plantation which can adapt to a wider range of climatic conditions.

1.3.2 Climate change and forests of the Western Ghats region of southern India

This study is focussed on the Western Ghats region (8°N-20° N lat and 73°E-78°E long) of southern India. It is one of the biodiversity rich locations in the tropics. It includes a large diversity of rainfall regimes (65-300 cm annual rainfall), about ten vegetation types ranging from wet evergreen forests to moist and dry deciduous forests, dry thorn forest and montane forests and grasslands. It is a location of great interest from an economic point of view because of its large forest product flows (Subhashchandran, 1994). Forest conservation and development programmes have been intensively implemented in the Western Ghats region. Finally, the Western Ghats region is one of the most researched regions in the tropics with significant knowledge already available on forests and human ecology.

2. PROJECTED CLIMATE CHANGE OVER THE WESTERN GHATS

Before we try to assess the impacts of climate change on forests and forest-based economies, it is necessary to understand the magnitude and direction of climate change, and associated uncertainties, at the global, continental and finally regional scales. We therefore outline the likely changes over the next century projected at a global level by several studies, and then the changes expected over South Asia and the Western Ghats in particular.

2.1 Projected climate change at the global level

Climate change due both to natural variability and human activity has to be considered if we are to have a complete picture of this phenomenon (IPCC, 1996). The relative role of these two factors in determining the future climate is not well understood, although some progress has been made recently in dissecting the complex interplay of factors.

The mean global temperature during the 20th century has been at least as warm as during any other century since 1400 AD. Since the late 19th century, the global mean surface air temperature has increased by 0.3-0.6o C, and recent years have been the warmest recorded, in spite of cooling induced by volcanic activity in 1991. At the same time, the atmospheric concentrations of greenhouse gases have increased - carbon dioxide by 30%, methane by 145% and nitrous oxide by 15% - since pre-industrial times (c. 1750 AD), primarily due to human activities such as burning of fossil fuels, land use change and agriculture. Greenhouse gases such as CO2 and N2O remain in the atmosphere for decades or even centuries and thus affect radiative forcing on a long-time scale. Radiative forcing is the "driver" of climate change and refers to the energy balance of the Earth-Atmosphere system.

Radiative forcing has perhaps not caused as much warming (positive forcing) as could have been anticipated from greenhouse gas emissions because of the cooling (negative forcing) caused by tropospheric aerosols. On a localised scale, the aerosols (microscopic airborne particles such as sulphur compounds) resulting from the burning of fossil fuels, biomass and other sources may even have offset the positive forcing caused by greenhouse gases. Aerosols are however short-lived and thus their radiative forcing adjusts rapidly to changing concentrations. In addition, the net radiative forcing by greenhouse gases such as CFCs and HCFCs has also been reduced because they have caused stratospheric ozone depletion which results in negative radiative forcing.

The earth's Climate is expected to continue to change in the future as a result of emissions of greenhouse gases and aerosols, and the perturbation of natural radiative forcing. Relative to 1990, the "best estimate" of climate sensitivity for the mid-range IPCC emission scenario (IS92a) including the effects of aerosols, is an increase in global mean surface air temperature of 2o C by 2100. The corresponding figures for the "low sensitivity" for the lowest emission scenario and the "high sensitivity" for the highest emission scenario are 1o C and 3.5o C respectively.

Global temperature projections can be generally made with greater confidence than other projections on a regional scale of changes in sea level, precipitation, soil moisture, etc. Coupled ocean-atmosphere simulation models, forced with increased greenhouse gases alone or in combination with aerosols, show the following general features of relevance to us:

- a greater warming of the land as compared to the oceans in winter;
- the maximum warming in high northern latitudes in late autumn and winter;

- a reduction in diurnal temperature range over land in most seasons and regions;
- a more vigorous global hydrological cycle resulting in increased precipitation;
- a general increase in the variability of climate, and thus an increase in the occurrence of extreme climatic events.

A key aspect to remember is that responses to forcing are usually non-linear, and thus the response may occur with time lags and be quite irregular. Thus, apparently quiescent periods with little or no climate change may be followed by rapid change.

2.2 Climate projections for South Asia

It is generally agreed that the South Asian region, dominated by the monsoon, is one of the most difficult regions to model, with considerable differences among models and high sensitivity to model parameters.

One consistent feature of model projections for South Asia is the difference between the southern and northern parts of the sub-continent in their response to climate change. In general, the southern peninsula seems better buffered against adverse change as compared to the central and northern land mass. Thus, with only greenhouse gas forcing, the mean surface air temperature is projected to increase during 1990-2040 by 1.5-2.5o C in southern India, while in the north the corresponding rise may be 2.5-3.5o C (Lal *et al.*, 1994,1995). Similarly, with greenhouse gases and aerosol forcing the projected increase in mean winter temperature is 1.5-2.0o C in the south, while it varies from -2.0o C to +2.5o C in the north.

Several General Circulation Models (GCMs) consistently indicate that the mean monsoonal precipitation over South Asia intensifies with increased CO2 because of the increased warming of the South Asian land area as compared to the Indian Ocean (Meehl and Washington 1993, Bhaskaran *et al.*, 1995). The increased land-sea thermal contrast combined with increased moisture from a warmer ocean intensifies the monsoonal precipitation. If the model incorporates sulphate aerosols in addition to CO2, the negative forcing of the aerosols results in lower warming of the land mass, a reduced land-sea thermal contrast and a weakened monsoon as compared to the present time (Lal *et al.*, 1995). Nevertheless, a decreased precipitation of up to 1.5 mm/day is projected for the land mass at latitudes higher than 20° N, while south of this there is either no change or an increase of up to 2 mm/day (Lal *et al.*, 1995). Interannual variability in the monsoon is also increased in models incorporating only CO_2, including those of the Hadley Centre (UKMO)(Bhaskaran *et al.*, 1995), Max Plank Institute (Lal *et al.*, 1994) and CSIRO (Chakraborty and Lal, 1994). A similar increase in the variability is seen when both CO_2 and aerosols are incorporated as in the MPI model (Lal *et al.*, 1995).

2.3 Climate projections for the Western Ghats

We base our scenario of climate change for the Western Ghats on the projections from various GCMs incorporating greenhouse gas forcing which have been summarized by Kelly (1996) in a special report commissioned for this project. The scenarios are derived from two sets of climate models following the method of Hulme (1994) and provide a guide to the change in regional climate that may be experienced for the years 2020, 2050 and 2080.

2.3.1 Global-mean temperature change

First, an energy-balance model of the climate system, developed by Wigley and Raper (1987) and used by the Intergovernmental Panel on Climate Change, is used to generate projections of global temperatures for the period 1990-2100. Forecasts of the likely rise in atmospheric greenhouse gas concentrations, using the IPCC business-as-usual scenario Is95a, are taken as inputs into the model. Climate sensitivity is expressed in terms of the CO_2 doubling temperature (i.e. the temperature change caused by a doubling of atmospheric CO_2). Following the IPCC, three estimates are presented for CO_2 doubling temperatures, low (1.5 C), moderate (2.5 C) and high (4.5 C), to take into account uncertainties in the models.

2.3.2 Regional temperature and precipitation change

Estimates of mean global temperature change are used in a General Circulation Model (GCM) to derive estimates of potential change in regional climate. Results from six GCM experiments (equilibrium models of UK Meteorological Office, BMRC, Canada Climate Centre and CSIRO, and transient models of UK Meteorological Office and Max Planck Institute) are averaged.

GCMs calculate the climate sensitivity during the course of each simulation. Thus, the climate sensitivity (the CO_2 doubling temperature) varies from one model experiment to another. Model results have been combined by standardising each estimate of the regional temperature and precipitation change by dividing each grid point value by the global-mean temperature change predicted by the model. This scaling results in an estimate of the regional change in temperature and precipitation for every one degree change in annual global mean temperature.

Each GCM uses a different gridding system. The scaling factors derived from each model simulation are first interpolated on to a standard 5 degree latitude by 5 degree longitude grid. The results are then averaged, grid point by grid point, to produce the central (i.e. most likely) estimate of the scaling factor for each point on the grid. The standard deviation of the model estimates is calculated grid point by grid point and used to define lower and upper bounds for the scaling factors at each point on the grid based on the 10% and 90% points of the distribution of the model estimates. A set of three scaling factors - low, central and upper - is thus produced for each of the two climate parameters, temperature and precipitation, for each grid point. A computer package SCENGEN (Hulme *et al.*, 1995) provides visual representations of the projections.

For each of the three years, 2020, 2050 and 2080, three scenarios have been presented defining the range of uncertainty in the underlying projections. These are based on:

Case 1: the central scaling factor and the moderate climate sensitivity global-mean temperature projection.

Case 2: the lower scaling factor and the low climate sensitivity global-mean temperature projection in the case of temperature projections or the high climate sensitivity global-mean temperature projections in the case of precipitation projections,

Case 3: the upper scaling factor and the high climate sensitivity global-mean temperature projections.

The difference in the Case 2 definition of temperature and precipitation is to maximise the range between the Case 2 and Case 3 scenarios. Kelly suggests that for assessing ecological impacts the Case 1 scenario can be taken to represent the *"most likely"* estimate, while combinations of the Case 3 temperature projections and the

Case 2 and 3 precipitation scenarios should also be considered as these represent the *"worst case"* estimates.

2.4 Summary of changes for the Western Ghats at 10°, 15° and 20° latitude

The Kelly report provides figures with climate projections on a seasonal basis. The seasons defined are January-March, April-June, July-September, and October-December. In addition, the changes averaged on an annual time scale are also provided. For temperature changes, the differences among the seasonal estimates and between the seasonal changes and the annual estimates are negligible. For precipitation projections, there are differences among the seasonal estimates of changes in percentage; in general, for any given scenario there is minimum change during the summer monsoon period of July-September, while the changes are higher during other months. We have however considered only the changes in temperature and precipitation averaged on an annual scale, because our baseline climatology for the study areas in the Western Ghats is based on annual figures.

Table 2.1 summarises the projected trends in temperature and precipitation at 10°, 15°, and 20° N latitude along the west coast of the peninsula as three representative places. For any given scenario of temperature and precipitation change for a given year, it can be seen that the lower latitude is projected to experience the least change from the baseline climatology (1961-1990) while the higher latitude shows the greatest change. This south-north gradient, with the south being better buffered against change, possibly as a result of the greater moderating influence of the ocean, is one of the most consistent and striking features of the climate modelling for South Asia as a whole.

Table 2.1 Climate change scenarios for the Western Ghats.

Scenario	Year	Temperature			Precipitation % change		
		10° N	15° N	20° N	10° N	15° N	20° N
CASE 1	2020	0.26	0.30	0.35	<2	3	5
	2050	0.60	0.68	0.80	3	6.5	12
	2080	1.05	1.19	1.40	5	12	20
CASE 2	2020	<0.15	0.20	0.20	-4	-3.5	-3.5
	2050	0.43	0.45	0.46	-8.5	-7.5	-8.0
	2080	0.75	0.79	0.80	-15	-13	-14
CASE 3	2020	0.35	0.40	0.50	6.5	9	14
	2050	0.80	0.90	1.15	15	21	30
	2080	1.35	1.60	2.00	25	36	55

CASE 1 - Moderate climate sensitivity and central scaling factor
CASE 2 - Low climate sensitivity and lower scaling factor
CASE 3 - High climate sensitivity and upper scaling factor

See text for further explanation. Changes in temperature are in degrees C change from present (i.e average of 1961-90): Changes in precipitation are in % change from present (1961-90)

2.5 Aerosol models of climate change

The climate change scenario is substantially different for the Indian sub-continent if sulphate aerosols are added to greenhouse gas forcing. It has been well recognised that sulphate aerosols have a strong negative radiative forcing. One recent experiment run at the Max Planck Institute for Meteorology in Hamburg by Lal *et al.*, (1995) is the only source of information for the Indian sub-continent. As opposed to the greenhouse gas scenario, the greenhouse gas plus sulphate aerosol model simulates a much lower increase in mean temperature over the sub-continent. More importantly, a reduced land-sea thermal contrast may actually lead to reduced rainfall of up to 2 mm/day during the summer monsoon over central and northern India.

However, the projected scenario for southern India in the aerosol model is not significantly different from the greenhouse gas model. The aerosol model projections of temperature for the decade of 2040s along the west coast at 15^{o} N is about 1.5^{o} C both during summer and winter; this is actually even slightly higher than the "high climate sensitivity" and upper scaling factor for temperature during 2040 in the greenhouse gas model (Kelly 1996, Table 2.1). Similarly, projected changes in precipitation for southern India from the CO_2 + aerosol model are comparable to the moderate or low climate sensitivity projections generated by Kelly (1996) using the six GCMs.

2.6 Conclusions

We thus feel justified in considering only the results from the greenhouse gas model of climate change for application to our study areas in the Western Ghats of southwestern India. This may not be justified if one were to consider the projected climate change over central or northern India. However, given the considerable uncertainties, the simpler greenhouse gas models may be adequate for the southern peninsula.

3. IMPACT OF CLIMATE CHANGE ON TROPICAL FOREST ECOSYSTEMS

3.1 Introduction

Forests are subject to a range of anthropogenic pressures including grazing by livestock, unsustainable extraction and conversion to other land uses. Climate change could be an additional stress on forest ecosystems. Tropical forests are rich in biodiversity and climate change could potentially affect adversely this diversity, biomass and forest regeneration.

Our current understanding of the response of forest ecosystems to projected change in climate is very limited. The IPCC 1996 report has attempted to synthesise the current state of knowledge on the potential impacts of climate change on forests (refer to Chapter 1 of IPCC, 1996 for details). Greenhouse forcing and consequent climate change can impact forests through the direct impact of increased CO_2 on species, and the impact of changes in temperature, precipitation and soil moisture availability. Populations of different species can be expected to show differences in their responses, and the response of the community or the ecosystem would depend on the interactions of the species population responses. We summarise below the current state of knowledge of plant responses to CO_2 and climate parameters, with special reference to tropical forests.

Tropical forests account for 40% of the global area under forests and cover 1 761 million ha (in 1990) according to an assessment by FAO (1995). Tropical forests occur between latitudes 25° N and 25° S. Rain forests dominate tropical forests with an area of 718 million ha (FAO, 1995). Tropical forests contain about half of all plant and animal species and account for 60% of global forest biomass. In India, tropical forests account for over 80% of the area under forests (of 64 million ha) and are dominated by tropical moist deciduous, dry deciduous and wet evergreen forests (FSI, 1987).

3.2 Direct impact of atmospheric CO_2 concentrations on plants

It is well-known that levels at which plants can fix CO_2 are relatively high in plants with the C3 pathway of carbon fixation, and that such plants are potentially likely to benefit from increased atmospheric CO_2 concentrations (Luxmoore *et al.*, 1993, Bowes, 1993). Photosynthetic rates and, hence, plant productivity may be stimulated by the direct increase in CO_2 levels and, also more indirectly, by increased water-use efficiency through closure of leaf stomata or reduction in leaf stomatal density (Kirschbaum, 1996a). As compared to this, C4 plants with low CO_2 compensation points are not likely to show increased photosynthetic rates. The C4 plants are mostly tropical grasses (Poaceae), some tropical sedges (Cyperaceae) and a few genera of dicots, while the C3 plants are the vast majority of dicot trees, shrubs and herbs, most monocots including temperate sedges and grasses.

However, the relationship of CO_2 and plant productivity continues to be controversial (Korner, 1993, Idso and Idso, 1994, Kirschbaum *et al.*, 1996b). The experimental evidence is inconclusive. Most experiments are of course carried out on a small scale and their results may not apply at the landscape or ecosystem level. There are several factors which may confound this relationship in practice with respect to tropical forests. The elevated temperature may result in increased respiration, thereby negating any increase in photosynthetic rates. Increased cloudiness may also lower photosynthetic rates. Feedbacks from plants and soils are poorly understood at present. Overall changes in plant productivity are likely to be ecosystem specific. The present consensus is that any positive consequence of enhanced CO_2 on productivity is likely to be small and negligible (Kirschbaum *et al.*, 1996a, 1996b).

3.3 Forest response to increased temperature

In the tropics, the year round temperatures are already sufficiently high to facilitate photosynthesis, high growth rates of plants, litter decomposition and nutrient cycling. Thus, an increase of 1-3° C in mean temperatures is not likely to enhance these appreciably. On the other hand, an increase in temperature would increase evaporative demand and, if precipitation does not increase correspondingly, result in water stress. In addition to lower growth rates, tissue damage and mortality may also result as a consequence of high temperature and water stress (Fitter and Hay, 1987).

Ultimately, the response of a plant community to increased temperature would depend on soil moisture balance (of precipitation and evapotranspiration). Models project increase in soil moisture for some tropical regions, such as parts of India and Eastern Africa, and decreases in others including Amazonia, Central Africa and Southeast Asia (Hulme and Viner, 1995).

3.4 Influence on soil nutrient processes

Increases in temperature and changes in precipitation can also be expected to have an impact on forests through their influence on soil processes and properties. Changes in soil carbon pools can be expected as a result of changes in carbon inputs (from plants and animals) and carbon losses (organic matter decomposition, burning, etc.). Soil nitrogen dynamics can also change. In CO_2 enrichment experiments, a shift of nitrogen from plant to the soil has been observed (Norby *et al.*, 1992, Diaz *et al.*, 1993). Climate change could enhance the supply of nutrients to plants by increasing root and mycorrhizal growth, increasing access to soil phosphorus and enhancing nitrogen fixation by leguminous plants (Kirschbaum *et al.*, 1996b). Nutrient leaching and soil erosion due to loss of forest cover and increased precipitation are also important considerations for the tropics.

3.5 Pests and diseases

Tropical forests are exceptionally rich in the diversity of insects and pathogens. Pathogens and many herbivorous insects may play an important role in regulating plant diversity in the tropics. Increased temperatures combined with lower soil water availability could stress plants sufficiently to make them vulnerable to pests and pathogens. Increased precipitation may promote fungal pathogens. Higher temperatures could also change insect life cycles. Some insects may undergo additional generations, thereby increasing levels of herbivory, while others may show reduced survival and fecundity (Wilson *et al.*, 1982). The diversity of tropical forests appears to confer some degree of protection against widespread outbreaks of pest and pathogen attack. However, this would not be true of monoculture plantations, most of which have a narrow genetic base and are highly susceptible to pests and diseases.

3.6 Forest fires

The frequency and intensity of fires in tropical forests is a major consideration in assessing the impact of climate change. Tropical dry forests are subject to dry season fires, often as a result of anthropogenic activity. Fires triggered by lightning are not infrequent in tropical forests (Goldammer, 1992). Although fires are rare in tropical rain forests, a prolonged drought can cause extensive fires in the moist forests as well. The drought caused by the El Nino Southern Oscillation (ENSO) of 1982-83, for instance, destroyed 3.6 Mha of primary and secondary rain forest in East Kalimantan of Borneo (Goldammer and Seibert, 1990).

Increased temperature, lower humidity and reduced precipitation can all increase the risks of forest fires. Any increase in forest biomass (especially in the understorey and in litter) from CO_2 fertilisation, could also provide increased fuel for more intense fires. Forest fires affect species composition by excluding fire-sensitive species and promoting the growth of fire-resistant species. The result is usually a lower diversity of plants and perhaps many other taxa as well.

3.7 Species migrations, forest succession and area changes

Each species or plant functional types (PFT) would have a different response to a changing climate. Species with a narrow geographical range, those with poor dispersal abilities and slow-growing, late successional species may be unable to adapt to a rapidly changing climate. These may be replaced by faster-growing, more mobile species. In a rapidly changing climate, there would be no chance for communities to reach a climax or equilibrium state, and they would be dominated by early to mid-successional species.

Based on paleoecological evidence, the rates of migration of several plant species of the temperate and boreal regions during the late Pleistocene and Holocene have been calculated. These "natural" rates of migration in response to climate change have been between 0.04 km and 2 km per year (Davis 1976, 1981, 1986; Ritchie and MacDonald, 1986). Similar data for tropical species are virtually non-existent.

Dynamic forest models are needed to simulate this transient response of vegetation to changing climate. In some of the existing models (e.g. Watt 1947, Shugart, 1984), there are several limitations which have been applied to the relatively poor temperate forests on small spatial scales (in hectares). None have been applied to the far more diverse tropical forests or can model landscape or ecosystem level dynamics. On the other hand, the so-called "equilibrium" models such as BIOME (Prentice *et al.*, 1992), MAPPS (Neilson *et al.*, 1992) and TVM-IMAGE (Leemans and van den Born, 1994) have been applied more extensively to model changes in the boundaries of major biomes of the globe.

Changes in the area under tropical forest as projected by these models under 2 x CO_2 are given in Table 3.1. BIOME projects a slight increase in potential area under tropical rain forest but no change in tropical dry forest. MAPPS projects a significant decrease in tropical rain forest and increase in dry forest. TVM-IMAGE, which incorporates future land-use changes and deforestation based on past rates, predicts decrease in both tropical forest types.

Even if tropical moist forests can potentially increase, it is highly unlikely that they actually would for several reasons. The climate shift over the next 100 years is projected at a rate so fast that most species might not be able to adapt to it. The result could be widespread tree mortality, a process requiring only a few years. Regrowth and succession might take several decades or a century even in the absence of climate stress (Solomon *et al.*, 1993). Warming scenarios require tree migration rates about an order of magnitude higher than the fastest historical rates calculated from pollen data (Davis, 1983, Gear and Huntley, 1991). There are hardly any data available on species migration rates in the tropics after the end of the last ice age.

Table 3.1: Likely changes in forested areas (Mha) with two biogeographical zones according to three different vegetation models: BIOME (Prentice *et al.*, 1992), MAPSS (Neilson, 1993), and terrestrial vegetation model (TVM) (Leemans and van den Born, 1994) from IMAGE 2.0 (Alcamo 1994).[1]

Forest type	BIOME 2 x CO_2 (GFDL)			MAPSS 2 x CO_2 (GFDL)			IMAGE-TVM 2050			Mean	
	D	S_o	D*	D	S_o	D*	D	S_o	D*	%D	%D*
Tropical Rain	57	706	19	281	1243	-234	129	296	-129	18.8	-14.4
Tropical Dry	153	640	-2	353	528	196	324	294	-304	37.2	-9.3

Source: IPCC 1996.
[1] For more details, refer chapter 1, pp 106, IPCC 1996.
D = Total forested area in transition from current type into a new one
S_o = Total forested area remaining within the same vegetation class
D* = Net change.

3.8 Biodiversity

The impact of climate change on the biodiversity of tropical forests is rather speculative at this stage. Biodiversity has to be considered both at local and regional scales. There is generally a positive correlation between productivity and plant diversity at localised sites, hence one could expect diversity at the local scale (alpha diversity) to increase in those tropical forests in which increased net primary productivity (NPP) is anticipated. However, increased drying and mortality of plants could negate this expectation. Forest plantations are likely to have lower tree diversity due to shading, density, competition and weeding. Forests under disturbed conditions with gaps in canopy could have higher plant diversity.

Turnover rates (recruitment and mortality) of tropical forests across the globe have been increasing since the 1950s with an apparent acceleration since 1980 (Phillips and Gentry, 1994). This may be directly related to tropical climate change as a result of increased atmospheric CO_2. Such an increase in turnover rates may result in enhanced levels of diversity over larger regional scales (Phillips and Gentry, 1994, Pimm and Sugden, 1994). It remains to be seen whether an increase in the turnover of individuals is also accompanied by an increased turnover in species, a process that is known to cause a decrease in the biodiversity of islands.

Climate change is projected to occur at a faster rate relative to the rate at which forest species are adapted to reproduce or regenerate or grow. Thus, the biodiversity of forests is likely to change and some forest types may disappear, while new assemblage of species may occur, leading to new ecosystems (IPCC, 1996). Any major changes in plant species diversity will have serious implications for forest dependent communities.

3.9 Tropical wood production and supply

The demand for tropical wood (fuelwood and timber) is projected to increase as the human population in tropical countries is expected to grow at a rate of 2-3% annually. IPCC (1996) concluded that, in tropical regions, land use change (or deforestation) will be much more important in determining forest product availability than changes in climate parameters, at least until the middle of the next century. In India, where deforestation rates have declined significantly since 1980 (Ravindranath and Hall, 1994), climate change could be an important factor in determining future wood production and availability. Biomass productivity in tropics is likely to be subjected to both positive (CO_2 fertilisation) and negative (nutrient limitations, soil moisture stress, pest attacks) impacts of climate change. CO_2 fertilisation is likely to have its greatest effect in the tropics, potentially leading to enhanced productivity. There is a general agreement that increased water use efficiency by plants in response to elevated CO_2 is likely to enhance productivity of vegetation in the drier tropical forest regions (IPCC, 1996). However, tropical regions facing a decrease in soil moisture and increased pest attacks will experience forest die back leading to increased supply of wood for short periods. Thus, currently there is uncertainty regarding the overall impact of climate change on tropical wood product supply. Uncertain wood supply levels will complicate formulation of any adaptation policies. India, with one of the lowest areas under forests/capita (0.07 ha/capita) and large dependence on forests for fuelwood and timber, will have to assess carefully the future wood product availability under changing climate scenarios.

3.10 Conclusions

IPCC (1996) concludes that global models, based on $2xCO_2$ climate, project that a substantial fraction of the existing forests will experience climatic conditions under which they do not currently exist. Thus large forested areas will undergo changes from the current forest types to new major vegetation types. Further, a recent review has suggested that under even the least dramatic global warming scenario, ecological impacts can be anticipated (Markham and Malcolm, 1996). Thus serious attempts should be made in different regions of the tropics to assess the potential impacts of climate change on forest diversity, biomass production and product flows. An improved understanding would enable forest planners to develop mitigation and adaptation measures to minimise the potential adverse impacts on forest ecology as well as forest based communities and economies. However, there is a need to keep in mind the limitations of the current state of knowledge and models in detecting the specific climate induced changes in diverse tropical forest ecosystems as they are subjected to complex multiple climate and non-climate factors (IPCC, 1996).

4. THE WESTERN GHATS: THE LAND, THE FORESTS AND THE PEOPLE

4.1 Introduction

The Western Ghats chain of mountains run parallel and close to the west coast of India. It is a tract of high biological diversity, second only to the Eastern Himalayan range in the Indian sub-continent. The ghats are also home to numerous indigenous peoples and cultures. In recent decades the region has been transformed substantially by development. Indeed, this transformation is threatening the very stability of the natural ecosystems of the ghats, the source of all major river systems in peninsular India. Climate change would be an added dimension to the rapid ongoing change of this region.

The ghats rise from the Arabian sea coast to elevations above 2 000 m in the south (highest peak, Anaimudi = 2690 m asl) and about 1 000 m further north. To the east, the ghats drop to the Deccan plateau at a general elevation of about 700 m. The distinctive rainfall and altitudinal gradient, combined with the complex topography, give rise to a diversity of vegetation types in the Western Ghats. The western slopes of the ghats receiving copious rains from the Southwest (SW) monsoon (>2500 mm per annum) are covered with tropical wet evergreen and semi-evergreen forests. These acquire a character more akin to those of highly seasonal evergreen forests as one proceeds from the south to the north along the ghats. Thus, the evergreen forests of Maharashtra have lower diversity as compared to the evergreen forests of the extreme south of the ghats in the Agasthyamalai range. The mountain tops emerging above 1500 m asl along certain portions of the ghats typically have stunted montane evergreen forest patches in valleys and folds of the hills, interspersed with grasslands along the hill slopes. To the east of the ghats the relatively lower rainfall regions (< 2000 mm) have a transition from tropical semi-evergreen forest through tropical moist deciduous and dry deciduous forest to dry thorn forest in the driest parts (<800 mm rainfall).

The Western Ghats have been identified as one of the “hot spots” of global biodiversity. They harbour an estimated 3500 species of flowering plants, which constitute 27% of the total plants described from India. Of the 15 000 species of flowering plants described from India, 12% are endemic to peninsular India. There are as many as 1 932 taxa which are endemic and have a large representation in the Western Ghats. The endemics are concentrated in families such as Poaceae, Rubiaceae, Acanthaceae, Orchidaceae and Fabaceae.

Diversity and endemism are also well represented in the animal groups. The Western Ghats has 48 genera of mammals, 275 genera of birds (including 28 endemic taxa) and as many as 60 species of reptiles. There are a good number of amphibians which are endemic to the ghats. Of the 89 genera of fish described from India, 58 genera are found in the ghats. Some of the endemic mammals of the ghats include the rusty spotted cat (*Felis rubiginosa*), Malabar civet (*Viverra megaspila)*, the brown palm civet (*Paradoxurux jerdoni*), the stripe necked mongoose (*Herpestes vitticollis*), the brown mongoose (*Herpestes macroura*), the Nilgiri martin (*Martes gwatkinsi*), the grizzled giant squirrel (*Ratufa macroura*), the Nilgiri thar (*Hemitragus hylocrius*), the lion tailed macaque (*Macaca silenus*) and the Nilgiri langur (*Presbytis johnii*). Along with them there are a number of rodents and bats which are endemic to the ghats. The ghats also have among the largest global populations of two charismatic and flagship species - the Asian elephant (*Elephas maximus*) and the tiger (*Panthera tigris*).

This region has undergone intensive development in recent decades. It has been a major source of a variety of timber species, most notably teak (*Tectona grandis*). Primary forests over most of the northern portion of the ghats, in the states of Gujarat and Maharashtra, have virtually disappeared, and even the relatively dense forest cover over the southern states of Goa, Karnataka, Tamilnadu and Kerala have suffered substantial human impacts in recent decades. Monoculture plantations of teak, eucalyptus, wattle, and rubber among other species have replaced significant areas of natural forest. Apart from the above anthropogenic interferences, irrigation and hydro-electric dams have submerged forests in river valleys. Coffee, tea and cardamom plantations are widespread in the southern states. Roads and railway lines have impeded the movement of many large mammal species. With the control of malaria during the 1950s, the hill tracts have become increasingly attractive for migration of human settlers from the plains, and hill resorts such as Mahabaleshwar, Udhagamandalam and Kodaikanal have grown into crowded towns.

It is in this context of the ghats being one of the richest tracts in biological diversity, being home to numerous indigenous tribal communities, and at the same time being subject to intensive development and conservation efforts that we consider the potential impact of climate change on the forests of the region.

4.2 The study areas

4.2.1 Land use pattern

We selected two regions, the Nilgiris and Uttara Kannada (Fig 4.1), for the contrast they provide, to carry out a detailed study of present day vegetation, land-use patterns, socio-economics of people's dependence on forests and potential impacts of climate change. Our study region in the Nilgiris comprised a portion of the Nilgiri Biosphere Reserve (Sukumar, 1987). We selected several vegetation zones in the region, which would be representative of the diversity of vegetation and land-use types seen here. These included the Nilgiri district (Tamilnadu state) and the Wyanad and Palghat districts (Kerala state). We use the term Nilgiris in the broader sense to cover these districts. In specific cases we also refer to the "Nilgiris district" which is only one district in the study region. The term Uttara Kannada is used to refer to Uttara Kannada district (Karnataka state).

Nilgiris: The Nilgiris are topographically one of the most complex hill ranges of the Western Ghats. Our study region between 10° 50' N to 12° 16'N latitude and 76°15' and 77°E longitude, lies at the junction of the Western Ghats and the Eastern Ghats, the other prominent hill range of peninsular India. Geologically the Nilgiris belong to the Archean continental block of peninsular India, made up of pre-Cambrian metamorphic rocks, mainly gneisses, charnockites and schists. From the western Malabar coastal plains the Nilgiri plateau rises steeply to a general elevation of 2000-2300 m asl (highest peak 2632 m) while on the east it drops to the Mysore plateau at an elevation of 750-1000 m asl. The Nilgiri plateau seems to have been uplifted from the ancient Deccan landmass as a result of tectonic movement. As a consequence, clear dynamic fault lines can be seen all around the plateau. The Nilgiris receives rainfall from the south-west and the north-east monsoons. During the south-west monsoon the rain-bearing clouds precipitate heavily on the south-west and western slopes of the region. The monsoon gets weakened as it progresses inland creating a distinct rainfall gradient along the west (wet) to east (dry) direction. There is considerable variation in the rainfall and number of rainy days. The rainfall can be as high as 5000 mm at Mukurti peak (2554 m) and as low as 500 mm at

Tengumarada village (600 m) in the Moyar valley. The length of the dry season varies from 2-6 months. This factor has a strong influence on the vegetation patterns of the district.

The forest cover in the Nilgiri district is 81.8% (208 500 ha) of the total geographical area and dense forests account for 70.9% (148 000 ha) of the forest area (Table 4.1). The extent of protected forest (sanctuaries and national parks) in the Nilgiri district is 19.1% of the total forest area.

The total cropped area in the Nilgiri district is 70 354 ha (24.1% of geographic area) with plantation crops accounting for 84% of the cropped area. Tea, coffee and potato cultivation are very popular in the hill ranges. Planting of tea began in the Nilgiris in 1833, and at present the tea plantations account for 78.8% (46 619 ha) of the plantation crop area. Coffee ranks second as a plantation crop. It is grown mostly in the western part of the district. Crops such as pepper and cardamom are also grown. Even though most staple crops are not cultivated, several vegetable crops are grown. The farm lands of the Nilgiris produce a major share (85%) of potatoes grown in the state.

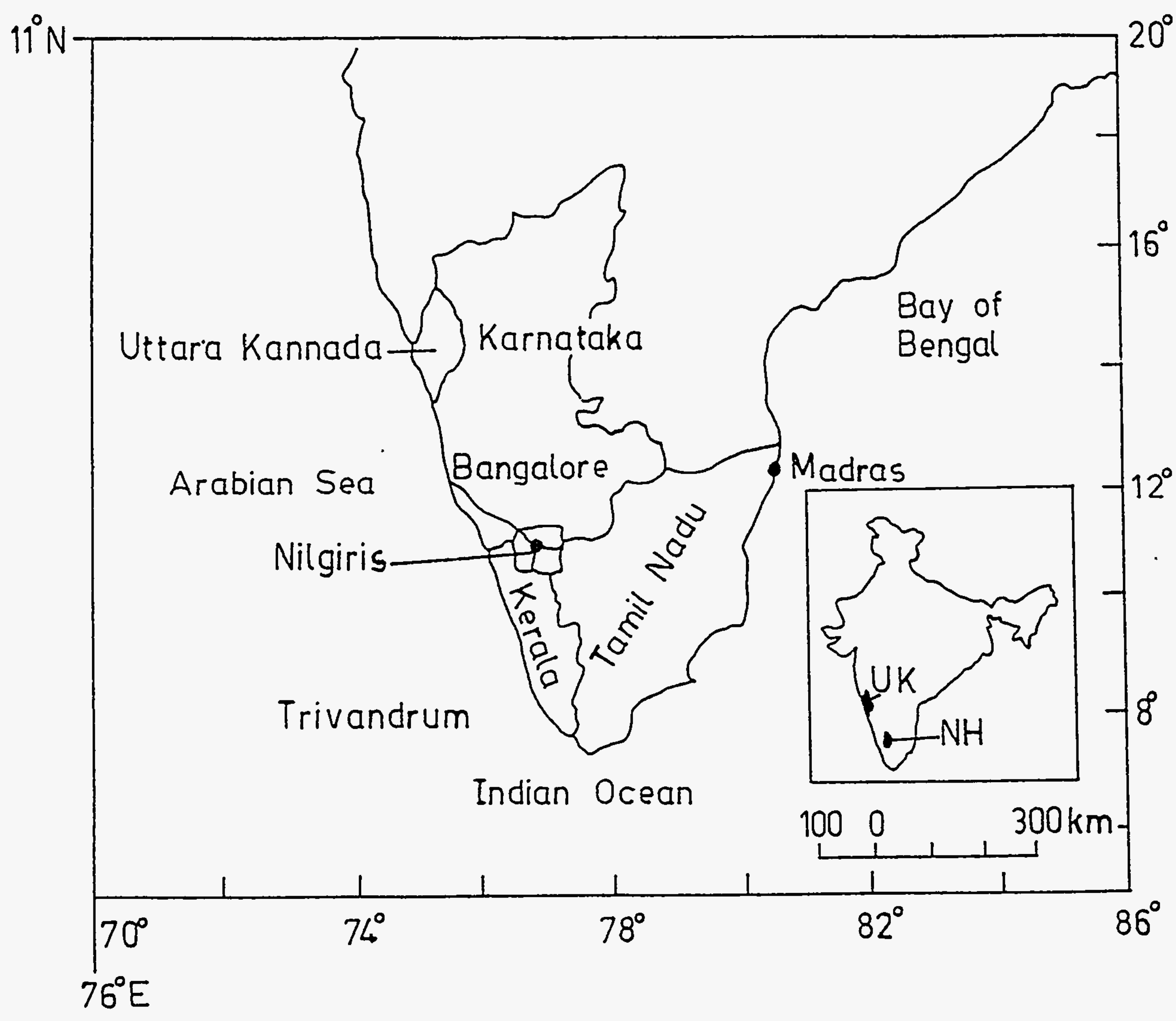


Figure 4.1. Map showing the study area.

Uttara Kannada: Uttara Kannada district is the northern most coastal district of Karnataka. It has a total geographical area of 10291 km^2 and accounts for 5.4% of the total area of the state. The Western Ghats cover a substantial portion of the district. The hills, however, seldom rise above 600-700 m. The narrow coastal strip is interrupted with wide river mouths, narrow creeks and low hills which often protrude into the sea. The average annual rainfall is 2 742 mm and the rainfall in the district generally decreases from the coast towards the hills and thereafter rapidly further eastward. Rainfall is mainly from south-west monsoon which is active from June to September.

The total forest cover is 781 600 ha which accounts for 75.9% of the total geographic area of the district (FSI 1995). Dense forests amount to 738 900 ha which is nearly 95% of the forest area. Of the total forest area, 620 218 ha is "Reserve Forest" under the control of the Forest Department. The "soppina bettas", which are sources of leaf manure for the arecanut gardens, cover 51 121 ha. Area under crops or the net area sown in the district is 112 121 ha (10.8% of the geographic area). Horticultural plantation crops such as arecanut, coconut, cashew, banana, sapota, mango, betel vine, pineapple, sweet potato, etc. account for 14.5% of the total cropped area (Table 4.1).

4.2.2 Human Population

In the Nilgiri district the total population, according to the 1991 census, is 710 214 of which 353 430 is urban population and 356 784 rural. The total number of households in the district is 156 733, of which 81 063 is rural. Due to the importance of towns such as Udhagamandalam (Ootacamund) and Coonoor as tourist centres, there has been an inflow of migrants in recent decades. During 1971-81 the migrants accounted for 41.4% of the total population of the district. This district also attracts immigrants from not only the adjoining districts but also from other states, particularly Kerala. The district is home to several indigenous forest dwelling communities including Todas (pastoral), Kurumbas (hunters and gatherers) and Kattunayaks (agriculturists and gatherers), Panias, Kotas and Irulas. Their population accounts for 3.5% of the total population of the district. The remaining population is a conglomeration of Badagas, Vokkaligas and other communities.

The population of Uttara Kannada district according to the 1991 census is 1.2 million of which 75.8% is rural and 24.1% urban. There are 224 470 households in the district of which 168 400 (75%) live in the rural areas. Tribal communities account for only one percent of the population. The tribes of the district are Gonds (agriculturists), Gouli (pastoral and agriculturists), Bhil, Nayaka, etc. The population densities of the Uttara Kannada and Nilgiri district are 119 and 244 per km^2 respectively, as compared to the national average of 257/km^2.

Table 4.1: Socio-economic features of Uttara Kannada and Nilgiri district.

	Uttara Kannada district	Nilgiri district	% in Uttara Kannada district	% in Nilgiri district
Total population	1072 034	710 214		
Rural	800 241	356 784[1]	75.8	50.2
Urban	271 793	353 430	24.1	49.7
Tribal	NA	25 048	NA	3.5
Total no of HHs	224 470	156 733		
Total no of rural HHs	168 400	81 063	75.0	51.7
Population density	119	244		
			Occupation pattern	
Cultivators	133 226	10 922	37.0	3.7
Agricultural labourers	56 401	24 992	15.4	8.6
HH industry	10 686	18 098	2.9	6.2
Livestock, forestry & fishing	NA	150 631	NA	52.1
Other workers	162 367	84 226	44.5	29.1
			Land holding pattern (ha)	
< 1	94 164	33 712	66.3	71.6
1 - 2	26 587	7 434	18.7	15.7
2 - 4	15 254	3 786	10.7	8.0
4 - 10	5 524	1 512	3.8	3.2
> 10	405	624	0.2	1.3
			Land use pattern (ha)	
Total geographic area	1029 100	291 381		
Total forest area *	781 600	208 500	75.9	71.5
Area under crops	95 789	11 211	9.3	3.8
Area under plantation crops	16 332	59 143	1.5	20.3
Others	135 379	12 527	13.1	4.2

*Based on National remote sensing agency estimates from FSI (1995)
[1] Rural population is inclusive of tribal population

4.2.3 Occupation and land owning pattern

The Nilgiris district is primarily a labour-based society with 52% of the work force engaged in animal husbandry, forestry and fishing. It is characterised by an intensification of animal husbandry production systems. This process has led to an increase in the numbers of livestock and the export of greater range of products like milk, dung for organic manure and meat. In addition to dairy products, there are commercial demands for cattle dung as organic fertiliser for the tea and coffee plantations. The cultivators and agricultural labourers constitute 3.7% and 8.6% of the work force respectively. About 95% of the farmers hold less than 5 ha of land each.

The main occupation of Uttara Kannada district is cultivation. The major crops are rice, followed by plantation crops such as arecanut (*Areca catechu*), coconut (*Cocos nucifera*), cashew (*Anacardium occidentale*), pepper (*Piper nigrum*) and cardamom (*Elaetaria cardamomum*). A substantial area of Uttara Kannada is covered with forests and the bulk of the population depends on agriculture for its livelihood. Uttara Kannada district is one of the agriculturally developed districts. Of the total workers, 37.0% are cultivators and 15.4% are agricultural labourers. Thus, the population depending on agriculture and allied professions amounts to about 53% of the total workers.

Land holding patterns show that about 61-67% of the landholding is below 1 hectare. Farms above 10 ha (0.3-1.3% of the land owning population) are usually owned by the horticultural cultivators in the Uttara Kannada district and the tea estate owners in the Nilgiri district.

4.3 Vegetation of the study area

4.3.1 Vegetation of the Nilgiris

The Nilgiris has the entire diversity of vegetation types seen in the Western Ghats. General descriptions of the floristics and vegetation of the region can be found in Hockings(1989). For the purposes of our study we used the Vegetation Map of the Nilgiri Hills by the French Institute, Pondicherry. The vegetation classification is based on the altitudinal distribution, the type and their degradation stages. We simplify our description and analyses to five major natural vegetation types (Table 4.2a).

Table 4.2a: Baseline area of different vegetation types in Nilgiris (including Nilgiri, Wyanad and Coimbatore districts).

Vegetation type	Baseline area (in ha)
Evergreen forest	58 500
Moist deciduous forest	103 200
Dry deciduous forest	167 000
Dry thorn forest	216 800
Montane forest/grassland	29 200
Total	574 700

a) Tropical wet evergreen forest

The wet evergreen forests are mainly confined to the southwestern slopes of the Nilgiris, in Nilambur, New Amarambalam, Silent Valley and western Attapadi reserves of Kerala, and a small belt in Gudalur division in Tamilnadu. These extend to an altitude of 1800 m asl, and can be floristically distinguished into lower and higher elevation types. The vertical stratification of the evergreen forest is pronounced with canopy trees, often buttressed, commonly reaching 3-40 m height. The dominant trees vary in different locations; in Silent Valley which is characteristic of the wet evergreen forest, *Palaquium ellipticum* and *Cullenia exarillata* are the most abundant canopy species followed by *Knema attenuata*, *Persea macrantha* and *Mesua ferrea*. In the New Amarambalam reserve, the most abundant (>10 trees/ha) evergreen trees are *Vateria indica*, *Polyalthia fragrans*, *Hopea parviflora* and *Calophyllum tomentosum*, with lower abundances (4-10 trees/ha) of *Mesua ferrea*, *Palaquium ellipticum*, *Myristica sp.*, *Canarium strictum*, *Cinnamomum zeylanicum*, *Bischofia javanica*, *Persea macrantha*, and *Elaeocarpus tuberculatus*.

The secondary stratum of the forest may feature trees such as *Cinnamomum wightii*, *Democarpus longan*, several species of cloves (*Syzygium arnottiana*, *S. calophyllifolium*, *S. montanum*) and nutmeg (*Myristica fragrans*). The understorey has various species of *Strobilanthes*, rattan canes (*Calamus spp.*) and palms (*Arenga wightii*, *Pinanga dicksonii*, *Caryota urens*). The herbaceous vegetation is also diversified with ferns, *Neurocalyx spp.*, and balsams. Epiphytes (chiefly orchids), climbers, lianas, ferns and mosses are other characteristic features of this vegetation type, which has its best representation at about 900-1000 m in places such as Silent Valley. Trees become more stunted with higher elevation, and invariably species found at lower elevations disappear above 1800 m where stunted montane forests and grasslands take over the landscape.

b) Tropical montane evergreen forest and grassland

The upper Nilgiri plateau (>1800 m asl) features stunted montane evergreen forest patches and extensive grasslands. The Lauraceae, Rubiaceae and Euphorbiaceae are three plant families that dominate the vegetation of the montane forests. Isonandra candolleana, *Cinnamomum malabathrum*, *Alseodaphne Semecarpifolia*, *Litsea floribunda*, *Ilex denticulata*, *Actinodaphne spp.*, *Symplocos spp.*, *Syzygium spp.*, *Phoebe spp.*, *Daphniphyllum neilgherrense* are the common trees. The understorey vegetation features *Psychotria sp.*, *Lasianthus sp.*, *Exocaria sp.*, etc. Along the fringes of the forests are seen shrubs such as *Strobilanthes spp.*, *Rhododendron sp.*, *Rhodomyrtus tomentosus*, *Heydotis stylosa*,along with grasses of the genus Arundinarea. Many of the shrubs along the forest fringe and the grasslands have temperate affinities. The montane grasslands cover extensive areas of the hill slopes and the plants here are mostly from families like Apiaceae, Fabaceae, Rosaceae and Euphorbiaceae in addition to Cyperaceae and Poaceae. Frost during winter limits the spread of forest trees and shrubs into the grasslands.

c) Tropical moist deciduous forest

Moist deciduous forest is seen largely in the Wyanad Division of Kerala, the western fringes of Bandipur and Mudumalai, and in Nilambur and New Amarambalam. *Terminalia crenulata*, *Tectona grandis*, *Kydia calycina*, *Grewia tiliaefolia*, *Pterocarpus marsupium*, *Lagerstroemia microcarpa* and *Anogeissus latifolia* are the most common trees. Commercially important rosewood *Dalbergia latifolia* also attains its best growth in this forest type. The moist deciduous forest belt is characterized by numerous grassy swamps, which are mostly under cultivation today. The thorny bamboo *Bambusa arundinacea* is also abundant in this forest tract. In disturbed areas the undergrowth has tall, perennial grasses of *Themeda cymbaria*, *Cymbopogon flexuosus* and *Imperata cylindrica*.

d) Tropical dry deciduous forest

The dry deciduous forests extend in a large contiguous belt over the Mysore plateau in the Bandipur National Park and Mudumalai Sanctuary. Typically, this forest type is dominated by *Anogeissus latifolia*, *Tectona grandis* and *Terminalia crenulata*, although in moister areas, *Lagerstroemia microcarpa* becomes increasingly common. Other common species of trees include *Emblica officinalis*, *Radermachera xylocarpa*, *Cassia fistula*, *Grewia tiliaefolia*, *Lagerstroemia parviflora*, *Diospyros montana*, *Diospyros melanoxylon*, *Terminalia chebula*, *Terminalia bellerica* and *Garuga pinnata*. The understorey usually features tall, perennial grasses of the genus *Themeda*, and is subject to dry season fires. Significant stretches of this forest type are also seen in the Talamalai plateau to the north-east of the Nilgiri plateau and in the Coimbatore Division to the south. These forests, however, have different species composition as compared to the teak-dominated forests.

e) Tropical dry thorn forest
The most significant stretch of this forest type lies in the rain-shadow region, namely, the Sigur plateau and the Moyar river valley to the north of the Nilgiri plateau. Most of the woody species are stunted and below 5 m, although some may grow to thrice this height (good examples being the umbrella-shaped canopies of *Acacia leucophloea* which have escaped being destroyed by elephants, or the silvery-barked *Gyrocarpus jacquinii*). Species of *Acacia* (*A. chundra*, *A. leucophloea*, *A. ferruginea*, *A. suma*, *A. pennata*), *Albizia* (*A. amara*, *A. chinensis*), *Ziziphus* (*Z. xylopyrus*, *Z. mauritiana*), *Dicrostachys cinerea*, *Gardenia turgida*, *Canthium parviflorum*, *Fluggea leucopyros*, *Gyrocarpus jacquinii* and *Hardwickia binata* characterize this forest type. Grasses are invariably of the shorter varieties and usually present only during the wet season.

4.3.2 Vegetation of Uttara Kannada

Unlike the Nilgiri hills, the Uttara Kannada district rises from the western coast to an elevation of only 600 m asl, which is the general elevation of the Deccan plateau. Consequently, the Uttara Kannada region has fewer natural vegetation types as described below (Table 4.2b). There is also a clearer west-east gradient in vegetation as one proceeds from a high to low rainfall zone, with evergreen forest showing a transition to semi-evergreen forest along the westerly slopes and eventually being replaced by moist deciduous forest on the plateau and dry deciduous forest along the eastern fringe of the forest boundary with cultivation. Some mangrove vegetation also occurs in the estuaries of rivers, but we have not considered this because the area of mangroves is insignificant.

a) Tropical wet evergreen forest
The wet evergreen belt of Uttara Kannada has been broadly divided into northern and southern zones (Subhashchandran 1994) and into lower elevation and medium elevation types (Pascal 1987). There are considerable differences in distributions of evergreen species. Among the relatively widespread and abundant trees are *Knema attenuata*, *Hopea wightiana*, *Olea dioica*, *Strombosia ceylanica*, *Syzygium gardneri* and *Democarpus longan*. Trees which are abundant on a more local scale include *Aglaia anamallayana*, *A. roxburghiana*, *Hemicyclia venusata*, *Diospyros candolleana* and, most notably, *Dipterocarpus indicus* (Gadgil and Subhashchandran, 1989).

The low elevation (0-650 m asl) forests have been differentiated into the *Persea macrantha-Diospyros spp.-Holigarna type* along the coast, the *Diospyros spp.-Dysoxylum malabaricum-Persea macrantha* type in eastern Sirsi, and the *Dipterocarpus indicus-Diospyros candolleana-Diospyros oocarpa* type (Pascal 1987) also along the coast. The last type found in the region of Honnavar and Kumta has a very sparse distribution, with *Dipterocarpus indicus* being largely restricted to patches of kans or sacred forests (Subhashchandran, 1994). Similarly, the rare *Myristica fatua* var. magnifica and *Pinanga dicksoni* (a palm endemic to the Western Ghats) are confined to a swamp at Kathlekan in the district. The medium elevation (650-1400 m asl) evergreen forest has been classified as the *Memecylon umbellatum-Syzygium cuminii-Actinodaphne angustifolia* type.

Table 4.2b: Baseline area of different vegetation types in Uttara Kannada district *

Vegetation types	Baseline area (in ha)
Evergreen forest	108 986
Semi evergreen forest	20 9204
Moist deciduous forest	226 589
Dry deciduous forest	47 826
Total	592 605

* Based on digitization of satellite imagery of UK district, excluding small fragments and degraded forest patches. this area is used for analysis in the study.

b) Tropical semi-evergreen forest

The semi-evergreen forests of the district generally seem to represent degradation stages of the evergreen type. Much of this are former areas of clear felling, silvicultural weeding of evergreen elements (to promote deciduous hardwoods) and shifting cultivation (Subhashchandran, 1994). In some of these forests the canopy is characterized by large deciduous tree species such as *Xylia xylocarpa*, *Terminalia crenulata* and *Lagerstroemia microcarpa*, while the understorey is composed of evergreen elements such as *Knema attenuata*, *Litsea spp.*, *Cinnamomum spp.*, *Olea dioica* and *Garcinia morella* (Subhashchandran, 1994). This indicates that succession is proceeding from deciduous towards evergreen forest in the absence of major disturbances such as fire and clearing of forests.

c) Tropical moist deciduous forest

The moist deciduous forests are found on the plateau within a rainfall regime of 1500-2000 mm. The most abundant canopy species are *Xylia xylocarpa* and *Terminalia paniculata*, followed by *Grewia tiliaefolia*, *Lagerstroemia microcarpa*, *Hopea wightiana* and *Holorrhaena antidysenterica*. The smaller trees include *Calycopteris floribunda* and *Ervataemia heyneana*, along with evergreen elements such *Knema attenuata* and the shrub *Leea indica*.

d) Tropical dry deciduous forest

Along the eastern fringe of the district, the low rainfall zone (< 1500 mm) has typical dry deciduous forest with the canopy species being *Anogeissus latifolia*, *Terminalia paniculata* and *Xylia xylocarpa*. Other abundant species include *Holorrhaena antidysenterica*, *Tectona grandis*, *Pterocarpus marsupium* and *Terminalia crenulata.*

4.3.3 Biomass and productivity of the forests

The evergreen forests of the Nilgiris have the highest basal areas (46-48 m^2/ha) and consequently the highest standing biomass (>380 t/ha) (Table 4.3a). The biomass has been calculated on the basis of a standard equation

Standing Biomass = -1.689 +8.32(BA) t/ha (R^2= 0.5 SE = 1.169) where BA = basal area in m^2/ha

Because trees in the montane forest are stunted, the calculated biomass would be an overestimate for this vegetation type. The lower biomass of evergreen forests (287 t/ha) of Uttara Kannada may be a reflection of poor representation of trees in the upper girth classes as compared to the moist deciduous forests (Table 4.3b). The biomass of human-impacted evergreen and semi-evergreen forests such as the betta forests and minor forests (range 136-207 t/ha) of Uttara Kannada is also considerably diminished and achieve levels of that of the dry deciduous forests (172 t/ha) of Nilgiris. Assuming a mean 2.8% annual increment in biomass, (NHR, unpublished), the productivity of the Western Ghats forests varies from about 2 to 11 t/ha per year, or a weighted mean of 9.4 t/ha/yr for natural forests of the Nilgiris and 7.2 t/ha/yr for Uttara Kannada.

Table 4.3a: Basal area, growing stock and mean annual increment in different forest types of Nilgiris.

Forest type	Basal area (m^2/ha)	Growing stock (t/ha)[1]	Mean annual increment (t/ha/yr)[2]
Evergreen	46.4	384	10.92
Moist deciduous	40.3	333	9.48
Dry deciduous	20.9	172	4.89
Dry thorn	9.3	76	2.16
Montane forest/grassland	48.2	399	11.34

Table 4.3b: Basal area, growing stock and mean annual increment in different forest types of Uttara Kannada.

Forest type	Basal area (m^2/ha)	Growing stock (t/ha)[1]	Mean annual increment (t/ha/yr)[2]
Evergreen RF	34.7	287	8.1
Evergreen MF	25.1	206	5.9
Semi evergreen RF	25.3	208	5.9
Semi evergreen MF	16.5	135	3.9
Moist deciduous RF	38.7	320	9.1
Dry deciduous RF	31.4	260	7.4

[1] Growing stock= (8.32*basal area)-1.689
[2] Mean annual increment= 2.84% of growing stock
RF = Reserve forest; MF = Minor forest (for community use)

4.3.4 Size-class of trees and regeneration

Size class distributions of woody plants in different vegetation types of Nilgiris and Uttara Kannada are presented in Tables 4.4a and 4.4b respectively. Size class abundance and number of plants per hectare for the first ten dominant species for Nilgiris and Uttara Kannada are presented in Appendix 4.1a and 4.1b respectively. Plants of the evergreen forests have, on average, the least abilities to regenerate by coppicing: only 50% of the species recorded in our samples showed the coppicing ability, while the species in moist deciduous and dry deciduous showed good coppicing ability (82% in moist deciduous and 80% in the dry deciduous forest), while those of drier forests regenerate extremely well from coppices. In the drier forests subject to annual ground fires, for instance, there is selection for coppicing abilities and a few species with these abilities dominate the community. Thus, sexual reproduction and dispersal of fruits by animal agents is quite common in the species-rich evergreen forests (71% of the species recorded in the vegetation study showed dispersal by animal agents), while vegetative reproduction and wind dispersal is the rule among trees in the dry deciduous forests.

Table 4.4a: Size class distribution of woody plants in different vegetation types of Nilgiris.

Vegetation type	DBH distribution in cms						
	1-5	5-10	10-15	15-20	20-25	25-30	>30
Evergreen forest	547	590	196	94	64	34	109
Moist deciduous forest	654	177	96	71	59	40	172
Dry deciduous forest	298	285	187	118	60	55	95
Dry thorn forest	430	300	108	79	45	20	18
Montane forest/grassland	442	482	190	112	95	76	137

Table 4.4b: Size class distribution of woody plants in different vegetation types of Uttara Kannada.

Vegetation type	DBH distribution in cms						
	1-5	5-10	10-15	15-20	20-25	25-30	>30
Dry deciduous RF forest	480	453	140	73	33	3	23
Moist deciduous RF forest	159	204	127	119	111	79	168
Semi evergreen RF forest	625	317	75	47	54	23	62
Semi evergreen MF forest	419	215	89	41	21	29	36
Evergreen RF forest	396	449	214	161	93	64	148
Evergreen MF forest	47	58	15	3	1	0	0

4.3.5 Plant diversity

Diversity is highest in the wet evergreen forests with an average of 38 species of woody plants (>3 cm dbh) recorded per 0.1 ha. We do not have specific data for a one hectare plot in this forest. The second most diverse forest type is the montane stunted forest with an average of 31 species per 0.1 ha or 67 species recorded in a single one-hectare plot at Thaishola. This is followed by moist deciduous forest (18 species/0.1 ha; 55 species per ha), dry thorn forest (14 species/0.1 ha; 33 species/ha) and dry deciduous forest (15 species/0.1 ha; 27 species/ha) (Table 4.5a). Interestingly, the number of species and heterogeneity of the dry thorn forest is slightly higher than those of the dry deciduous forest where rainfall is higher by 30-50%, probably as a consequence of the higher frequency of dry season fires in the latter (H. S. Dattaraja, unpublished results).

The levels of diversity in the forests of Uttara Kannada show a very similar pattern with the most diverse being evergreen forest (35 species/0.1 ha) and semi-evergreen forest (36 species/0.1 ha), while moist deciduous (18 species/0.1 ha) and dry deciduous (17 species/0.1 ha) have lower diversity (Table 4.5b).

Given the background of very diverse vegetation patterns in the Western Ghats, we now go on to evaluate the potential impacts of climate change on the different vegetation types in the Western Ghats.

Table 4.5a: Diversity of different vegetation types in Nilgiris.

Vegetation type	No. of species Mean ± SD	Diversity index (H')
Evergreen forest	39±7.9	3.10±0.4
Moist deciduous forest	18±6.6	2.45±0.3
Dry deciduous forest	15±5.3	2.11±0.4
Dry thorn forest	14±3.3	2.29±0.3
Montane forest/grassland	31±8.9	2.85±0.3

Table 4.5b: Diversity of different vegetation types in Uttara Kannada.

Vegetation type	No. of species Mean±SD	Diversity index(H')
Evergreen RF forest	35±7.06	2.79±0.55
Evergreen MF forest	34±10	2.27±0.32
Semi evergreen RF forest	36±5.12	2.88±0.29
Semi evergreen MF forest	33±11.68	2.95±0.42
Moist deciduous RF forest	18±6.06	1.93±0.35
Dry deciduous RF forest	17±5.73	2.20±0.41

5. IMPACTS OF PROJECTED CLIMATE CHANGE ON FORESTS OF THE WESTERN GHATS

We now present the results of a simple equilibrium model linking climate change projections (as summarised by Kelly, 1995) with the vegetation of the Nilgiris and Uttara Kannada in order to assess the potential impacts of a changing climate on the areas under different vegetation types. This forms the background to our assessments of impacts on climate change on a forest-based economy.

5.1 Past climatic and vegetational changes in the Western Ghats

Before we go on to look at the likely impacts of future climatic change on vegetation, it would be useful to consider the evidence for past climatic and vegetational changes due to natural causes in the Western Ghats. Much of the evidence for this during the past 20 000 years comes from carbon stable isotopic studies of peat deposits in the Nilgiris (Sukumar *et al.*, 1993, 1995a) and pollen studies in the Nilgiris (Vasanthy, 1988) and coastal Uttara Kannada (Caratini *et al.*, 1991).

The Nilgiri studies show that the balance of C3 plants (most tropical trees, shrubs and herbs, and temperate grasses) and C4 plants (tropical grasses and sedges) has fluctuated considerably as a result of climatic change (Sukumar *et al.*, 1993, 1995a). During the Last Glacial Maximum (16 000-18 000 yrs BP), when mean global temperatures were considerably lower than at present, there is evidence for an arid climate with a dominance of C4 vegetation. During the deglaciation (14 000-10 000 yrs BP) there is a gradual increase in C3 vegetation, suggesting an expansion of C3 herbs and possibly montane forest as well under a warming and moister climate. The Holocene Optimum (10 000-9 000 years BP) is marked by a predominance of C3 vegetation under conditions of peak soil moisture. An arid period with C4 vegetation is again clearly established during 5 000-2 000 yrs BP. With an almost equal mixture of C3 and C4 vegetation, the present-day climate is moderate as compared to the extremely arid or moist phases indicated during the late Quaternary period.

The pollen evidence from coastal Uttara Kannada (Caratini *et al.,* 1991) suggests the spread of grassland perhaps with the onset of an arid phase from c. 3 500 yrs BP. It is not clear if this was entirely due to natural climate changes or due to clearing of forests by people.

Correlations between global atmospheric CO_2 levels and the proportions of C3 and C4 plants in the Nilgiris (Robinson 1994) also suggest that the vegetational changes may be also influenced by CO_2 rather than soil moisture alone. Some of the above studies provide a useful background to considering the likely impacts of future climate change on the vegetation of the Western Ghats.

5.2 Methods of modelling projected changes in vegetation

Equilibrium models such as BIOME have been used to project changes in vegetation types or biomes on a global and regional scale (IPCC, 1996, Deshingkar *et al.*, 1997) with changing climate. BIOME 3 uses a grid of 0.5 x 0.5 degrees to model vegetation distribution and change. Unfortunately, for reasons which are not clear to us at this time, BIOME and BIOME 3 fail adequately to represent vegetation biomes in the Western Ghats (Prentice *et al.*, 1992, and personal discussions). For instance, for the greater part of the Western Ghats they fail to predict the occurrence of "tropical seasonal forest" (the tropical wet evergreen forest which occurs as a narrow belt all along the western slopes of the ghats). For a topographically complex area with a diversity of climatic and vegetation regimes, a very high resolution model is needed for an adequate description. One possible reason for the failure of BIOME to predict accurately the vegetation biomes in the Western Ghats is the inadequacy of the climate data set used in the model. As the outputs from BIOME in the present form were of no use to us, we set up an alternative model for the purpose of our study.

In order to assess the potential impacts of climate change on forests of the two study areas, the Nilgiris and Uttara Kannada, we set up a simple model interlinking present-day vegetation with climate, and then used the outputs of GCM based climate projections as reported by Kelly (1995) to derive potential shifts in vegetation boundaries. For both the regions we digitised vegetation maps at 1:250 000 scale and converted these to a raster image with a resolution of 0.5 x 0.5 minutes. Each cell was assigned to one of the major natural vegetation types defined by us. We excluded all vegetation categories which are primarily anthropogenic in origin (such as monoculture plantations, cultivation or completely transformed vegetation).

For the Nilgiris, the six major natural vegetation types defined are a) wet evergreen forest, b) montane stunted evergreen forest and grassland, c) degraded moist forest, d) moist deciduous forest, e) dry deciduous forest, and f) dry thorn forest (Fig 5.1). For Uttara Kannada district we defined four major vegetation types, a) wet evergreen forest, b) semi-evergreen forest, c) moist deciduous forest and d) dry deciduous forest (Fig 5.2).

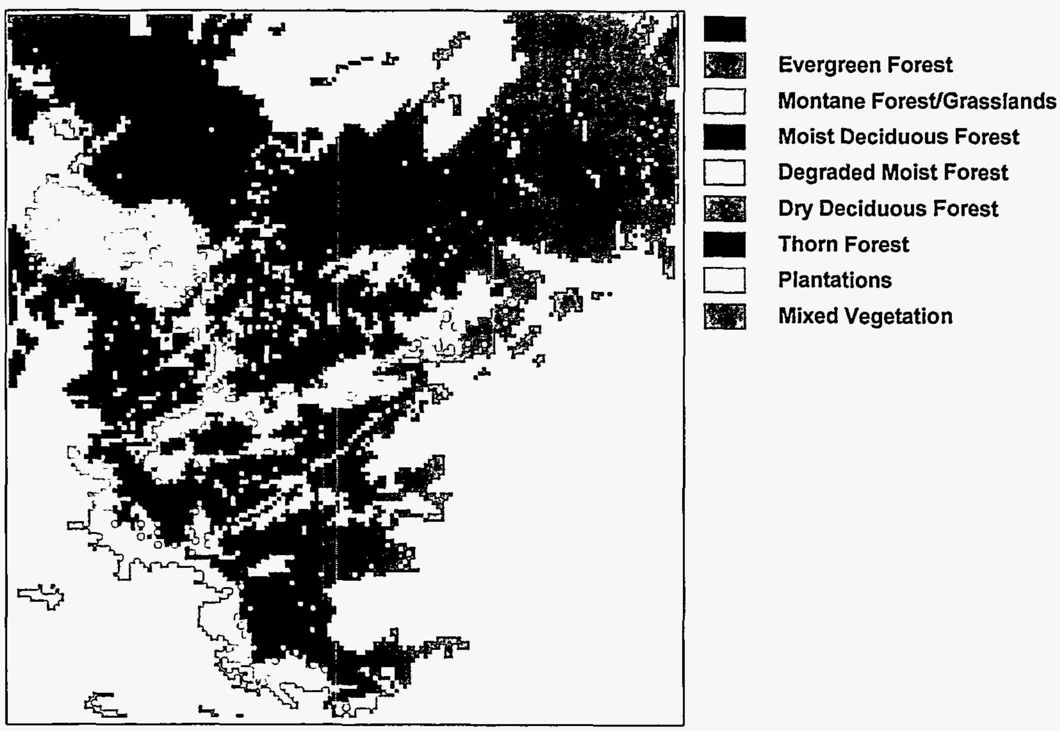


Figure 5.1. Vegetation types of Nilgiris.

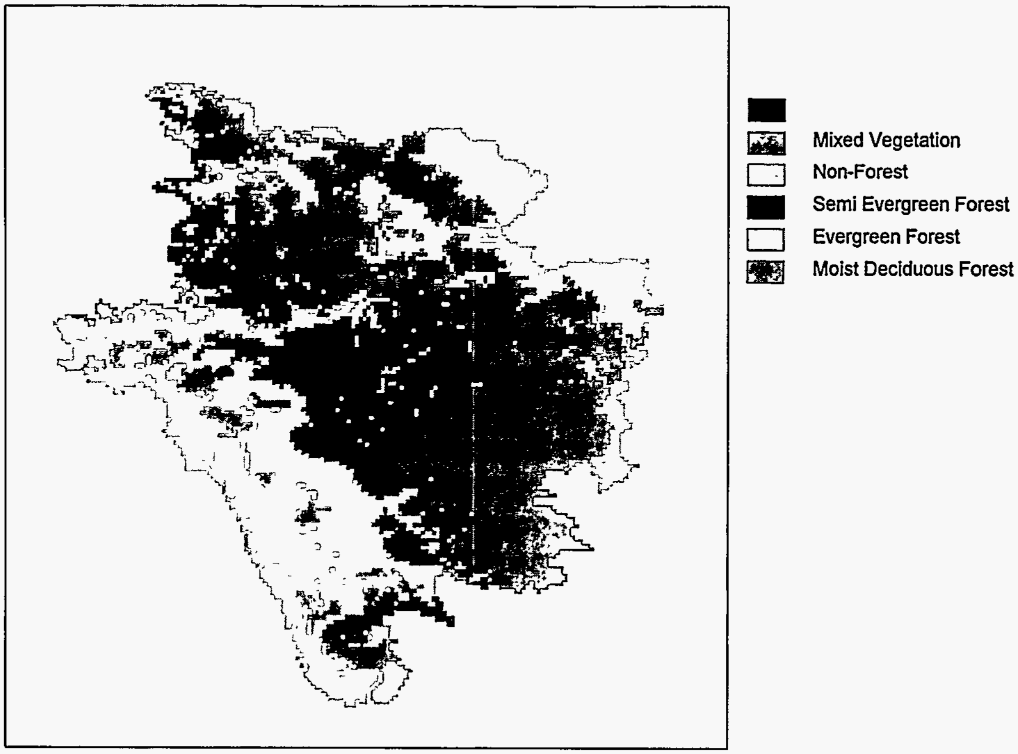
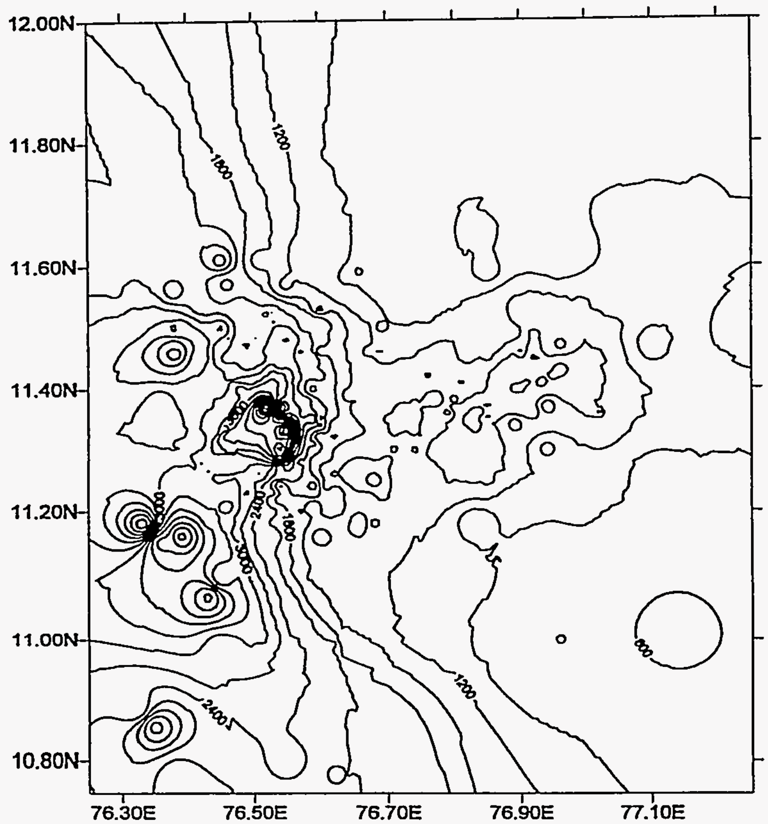


Figure 5.2. Vegetation types in Uttara Kannada.

Using data on total annual rainfall averaged over a minimum of 20 years for 319 stations in the Nilgiris, and 96 stations in Uttara Kannada, we generated isohyets for the map area (Fig 5.3 and 5.4) and converted this to a raster image of 0.5 x 0.5 minute resolution, with each cell assigned to one rainfall class (see Table 5.1).

Table 5.1: Mean annual temperature and rainfall classes used for modeling.

S.No	Rainfall (in mms)	Temperature (°c)
1	400-700	11-12
2	700-1000	12-13
3	1000-1300	13-14
4	1300-1600	14-15
5	1600-1900	15-16
6	1900-2200	16-17
7	2200-2500	17-18
8	2500-2800	18-19
9	2800-3100	19-20
10	3100-3500	20-21
11	3500-4000	21-22
12	4000-4500	22-23
13	4500-5000	23-24
14	5000-5500	24-25
15	5500-6000	25-26
16	6000-6500	26-27
17	-	27-28
18	-	28-29
19	-	29-30



Figur 5.3. Rainfall countour map of Nilgiris

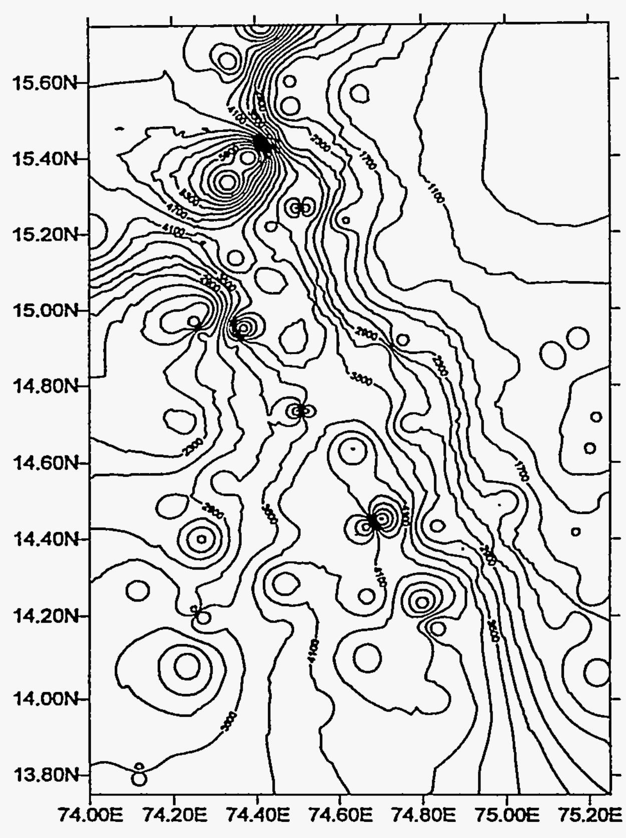


Figure 5.4 Rainfall contour map of Uttara Kannada.

We had information on mean monthly minimum and maximum temperatures for only 27 stations in the Nilgiris and 2 stations in Uttara Kannada. For the Nilgiris we developed a regression model of elevation versus mean annual temperature using data from the rain gauge stations. The best fit line was given by

$$t = -0.00643x + 28.72$$

where t = temperature (in C) and x = elevation (in metres).

This regression was used to extrapolate temperature for the 319 stations used for generating isohyets in the Nilgiris and 96 stations in Uttara Kannada. We then generated isotherms for the Nilgiri region and Uttara Kannada (Fig 5.5 and 5.6) and produced an image of 0.5 x 0.5 minute resolution assigning each cell into one of several temperature classes at 1 degree C interval from 11°C to 28°C.

The three images (vegetation type, mean annual temperature class and mean annual rainfall class) were then superimposed and frequency distributions of these variables generated for the Nilgiri and Uttara Kannada regions. Temperature was taken as the primary variable, rainfall as the secondary variable and vegetation as the tertiary variable. Because of the topographic complexity of the Nilgiris and the relatively heterogeneous distribution of rainfall stations over this region (there are no rainfall data for very steep slopes, for instance), there is always the possibility of noise in the data arising out of a mismatch of temperature, rainfall and vegetation categories. We therefore decided to generate smoothed frequencies through an averaging procedure as detailed in Box 5.2.

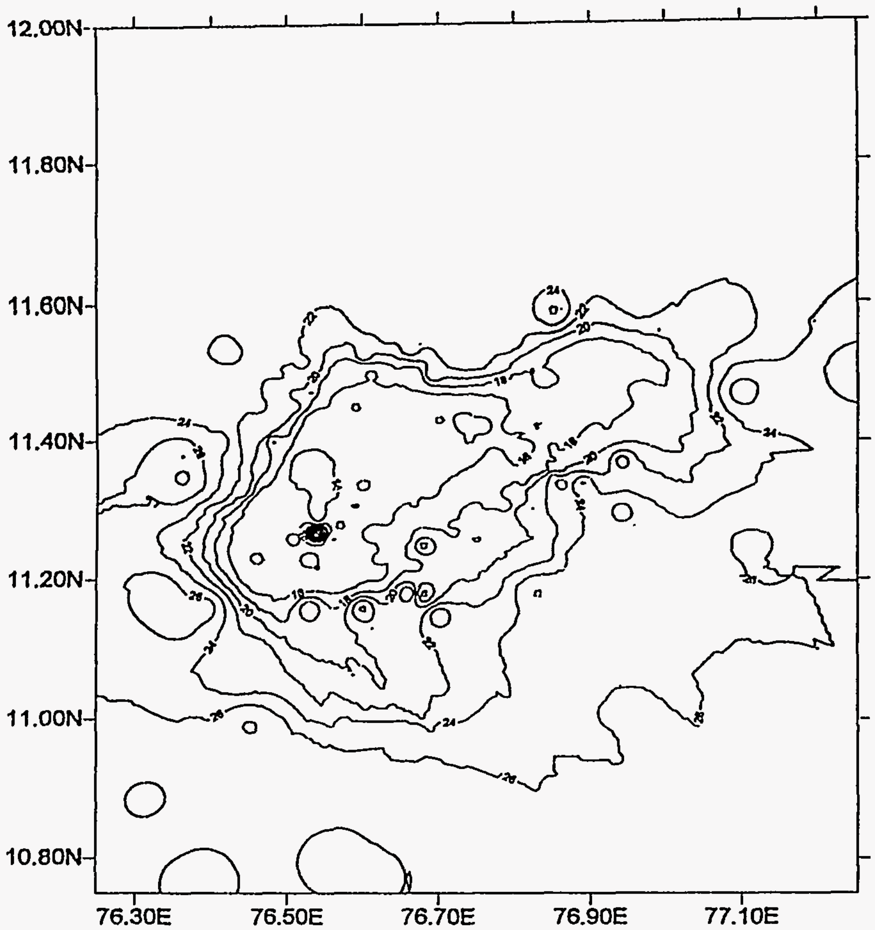


Figure 5.5. Temperature contour map of Nilgiris.

The percentages of cells occupied by each major vegetation type for a given combination of temperature and rainfall for the Nilgiris and Uttara Kannada are summarized in Table 5.1. These frequency distributions were then used to make projections about vegetation changes in response to climatic change as will be described in the following section.

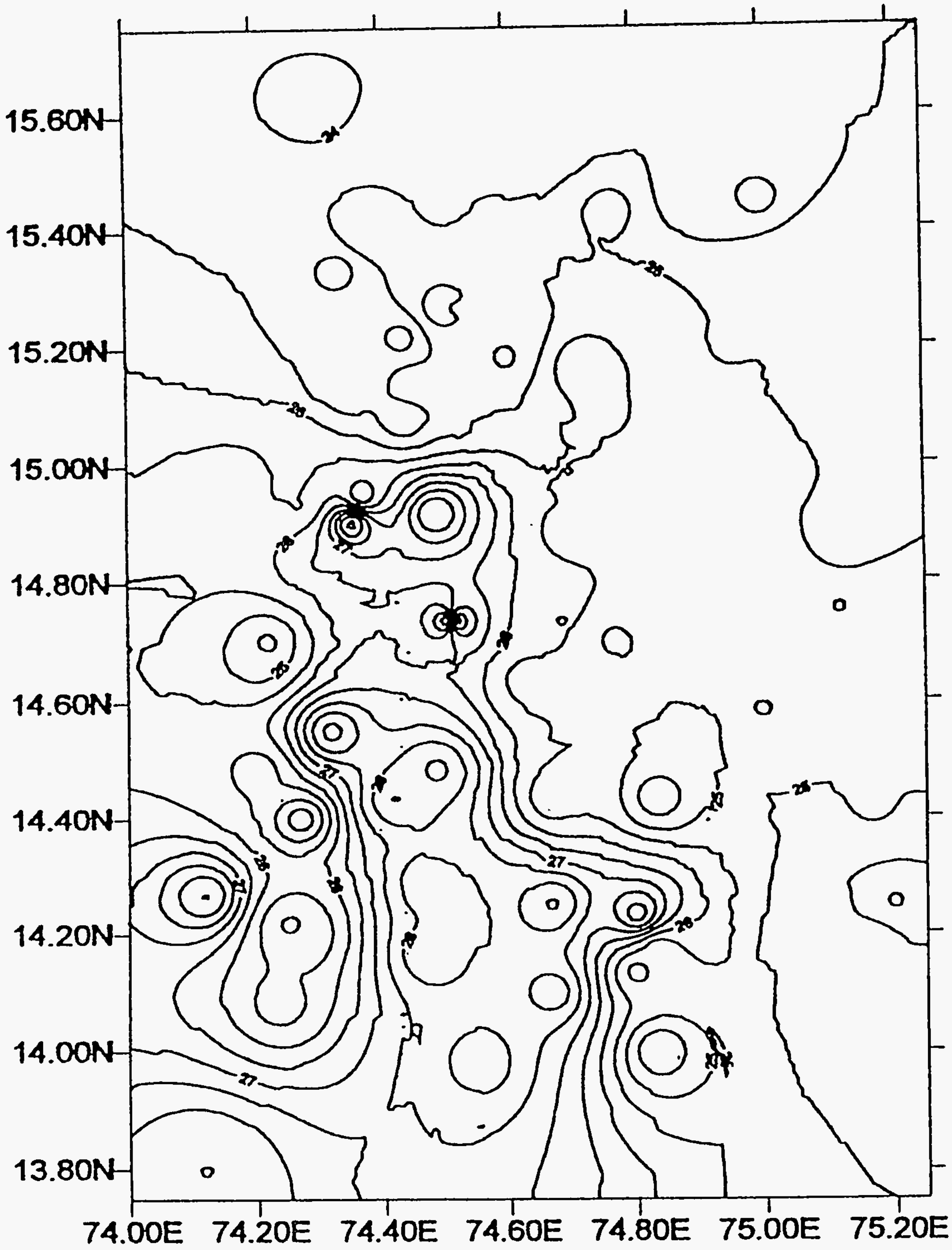


Figure 5.6 Temperature contour map of Uttara Kannada.

Box 5.1. Procedure for generating smoothed frequencies of vegetation types in relation to temperature and rainfall classes.

Each temperature-precipitation combination is represented by TP(i,j), where i and j respectively denote the i th temperature class and the j th precipitation class (i = 1, ...m; j = 1,...n). The percentage of cells falling in each of the six vegetation types (V) for each TP(i,j) is represented by TPV(i,j,k) where k=1,...6. For each i,j combination

$$\sum_{k=1}^{6} TPV(i,j,k) = 100\%$$

The averaging was done in three steps.

a) Keeping i constant (i.e. same temperature class), the average of TPV (i,j-1,k), TPV(i,j,k) and TPV(i,j+1,k) was calculated and denoted as $TPV_1(i,j,k)$. Now

$$\sum_{k=1}^{6} TPV(i,j,k)$$

need not necessarily be 100% and so a normalisation is required. The normalised values are represented by a bar.

$$TPV_1\,(i,j,k) = \frac{TPV_1\,(i,j,k)}{\sum_{k=1}^{6} TPV_1(i,j,k)} \times 100$$

This was done for all values of k from 1 to 6.

b) Keeping j constant (i.e. same precipitation class), the average of TPV (i-1,j,k), TPV(i,j,k) and TPV(i+1,j,k) was calculated and denoted as $TPV_2(i,j,k)$. Again these values were normalised as

$$TPV_2\,(i,j,k) = \frac{TPV_2\,(i,j,k)}{\sum_{k=1}^{6} TPV_2(i,j,k)} \times 100\%$$

This was done for all values of k from 1 to 6.

c) The average of $TPV_2(i,j,k)$ was calculated and denoted as TPVA(i,j,k). This is normalised as

$$TPVA\,(i,j,k) = \frac{TPVA\,(i,j,k)}{\sum_{k=1}^{6} TPVA(i,j,k)} \times 100\%$$

Obviously, the averaging procedure does not apply to i values of 1 and m, and to j values of 1 and n. For Uttara Kannada there were relatively few temperature classes and thus we did not carry out this averaging procedure.

5.3 Potential vegetation response in the Western Ghats to climate change

The climate scenarios used to model vegetation in this study are based on the report for the Western Ghats by Kelly (1995). We have considered the following scenarios:

1. *The most likely scenario* : The Case 1 scenario based on moderate climate sensitivity and central scaling factor for both regional temperature and precipitation changes for the years 2020 and 2050 (see section 2.3.2). This represents the "most likely" estimate of mean changes in temperature and precipitation (Table 2.1).

2. *The worst case scenario* which is a combination of the Case 3 scenario (high climate sensitivity upper scaling factor) for regional temperature change with a Case 2 scenario (high climate sensitivity and lower scaling factor) for regional precipitation changes for the year 2050 (see section 2.3.2). This combination represents the "worst case" scenario of higher temperature and lower precipitation (Table 2.1).

We have considered only the mean annual temperature and precipitation consistent with our data base. The magnitude of differences between seasonal variations in these values for a given scenario is relatively negligible.

To model potential change in areas of vegetation types we used the following procedures. For a given scenario of temperature and precipitation change, we increased the baseline temperature-precipitation values of all cells by those projected changes. Thus, in *the most likely scenario* for the year 2020 for the Nilgiris, the temperature in all cells was uniformly raised by 0.3° C and the precipitation by +3% over the baseline values. The number of cells falling within different temperature-precipitation (TP) combinations was derived for this scenario. For each TP combination the cells were then distributed among the natural vegetation types (six for the Nilgiris) by comparison with the current data base. The proportion of cells falling within the different vegetation types for a new TP combination was assumed to be the same as that for the old TP combinations (i.e. current data base). The smoothed frequency data base was used for the Nilgiri comparisons. When a new TP combination was obtained which did not exist in the current data base, we took the vegetation distribution for the closest TP combination. This was not a problem with increasing or decreasing precipitation (as these were placed in relatively broad classes) but for the temperature classes a certain number of cells moved up into a class which was 1° C higher than the currently existing class.

Qualitatively, the vegetation shifts that could be expected under climate change are an increase in area under the moister vegetation types with increased rainfall and a shift towards drier types with increased temperature. The areas under different vegetation types in Nilgiris under the climate change scenarios as modelled are shown in Table 5.2b.

5.3.1 Likely vegetation changes in the Nilgiris

With *the most likely scenario*, there is an increase in evergreen, moist deciduous and dry thorn forest types, and a decline in the montane forest/grassland and dry deciduous forest. As expected, the moister forest types show an increase with increasing rainfall. A typical sequence could be a shift from dry deciduous forest through moist deciduous forest, semi-deciduous forest to wet evergreen forest as a result of increased moisture. The dry deciduous forest thus declines, by as much as 36% by the year 2050, probably as a result of some shift to moist deciduous forest in response to increasing precipitation, while other parts shift to dry thorn forest as a consequence of increasing temperature. The montane ecosystem characterised by low temperatures declines by 7% (year 2050) in the area in response to increasing temperatures.

Under the *worst case scenario,* where temperature increases and precipitation decreases, there is a substantial increase in the driest vegetation type (the dry thorn forest increasing by 33%), at the expense of dry deciduous forest (-48%), with modest change in other vegetation types by the year 2050.

Table 5.2a. Projected changes in areas (in sq kms) under different vegetation types with climate change in Uttara Kannada.

Vegetation Type	Baseline	Most likely scenario 2020 Temp +0.3°C Rainfall +3%	Most likely scenario 2050 Temp +0.7°C Rainfall +7%	Worst case scenario (2050) Temp +1°C, Rainfall -7%
Evergreen forest	1089	1284(+17.9%)	1582(+45.4%)	1761(+61.8%)
Semi evergreen forest	2092	2205(+5.4%)	2261(+8.13%)	1583(-24.3%)
Moist Deciduous forest	2265	2055(-9.27%)	1779(-21.5%)	2045(-9.71%)
Dry Deciduous forest	478	380(-20.5%)	302(-36.8%)	535(+11.9%)
Total	**5924**	**5924**	**5924**	**5924**

Table 5.2b. Projected changes in areas (in sq kms) under different vegetation types with climate change in Nilgiris.

Vegetation Type	Baseline	Most likely scenario 2020 Temp +0.3°C Rainfall +2%	Most likely scenario 2050 Temp +0.6°C Rainfall +4%	Worst case scenario 2050 Temp +0.9°C Rainfall -8%
Evergreen forest	585	664(+13.4%)	714(+22%)	563(- 563(-
Moist Deciduous forest	895	1021(+14%)	1136(+26.9%)	1046(+16.8%)
Dry Deciduous forest	1624	1179(-27.4%)	1032(-36.4%)	850(-47.7%)
Dry Thorn forest	2083	2350(+12.8%)	2339(+12.3%)	2767(+32.9%)
Montane forest/Grassland	289	280(-3.1%)	268(-7.3%)	263(-9.1%)
Total	**5477**	**5495**	**5491**	**5491**

5.3.2 Likely vegetation changes in Uttara Kannada

For Uttara Kannada the *most likely scenario* of climate change (increasing temperature and precipitation) shows a similar shift from the dry deciduous and moist deciduous forest towards semi-evergreen and evergreen forest (Table 5.2a) for 2020 and 2050. The dry deciduous and moist deciduous forests decline by 38% and 22% respectively, while the semi-evergreen and evergreen forests increase by

8% and 45% respectively by the year 2050. With the *worst case scenario* of increased temperature and decreased precipitation by the year 2050, there is some increase in evergreen forests which is obviously incorrect. As the baseline vegetation of Uttara Kannada does not have dry thorn forest, an incorrect projection is made. Logically, one could expect that the drier forest types would increase at the expense of the moister types, and this could include a shift in the vegetation of the low precipitation areas of the eastern region to dry thorn forest.

The simple phenomenological model used here has limitations when compared to a process-based model such as BIOME. Therefore the vegetation change scenarios should be taken as an indication of the direction of change rather than precise quantitative estimates. One of the main limitations is that the spatial distribution of vegetation change is not modelled. Thus, no vegetation map is generated for the years 2020 and 2050 under the climate change scenarios, although there is information on the probable areas under different types. The response of a given patch of vegetation to climate change would depend on a number of factors such as the proximity of seed sources, the degree of fragmentation, animal dispersal agents, and topography. Thus, two patches of the same vegetation type may respond differently to climate change depending on the influence of the above factors. In fact, all "equilibrium models" (including BIOME) have their limitations, in that "transient" responses of vegetation are not modelled.

5.3.3 *Species response to climate change*

While "equilibrium models" give us a picture of likely changes in the boundaries and areas of major vegetation types, it is important to understand the likely response of individual species to climate change. This requires a detailed knowledge of the autecology and life histories of species, which is largely lacking for the majority of tropical forest plants. At this stage we can only speculate on the likely responses of a few representative species (of ecological or economic importance) of the major vegetation types in the Western Ghats.

a) Evergreen forests

The evergreen forests are characterised by a large number of species which are dispersed by animals. Such species would have higher mobility and potentially be able to adapt better as compared to passively-dispersed species. However, the ability of such species to adapt to climate change will thus depend on the response of the dispersed populations. Many species are also extreme habitat specialists and may be sensitive to even small changes in climate. Trees which are habitat specialists and animal-dispersed include *Agrostistachy meeboldii, Cinnamomum malabathrum, C. verum, C. sulphuratum, Cryptocareya bounrdillonii, Cullenia exarillata, Garcinia indica, G. morella, G. gummi-gutta, Mesua ferrea, Myristica malabarica, M. dactyoloides, Palaquium ellipticum* and some species of *Syzygium*. Under the *worst case scenario*, an increased temperature and decreased precipitation would almost certainly stress the habitat specialists and moisture loving species listed above.

Dipterocarpus indicus which has a very restricted distribution (at low elevations) is one tree which would be negatively affected. Certain species which are common in evergreen forests and are also not uncommon in semi-evergreen or even moist deciduous forests include *Aphanamyxus polystachya, Artocarpus hirsuta (wild jack fruit), Canarium strictum, Clerodendron viscosum and Macaranga peltata.* Such species may adapt better to a changing climate, including a reduction in precipitation.

b) Montane forests and grasslands

The balance between montane forest patches (or sholas) and grasslands is critically dependant on the temperature regimes under the natural conditions (Sukumar *et al.*, 1995a). Under the *most likely scenario,* the increase in temperature may facilitate the migration of species from lower elevation forests to the montane areas, thus reducing this area slightly. More important is the likely response of plants within the montane ecosystem. Potentially, the higher temperature and lower incidence of frost would set the stage for an expansion of the forest species into the grasslands. Trees and shrubs along the forest edge would be best able to take advantage of the changing climate. These include shrubs such as *Hedyotis stylosa, Rhodomyrtus tomentosus* and trees such as *Symplocos cochinchinensis, Ternstroemia japonica,* and *Ligustrum spp.*

On the other hand, anthropogenic pressures are likely to retard the spread of forest plants. Fires during the dry season in the grasslands may check the growth of such species. More important, the large-scale planting of exotic species such as wattle (*Acacia meansii, A. melanoxylon)* and Eucalyptus (*Eucalyptus globosus*) in the grasslands is likely to interface with any possible spread of forest plants. The wattles have a strong tendency to spread widely over the grasslands. In the past the harsh climatic conditions (low temperatures) have checked the growth of wattles in the southwestern part of the Nilgiri plateau. However, with an increased mean temperature, reduction in forest frost incidence and possible CO_2 fertilisation (which should favour the wattles, which have C3 photosynthesis), there is a real danger of wattles spreading over the grasslands.

The species with temperate affinities, such as *Rhododendron nilgiricum, Mahonia leschnaultii* and *Gaultheria frangrantissima* are likely to be at a disadvantage under conditions of increasing temperature. These are mostly found along the fringes of shola forests or in the grasslands.

c) Deciduous forests

Trees in the deciduous forests are largely adapted to occurrence of fires, herbivory by large mammals such as elephants and anthropogenic disturbances. Most of them are wind dispersed or reproduce vegetatively through coppicing from roots. To that extent many of the species may be relatively resilient to change.

One of the most economically valuable species in the deciduous forests is teak (*Tectona grandis*) which has been extensively exploited for timber. Teak has a widespread distribution, from moist deciduous forest through dry deciduous forest and even parts of dry thorn forest. The species regenerates well through coppicing and is adapted to fire. Our observations in the Nilgiris show that teak has a higher rate of regeneration as compared to other dominant trees in the deciduous forests (Sukumar *et al.,* 1995b). Whatever the direction of climate change, it can be expected that teak would adapt well. Similarly, a species such as amla (*Emblica officinalis*) whose fruit is an important non-timber forest product, has a widespread distribution. It is dispersed by animals such as the axis deer (*Axis axis*), and also spreads through coppicing.

Lagerstroemia microcarpa is a timber tree which is distributed in the moisture areas of deciduous forests. It is known to regenerate well in the forests of the Nilgiris and would benefit from an increase in precipitation. However, with a decrease in precipitation it is certain that the species would retreat. Other deciduous trees such as rosewood (*Dalbergia latifolia*) and *Xylia xylocarpa* could also be expected to respond in a similar fashion.

On the other hand, species such as *Terminalia crenulata* and *Anogeissus latifolia* are abundant in the dry deciduous forests. It is possible that such species may not be very mobile in the face of changing climate and thus decline, whatever the direction of change.

Under the *worst case scenario,* the deciduous forests with abundant grass in the understory would also be more susceptible to fires as a result of decreases in precipitation. This would change the composition and structure of the forests toward a savanna-woodland type.

5.4 Conclusions:

We can thus summarise the likely impacts of climate change on vegetation in the two study regions as follows:

1. The projected climate change will result in shifts in forest boundaries and changes in area under different vegetation types. There may be corresponding shifts in plant diversity, the magnitude of which is not understood at present because of the absence of a suitable transient response model.
2. Under the *most likely scenario* there may be an expansion of evergreen and moist deciduous forests due to increased precipitation and also of dry thorn forests due to an increase in temperature. Concurrently, there might be a decrease in the dry deciduous forests. Under the *worst case scenario* there could be significant shifts from the moist to the drier vegetation types as a result of increasing temperatures and decreasing precipitation. Forests may also decline due to death of trees, especially under the *worst case scenario.*
3. In the montane ecosystems of the Western Ghats there is a risk of exotics such as wattle expanding into the natural grasslands due to increasing temperatures and CO_2 levels.
4. Human activities (cultivation, fire, water bodies) and the resulting fragmentation of forest areas could prevent or slow down the natural migration of species in response to a changing climate. In addition, the direct impact of human activities on natural ecosystems would also dictate the response of vegetation to a changing climate.

Given the potential for large scale impacts of projected climate change on forests, there is an urgent need to improve the existing vegetation response models for a better assessment of change. This will assist in formulating better policies to improve forest resilience and adaptation to climate change.

6. SOCIO-ECONOMIC ASPECTS OF DEPENDENCE ON FORESTS IN THE WESTERN GHATS

Forests provide a range of products and services to local communities, the national economy and international trade. These include timber and the so-called Non-Timber Forest Products (NTFPs). The importance of NTFPs in the economy has always been underrated because most of the products are largely for subsistence, and most governments still consider timber as the main revenue source from the forestry sector. Even though the 'Agenda 21' of the United Nations Conference on Environment and Development (1992) has recognised the role of NTFPs in sustainable forest management, there prevailing ignorance regarding the diversity of products gathered, quantities extracted, their economic value and contribution to employment and income levels of rural communities and trade.

A range of NTFPs is collected and used by communities for various purposes - food, fibre, fodder, flavour/fragrance, fatty oils, gums, resins, medicinal herbs, religious purposes, structural material, household articles, agricultural implements, etc. NTFPs are of importance to forest-dependent communities for subsistence and as raw material for sale to industry. India is one of the 12 Mega Diversity' nations of the world. Nearly 21,000 plant species occur in India. NTFPs are derived from nearly 3 000 species of which only 126 have been developed commercially (Maithani, 1994). In India about 30% of the population living below the poverty line resides in and around forest areas. According to a conservative estimate, about 1.6 million person years are employed in NTFP activities (the forestry sector employs 2.3 million person years). About 40 to 50% of state forest revenues in India and 80% of net export earnings from forests come from NTFPs (Tewari, 1993).

Forests in tropical countries are subject to anthropogenic pressures leading to forest degradation, forest fragmentation and ultimately deforestation (FAO, 1993a). The impact of projected climate change will be an additional factor affecting the forest area, distribution, biodiversity and productivity, ultimately affecting the flow of forest products to communities and industries. The first step in any assessment of socio-economic implications of climate change impacts on forests, is to gain a good knowledge of current dependence of communities and economy on forests.

This dependence is assessed below, followed by an assessment of changes in forest production and product flows under climate impacted situations and the resulting effects on communities and the economy. Fuelwood, grass and leaf manure extraction is not included while assessing NTFPs as these products are not species specific.

6.1 Current flows of forest products to communities

The current dependence of communities and industries in Uttara Kannada and Nilgiris was assessed through field studies conducted during 1995. The two locations are largely forested districts (with >70% of geographic area under forests) with different socio-economic conditions. Uttara Kannada has an advanced agricultural economy dominated by rice, areca, and coconut plantations. In the Nilgiris, the tribal population (3.5% of the total population) largely depends on forests. The flow of forest products was assessed by sampling villages and households from different forest types (the sampling procedure is described in the Appendix 6.1) and conducting questionnaire based household surveys. Socio-economic features were considered while selecting the households. The household study was supplemented by data from the Forest Department and marketing outlets of forest products. It is necessary to keep in mind the limitations of a single visit based household survey where information is gathered through recall rather than direct observation or measurement.

6.1.1 Diversity of plants and plant products used

A study of the tribal economy of Kerala State, which is largely a part of the Western Ghats, has shown that up to 120 plant species components are collected from the forests (Thomas and Bai, 1993). As the plant species diversity increases, one would expect that larger numbers of plant species would be gathered and used. In the Western Ghats region the number of plant species extracted is assessed for different forest types.

The number of plant species used in Uttara Kannada is high in the evergreen (59) and semi-evergreen (40) forest zones. In the Nilgiris the species numbers are also high in the evergreen (37) and moist deciduous (49) forest zones. The number of plant species used from the dry deciduous forest zone is low in both the regions. As seen earlier (Chapter 4), the plant species diversity declines overall from the moister to drier forest types. The total number of plant species recorded as being gathered and used is 95 in Uttara Kannada and 119 in Nilgiris. In both the regions, a large number of plant species are used as food and for commercial purposes. Twenty six species in the evergreen and 11 species in the semi evergreen forest types of Uttara Kannada were recorded as being used for medicinal purposes (Table 6.1). Similarly, 11 and 10 plant species respectively are used in the moist deciduous and evergreen forest types of Nilgiris. Two shops in Uttara Kannada selling medicinal plants were found to stock 42 and 80 plant components (not species). The details of end uses for the dominant plant products are given in Tables 6.2a and 6.2b for Uttara Kannada and Nilgiris respectively.

6.1.2 Access to forest products

Traditionally, local communities had free access to the forest products, particularly NTFPs. However, with state control of forests and the passing of several forest legislations (Forest Conservation Act 1980, Wild Life Act, etc.) access to local communities, traders and industries to forests and forest products is being increasingly regulated. Access of households to forest products for households depends on the forest category and ownership (Box 6.1). In the state controlled Reserve Forest areas of Uttara Kannada, communities have free access to very few products. The extraction of all products which have commercial value (such as *Acacia sinuata*, honey, cane, *Terminalia chebula*, *Sapindus emarginatus*, *Garcinia sp.*, *Artocarpus lakoocha*) is regulated by the Forest Department. The Department auctions these products to contractors, generally for a price much lower than the market potential. Industries had large scale access to bamboo and softwood in the past, which are also now regulated.

In the Nilgiris, where a large part of the forests is designated “protected area” status, extraction of most of the products is banned. For some products (such as *Emblica officinalis, Tamarindus indicus, Terminalia chebula*), licenses are issued to local people by the forest department. The products gathered must then be sold in recognised outlets (local co-operative societies). However, in all the forest locations in the region, irrespective of the regulations, households gather forest products for consumption, and in many cases even for sale.

6.1.3 Proportion of household gathering, quantities of forest products gathered and financial value

An important step in assessing the dependence of local communities and the economy on forests is to estimate the quantities of forest products extracted and their monetary value. NTFPs are collected in varying quantities, at varying periods, and some of them cannot be quantified or monetised. The percentage of households gathering NTFPs, the quantities gathered and monetary value for the dominant forest products in different forest types in Uttara Kannada and Nilgiris are given in Table 6.2a (for Uttara Kannada) and 6.2b (for Nilgiris). The data was collected through a household survey in different forest zones.

Uttara Kannada: There are differences in the plant products gathered in different forest types, for example; *G. indica* and *G. cambogea* fruits are gathered only from evergreen and semi evergreen forests. Some products such as bamboo and honey are gathered in all the forest types, though in small quantities in some forest regions. One of the factors determining the products gathered is the plant diversity, which varies among different forest types (Section 4)

When the percentage of households gathering different NTFPs is considered in the evergreen zone, over 50% of households gathered *Artocarpus lakoocha*, bamboo, *Calamus sp.*, and *G. indica*. Similarly over 50% of households gathered *A. lakoocha, G. cambogea* and *Sapindus emarginatus* in the semi evergreen forest region. In the dry deciduous forest region only honey is gathered by over 50% of households. The dominant NTFPs are gathered by over 50% of households in evergreen, semi evergreen and moist deciduous areas.

When the quantities of NTFPs gathered by only the gathering households is considered (Table 6. 2a); in the evergreen zone 91 kg of *G. indica* and 129 kg of *A. lakoocha* are gathered/HH annually. In the semi evergreen forest area 182 kgs of *G. cambogea* fruits and 25 kgs of *A. lakoocha* are gathered annually/HH. The quantity of honey collected is 16 and 5 kgs/HH/year in dry deciduous (73% of households) and moist deciduous forest areas, respectively. The variation in quantities gathered (Table 6.2a) is high for some products (such as *Garcinia indica and G. cambogea*) and low for others (*A. lakoocha, A.sinuata* in moist deciduous, bamboo and cane in evergreen forest zones).

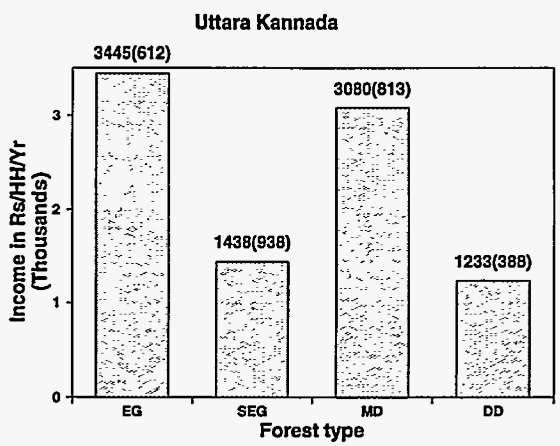
Value of forest products gathered: The monetary value of different gathered products, estimated by taking 1996 market prices and considering only the gathering households is Rs.1935 per household per year for *A. lackoocha* in the evergreen zone, Rs.1820/HH/year for *G. cambogea* in the semi evergreen forest area and Rs.1600/HH/year for honey in the dry deciduous forest area.

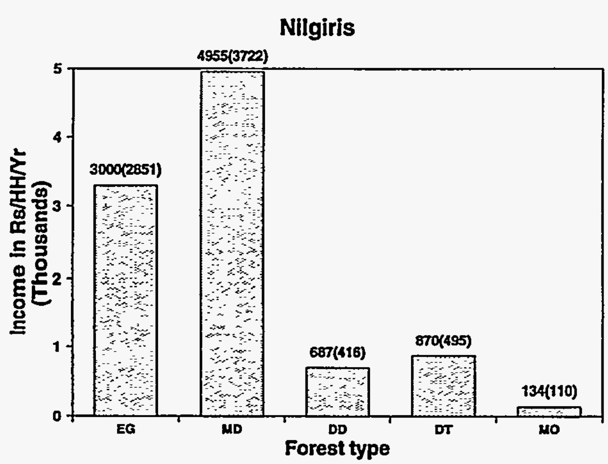
The overall income from NTFPs, including all households whether gatherers or not, is given in Fig 6.1. The monetary value ranges from Rs.3445/HH in the evergreen to Rs.1223/HH in the dry deciduous forest area. The majority of households seem to derive incomes close to the mean value as indicated by the low standard deviation of the mean monetary values. However note that the value of medicinal herbs is not considered; and that with future increases in rainfall and plant diversity due to climate change, the value of products derived from forests by the communities can also be expected to increase.

Nilgiris: In evergreen and moist deciduous forests of the Nilgiris, the percentage of households gathering some of the products is very high; *E. officinalis* (97%), *A. sinuata* (>65%), and *Bambusa arundinaceae* (95%): see Table 6.2b. However, the number of products gathered and the percentage of households gathering is lower for dry deciduous, dry thorn and montane forest areas. Despite the restrictions on gathering, a large percentage of households gather NTFPs in the region.

In the Nilgiris area, the quantity of *gathered E. officinalis* (69 kgs/HH/yr in the dry thorn forests but upto 480 kgs/HH/yr in the moist deciduous zone) *A. sinuata*(145 kgs/HH/yr in the evergreen and 215 kgs/HH/yr in the moist deciduous zone), and honey is large among the gathering households (Table 6.2b). The quantities of some of the NTFPs such as *Phoenix sylvestris* and *Mangifera indica* gathered in dry thorn and dry deciduous forests respectively are also large. Honey is gathered in all the forest types and the quantity gathered is in the range of 11 to 27 kg/gathering HH/year in dry thorn and moist deciduous zones respectively.

Monetary Value of NTFPs gathered in Nilgiris: The overall annual financial value of NTFPs gathered, considering all the households in the selected villages, ranged from a low of Rs.687/HH in the dry deciduous zone to Rs.4955/HH/yr in the moist deciduous zone (Fig 6.1). When only gathering households are considered, the value of some of the individual gathered products such as *E. officinalis* (Rs.1440/HH in the moist deciduous zone), *A. sinuata*(Rs.1075/HH in the moist deciduous zone) is very high. The variation in financial value (Table 6.2b) for some products like honey in all the zones is high but it is low for *Emblica* in the moist deciduous and evergreen zones.





EG - Evergreen, SEG - Semi Evergreen, MD - Moist Deciduous, DD - Dry Deciduous, DT - Dry Thorn, Mo - Montane. Figure in parentheses indicate standard deviations.

Figure 6.1. Mean financial value of NTFPs gathered by household (HH) in Uttara Kannada and Nilgiris.

The variation of the financial value of NTFPs gathered is low for the dry deciduous, dry thorn and montane zones but it is high for the evergreen and moist deciduous zones, indicating a wide variation in the incomes among the households in some forest zones.

6.1.4 Significance of financial value of NTFPs gathered

The ideal approach to assessing the importance of NTFPs to household finance would be to estimate the total household income from all sources in each forest zone and weigh the contribution of NTFP source to the total household income. There are limitations in estimating household income through the questionnaire survey method as respondents do not wish to reveal their actual income. Thus, the contribution of NTFP to household earnings could at best be compared to per capita (or per household) income from other studies in the region, and to the current wage rate in rural areas in the region.

The financial value of NTFPs reported as income in Fig. 6.1 does not include other products gathered by households such as firewood, leaf manure and grass from forests. The financial value of NTFPs gathered in both the regions is significant when compared to the potential wage rate in rural areas (daily rate of Rs.35-40 in Uttara Kannada and Rs.30-40 in Nilgiris). For example, in the moist deciduous forest zone, the annual financial value of NTFPs gathered is equivalent to wage earnings of 77 and 123 person days/household/yr in Uttara Kannada and Nilgiris, respectively.

6.2 Quantities of NTFPs extracted by the Forest Department in Uttara Kannada

The extraction of most forest products in Uttara Kannada and the Nilgiris is regulated and the extraction of some products are contracted out by the Forest Department through auctions. The quantity and value of NTFPs extracted by the Forest department is likely to be an under-estimate of the quantity actually collected for several reasons. Firstly, the afore mentioned contracts are often contracted out at low values. Secondly, the contractor reports lower values of quantities actually extracted to avoid paying royalties to the Forest Department. Finally, although some of the products are on the list of regulated products, they are not auctioned in some forest divisions. Thus, the quantities recorded by the Forest Department are very low compared to what is gathered by households. The quantities extracted by the Forest Department are added to the quantity extracted by households to obtain district level aggregates.

According to Forest Department records, the total value of forest products collected annually (mean of 1992 to 94) in Uttara Kannada district through Forest Department channels is Rs. 18 million (or Rs. 30/ha at 1996 prices).

The trends in extraction of some of the major NTFPs in Uttara Kannada and Nilgiris over the past few years are given in Fig. 6.2.

Uttara Kannada: The major products collected are *Garcinia cambogea*, *Acacia Sinuata*, *Terminalia chebula*, and canes. The trends in collection of NTFPs over the years in two forest divisions, namely Honnavar and Yellapur show no consistent patterns. Factors such as climate and pest attacks could be possible reasons for the fluctuating trend.

Nilgiris: Data on quantities of NTFPs are obtained from the Working Plans of the Forest Department and the cooperative societies (LAMPS) for Nilgiri and Wyanad districts. In the predominantly tribal regions of Wyanad there seems to be a consistent annual trend in the quantity of the four dominant NTFPs gathered over the past 10 years. In Nilgiris there is an irregular trend and only some products such as *Emblica officinalis* are gathered consistently (Fig 6.2).

Extraction of some products such as *Tamarindus indicus*, *Solanum tarvum*, *Pongamia pinnata* seeds has stopped in recent years. In the pre-1986 period, many more NTFPs were collected. These were later either banned by the Forest Department or the demand for them has ceased. In recent years *Emblica officinalis* (44 t/yr), *Acacia sinuata*(4 t/yr), *Sapindus emarginatus* powder (44 t/yr) and *Phoenix sylvestris* are the major products gathered. It should be recognised that all the products gathered may not necessarily be sold to the societies recognised by the Forest Department or sold to the authorised contractors, and thus may not be reflected in the data of the Forest Department.

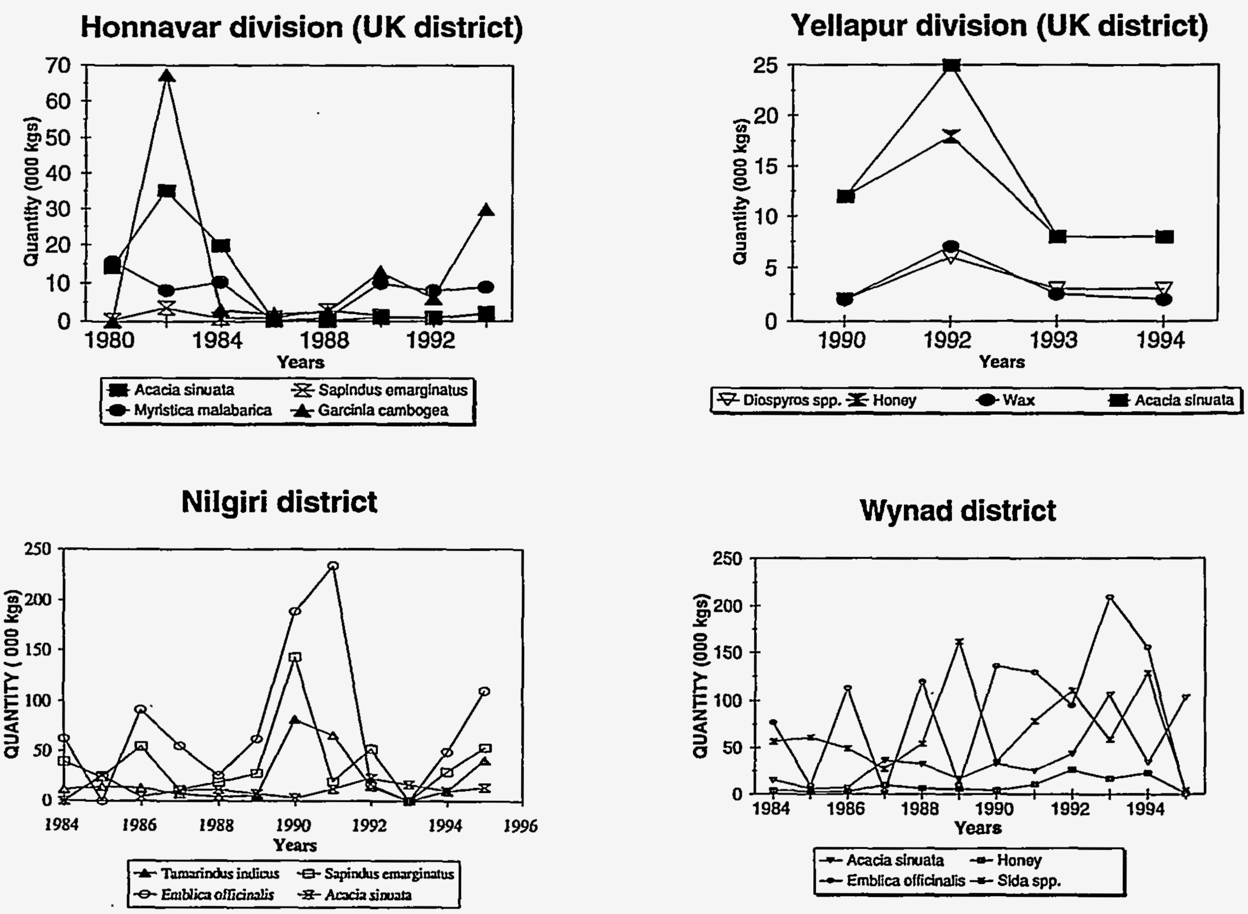


Figure 6.2. Trends in extraction of major NTFPs by forest department over the years.

6.3 Total quantity of NTFPs gathered

In the earlier sections, the quantity and value of NTFPs extracted was assessed at the household level. In this section an attempt is made to estimate the quantity and value of NTFPs extracted per hectare for various forest zones. The per household values obtained from the sample household survey are projected to the rural population in each forest zone considering the total number of rural households. Further, the total quantity and financial values estimated for each forest zone are divided by total area under the forest type to obtain per hectare values. The limitations of extrapolation from sample survey to the whole forest zone have to be kept in mind when drawing inferences from the findings. The main purpose of obtaining forest zone level aggregate estimates of quantities and financial values is to assess the current aggregate value of forest products extracted and in turn the dependence of communities on forests. Further, these baseline (1995) aggregate values will be used in comparisons with the aggregate flow of forest products under climate impacted scenario (for the year 2050). Here the NTFPs gathered by the households as well as the Forest Department are combined to obtain the total quantity and financial value of forest products extracted per hectare in different forest types.

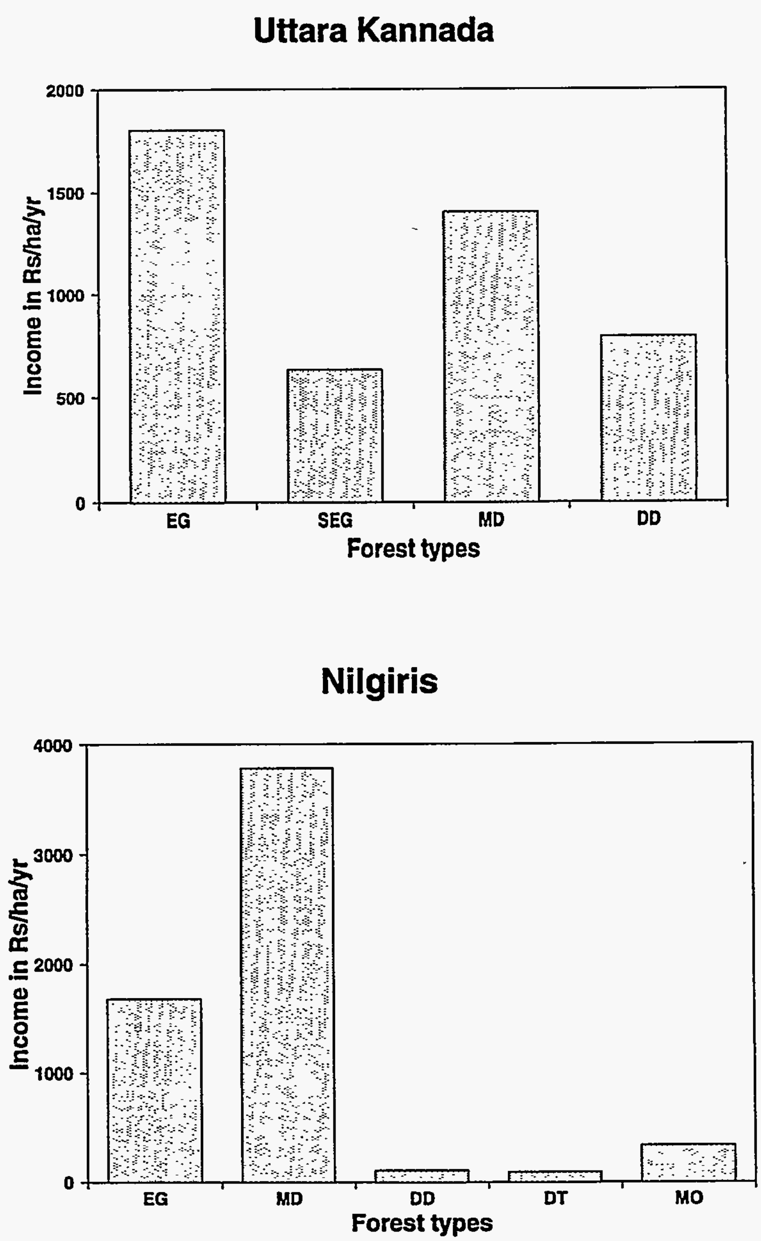
Uttara Kannada: In Uttara Kannada the NTFPs gathered have three broad destinations;

- partly used by the households
- partly sold to forest department designated contractor
- partly sold to other traders directly as raw material or as finished products.

Further, some of the NTFPs are leased out to contractors for a fixed price in some forest divisions. The forest department contractors also engage contract labour for gathering NTFPs and these collections are not covered in the household survey. Further, it is well known that the contractors get lease over NTFPs at very low rates. Thus to account for the total quantity and value of the NTFPs extracted in each forest division, the quantities of NTFPs gathered estimated from the household survey is added to the quantities reported by the forest department. This way there is marginal or no double counting. The quantity and values of NTFPs gathered by the households are converted to quantities per 1 000 ha and added to the Forest Department recorded values for each forest type, which are also converted to an area basis. The physical quantities obtained per 1 000 ha are converted to financial values using 1996 market prices.

The monetary values of forest products which are quantified and monetised per hectare in different forest types are given in Fig 6.3 (The productwise details are given in Appendix 6.2 for Uttara Kannada and 6.3b for Nilgiris). The value of NTFPs obtained is highest for the evergreen zone at Rs. 1801/ha, followed by the moist deciduous zone at Rs. 1404/ha, and a low value of Rs. 634/ha for semi evergreen zone. The total area under forests according to a satellite assessment map which was digitised for the study is 592 605 ha excluding the fragmented mixed vegetation (157 753 ha). The total monetary values of all NTFPs gathered is Rs.685 million at Rs.1156/ha and Rs.1063/capita. This level of income generation from the forests is significant compared to the per capita income of Rs.6339 in Uttara Kannada district in 1991 (Pasha, 1996) and a daily wage rate of Rs.35-40/person day. It has to be noted again that the financial flow estimated does not include the value of fuelwood, timber and leaf manure extraction from the forest.

Nilgiris: In the Nilgiris, 43% of the area is under Wildlife Sanctuaries, where there is a strict regulation on NTFP gathering. Most of the products are either consumed by the gathering family or bartered, and some products are sold to the recognised outlets of the Forest Department as well as to outside traders for a higher price. Thus, to get an estimate of the value of NTFPs gathered for each forest type, the quantity and financial value of NTFPs gathered by the households are taken to estimate the overall quantity and financial value per 1 000 ha. The quantities of NTFPs procured by the recognised societies or outlets are not added to the household survey data as this may lead to double counting. The total value of NTFPs gathered is given in Fig 6.3 and details of the products are given in Appendix 6.3b. The overall value of NTFPs gathered is Rs. 3780/ha in the moist deciduous zone, followed by Rs. 1681/ha in the evergreen zone and lower values for the dry deciduous, dry thorn and montane forest zones.



EG - Evergreen, SEG - Semi Evergreen, MD - Moist Deciduous, DD - Dry Deciduous, DT - Dry Thorn, Mo - Montane.

Figure 6.3. Financial value of NTFPs gathered/ha/yr in different forest types (in Rs).

6.4 Quantity and value of timber and fuelwood extracted in Uttara Kannada

In Uttara Kannada, there is a legal ban on logging green trees and thus only dead, fallen and over-mature trees are felled to supply timber and fuelwood. The quantities and financial value of legally extracted timber and fuelwood according to Forest Department records are given in Fig. 6.4. It should be noted that there could be some illegal removal of timber by households or traders which is not accounted for here. Fuelwood gathered by the households in the form of twigs and branches is not included either. Given the regulations and strict vigilance, large scale felling of trees for timber or fuelwood is unlikely in the 1990s.

The quantity of timber extracted is around 0.4 m^3/ha/yr (during 1994/1995), which is equivalent to felling about two medium sized trees/ha/yr in the district. The financial value of timber extracted is Rs.2814/ha of forest area in Uttara Kannada.

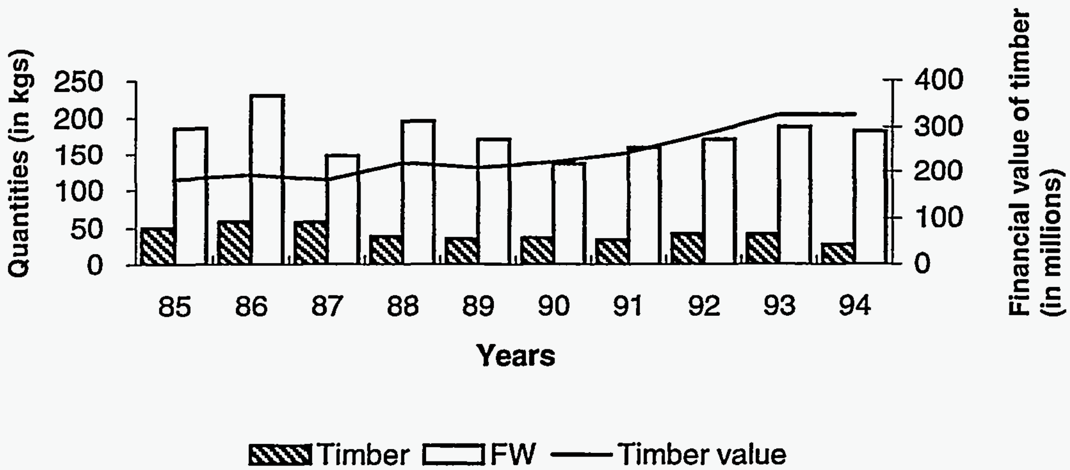


Figure 6.4. Quantity (in 1000t/yr) and financial value (in Rs/yr) of timber extracted by the forest department.

6.5 Comparison of contribution of timber and NTFPs in Uttara Kannada

Forests have traditionally been managed for timber in India. The contribution of NTFPs is generally under-estimated and not fully recognised. Thus, it is useful to compare the financial value of extraction of timber with NTFPs. The correct method would be to compare the present value of potential sustainable financial flows from timber and NTFPs over a period of time. Due to limitations of data, what is attempted here is to compare the financial value of NTFP flows for one year with the financial value of timber extracted during the year.

Data compiled for Uttara Kannada show that the annual value of timber extracted was Rs. 327 million during 1994 (with a 10-year mean of Rs. 239 million) compared to Rs. 685 million from NTFPs (during 95-96). Thus, the contribution of NTFPs to the economy is double that of the financial value of timber extracted at current market rates. Further, it is important to note that part of the timber extracted by the state forest department is also exported out of the district. The benefits from

NTFPs flow directly to the local households either as products for family consumption or for sale as a source of income.

6.6 Social and gender aspects of dependence on forests

It is generally thought that indigenous communities depend on forests more than agricultural communities. Even among the agricultural communities it is possible to hypothesise that the landless or the poorer households are likely to depend more on the forests than the landed and richer. The percentage of households gathering different NTFPs according to socio-economic status is given in Table 6.3a (for Uttara Kannada) and 6.3b (Nilgiris).

Uttara Kannada: The percentage of households gathering different products is generally lower among landless compared to land owning (mainly rice growing) and the richer garden (Areca) owning households, in the evergreen, semi evergreen and moist deciduous zones. When garden owning and other land owning households are compared, the percentage of households gathering forest products is lower among garden owning households. In the dry deciduous zone, where the annual precipitation is lower (<100 cms), the landless seem to depend more on forests. Thus, it is possible to conclude that in high and moderate rainfall regions with evergreen or moist deciduous forests, landless households depend less on forest products. The landless migrate to other regions during the summer season and during the peak crop season they derive higher wage earnings per person day as agricultural labor compared to earnings from dedicating their time to gathering forest products. The affluent garden owners depend less on forests as they derive income from plantation crops.

Nilgiris: The percentage of households gathering NTFPs is the same for landless and small farmers. The other household category (which includes those in service and large farming households), whose income levels are higher, depend less on NTFPs.

In highly developed agricultural communities such as in Uttara Kannada, the landless or poor seem to depend less directly on NTFPs as their opportunity cost of labour for agricultural operations is high. In less agriculturally developed regions such as dry deciduous zone of Uttara Kannada and the forest regions of Nilgiris, the dependence of indigenous communities and landless on forest is higher.

Gender aspect of NTFPs extraction: Women contribute about one-third to a half of the human effort for gathering forest products in all the forest zones (Table 6.2a and 6.2b). It is important to note that the contribution of adult men and children is nearly the same or higher than that of women for gathering many products such as Bamboo, *Garcinia* fruits, *Acaica sinuata* and *Artocarpus lakoocha.* Women do not gather some products such as honey, *Emblica officinalis* and Mango which involve climbing trees. Thus it is concluded that men as well as women are equally involved in gathering forest products, whereas the general assumption is that women alone extract NTFPs. In both the regions, men as well as women contribute nearly equally to the gathering of NTFPs in terms of human effort.

6.7 Employment generation potential of NTFP gathering

Uttara Kannada: The employment generation potential of NTFP gathering is given Table 6.3a. Human labour hours dedicated to gathering NTFPs are estimated for the population from the sample data. If two or more products are gathered in a trip, the human hours are assigned to the major product gathered. Different products dominate in different forest zones for example: *Calamus sp.* in evergreen (384 hours/HH/yr), *G. cambogea* in semi evergreen (466 hours/HH/yr), wild mangoes in moist deciduous (350 hours/HH/yr) and honey in dry deciduous (220 hours/HH/yr) forest zones. The total employment potential is high, in the range of 198 days/HH/yr in evergreen to 148 days/HH/yr in dry deciduous zones assuming a gathering day of 6 hours/day. Thus even when human labour used for gathering firewood, poles, green and dry leaves (for manure) and grass (for livestock) is excluded, a typical household spends about 148 to 198 days /yr on gathering NTFPs.

Table 6.3a. Social aspects, employment generation, and contribution of women labour in NTFP gathering in Uttara Kannada district.

NTFPs	% of HH gathering			No of trips[1]/HH/Yr considering total population	Total human hours/HH/Yr for NTFP gathering considering total population	% contribution of women hours for gathering
	LL	LO	GO			
EVERGREEN ZONE						
Artocarpus lakoocha	25	88	50	44	110	38
Bambusa arundinacea	0	81	61	76	304	53
Calamus rotundus	50	64	40	128	384	52
Garcinia indica	25	79	62	52	156	37
Garcinia cambogea	0	11	7	32	128	15
Others [5]	23	35	22	67	109	56
TOTAL				**399**	**1191**	
SEMI EVERGREEN ZONE						
Artocarpus lakoocha	32	0	56	45	135	44
Acacia sinuata	4	0	21	48	168	18
Garcinia indica	27	0	43	35	105	44
Garcinia cambogea	47	0	76	133	466	44
Sapindus emarginatus	0	0	50	26	78	34
Others [3]	34	0	53	47	123	47
TOTAL				**334**	**1075**	
MOIST DECIDUOUS ZONE						
Artocarpus lakoocha	57	0	69	30	90	33
Acacia sinuata	100	100	55	25	75	29
Bambusa arundinacea	0	50	20	36	108	29
Mangifera indica	4	0	17	10	350	0
Ochlandra sp.	14	0	3	64	248	64
Others [8]	22	27	46	59	48	20

TOTAL				**224**	**919**	
DRY DECIDUOUS ZONE						
Bambusa arundinacea	14	15	0	44	110	60
Honey	46	26	0	44	220	0
Emblica officinalis	2	27	0	18	36	0
Others [2]	3	12	19	20	35	17
TOTAL				**224**	**891**	
Anogeissus latifolia	88	50	0	98	490	27

LL - landless ; LO - land owner ; GO - garden owner (Arecanut)
- [1] no of trips is actually no of person trips made ; if 3 persons go together for gathering a product on a day , it is considered as 3 trips
- [ ] indicates the no of species included in 'others' category.

Nilgiris (Table 6.3b): The NTFPs that dominate the human labour employment are: honey (288 hours/hh/yr) and *Emblica Officinalis* (244 hours/hh/yr) in evergreen and moist deciduous forest zones respectively. Human employment generated is high in moist deciduous as well as evergreen zones at 227 and 195 human days employed per HH/yr, respectively. The number of human days spent in gathering in other zones is lower than the moist deciduous and evergreen zones.

Considering both the locations it is possible to conclude that employment of over 150 person days per household is generated in the majority of forest zones in gathering forest products both for family consumption and for sale as raw material or as processed product.

Table 6.3b: Social aspects, employment generation, and contribution of women labour in NTFP gathering in Nilgiris.

NTFPs	% of HH gathering			No of trips[1]/HH/yr considering total population	Total human hours/HH/yr for NTFP gathering considering total population	% contribution of women hours for gathering
	LL	SF	OT			
EVERGREEN ZONE						
Emblica officinalis	92	90	50	31	122	33
Acacia sinuata	91	90	50	27	111	33
Bambusa arundinacea(nos)	52	50	100	18	15	50
Curcuma aromatica	22	10		26	104	50
Honey	40	42	50	12	288	
Others				234	529	{1169} [304]
MOIST DECIDUOUS ZONE						
Emblica officinalis	96	97	80	48	244	33
Acacia sinuata	72	71	80	24	98	33
Bambusa arundinacea(nos)	93	92	80	3	18	50
Honey	53	37	40	12	288	
Solanum indicum	66	35	40	17	67	50
Others				260	647	{1362} [364]
DRY DECIDUOUS ZONE						
Emblica officinalis	58	40	33	17	16	50
Honey	40			12	240	
Curcuma aromatica	22	0	15	9	14	50
Phoenix sylvestris	8.7		6.7	22	16	50
Others				36	187	{573} [96]
DRY THORN ZONE						
Mangifera indica	44		15	12	45	33
Honey	61	22	12	12	240	0

Emblica officinalis	42	27	15	10	38	50
Phoenix sylvestris	28	5	31	22	88	50
Others				67	261	{672} [123]
MONTANE ZONE						
Bambusa arundinacea		18		3	18	50
Honey		18		9	126	
Honey wax		18		9	126	
Total				[21]	{270}	

LL:Landless labourers; SF: Small Farmers ; OT: Others
[ ] Indicates the total number of trips/HH/yr considering total population
{ } Indicates the total number of human hours /HH/yr considering total population.

6.8 Dependence of industries on forests.

Forests provide raw materials to several industries. Forest based industries can be grouped depending on; type of forest raw material (fuelwood and non-fuelwood), type of organisation (organised and unorganised) or scale of the industry (household, small scale and large scale). The fuelwood and softwood based industries are not species specific.

Uttara Kannada (Table 6.4a);

Fuelwood based industries: In the district there are a large number of fuelwood using industries namely; tile manufacturers (17), cashew processing (32), bakeries (54), lime making (33), desiccated coconut industries (3) and many brick kilns. All these industries together consume annually 42 169 t of fuelwood, which is equivalent to 71 kg of fuelwood extraction per hectare of forest area.

Non-fuelwood industries: The list of industries, raw materials used, dependence on the forests in the district for raw material and quantity used is given in Table 6.4a. In majority of cases raw material comes wholly from within the district. Some of the industries such as wooden furniture, handicrafts and cane furniture are highly labour intensive.

It is interesting to note that the paper mill and the veneer industry do not obtain raw material from the district. Further, the plywood industry has been shut down since 1988. The implications of these observations are discussed in Chapter 8.

Table 6.4a. Dependence of industries on forests in Uttara Kannada district.

Type of industry	No of units	Raw material used	No of persons employed/unit		Typical no of days operated/Yr	% dependence on district for raw material
			Men	Women		
Large industries (timber)						
Paper & pulp	1	RW logs	3688	112	300	0
Plywood industry	1	RW logs	580	0	not operating since 1988	Raw material supply stopped
Veneers	1	Rose wood	223	2	300	3
Saw mills	41		7	0	290	98
Fuelwood using industries						
Cashew processing	32	FW, cashew	4	49	250	100
Tile factory	17	FW	80	60	300	100
Bakery	54	FW	4	0	260	100
Lime industry	33	FW	4	2	190	100
Burnt bricks	21	FW	3	4	120	100
Dry Coconut processing	3(2)	FW, Coconut	30	30	288	100
Other raw material						
Cane furniture	21(3)	Canes	3	0	185	100
Wooden handicrafts	29(3)	SW			166	100
Wooden furniture	124(10)	Sawnwood, HW logs	4	0	272	100
Pickle industry	7(1)	Mango, *Carissa carandas*	3	12	300	100
Ayurvedic medicine	6(2)	biomass				100

RW - round wood ; SW - sandalwood ; FW - fuelwood ; HW - hardwood

Nilgiris (Table 6.4b):

Due to the severe restrictions on the extraction of NTFPs as well as fuelwood in the Nilgiri hill region, there are not many forest product based industries. The major industries are tea drying (57 units using fuelwood for drying), Eucalyptus oil extraction (12 units using Eucalyptus leaves), the tanning industry (using wattle bark extract) and the Citronella oil industry (8 units).

However, in both the districts thousands of households are involved in household scale activities such as weaving mats, storage bins and baskets using bamboo, brooms using grass reeds, leaf plates using *Butea monosperma* etc. and are not covered in the survey. The products of these units are for home consumption or for sale in the local market. Every household requires several articles made from plant products, such as baskets, brooms, mats, leaf plates, storage bins and sickles. Thus, taking the recorded organised and the unorganised industry as well as unrecorded household level industries, the employment and income generation potential of forest products could be very large in both the regions.

Table 6.4b. Dependence of industries on forests in Nilgiri district.

Type of Industry	No of Units	Raw material used	Product	Quantity (in Kgs)	Rs/Kg	Value (in '000 Rs)
Eucalyptus oil	12	Eucalyptus leaf	Eucalyptus oil	42 421	200	9 117
Geranium oil	8	Geranium sp.	Geranium oil	23 318	12 000	34 977
Citronella oil	8	Cymbopogon	Citronella oil	34 821	2 200	9 575
Tea boxes	8	Forest wood	Tea boxes(no)	22 650	25	566.0
Tea	57	Tea leaves	Tea	63362 000	50	3168 100

6.9 Summary

In this chapter, the current dependence of communities on forests is assessed. The field studies in Uttara Kannada and Nilgiris showed that 50 to 75% of households in both the regions gather a large variety of products; the employment generated in gathering NTFPs ranged from 150 to 200 person days/year, the financial value of NTFPs gathered for subsistence consumption and for commercial purposes is significant compared to daily wage earnings, households belonging to all socio-economic groups depended on forests and the dependence of poorer households on forests is higher in low rainfall regions compared to land owning and affluent households. Both men and women contributed almost equal human effort to gathering NTFPs. The financial value of NTFPs gathered in the district is double that of timber extracted in a year, indicating the importance of diversity of plant products to the local economy. Given the large dependence of communities and economy on forests, it is necessary to assess the potential impacts of climate change on forest vegetation and forest product flows.

7. IMPACTS OF CLIMATE CHANGE ON FLOW OF FOREST PRODUCTS AND INCOMES

The impacts of projected climate change on the forests of the Western Ghats region, particularly the shifts in forest boundaries leading to changes in area under different forest zones, were presented in Chapter 5. In this Chapter, an attempt is made to assess the impact of climate change on the flow of forest products, income and employment. The method adopted is as follows;

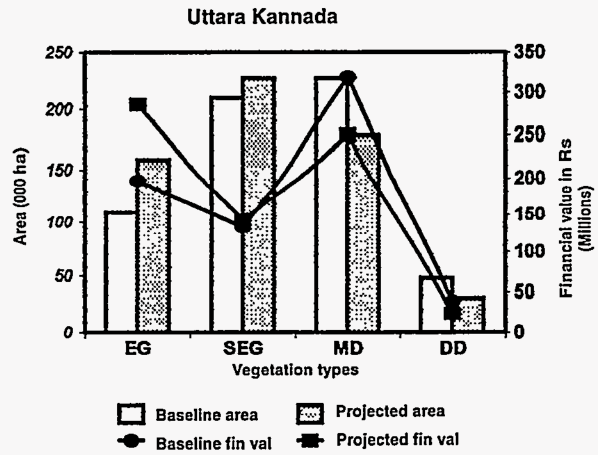
1. calculate the baseline area, quantities of NTFPs extracted and their financial values,
2. estimate baseline financial values of NTFPs for the total area under each forest zone,
3. estimate the altered area under different forest zones under the climate impacted scenario (for the year 2050),
4. estimate the quantity of NTFPs potentially available and the financial value for each forest zone, for the altered forest area under the climate impacted scenario,
5. compare the financial value of NTFPs for the baseline scenario and for the climate impacted scenario for the year 2050, on a per hectare basis and for the total area in each forest zone.

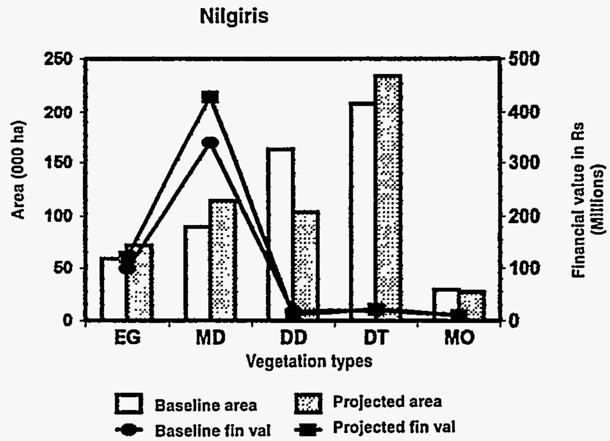
The model used in this report is an equilibrium model as is the case with BIOME and IMAGE models (Solomon *et al.,* 1996, Chapter 5). The assumption used for assessing the future flows of forest products under a climate impacted scenario is that the climatic limits to forest growth implied by the current geographic distribution will operate in the future, say in the projected year 2020 or 2050. If the model output shows that the moist deciduous forest zone expands into the current dry deciduous zone due to enhanced precipitation, the vegetation of moist deciduous forests is expected to replace the vegetation of the dry deciduous forests. This is a limitation of all the current models as firstly, the climate or environmental equilibrium is less likely and secondly, vegetation responses to changing climate could be uncertain given the increased atmospheric CO_2 (Solomon *et al.,* 1996). Thus the projected changes in product flows and the socio-economic impacts should only be taken as likely indicators of direction of change. No significant value should be attached to the magnitudes of change.

For assessing the impact of climate change the moderate climate sensitivity and central scaling factor' scenario (referred to as 'the moderate scenario' hence forth) is considered as the 'most likely scenario' and the impacts on forest product and income flows are assessed for this scenario.

7.1 Impacts on forest product flows and financial values

Uttara Kannada: In Uttara Kannada, with the likely projected increase in area under evergreen (by 45%), and semi evergreen (by 8%) forests and a corresponding decline in area under moist deciduous and dry deciduous forests, the aggregate quantity of potentially extractable NTFPs available from evergreen and semi evergreen forests areas is likely to increase. For the district as a whole, considering all forest types, the financial value of potentially extractable NTFPs is likely to increase marginally as the area under the high income yielding evergreen forest zone is projected to increase and the low income yielding dry deciduous forest zone is projected to decline (Fig 7.1 and Appendix 6.3a).





EG - Evergreen, SEG - Semi Evergreen, MD - Moist Deciduous, DD - Dry Deciduous, DT - Dry Thorn, Mo - Montane.

Figure 7.1. Area under different forest types and total financial value of NTFPs under "Baseline Scenario" and under "Moderate Scenario" for the year 2050.

Nilgiris: The aggregate quantity of potentially extractable NTFPs is likely to increase in the evergreen and moist deciduous zones, as the area under these forests is expected to expand by 22% and 27% respectively under the climate impacted moderate scenario (Table 5.2a and Appendix 6.3b). Similarly the aggregate flows are likely to decline for dry deciduous, dry thorn and montane forest areas. The flows of incomes from NTFPs per hectare are expected to be at the same rate as shown in Fig 6.5. What is significant is that the income flows are likely to increase from Rs.483 million to Rs.591 million largely due to an increase in the area of high income yielding evergreen and moist deciduous forests. The overall income flow per hectare in the region is likely to increase by about 22%.

The main conclusion could be that under the 'moderate scenario' with a projected warming of 0.6 to 0.7°C coupled with an increase in precipitation by 4 to 7% the current levels of income flows from NTFPs are not likely to decline. Indeed, the overall income flow may marginally increase by the year 2050 in both these regions of the Western Ghats.

7.2 Social implications of changing climate

In Uttara Kannada over 50% of households; and in the Nilgiris over 75% of households, gathered multiple products from forests (Section 6.6). If the projected climate change impacts are realised, the resulting increase in the availability of NTFPs of the type currently gathered in evergreen, semi evergreen and moist deciduous areas, is likely to lead to potentially higher employment levels for all the socio-economic groups as well as for women.

Some of the plant species (and NTFPs) occur in all the forest types (such as *E. officinalis, A. sinuata*) but others (such as *G. indica and G. Cambogea*) occur mainly in evergreen and semi evergreen forest types. The communities adapted to gathering a given set of NTFPs (such as those available in dry deciduous and moist deciduous forest areas) may have to shift to gathering and using new NTFPs from migrated species from evergreen or semi evergreen forests.

The indigenous communities of moist deciduous forests in Nilgiris collect tubers and other forest products as a source of nutrition. But if these tubers become available in the current dry deciduous forest zone [as dry deciduous vegetation is likely to be replaced by moist deciduous forest vegetation], the settled agricultural communities may not gather these tubers as a source of nutrition. Thus it may not be possible to conclude that shifts in forest boundaries, leading to availability of new NTFPs to rural or indigenous communities, will necessarily lead to increased extraction and use of all forest products, particularly those used domestically (such as food) due to cultural practices and economic status. However, NTFPs which have commercial value such as *Acacia sinuata, S. emarginatus* and honey are likely to be collected by households belonging to all forest zones. Thus any climate change induced enhanced availability of such commercially valuable products brought about by climate change will lead to increased gathering and employment generation.

What is uncertain and thus of concern is the potential transient response of vegetation to changing climate until an equilibrium climate situation is reached. For example there could be large scale dieback of standing trees or increased incidence of pests and fire. This could have adverse impacts on the availability of forest products. The projected impacts of climate change are unlikely to have any gender specific implications. The impacts of increased or decreased availability of NTFPs due to projected climate change are likely to be same for men and women.

7.3 Impact on fuelwood and timber production:

The forests of the Western Ghats region may come under increased pressure for meeting the roundwood (fuelwood and timber) demands due to population growth. The potential impact on roundwood production is uncertain. On the one hand the forest growth may decline and mortality may increase from increasingly inappropriate climate (Solomon and Leemans, 1990). The opposite impact on annual growth increment is also possible. The annual woody biomass growth may increase in different forest types with increased rainfall as projected in the moderate scenario for both the Nilgiris and Uttara Kannada. Higher growth rates may also occur due to the fertilization effect of increasing atmospheric CO_2 and increased water use efficiency (Kirschbaum *et al.,* 1996b). In balance the annual growth rates are unlikely to decline and infact may potentially increase in the Western Ghats region with projected warming along with increased precipitation and higher atmospheric CO_2 concentration.

7.4 Summary

The impact of climate change on forest product flows was assessed by using the "moderate climate sensitivity and central scaling factor" scenario. The area under high NTFP and income yielding evergreen and moist deciduous forest types is projected to expand, leading to an overall increases in the availability of NTFPs of the kind currently available in these zones. At the district or regional level, the overall financial value of potentially extractable NTFPs is likely to increase. This will lead to enhanced employment and income levels for indigenous and rural households. This conclusion is based on the assumption of an equilibrium response of vegetation. What is uncertain is the transient response of vegetation until an equilibrium stage is reached; this could lead to forest dieback and a loss of vegetation. Fuelwood and timber production might not decline, but in fact might increase due to increased productivity from CO_2 fertilisation and increased precipitation.

8. FOREST LAND USE CHANGES IN WESTERN GHATS; EXTENT AND CAUSES

We have seen that climate change is predicted to lead to shifts in forest boundaries. We also need to assess how various non-climate driving forces could also alter these boundaries. For example, in the Western Ghats, climate change might lead to an expansion of total forest area - but only if the land required for this expansion is available. We therefore need to examine the sustainability of the current areas under forests and anthropogenic barriers to potential or projected shifts in forest boundaries. Information about past and current rates of conversion of forest land to non-forest purposes, and the contributing factors, is a necessary first step in this process, since it establishes the role of non-climate factors in determining the forest land use.

In India, forest land use has been influenced by state policies ever since the forests were taken over by the British in 1865. Currently, forest land use, particularly forest conversion of the reserve forests which account for over 65% of forest land, is covered under various acts and legislations of National Governments.

State legislature has no role in framing such policies. Consequently, it is very important to consider forest land use changes at the national level before assessing changes within the Western Ghats region.

i) Forest policies apply uniformly to all regions including the Western Ghats region. National trends in forest land use are likely to reflect the changes at the regional level.

ii) Data on forest land use change are published largely at state and national level rather than at forest type or regional level, particularly the post-1980 satellite imagery assessments (FSI 1988, to FSI 1995).

iii) According to a national level assessment (Forest Commission, 1991) diversion of forest land to agriculture was the dominant cause for deforestation (accounting for 62%, during the period 1952 to 1980). Food grains are transported and marketed across India and the National government often determines the price of food grains. Thus, the national trends in area under food grains and food production are important for understanding forest land conversion to food production even at the regional level.

8.1 Forest land use changes in India

India is a densely populated country with a population of 854 million (1991) for a geographic area of 328 Mha. The area under forest and the deforestation rate have always been subject of intense debate and controversy. India launched a systematic periodic assessment of forest area using satellite imagery starting with the 1980-83 assessment. In this section, the analysis of forest land use changes is focused on the post-1980 period for two reasons; firstly, the Forest Conservation Act was passed in 1980 regulating conversion of forest land and, secondly, systematic periodic satellite assessments were initiated in 1980.

The area under forests in India according to the latest satellite assessment is 63.96 Mha (FSI 1995). When the pre-1980 period is considered, according to an Indian government estimate, about 4.3 Mha of forest area were officially diverted to non-forest uses during 1951-80 (FSI, 1988). In reality more forest land may have been diverted to non-forest uses. According to a study of the Government of India (Forest Commission 1991) forest land was diverted to the following purposes: 62% for agriculture; 12% for river valley projects, 4% for industrial purposes, and 22% for other purposes. Thus, the demand for land for agriculture seems to have been the dominant cause of loss of forest area during the period 1950-80. During the 1950s and 60s the priority of the Indian government was to increase food production and to provide land for the landless people.

It is important to observe the recent changes in forest area, particularly for the post-1980 period. Using the five satellite assessments covering the period from 1980-83 to 1991-93, changes in total area under forests in India is given in Fig 8.1. The total area under forests seems to have stabilised at around 64 Mha during this period and, further the area under dense forest (>40% tree crown cover) has shown a marginal increase during the period 1982-92. The factors contributing to the stabilisation of area under forests in India are discussed in a later section.

Stabilisation of forest area is further supported by Fig. 8.1 which shows that in spite of an annual population growth of over 2% the area under food production has stabilised since 1970 at around 110 Mha, whereas food production increased from 110 to 180 Mt during the period (Ravindranath and Hall, 1995). A similar trend is observed in Karnataka state (population 45 million) where the Uttara Kannada district is situated. The area under crops was 10 Mha during 1965/66 and 10.6 Mha during 1988/89 (Ravindranath and Hall 1995). The inference from these observations is that large scale conversion of forest land to agriculture (particularly, food production) has not occurred during the past two decades in the country.

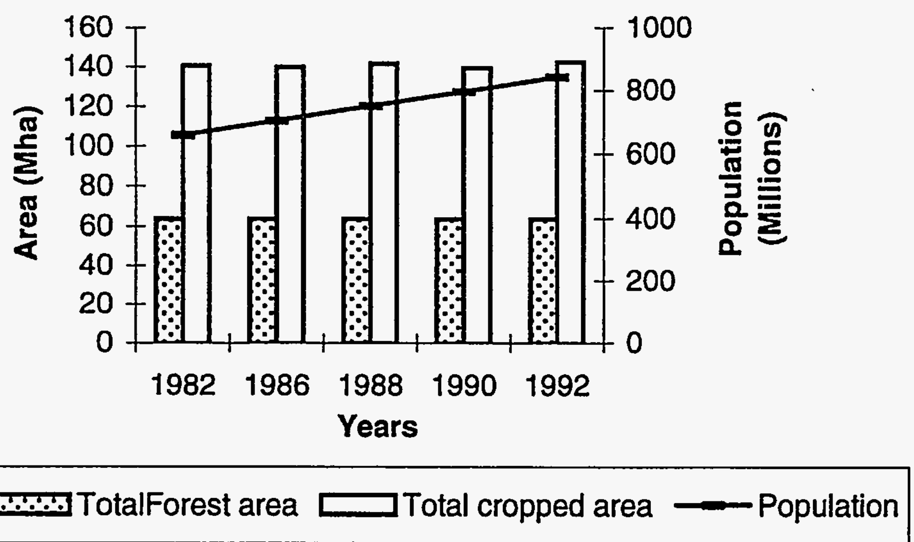


Figure 8.1. Changes in population, area under forest and total cropped area in India.

8.1.1 Forest land use changes in Uttara Kannada

The total area designated officially as forest in the district is 829 215 ha, of which 75% is under Reserve Forest category which is fully under the control of the state Forest Department. Uttara Kannada has experienced large changes in area under forest as well as vegetation. There are many accounts of these historical changes for the pre-British, British and post-independence periods (Gadgil and Guha, 1995, Subhashchandran, 1994, Gadgil and Subhashchandran, 1989). According to Gadgil and Subhashchandran (1989) the forests of Uttara Kannada have declined in extent and have lost valuable timber, bamboo and NTFP trees. Plantations have significantly replaced the forests and degraded forest areas. For example, the area under teak increased from 24 388 ha during 1960-61 to 53 354 ha during 1985-86. The post-independence period witnessed a large drive to industrialise the district and several industries requiring timber and bamboo were set up here.

Forest land conversion: Data on diversion of forest lands to various purposes are normally maintained by the Forest Department. Data available for the 25 year period 1957 to 1993 show that 78 000 ha have been diverted to non-forest uses (details are given in Table 8.1). Thus, annually about one-fourth of a per cent of forest area has been converted to non-forest purposes in the past 36 years. This includes the period prior to the Forest Conservation Act of 1980. Detailed yearly conversion is not published. The major purposes for which forest land was converted during the period 1957-93 (Table 8.1) was infrastructure (53%), agriculture (38%) and housing (8%).

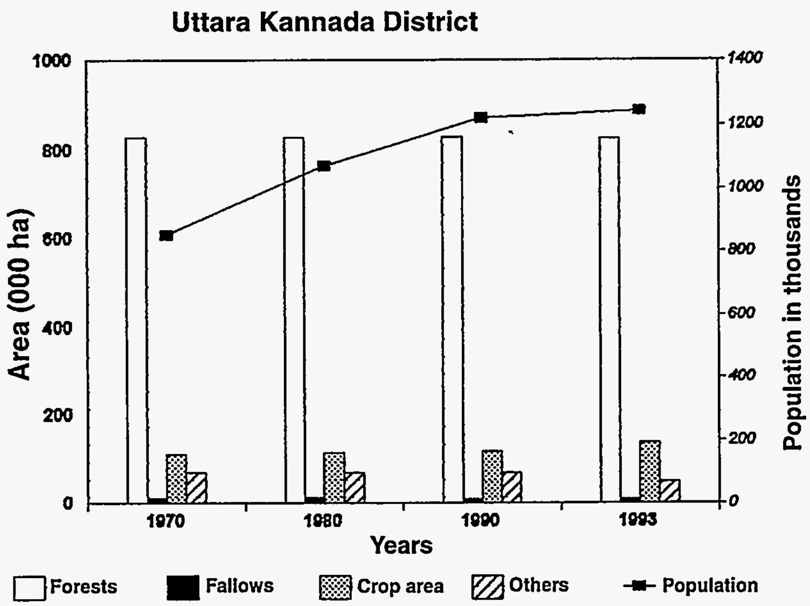
Forest conversion to infrastructure: A key feature of conversion to infrastructure is that it is highly regulated and the majority of projects are related to the natural resources of the district. In the post-1990 period, a nuclear power plant, a naval base and a railway line were the major projects for which forest land was released. All these projects account for only 3 906 ha (0.63% of reserve forest area). Conversion of forest land to infrastructure projects is being closely monitored by local environmental groups as well as communities.

Table 8.1. Diversion of forest land during 1957-93 in Uttara Kannada.

Forest area released for	Area (in ha)	% of area diverted	% of total forest area
Cultivation	21 483	27.5	2.59
Mining and industrial purpose	21 449	27.5	2.59
Hydroelectric project	16 383	21.0	1.98
Rehabilitation project	4 548	5.8	0.55
Temporary lease for Cultivation	8 034	10.3	0.97
Housing and township	1 853	2.4	0.22
Project sea bird (naval Base)	2 902	3.7	0.35
Kaiga project (nuclear)	732	0.9	0.09
Konkan project (railway)	272	0.3	0.03
Other purposes	444	0.6	0.051
Total	**78 100**	**100**	**9.41**

Agriculture: During the period 1957-93, about 29 517 ha have been converted to agriculture. It is not clear if most of this conversion happened during pre-1980. Given that the Forest Conservation Act was passed in 1980, it is likely that most of the conversion reported was in the pre-1980 period. This conjecture is supported by the fact that the net cropped area (including plantations) in Uttara Kannada increased by only 1 976 ha (by 1.7%) during the period 1981/82 to 1993/94 (Fig. 8.2)

According to FSI (1995), the area under forests is 781 221 ha (76% of the geographic area). The area under the dominant forests types based on satellite imagery used in Chapter 4 of this report shows that 592 605 ha are under contiguous forests and the remaining forest area is dispersed as a large number of small fragments of degraded forests (which could not be easily digitised from maps based on satellite imagery).



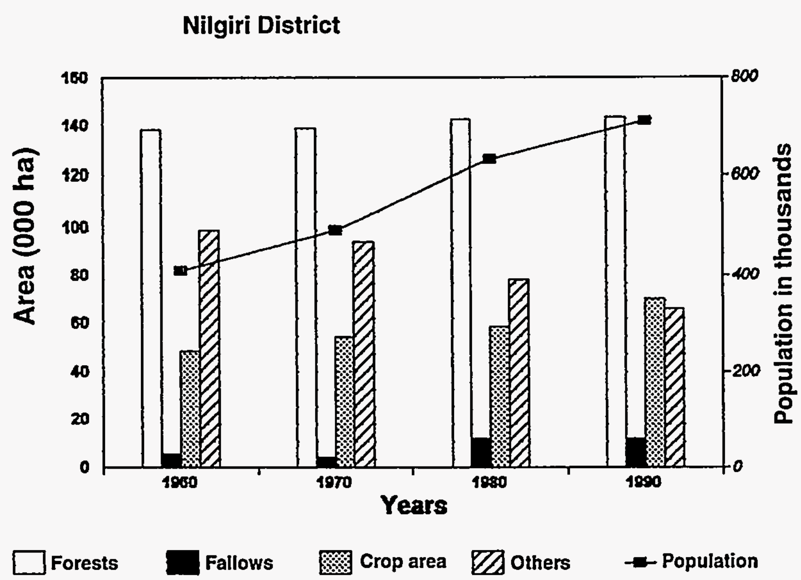


Figure 8.2. Landuse pattern and population growth in the Western Ghats region. (Crop area includes annual and plantation crops.)

8.1.2 Changes in forest area in Nilgiris

The total area under forests, according to the latest satellite assessment is 208 500 ha, accounting for 82% of the geographic area of the district (FSI 1995). The area under forests in the district seems to have remained unchanged over the last few decades, particularly since 1980. Although there are no clear records, field observations in the past 10 to 15 years in the district show no major conversion of forest land to non-forest purposes such as for projects or resettlement. Further, nearly 15.4% of the forest area in Nilgiris is covered under the Mudumalai Wildlife Sanctuary, where regulations do not permit any conversion of forest land. In Nilgiri only 3.85% of the geographic area was under annual crops during 1992/93 (Table 4.1) compared to 44% nationally. Thus, forest land conversion to food production is not an issue at all in the district. However, the area under plantation crops (dominated by tea) accounts for 20% of the geographic area (Table 4.1). It is not clear what percentage of the forest area was converted to tea gardens and when, as tea gardens in the district have a long history. There are no recorded data to show the extent of conversion of forest area to tea gardens in the post 1980 period. However due to several regulations (including the Forest Conservation Act 1980), it is unlikely that reserve forests and wildlife sanctuary land would now be converted to tea gardens.

8.2 Future demands on forest land

The population in India including the Western Ghats region is growing at a little over 2%. Most recent models including IMAGE-2 (Alcamo, 1994), assume and project that with population growth, the area under food production will increase to feed the growing population. Further, the land required for food production is assumed to come from the clearing of forests.

Thus, the demand for food grains (in turn, the area under food grains), demand for biomass (round wood), land for infrastructure (settlement, industry, river valley projects) and livestock grazing is likely to grow, leading to increased pressure on forest land and biomass.

i) *Land for food production:* The area under food production in Uttara Kannada (only 9.3% of the geographic area) did not increase during the 17 year period between 1976/77 to 1993/94 and only 3.8% of the geographic area is under crops in Nilgiri district. Given that the trade in food grains is open, it is not necessary to grow all the food grains requirement of the district from within the district or region. Based on the observation that during the 30 year period of 1960-90, the population of India doubled, but the area under crops increased by only 10%, a recent study concluded that the future demands could be met by increasing the current low crop productivity, without expanding the cropped area (Ravindranath and Hall, 1995). Further, given the Forest Conservation Act and Wildlife Acts, large scale conversion of the dominant reserve forest land or wild life sanctuaries in the Uttara Kannada and Nilgiri region is unlikely. However, small dispersed encroachments into forests by farmers in the fringes of forests may continue to occur. Thus, it is possible to conclude that the area under crops at national level, at Karnataka state level, and even at Uttara Kannada district level seems generally to have stabilised in the recent past even in the face of the growing population. Further, these areas are unlikely to increase in the future significantly.

ii) *Demand for fuelwood and timber:* The demand for fuelwood and timber (industrial wood and sawn wood) is likely to grow from within the districts as well as other areas. Currently there are no data to suggest that any significant forest clearing is taking place in Uttara Kannada or Nilgiri in reserve forests or Wildlife Sanctuary to meet fuelwood and timber demand. In Uttara Kannada in the past 10 years, 77 923 ha of forest plantation has been raised which include both fuelwood and timber plantations. Currently, about 7 000 ha are brought under plantation each year. Thus, the reforested land could contribute to meeting future demands. Given the strict regulations (Forest Conservation Act and ban on logging) and close monitoring by local and national NGOs and even by local communities, any large scale clearing of forests to meet fuelwood or timber demand in Western Ghats region is unlikely. Due to regulations on extraction of timber, it was shown in Section 6.8 that in Uttara Kannada the paper mill and veneer industry do not obtain timber from the forests in the district and, further, the plywood industry has been closed down since 1988 due to stoppage of timber supply from forests. However, extraction of fuelwood and timber by local communities and contractors is likely to continue without causing any large scale deforestation although some forest degradation may occur.

iii) *Demand for forest land for infrastructure projects:* Pressure on forest land is likely to continue for infrastructure projects in the region. In the past 36 years, the rate of conversion of forest land for infrastructure projects (excluding housing) has been about 1 160 ha annually. It is difficult to project the future demand for forest land. It could be higher or even lower (given that the last major river valley project was approved around 1979 in Uttara Kannada and in 1966 in Nilgiri). Any new infrastructure project requiring any large scale loss of forests is likely to be highly contested, debated and fought in the parliament, courts and mass media (based on the experience of Silent Valley and Bedthi in Western Ghats, the Narmada river valley project in West and Central India and the Tehri dam in the North).

iv) *Livestock grazing land:* Uttara Kannada and Nilgiri are forest dominated districts, so the livestock population density is only 0.5/ha and 0.4/ha respectively , compared to 1.2/ha nationally. The livestock population density is even lower in forest dominant districts. In Nilgiri the livestock population is growing at a very low rate (Fig. 8.3). In Uttara Kannada the population shows a mixed trend. There is no evidence to show that livestock grazing leads to conversion of forest lands or deforestation. In India, livestock are maintained as part of the agricultural ecosystems where they derive their feed requirement from croplands. Forests are not going to be cleared for raising cattle as in other tropical countries such as Brazil. However the current as well as any new additions to livestock populations may contribute to increasing grazing pressure leading to suppression of forest regeneration and possibly forest degradation in the long term.

8.3 Conclusions on future land use changes

Based on the observations made in the earlier sections it may be possible to make a tentative conclusion that in the Western Ghats region large scale forest clearing and forest land use change are unlikely, despite contrary predictions for tropical countries in general (IPCC, 1992, Zudiema *et al.*, 1994). This conclusion could also be extended to the national level with some caution. Even though large scale deforestation has generally been controlled, forest degradation may continue due to growing anthropogenic pressures. The IPCC conclusion (Solomon *et al.*, 1996) that forest land use change will be a dominant factor in determining forest area and product supply may not be applicable to the Western Ghats region or even to countries such as India. Thus, climate change could be an important factor in determining forest area, diversity and production in the next century. Three of the critical factors that could potentially prevent large scale forest conversion are;

firstly, the need to increase agricultural productivity, which is already happening and with a large potential for further increases in food grain productivity; secondly, a large reforestation programme to meet the growing woody biomass demand, again which is happening as part of the tropical worlds largest reforestation effect and thirdly, strong legislation to conserve forests supported by a well established Forest Department.

There are always dangers of unexpected changes in policies towards conservation or deforestation depending on governments and their political imperatives, demands for biomass and land, and public opinion. Our conclusion is based on the assumption that the current policy trends and the direction of policies observed in the 1980s and 1990s are likely to continue. These issues are discussed in the next chapter. In the future, apart from the local and national concerns about forests, there will also be global concerns and commitments to conserve forests.

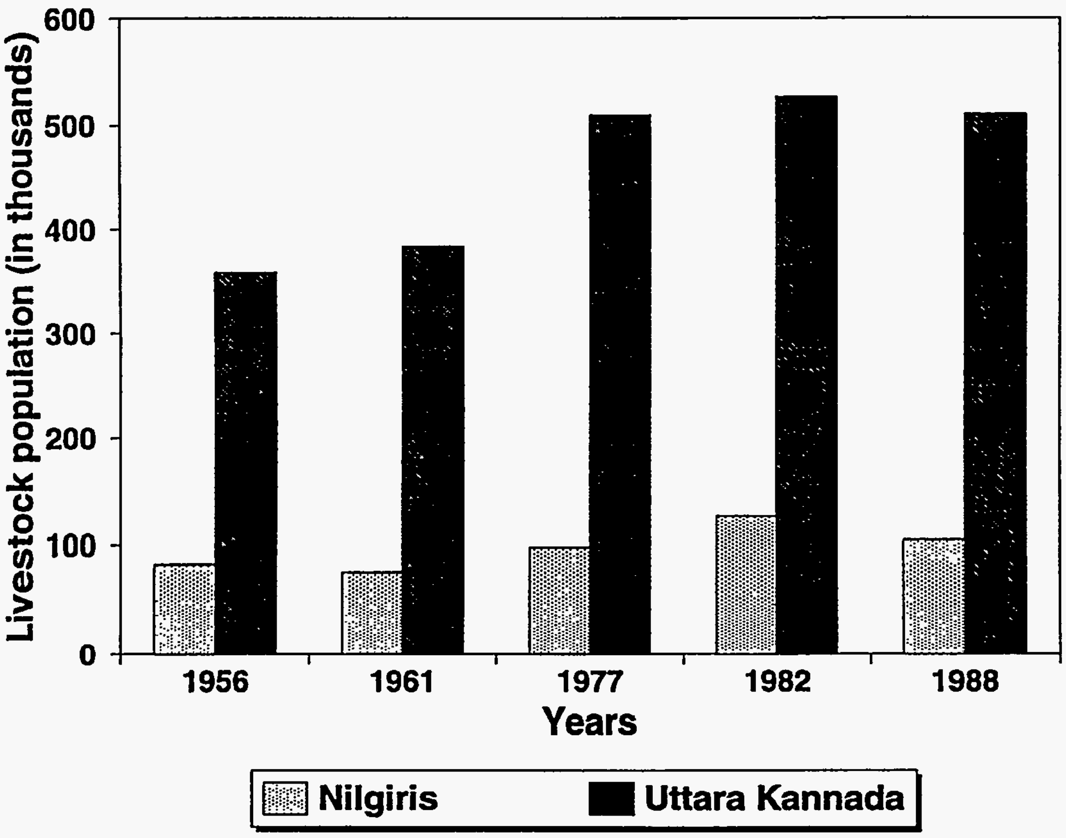


Figure 8.3. Livestock population growth in the Western Ghats

9. FOREST MANAGEMENT UNDER NO CLIMATE CHANGE

In the Western Ghats region and in India as a whole the trend observed for forest land use changes is different from that of other tropical countries. It was concluded in Chapter 8 that, even though the population has been growing at over 2% annually, the area under crops seems to have stabilised in the past two decades and the forest area seems to have stabilised in the last 15 years. A study on deforestation has concluded that forest policies have contributed significantly in conserving forests in India (Ravindranath and Hall, 1995). The future forest area and status is also likely to be significantly determined by the forest conservation programmes and development policies. Thus it is necessary to understand the current forest policies and programmes that are likely to influence future forest land use. In this chapter an attempt is made to assess the impact of forest management policies on current forest land use change. This analysis demonstrates the relevance of current forest policies or programmes to any strategy to enhance forest resilience or to adapt to changing climatic conditions.

9.1 Forest Land use Policies

The forest policies considered are: the Forest Conservation Act 1980; the Forest Policy 1988; and the Wildlife Act 1972. These are normally framed at the national level and apply to all regions.

9.1.1 Forest Conservation Act 1980 with Amendments made in 1988:

India lost over 4 Mha of forest land during 1950-80. This led to the strict regulation of forest exploitation. The result was the Forest Conservation Act of 1980. The Act aims to conserve forests for their ecological role, by strictly regulating forest conversion. It also aims at restricting indiscriminate release of forest lands for non-forestry uses. Salient Features of the Act are:

- All diversion of forest lands to any non-forest purpose, even if the area is privately owned, requires approval of the central Government.
- Leases of forest lands to any organisation or individual require approval of the central Government.
- Mining leases, and the removal of boulders and stones in forest areas as well as river beds is restricted.
- Proposals for diversion of forest land for construction of dwelling houses are not to be entertained.

This strong Act backed by a strong administrative apparatus to enforce it has significantly contributed to reducing forest conversion to non-forest uses. This act has not been repealed since 1980 or its provisions diluted. Therefore it is likely to be instrumental in regulating forest conversion also in the future. The Act has had a significant impact even at regional level such as in the Uttara Kannada district and Nilgiri hills region. The following achievements in Uttara Kannada can be attributed to the Act:

i) Expansion of mining for iron and manganese ores in the district has been restricted.

ii) Many industrial leases or licenses to wood-based industry for sourcing raw materials have not been renewed or have been cancelled.[1]

[1] In UK district (as shown in section 6) a plywood factory was shut down due to stoppage of timer supply. A survey of the veneer industry reveals that it obtains all the raw material from outside the district. Even the large paper mill which was earlier sourced by the district obtains all its raw material from outside the district.

However, implementation is not always straightforward in a situation where there are many competing demands on forest resources. The pressure on politicians to meet the demand for forest land is intense. In 1995 the chief minister of Karnataka regularised claims to 16 900 ha of unauthorised cultivation on forest land. In 1988 claims to over 4 000 ha of unauthorised cultivation were filed in Wyanad district of Kerala alone. Similarly, many tea cultivators in the Nilgiris occupy land illegally.

9.1.2 The National Forest Policy, 1988.

The success of experiments in participatory management systems prompted the Ministry of Environment and Forests to pass a new National Forest Policy in 1988. The policy represents a significant departure from previous policies because it mandates that the people must be actively involved in programmes of protection, conservation and management of forests. The policy also aims to protect and enhance the yields of non-timber forest products in order to generate employment and income for forest communities. The general theme of the policy is that forests should not be looked upon as a source of revenue but as a national asset to be protected and enhanced for the well-being of the people and the nation. Following the 1988 policy the government of India passed a national resolution in June 1990 providing more specific guidelines regarding the formation, functioning, rights and responsibilities of community forest management groups. It specifies sharing arrangements in which village forest committees that "successfully protect the forests, may be given a portion of the proceeds from the sale of trees when they mature", as well as non timber forest products for subsistence (Poffenberger *et al.,* 1992). Since 1990 there have been many state government orders which support this concept of Joint Forest Management (JFM).

9.1.3 Joint Forest Management (JFM)

Sixteen states have already adopted the JFM approach in their forestry programmes. There are variations in operational details and the share of control and forest produce between the Forest Department and rural communities across different states. Here the features of programmes in Karnataka and Tamil Nadu are described briefly to highlight some differences.

JFPM in Karnataka: The Government of Karnataka issued an Order on 12.4.93 to launch a Joint Forest Planning and Management Programme (JFPM) in the State.[2] The programme is partially funded by the Overseas Development Administration of the United Kingdom. For the purposes of JFM forests are divided into five zones:

- Zone 1 - intact and in excellent condition, these forests are to be preserved for scientific enquiry. No human interference permitted.
- Zone 2 and 3 - Forests to be kept for timber extraction under the control of the Forest Department.
- Zone 4 - Forests with a canopy cover of less than 0.25 which are to be given to rural communities for JFM.
- Zone 5 - Forests under the Revenue Department and private ownership.

The government Order states that Village Forest Committees (VFCs) should be established and these should help the government in protection, regeneration and development of degraded forest land with a canopy cover of 0.25 and less. The VFCs will be registered under the Karnataka Societies Act by the respective Deputy

[2] Social forestry is being implemented in the areas where the forest cover is not significant.

Conservator of Forest. Ex-officio members will comprise panchayat members elected in that area, officers of government departments, the forest guard and forester and a representative of an NGO appointed by the Deputy Conservator. The ex-officio members of the panchayat may vote and contest the election for the post of chairman. The formal stipulations of the Order, furthermore, directs that Scheduled castes and tribes should have two representatives, two women, one landless and one artisan. The forester will be ex-officio member secretary and be in charge of the cash book. The proceeds arising after Forest Department (FD) has deducted expenditure will be shared as follows: 50% to the FD, 25% to the "beneficiaries" through the VFC and 25% to a Village Forest Development Fund which will be operated according to rules set by the FD to develop the forest.

JFM was intensively initiated in UK district of the Western Ghats during 1993. During the period of 1993-94 to 1995-96, 216 VFCs have been formed and about 6 824 ha have been reforested. Even though the programme is nearly 5 years old, there are no published studies which give an account of the performance of the JFPM in UK district. However, field visits indicate that the reforestation programme has been largely carried out in the traditional mode of raising social forestry plantations, with marginal participation of local communities. Discussions with the NGOs, members of VFCs and researchers in the region indicate that for JFM to succeed some of the following issues become critical.

Currently in the JFM programme, particularly in the formation and functioning of VFCs and the decision-making process regarding reforestation, its protection and management, the participation of village communities is marginal. The Forest Department still largely controls the decision-making process. One of the key factors for successful implementation of the JFM programme is genuine and adequate empowerment of village communities and VFCs. This also necessitates the re-orientation of the staff of the Forest Department towards participatory forest management. Under the JFM programme the focus is largely on the degraded forest lands. The good primary forests which yield a large diversity of forest products to communities are not included under VFC management. Thus there is a need to include primary forests under JFM to create incentives to local communities.

Conflicting interests: Forests fulfil a range of needs for different social groups and the interests of different groups may clash. For example, in Uttara Kannada, arecanut farmers are interested in continued supplies of leaf manure from soppina betta lands (special category lands) and labour from nearby landless households. It has been brought to the notice of the FD that it is important to create awareness amongst the arecanut farmers about the positive implications of JFM for all stakeholders.

Government retaining too much control: Although in theory the government should enable or empower collective management institutions, this may not be realised under JFM. It is the opinion of some analysts that JFM orders such as the one for Karnataka dated 1993, are so rigid as to preclude the formation of viable institutions for genuine joint management (Andersen, 1995). Instead, she argues that plans should be more flexible and should be adapted to location specific conditions. The biophysical characteristics of the resource must also be taken into account because this sets the conditions for ecological sustainability.

Women's concerns neglected: There are also problems of inadequate representation of less powerful groups in VFCs, such as the women of the households and the poor. Women's representation on VFCs is poor in Karnataka because VFCs require only one member per household, and that is usually the male head. This contrasts with Andhra Pradesh where each household has a male and a female member in the VFC. Women complain that they are only token participants at VFC meetings. The timing of the meetings is decided by men and this makes it difficult for women to be present (Jennings, 1994). Even when women have been present at the meetings their views have not been voiced. Their interaction and participation has been hampered by established power dynamics and entrenched behaviour patterns towards women (Hobley, 1994).

Consequently the choice of species for plantation in JFM areas has frequently been decided by men who choose cash profits over fuel and fodder yields. Many women in JFM project areas have expressed anxiety about the distribution of the cash benefits from JFM. The government order specifies that 25% of the proceeds will accrue to the VFC but since the latter is made up mainly of male heads of households there is a fear that the money will not be passed on to the women (Jennings, 1994). Certain measures could be taken to improve the participation of women. These are:

- Increasing the representation of women to equal level.
- The household should not be the unit of participation and women should also be given the opportunity to become VFC members together with their men.
- Gender analysis must be undertaken in order to understand the differences between the dependence of women and men on forest products and the ensuing gender divisions of labour. Efforts should also be made to understand the differential impact of JFM programme components on women. This may involve holding separate meetings with women, incorporation of gender analysis in the training courses, special training of women and also the enrollment of more female extension workers.

Forest Department staff mobility: JFM carries few incentives for forest officials because it is perceived by many officers as involving extra work for little or no extra remuneration. The result has been a frequent movement in staff out of JFM project areas to non-JFM areas where they stand to gain more through existing unofficial reward systems. Some officers have used the JFM system to their advantage in a rather cynical way. The result has been a waste of the resources invested in their training. JFM in theory is adopted in all the districts, thus trained officers are required in all the regions, not only in Uttara Kannada district.

In recognition of this problem the FD is devising other ways of making the job rewarding, by boosting the self esteem of the officers and increased recognition within the FD hierarchy for tasks performed conscientiously.

Tamil Nadu Interface Forestry Programme: In Tamil Nadu where the Nilgiris is located the Interface Forestry Programme (IFFP), with elements similar to JFM, was introduced as part of the SIDA-funded Social Forestry Programme in 1981. The key difference between JFM and the IFFP is that the latter gives less control to rural communities compared with JFM. It aims to decrease the pressure on forests by giving forest users a stake in forest restoration and by providing alternative sources of income. Elected village bodies or Interface Forestry Committees are expected to oversee the distribution of produce. However, the responsibility of protecting the forest and controlling use will remain with the Forest Department. This has lead to the continuation of old patterns of conflict between the FD and users (SIDA 1992). No mechanisms for conflict resolution have been developed and the ultimate power remains with the FD.

IFFP is an integrated project which aims to improve ecosystem management and watershed maintenance in villages adjacent to forests. Forests in Tamil Nadu have been demarcated into three zones: Zone 1 or People's zone, Zone 2 or

Development zone and Zone 3 or Conservation zone. In zone 1 collection of MFPs (NTFPs) is allowed through village societies (the equivalent of VFCs). MFP species are also being planted. All the income from these activities flow to the village. People are being urged to reduce the number of goats. They are also encouraged to switch to cattle by offers of employment and fodder at concessional rates. In Zone 2 planting and soil and conservation activities predominate. Local people are employed for the work by giving the contracts to village institutions. No access is allowed in Zone 3.

Common problems encountered in joint forest management programmes also apply to IFFP. For example there is a lack of clarity surrounding who becomes a member and the exact definition of village societies. The distribution of benefits has also not been made sufficiently explicit through formal mechanisms (Andersen, 1995). It is also feared that IFFP has achieved such momentum that it threatens to pre-empt the "process approach" inherent in the original design and overlook the need for a strong foundation in participation. Also, responsibility for the programme is split between two major and separate wings in the Forest Department (Territorial and Social) which has hampered effective implementation (Sida, 1992).

9.1.4 Wild life Protection Act 1972:

In response to the threat to wildlife from deforestation, forest degradation and forest encroachment, the Government of India passed the Wildlife Protection Act in 1972. Goals of the Act are to ensure the protection of wild animals and to conserve their population and habitats; to restrict the hunting of wild animals and to declare the forests and habitats of wild animals as sanctuaries and national parks. In India 12.3 Mha are devoted to wild life sanctuaries.

The regulation of the conversion of land in sanctuaries is very stringent. Any conversion of forests in wildlife sanctuaries is banned. Even the extraction of NTFPs is regulated. In the last 15 years no protected area has been converted, on a large scale, to non-forest uses or denotified. Some of the achievements of the Act in Uttara Kannada district are:

i) Hunting of wild animals has decreased considerably.
ii) A wildlife sanctuary has been established in Dandeli (North-East of the district covering an area of 4750 ha) during 1994.
iii) The area of Anshi, near Karwar, (West coast of the district) covering an area of 2 500 ha was declared a National Park in 1992.
iv) A bird sanctuary has been established in Attiveri near Mundgod (Eastern dry belt of the district)

In theory, human activities in the sanctuaries are to be minimised or altogether banned. But in practice this has not been possible because people who have lived within the boundaries of the sanctuary for centuries are reluctant to give way to measures which they perceive as putting the well being of animals before their own.

Take the case of the Mudumalai Sanctuary in Tamil Nadu, Bandipur Sanctuary in Karnataka and Wyanad Sanctuary in Kerala which are contiguous and cover an area of roughly 2080 km^2 in the Nilgiris. There are 236 families in Mudumalai Sanctuary which covers an area of 321 km^2. The indigenous population consists of tribes - Jenkurumbas (honey collectors), bettakurumbas (wood cutters), mullakurumbas (cultivators and hunters), paniyas (landless labourers) and Chettis (landed cultivators). These families depend on the resources within the sanctuary for their livelihoods. In addition 760 outside families collect fuelwood from the sanctuary to the tune of 2000 tonnes per year (BNHS, 1994).

The government has been trying to resettle these people outside the sanctuary. But there is a shortage of suitable land elsewhere and the issue has been pending for the last two decades. Similarly, there are 96 settlements inside the Wyanad Sanctuary in Kerala. The government has not succeeded in relocating these villagers either.

9.2 Forest Conservation and Development Programme

Roughly 1.5 to 2 Mha of degraded lands have been reforested annually since 1980. Nearly half of this is on farm land, under the farm forestry programme (Ministry of Environment 1990). Studies have shown that most of the timber (largely industrial wood from Eucalyptus) from farm forestry is supplied to the paper and rayon industry and the rest to meet urban demand. Currently many paper mills have agreements with farmers to grow and supply Eucalyptus.

These programmes have reduced the dependence of industries on forests. There are also severe restrictions on transport of timber within India, making it difficult to transport timber illegally from the locations of production to demand. Village trees on farm land and other categories of land such as along cropland bunds, avenues and in homestead gardens also contribute to timber supply, thereby reducing the pressure on forests. Based on the above observations it may be possible to make a tentative conclusion that only a small proportion of the sawn timber demand may be coming from clearfelling of forest lands and most of the industrial wood demand is met from plantations, particularly on farm lands (excepting bamboo contracted out to industries in some selected locations).

9.2.1 Afforestation/Reforestation in Uttara Kannada

In Uttara Kannada district (with 75% of the geographic area under forests) nearly 6 500 ha of forest plantations are raised annually. The reforestation programme is wholly dominated by exotic species such as *Acacia auriculiformis* (Bhat and Ravindranath 1994). Elsewhere in India monocultures of species such as *Eucalyptus, Casuarina equisetifolia*, pines and teak dominate (Ravindranath and Hall 1995).

Afforestation operations were carried out as far back as 1842 in Uttara Kannada district. Large scale development of plantations was carried out in 1865. At that time, the only objective was to raise economically valuable species like teak. Large scale plantations of softwood and Eucalyptus were raised throughout the district for supplying wood to industry. This was done largely by clear felling existing forests. About 50 000 ha of teak plantations and 30 000 ha of match wood plantations were raised, after clear felling the forests and after extraction of timber and firewood.

However, in the post 1980 period, felling and exploitation especially in the evergreen and semi-evergreen forests have largely been stopped. On degraded forest lands, large scale plantations have been raised under programmes like social forestry, the Western Ghats development programme and most recently Western Ghats Forestry and Environment Projects. The area brought under plantations in Uttara Kannada (Kanara circle) from 1985 onwards is shown in Table 9.1. On an average 6 000 to 8 000 ha of new plantations have been raised annually since 1985. The main species of plants raised on these plantations include Teak, Eucalyptus, Acacia, various indigenous plants and bamboo and canes. In the recent years the dominant species planted in the district has been Acacia auriculiformis.

According to an assessment (Bhat and Ravindranath, 1994) of reforestation programmes in Uttara Kannada district, the survival rate of tree seedlings planted is in the range of 78 to 100% and the mean annual woody biomass productivity is in the range of 5.3 to 7.9 t/ha/yr. The plantation forestry programme in Uttara Kannada is a success in terms of the high rates of reforestation, high survival rates and moderate productivity. It is likely to have made an impact on forest conservation by supplying poles, industrial wood and fuelwood.

Table 9.1. Extent of reforestation and spread of fuel conserving biogas and improved stove programme in Uttara Kannada district (Total number of rural households in the district is 168 400).

Years	Area reforested (in ha)	No. of households with improved stoves	No. of households provided with biogas units
1983-84			458
1984-85		656	487
1985-86	6978	2260	375
1986-87	8836	2822	1287
1987-88	9439	3059	1074
1988-89	6424	2350	964
1989-90	8042	2510	1144
1990-91	8559	2250	684
1991-92	6147	1900	1394
1992-93	5852	700	1474
1993-94	8829	1000	1476
1994-95	8818	760	1361
1995-96	NA	2000	937

9.2.2 Fuelwood conservation programmes

Fuelwood is the dominant type of woody biomass extracted from forests. Fuelwood is used for cooking, heating water for baths and various industrial purposes, in that order. The total quantity of fuelwood used by the rural households in the district annually is 488 000 tons (at an estimated 1.67 kg/capita/day). This level of extraction amounts to 0.6t/ha/yr. It has to be noted that fuelwood is not extracted from all the forest area, resulting in higher extraction in some locations (see case study of headloaders in Uttara Kannada). To reduce the pressure on forests, fuelwood conservation programmes have been launched in Uttara Kannada district (Table 9.1).

Annually about 2-3000 fuel efficient stoves and 500 to 1400 biogas plants are being built in Uttara Kannada district. During the ten year period of 1986-96, 11 795 biogas plants were built, covering a population of about 59 000 (average family size of 5). Each household shifting to biogas will save about 3050 kg of fuelwood annually. In the past 8 to 10 year period about 19 000 fuel efficient stoves have also been built. The number of rural households requiring improved stoves or biogas plants is 168 400. Thus the current rate of dissemination is low and there is a need to enhance it significantly. Fuel efficient stoves and biogas plants could reduce demand the for fuelwood by over 50%, resulting in a reduction of pressure on the forests.

Headloaders in the coastal areas of Uttara Kannada are mainly from a caste known as the Halakki Vokkaligas. Paddy cultivation is their traditional source of livelihood but selling wood from the forests has also become an important source of income recently. The wood is sold to hoteliers along major roads in Ankola and Talagadde towns. The actual cutting of the wood is usually done by men who carry it to their homes. Forest Department officials and NGOs in the area such as MYRADA believe that most of this wood is collected for sale but feel that they cannot take action because headloading for personal use is allowed. The sale of the wood is done by women who carry it to sale points in Talagadde. According to the Forest Department this is a strategy to escape prosecution because officials are reluctant to harass women. The Forest Department is concerned about headloading because forests around these areas have been degraded up to a depth of 5 km and regeneration has not kept up. For the headloaders, this mining has become an essential source of income because their farming systems are not remunerative enough. Off farm employment is seasonal and they cannot earn from that through the year. Alternatives such as tailoring or agarbathi making are being explored by NGOs but marketing outlets remain a problem. If irrigation becomes available and a second crop becomes possible then the pressure on forests could be eased.

9.3 The significance of current forest policies for adaptation

With over 700 million rural people and 400 million head of livestock against a forest area of only 64 Mha, India is very poorly endowed with forest resources. Yet a comparison of the rates of deforestation in the 1980s in South-east Asia, Sub-saharan Africa and South America proves the effectiveness of forest conservation measures in India (Ravindranath and Hall, 1994). With our current understanding of forest regulation in the Uttara Kannada and Nilgiri hills regions in the Western Ghats, one can state with confidence that it is not possible to clearfell a large patch of forest say 50 to 100 ha. But some degradation of forests continues due to unresolved conflicts between the demands of different user groups. What becomes clear from the foregoing discussion is that effective co-ordination and conflict resolution are important prerequisites for any successful initiative in forest conservation and adaptation to climate change. The relationship between people and environmental resources is complex and needs to be better understood. India is well endowed with qualified personnel and dynamic NGOs. More progress has thus been made relative to many other developing areas. The evolution of measures such as JFM towards a more genuinely participatory approach must be encouraged.

The relative success in forest conservation and large reforestation programmes in India shows that India has the necessary institutions and capacity to plan and implement adaptation measures to enhance forest resilience and to minimise adverse impacts of projected climate change on the forests and forest dependent societies.

10. STRATEGIES TO PROMOTE FOREST RESILIENCE AND ADAPTATION TO CLIMATE CHANGE

The IPCC Second Assessment Report concluded that even a sustained increase of 1° C in global mean temperature is sufficient to cause changes in regional climate that will affect the growth and regeneration capacity of forests in many regions (Krishbaum *et al.,* 1996b). In several instances it will alter the function and composition of forests. Present studies for the Western Ghats region show that under the moderate central scaling scenario significant changes in area under different forest types are likely. There are uncertainties with respect to regional climate predictions as well as regional assessments of the nature and extent of impacts on different forest types (Solomon *et al.*, 1996). Despite these uncertainties it can be assumed that there will be some impacts.

In Uttara Kannada and Nilgiri regions, local communities and industry depend significantly on forest diversity and production. Over 75% of households gather a number of products for family consumption, producing articles for sale (baskets, mats, furniture, wood carvings) and as raw material for industry. There is also a significant contribution to local industry. Thus any impact on the forests due to the projected climate change could have adverse impacts on local communities, industry and economy.

The question that we now address is what strategies or policies should be adopted in the face of uncertainties involved in the current understanding of climate change and its impacts. It is possible to take the view that a perfect understanding of climate change and its impacts may not be required to develop adaptation measures and policies. (Deshingkar, 1997a) This is based on the premise that forests face many threats even now and many measures aimed at mitigating the current threats will also be applicable in climate impacted situations Practices which promote biodiversity conservation or reduce current pressures on forests are also likely to enhance forest resilience under climate stressed situations. (Secrett, 1996).

10.1 Approaches to adaptation based on risk

Whether or not policy makers consider adaptation options will depend on their perception of the risks and costs involved. Four different types of policy response can be identified based on the approach to adaptation.

i.) *Maintaining the status quo:* Due to the uncertainties involved, forest planners and policy makers could ignore climate considerations in framing forest practices and policies. Such a response carries the risk of high mitigation costs in the future and /or irreversible changes to biodiversity, occupation structures and the economy generally.

ii.) *No regrets strategies:* Certain strategies could minimise the difficulties associated with having to choose between current consumption needs and long-term protection of forests. Such "no regrets" strategies which combine social and ecological goals are particularly suitable for forests which are subject to anthropogenic pressures. (Deshingkar, 1997a, Deshingkar, 1997b) Some examples are promotion of natural regeneration in degraded forest lands, conservation of forests and sustainable harvest practices.

iii.) *Precautionary measures:* Some precautionary measures can be specifically aimed at promoting forest resilience against climate change even if there is some uncertainty. In order to do this, a set of specific adverse impacts on forests has to be identified, along with the level of uncertainty involved. Precautionary measures need to be carefully assessed for their relevance, costs and impacts. Above all they should not have any adverse ecological or socio-economic impacts. They should also be cost effective, should be feasible to adopt, and should enhance the resilience of forests. Examples include the ex-situ conservation of threatened species and anticipatory planting of threatened species.

iv.) *Pro-active strategies:* These strategies are wholly aimed at mitigating a set of identified adverse impacts of climate change. These measures are implemented with the perception that climate change impacts will be adverse and mitigation measures must be adopted to prevent species extinction or large scale forest dieback. These measures may involve some costs with uncertain benefits. Some examples of such measures are: provision of corridors for promoting migration of species and shortening plantation rotation periods.

10.2 Potential adaptation strategies for the Western Ghats

Given the potential for significant impacts on the forests of the Western Ghats and the heavy dependence of communities and the economy on forests, it is necessary to consider adaptation strategies which will enhance forest resilience and reduce adverse socio-economic impacts. In view of the findings of the present study, it is recommended that a mixture of no regrets and precautionary measures be implemented. Potential adaptation measures for the Western Ghats can be classified as:

i.) Technological and silvicultural adaptation practices
ii.) Forest land use policies
iii.) Forest conservation and development programmes

10.2.1 Technological and silvicultural adaptation options

Analysis of impacts of projected climate change for the Western Ghats region has shown that significant shifts in boundaries and area are likely to occur for different forest types (Section 2.3). As the climate becomes unsuitable, the forest growth rate may decline and mortality may increase (Solomon and Leemans, 1990). Some measures and practices based on the IPCC recommendations (Solomon *et al.* 1996) and other studies are listed here. These aim to facilitate shifts in forest boundaries and migration of species, increase the resilience of forest vegetation to changing climate and increase the diversity and flexibility of adaptive management.

Establishment options: Establishment options to reduce the negative effects of climate change can be selected from common silvicultural practices. These practices should be viewed in the context of the large reforestation programme being implemented in the Western Ghats region which is largely dominated by monocultures of exotics. The following points should be borne in mind:

- In the face of uncertainty, reforestation strategies should emphasise conservation, diversification, and broader deployment of species, seed sources, and families. Planting programmes may have to deploy non-local seed sources, imported from further south or from lower elevations (Ledig and Kitzmiller, 1992).
- Leaving one-quarter to one-third of the plantation area in its natural state for promoting forest succession through natural regeneration reduces the pest and disease occurrence (Carpentieri *et al.,* 1993)
- Short rotation plantation forestry provides opportunities for any adaptation options in terms of changes in species mix or silvicultural practices to adapt to climate change.

- In-situ and ex-situ reserves of key forest species can be established to ensure that a gene pool of sufficient variability is available for tree improvement programs which can have the ability to adapt to climate change.
- Choice of species in anticipatory planting. Mixed species for current planting should be considered wherever possible, as a means to increase diversity and flexibility in adaptive management.
- Vulnerability of young stands and anticipatory planting. The planting of species and varieties better adapted to future conditions may well increase vulnerability of the resulting stands during their early establishment. Selection of provenance offers an important tactic to reduce the vulnerability.
- Assisting natural migrations in Protected Areas. Protected areas are a rich source of genetic materials and warrant expansion into comprehensive systems. To be effective they must function in landscapes where ecological integrity is sufficient to permit the movement of living organisms. There must be a comprehensive approach to both community and reserved lands (Franklin *et al.,* 1990).
- Assisting natural migrations by transplanting species. Large numbers of seedlings raised in nurseries many hundreds of kilometres from planting sites could be planted to assist migration (Farnum, 1992).
- Gene pool conservation. Specialist species (indicated by restricted geographic ranges) will be most at risk, and their only chance of surviving may be through conservation in forest reserves, arborata and conventional seed banks and cryogenic storage.

Harvest options: Sustainable harvests: Since local communities and the economy will continue to depend on forests for fuelwood, timber and NTFPs, it may be very difficult to ban completely wood extraction in all forest locations. To minimise damage to vegetation, sustainable harvesting practices should be adopted. There is a need to develop and prescribe sustainable modes and rates of extraction for different forests and plantations. The empowerment and involvement of local communities in the conservation, use and management of forest resources will help to make such practices sustainable (Agarwal and Narain, 1989).

Shortening rotations: Reduction of rotation age is a simple tactic for reducing exposure of maturing timber stocks to deteriorating conditions, as well as increasing opportunities for modifying the genetic makeup of the forest. Gains may be offset by diminished timber quality and a lower mean annual increment.

Increased thinning: The stimulation of tree vigour following stand thinning has special application under increasing moisture deficits. The modification of forest microclimate by thinning offers considerable potential for management of pests.

10.2.2 Forest land and product use policies to promote forest resilience

The dominant impact of projected climate change is a shift in the boundaries of forest types, changes in the area under different forest types and the accompanying changes in plant diversity and plant productivity. Thus there is a need to facilitate migration or shifting of species and forest boundaries and, if feasible, to promote anticipatory planting of species under threat. The main goal is to minimise anthropogenic pressure and facilitate the shifting of boundaries and migration of plant species. The spatial distribution of different forest types in Uttara Kannada and the Nilgiri hills regions is largely contiguous along the rainfall gradient from wet evergreen to semi evergreen to moist deciduous to dry deciduous forest types.

This could enable climate driven shifts or migration of plant and animal species. There are some barriers such as roads, farms, plantations and settlements. The following policies may potentially help to minimise anthropogenic pressure to facilitate species migration. But certain barriers to their implementation may exist. These were dealt with in the previous chapter.

i) *Forest conservation policies:* The Forest Conservation Act of 1980 needs to be more rigorously implemented to prevent fragmentation of forests and to preserve seed sources to enable migration.

ii) *Protected areas (PA) expansion:* Using the provisions of the Wildlife Act 1972, it is necessary to preserve the existing protected areas and include more forest area under wildlife sanctuaries. PAs lead to better enforcement of forest conservation measures. This facilitates forest regeneration to occur under the influence of climate change. In addition, PAs provide habitat for migrating plant and animal species and lead to *in situ* conservation of biodiversity which could potentially become a source of seed material for migration of species. For large mammals, if feasible, the PAs could be connected by corridors to enable their migration. This would also enable migration of other species. However, the establishment of protected areas in the Western Ghats has been problematic due to the lack of adequate mechanisms to fulfil simultaneously the needs of local people and wildlife protection goals (see section 9.1.4.)

iii) *Small refuges as stepping stone reserves*: Small, *in situ* stepping-stone reserves could be set up to facilitate species dispersal. Ideally, this could be along the lines of "Sacred groves" that existed in large numbers in the Western Ghats region (Gadgil and Guha, 1996). However the institutional arrangements for maintaining these groves are now largely defunct and would have to be revived. Community managed forests could also serve as stepping stone reserves (see section 10.3.5).

iv) *Ban on extraction of wood for industries from primary forests:* There is already a ban on clear felling as well as selective logging of trees in reserve forests which account for most of the primary forests in Uttara Kannada and Nilgiri hills regions. If necessary this needs to be strengthened. This leads to reduction or elimination of extraction of wood, ultimately to conservation of forests and biodiversity

v) *Promotion of industry and farm linkages:* Industry could be made to rely entirely on non-forest land sources for industrial wood such as farm land with appropriate policy and financial incentives to conserve forests.

vi) *Promotion of NTFP based forest management:* NTFPs could be extracted sustainably from forests without affecting forest diversity, standing biomass and regeneration. NTFP extraction could be a significant incentive to communities to protect and manage forests, as the income derived is high (Section 6.3). Promotion of NTFP based forest management could lead to protection and conservation of forests which would enhance the ability of forests to adapt to changing climate. It also generates financial incentives and long-term stakes for local communities to protect and manage forests.

vii) *Participatory approach to forest management:* JFPM could be an ideal approach to promote many adaptation options such as: promotion of small dispersed *in situ* biodiversity conservation forests at a village level extending from a few hectares to a few hundred hectares; promotion of natural regeneration in degraded village commons; and promotion and monitoring of sustainable harvests of wood or extraction of NTFPs; protection and conservation of natural forests.

10.2.3 Forest conservation and development strategies

Some forest conservation and development programmes that promote forest resilience to changing climate are listed in this section.

1. Wildlife conservation programmes: India has implemented a number of focused programmes aimed at conserving the populations of selected wild animals such as the tiger and elephant. If these programmes are implemented on a large scale it would not only conserve the animal population and habitat but would also promote forest resilience as forest conservation measures are implemented. Problems may arise in cases where there are competing claims to the same patch of forest. See section 9.1.4.

2. Promotion of natural regeneration: India has vast degraded forest lands subjected to over grazing, fire, and soil erosion. Protection and promotion of natural regeneration would facilitate shifts in vegetation under changing climate situations. According to one assessment 29 Mha is estimated to be suitable for natural regeneration (Bajaj, 1992). Protection of land from grazing, fire and extraction will prepare the ground for establishment of migrating species. In Uttara Kannada and Nilgiri hills as well as at the national level, promotion of natural regeneration has received marginal attention compared to artificial plantation forestry. Community involvement and participation is necessary to promote natural regeneration. Several successful natural regeneration systems managed by local communities are present in the Western Ghats region (Ravindranath *et al.,* 1996).

3. Afforestation/Reforestation: Large reforestation programmes could present an opportunity to incorporate anticipatory planting for adaptation. Mixed species must be adapted for current planting to increase diversity and flexibility in adaptive management (Solomon *et al.,* 1996). Due to the unpredictable nature of epidemics and climate change, the maintenance of genetic diversity in plantations is necessary (FAO 1993b). Greater diversity (within and between species) gives a better chance for tree communities to evolve and to cope with new conditions and also provides insurance against total loss.

4. Fuelwood conservation programmes: There is a need to conserve fuelwood to reduce the pressure on forests and conserve forest resources. Biogas (from cattle dung) for cooking and improved fuel efficient stoves are the two prominent fuelwood conservation techniques. In Uttara Kannada district, out of 168 400 rural households 4% have biogas plants and 10% have improved stoves. It is possible to conserve over 50% of fuelwood used through family Biogas plants and fuel efficient stoves. There is a need to enhance the rate of dissemination of Biogas (which replaces fuelwood) for all households who have adequate cattle . The uptake of fuel efficient stoves should also be improved.

10.3 Institutional structure for planning and Implementation of Adaptation Measures

Appropriate institutional structures are necessary for the planning and implementation of adaptation measures. Some lessons can be drawn from older institutional arrangements such as forest Panchayats. Most of the older systems have been rendered dysfunctional due to pressures of commercial exploitation, breakdown of regulatory mechanisms and factionalism within village societies. Modern institutional arrangements such as Joint Forest Management (see section 9.1.3) may offer a greater chance of success than the mainstream approach, enshrined in the Working Plans, which has been the dominant model for the last 150 years. Here the structure, organisation and functions of these institutions are briefly considered to assess their ability to undertake planning and implementation of adaptation measures.

10.3.1 Organisation of Forest Departments

The Forest Department will play a crucial role in planning and implementation of mitigation and adaptation measures. It is necessary to understand the forest department organisation in order to analyse its capacity to plan and implement mitigation options. Here a case study of Uttara Kannada district is presented to understand the organisation of the Forest Department.

The entire area of forest lands in the district together with a small area of the adjacent Dharwad division lies under one unit of administration known as 'Kanara Circle', which was created in 1967. The total area of forest lands in Kanara Circle is 8292 square kilometres. The Circle is headed by the Conservator of Forests with his headquarters at Sirsi. The circle is divided into 5 divisions. These five divisions are further divided into 14 sub-divisions which are again divided into 38 territorial ranges. A forest division is the administrative unit for the working plan and all other programmes. There is a Deputy Conservator of Forests (DCF) at each divisional level and Assistant Conservator of Forests at the sub-divisional level. Then at each range there is a Range Forest Officer. Each range is further sub-divided into forest sections and each section into beats. There are Foresters at section level and guards at the beat level. In all there are 147 sections and 470 beats in the Kanara circle. After the introduction of the Western Ghats Environment and Development project and JFPM in the circle, five more posts of DCFs have been created at divisional level, who are responsible for the implementation of JFPM in the circle. Two DCFs are in charge of the project monitoring cells at the office of Conservator of Forests. Apart from these there are wings for wildlife sanctuary, social forestry and research in the Kanara circle.

This example illustrates the scale of the organisational structure of the Forest Department. Such a formidable structure has enormous potential to undertake adaptation measures provided it is reoriented in the right direction.

10.3.2 Working Plans

The Working Plan is the field guide for foresters. It covers all categories of forest land and is a key document for planning and management. Felling, planting and lopping of trees must be conducted under regulations specified within it. In its most basic form it outlines silvicultural techniques as well as forest statistics and rights granted to local communities under the Settlement process. A degree of uniformity is maintained in WPs across the country because they are required to adhere to the All India Working Plan Code. Regional variations do exist, however, depending on the biophysical features of the forest base, demands of local communities, value of species and yields. Working Plans should ideally be revised every 10-15 years but the process is typically slow and it is not unusual to find the same Working Plan being used for three decades or even more.

Management techniques and silvicultural practices enshrined in the WPs are determined by the overall objectives expressed in the National Forest Policy of the time. Therefore there has been a change in focus over the last century. In recent years, importance has been given to watershed management, environmental conservation, wildlife management, recreation and tourism. People-oriented policies have been slow to trickle down to the WPs. Consequently many of them continue to be dominated by timber management concerns.

There are ambitious plans under JFPM to revise Working Plans to reflect the devolution of control to rural communities. In view of impending climate change, it would also make sense to incorporate climate considerations in working plan preparation. This would require:

1. A longer period perspective plan - say 30 to 50 years to incorporate long-term adaptation measures.
2. The inclusion of silvicultural practices such as anticipatory planting of species; planting mixed species and multi-use plantations; promotion of natural regeneration; increased thinning; sanitation harvests and sustainable harvests.
3. A shift away from timber oriented system to NTFP focussed management system to promote biodiversity as well as flow of forest products.
4. A move away from traditional forest management which strives to impose a predictable stable state production system in natural and plantation systems. Stable systems are rarely resilient and are less likely to adapt to climate change and stress (Secrett, 1996).
5. To give adequate attention to promotion of natural regeneration and forest succession in degraded lands, as currently only plantation forestry is being stressed.

10.3.3 NGOs in Forest Conservation and Development

NGOs (Non Governmental Organisations) could play a crucial role in planning and implementation of mitigation options. NGOs could facilitate participation of local communities in all the forest conservation, development and adaptation programmes. There are at least fifteen NGOs in the Uttara Kannada district which are actively involved in afforestation, forest conservation, education and training programmes related to forestry. The voluntary organisations in the district now have an important role to play in the Western Ghats Forests and Environment Project implemented by the Forest Department. The NGOs in the district have now formed a district level federation. NGO representatives are on the various committees at the forest division, at forest circle as well as at the village levels.

10.3.4 Village Forest Committees (VFC)

These committees, consisting of different sections of village society and Forest Department staff, are organised at the village level to participate in planning and implementation of forest conservation and reforestation programmes. Even though there is a commitment in principle to provide adequate power to VFCs to take decisions, in practice the Forest Department still dominates the decision making process. Until genuine efforts are made to transfer decision making power to the VFCs, they cannot effectively participate in forest conservation and regeneration programmes.

All women VFCs: The latest step towards improving the devolution of forest management has been the establishment of a few all-women VFCs. To those who see JFM as perpetuating gender inequalities this is a positive step (see section 9.1.3). However the motives of such VFCs in Uttara Kannada are not necessarily to reduce the burdens on women and empower them. Take for example the coastal areas of Uttara Kannada where 7 new all women VFCs have emerged. Feedback from the villages of Banasgere and Majugunihalle suggests that these were set up because:

- men in the village do not have the time to become involved in forest management activities,

- outsiders have claims to the village forests and women were chosen as the "leaders" because they are less likely to be harassed when conflicts arise, and;
- in fishing communities the men are away and the women have greater knowledge of the forests.

All of these VFCs are less than a year old and as such it is too early to judge their performance.

10.3.5 Community Management Institutions

In the Western Ghats as well as rest of India, a number of wholly self initiated 'Community Forest Management' institutions have emerged in response to degradation of forest lands. These community management systems have evolved their own institutional arrangements (Ravindranath *et al.,* 1996) with the aim of promotion of revegetation through protection and natural regeneration in degraded village commons and forest lands. Such community managed forests (ranging from a few hectares to several hundred hectares) spread over hundreds or thousands of villages could act as `stepping stone reserves' and play a crucial role in promoting adaptation to changing climate.

10.3.6 Village Panchayats (level government)

In 1931 parts of protected forests, also known as "civil" forests, were placed under the control of village panchayats on a nation-wide basis in order to minimise conflicts between the Forest Department and people. In Uttara Kannada district 20 villages were given the permission to form panchayats. Forest panchayats were derecognized by the government in 1976. This led to over exploitation of many panchayat forests by commercial interests. A handful of panchayats managed to obtain a stay order from the supreme court and are successfully managing their forests till today. Currently, the national and state governments are committed to transfer financial and administrative powers to Panchayats to undertake conservation and development programmes. The Panchayats are in place in the Western Ghats region, but they lack adequate powers to take decisions on forestry programmes. Panchayats along with VFCs could ensure proper implementation of forest conservation programmes and indeed long-term adaptation measures.

10.4 Barriers to Implementation of Adaptation Measures

Many different kinds of barriers impede the effective implementation of forest conservation and adaptation strategies. Some of these are listed below.

Technical barriers: Before changing silvicultural practices to accommodate climate change concerns, the following questions must be answered:

- what species or mix of species should be adopted for anticipatory planting?
- which species have to be conserved in ex-situ reserves?
- what are sustainable modes and rates of extraction of wood and NTFPs?.

Thus there is a need to initiate research into potential silvicultural practices. Such research involves long gestation periods. Research institutes that could undertake long-term research projects are required and existing institutions in the regions may have to be strengthened.

Financial barriers: Generous funding is currently available from the local forest department as well as external sources for undertaking forest conservation and reforestation programmes. All funding for all programmes on forest lands comes from the State budget and international sources. Any new adaptation measures such as the large scale expansion of reforestation or PAs and long-term research would require additional funding.

Institutional barriers: The lack of required institutional capacity could be the most important obstacle to effective implementation of adaptation strategies. Experience with existing forest conservation programmes such as JFPM has shown that institutional barriers must be addressed and the lessons must have affect on policy. With regards to adaptation, institutional capacity must be strengthened in the areas of:

- long-term scientific research,
- communicating information on climate change impacts to communities and foresters,
- community management of forests
- financial support for adaptation
- monitoring changes in forest status or implementation of forestry programmes.

10.5 Conclusions:

1. IPCC (1996) concludes that global models, based on 2xCO_2 climate, project that a substantial fraction of the existing forests will experience climatic conditions under which they do not currently exist. Thus, large forested areas will undergo changes from the current forest types to new major vegetation types. Thus, serious attempts should be made in different regions of the tropics to assess the potential impacts of climate change on forest diversity, biomass production and product flows. However, there is a need to keep in mind the limitations of the current state of knowledge and models in detecting the specific climate induced changes in diverse tropical forest ecosystems as they are subjected to complex multiple climate and non-climate factors (IPCC 1996).

2. Under *the most likely climatic scenario* in the Western Ghats there may be an expansion of evergreen and moist deciduous forests due to increased precipitation and also in dry thorn forests due to an increase in temperature. Consequently there might be a decrease in the dry deciduous forests. Under *the worst case scenario* there could be significant shifts from the moist to the drier vegetation types as a result of increasing temperatures and decreasing precipitation. Forest die-backs could occur, especially under *the worst case scenario.* Changes in natural vegetation are also likely to have socio-economic implications for local communities and commercial trade due to changes in the availability and flow of forest products. Human activities and the resulting fragmentation of forest areas could prevent or slow down the natural migration of species in response to a changing climate. In addition, the direct impact of human activities on natural ecosystems would also dictate the response of vegetation to a changing climate.

3. Given the potential for large scale impacts of projected climate change on forests, there is an urgent need to improve the existing vegetation response models for a better assessment of change. This will assist in formulating better policies to improve forest resilience and adaptation to climate change.

4. The field studies in Uttara Kannada and Nilgiris showed that 50 to 75% of households in both the regions gather a large variety of products; the employment generated in gathering NTFPs ranged from 150 to 200 person days/year, the financial value of NTFPs gathered for subsistence consumption and for commercial purposes is significant compared to daily wage earnings, households belonging to all socio-economic groups depended on forests. The financial value of NTFPs gathered in the district is double that of timber extracted in a year, indicating the importance

of diversity of plant products to the local economy. Given the large dependence of communities and economy on forests, it is necessary to assess the potential impacts of climate change on forest vegetation and forest product flows.

5. The impact of climate change on forest product flows in the Western Ghats region was assessed by using the "moderate climate sensitivity and central scaling factor" scenario. The area under high NTFP and income yielding evergreen and moist deciduous forest types is projected to expand, leading to an overall increases in the availability of NTFPs of the kind currently available in these zones. This will lead to enhanced employment and income levels for indigenous and rural households. This conclusion is based on the assumption of an equilibrium response of vegetation. What is uncertain is the transient response of vegetation until an equilibrium stage is reached; this could lead to forest dieback and a loss of vegetation. Fuelwood and timber production might not decline, but in fact might increase due to increased productivity from CO_2 fertilisation and increased precipitation.

6. The analysis of the current and past land use changes led to the conclusion that in the Western Ghats region large scale forest clearing and forest land use change are unlikely, despite contrary predictions for tropical countries. This conclusion could also be extended to the national level with some caution. In India even though large scale deforestation has generally been controlled, forest degradation may continue due to growing anthropogenic pressures. In regions such as the Western Ghats climate change could be an important factor in determining forest area, diversity and production in the next century. Three of the critical factors that could potentially prevent large scale forest conversion are; firstly, the need to increase agricultural productivity; secondly, a large reforestation programme to meet the growing woody biomass demand, again which is happening as part of the tropical world's largest reforestation effect and thirdly, strong legislation to conserve forests supported by a well established Forest Department and empowered community institutions.

The relative success in forest conservation and large reforestation programmes in India shows that India has the necessary institutions and capacity to plan and implement adaptation measures to enhance forest resilience and to minimise adverse impacts of projected climate change on the forests and forest dependent societies.

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APPENDIX

Appendix 4.1a. Size class distribution and number of stems per hectare for the first ten dominant species in the Nilgiris.

Forest type	No of individuals/ha	Basal area/ha (sq.m)	DBH distribution (%)			
			1-5	5-10	10-30	>30
Dry Deciduous forest						
Anogeissus latifolia	132±88.2	4.28	9	21	59	10
Cassine glauca	12±23.3	0.41	7	24	66	3
Ligustrum roxburghii	18±44	0.36	14	25	57	4
Olea dioica	22±68.9	0.59	3	19	71	6
Emblica officinalis	38±39.6	0.43	43	34	21	1
Xeromphis spinosa	22±68.9	0.27	52	13	35	0
Shorea roxburghii	74±162.9	0.49	78	10	10	2
Strychnos potatorum	16±34.5	0.27	24	20	56	0
Tectona grandis	30±38.8	1.80	34	5	41	20
Terminalia crenulata	55±90.4	1.14	15	33	48	4
Others		10.86	24	33	31	12
Dry Thorn forest						
Acacia pennata	14±23.8	0.01	98	2	0	0
Albizia chinenesis	40±62.8	0.01	0	16	84	0
Canthium parviflorum	17±33.8	0.18	0	57	43	0
Clausena indica	31±60.2	0.35	0	55	45	0
Commiphora caudata	14±15.5	1.72	0	0	84	16
Ehertia cancannensis	20±22.5	0.22	0	41	59	0
Erytroxylon monogynum	20±36.2	0.25	91	9	0	0
Flacourtia indica	12±25.5	0.03	0	91	9	0
Gyrocarpus americana	11±21.1	0.65	9	9	77	5
Xeromphis spinosa	12±18.1	0.06	70	30	0	0
Others		5.86	32	28	36	4

Montane forest						
Alseodaphne semecarpifolia	58±67.8	4.12	8	19	59	14
Cinnamomum malabathrum	64±77.3	3.37	12	28	45	15
Euphorbiaceae sp.	46±94.9	0.14	49	49	2	0
Isonandra candolleana	54±81.8	3.24	11	20	36	32
Lasianthus velutinum	133±187.6	0.56	64	27	8	0
Litsea floribunda	90±101.9	0.96	26	40	33	1
Litsea stosksii	59±91.0	1.66	31	47	18	4
Memecylon malabaricum	86±224.4	0.68	31	44	25	0
Psychotria congesta	51±68.5	0.10	79	21	0	0
Vibernum sp.	69±98.5	0.51	8	57	35	0
Others		32.85	25	29	34	12
Evergreen forest						
Agrostachys meeboldii	83±153.4	0.44	35	48	17	0
Casearia esculenta	43±46.3	0.65	18	43	36	2
Casearia ovoides	45±119.1	0.24	42	50	8	0
Democarpus longan	59±49.4	0.73	30	37	33	0
Garcinia morella	50±51.5	0.43	29	32	38	0
Gomphandra tetrandra	85±50	0.90	31	35	34	0
Myristca dactyloides	119±114.2	3.97	30	28	26	16
Palaquium ellipticum	59±49.4	3.21	20	20	41	20
Poeciloneuron indicum	109±207.7	3.22	25	23	29	23
Trichalisia apiocarpa	41±84.2	0.05	26	50	21	3
Moist Deciduous forest						
Helicteres isora	193±257.9	0.22	90	10	0	0
Kydia calycina	108±142.9	1.33	51	12	35	2
Terminalia crenulata	60±58.9	7.21	1	10	44	45
Anogeissus latifolia	43±59.9	1.87	2	11	76	11
Ziziphus rugosa	37±63.3	0.10	63	36	2	0
Xeromphis spinosa	28±40.4	0.45	43	20	34	2
Grewia tiliifolia	28±25.2	3.16	15	9	18	58

Xylia xylocarpa	27±46.9	3.51	19	0	22	59
Cassia fistula	23±19.7	0.13	59	24	17	0
Pavetta indica	20±57.6	0.01	96	4	0	0
others		20.49	33	18	26	24

Appendix 4.1b. Size class distribution and number of stems per hectare for the first ten dominant species in Uttara Kannada.

Forest type	No of individuals/ha	Basal area/ha (sq.m)	DBH distribution (%)			
			1-5	5-10	10-30	>30
Dry Deciduous forest						
Anogeissus Latifolia	250±70	2.69	45	32	22	2
Terminalia paniculata	103±12	1.28	38	32	27	2
Holarrhena antidysenterica	93±49	0.27	67	33	0	0
Tectona grandis	70±37	0.43	37	56	7	0
Xylia xylocarpa	50±64	0.73	33	44	12	11
Terminalia crenulata	37±210	0.44	6	27	67	0
Pterocarpus marsupium	27±31	0.45	10	22	66	0
Acacia sinuata	13±19	0.14	38	38	24	0
Zizyphus oenoplea	10±14	0.10	13	87	0	0
Others		5.4	34	42	21	3
Moist Deciduous forest						
Calycopteris floribunda	32±15	0.32	13	74	11	2
Ervatamia heyneana	31±39	0.54	5	43	53	0
Grewia tiliifolia	22±26	1.57	5	5	41	50
Holarrhena antidysenterica	14±37	1.78	23	8	8	62
Hopea wightiana	73±155	2.21	42	23	21	13
Knema attenuata	17±47	0.38	33	33	20	13
Lagerstroemia microcarpa	31±19	0.77	2	19	61	19
Leea indica	18±50	0.02	95	5	0	0
Terminalia paniculata	96±67	4.33	13	24	44	20
Xylia xylocarpa	306±248	15.14	5	8	64	23
Others		9.67	24	25	37	13
Semi Evergreen forest						
Hopea wightiana	335±270	2.11	57	32	7	2
Knema attenuata	227±128	1.79	42	31	24	4
Diospyros montana	180±154	1.44	55	18	25	3

Holarrhena antidysenterica	113±63	2.25	47	27	11	15
Ixora brachiata	100±61	0.71	41	37	21	2
Myrystica malabarica	83±86	0.15	80	12	8	0
Garcinia cambogea	108±58	0.68	45	35	18	2
Aporosa lindleyana	82±108	1.14	55	16	22	5
Mimusops elengi	75±54	0.23	47	53	0	0
Terminalia crenulata	63±124	2.29	45	24	23	8
Dysoxylum malabaricum	1130±63	1.04	42	12	36	9
Others		11.48	52	23	17	8
Evergreen forest						
Aglaia roxburghii	33±42	0.48	36	22	36	6
Aporosa lindleyana	26±31	0.99	7	19	72	2
Diospyros candolleana	65±69	1.11	25	30	38	6
Garcinia morella	60±70	0.57	17	42	42	0
Holarrhena antidysenterica	62±57	2.14	10	37	37	15
Hopea wightiana	175±102	0.22	9	24	48	19
Knema attenuata	106±102	1.62	16	32	43	9
Memecylon terminale	40±58	0.08	62	36	2	0
Memecylon umbellatum	70±131	0.17	78	20	2	0
Nothopegia colebrookiana	39±84	0.52	10	52	39	0
Olea dioica	44±26	4.22	16	13	39	33
Others			30	31	30	9

Appendix 6.1a. Sample size for household survey on NTFP gathering and use in Uttara Kannada.

Forest zone	No of villages	Total no of households	No of sample households			
			Total	LL	LO	GO
Dry Deciduous	3	208	114	27	58	29
Moist Deciduous	4	241	75	27	46	2
Semi Evergreen	3	124	74	25	7	42
Evergreen	11	320	245	25	85	135
Total	**21**	**893**	**508**	**104**	**196**	**208**

Appendix 6.1b. Sample size for household survey on NTFP gathering and use in Nilgiri Hills.

Forest zone	No of villages	Total no of households	No of sample households			
			Total	LL	SF	OT
Dry Deciduous	3	379	106	46	33	27
Moist Deciduous	8	199	95	45	5	45
Dry Thorn	4	453	145	91	32	22
Evergreen	6	106	42	20	2	20
Montane	6	307	92	19	24	49
Total	**27**	**1444**	**480**	**221**	**96**	**163**

GO: Garden Owner
LO: Land Owner
SF: Small Farmer
LL: Landless
OT: Others

Appendix 6.2. Total quantity and value of NTFPs obtained/1000 ha from Forest Department and Household Survey in Uttara Kannada.

Ntfp	Per 1000 Ha From Hh Survey	Per 1000 Ha From Fd Data	Total Per 1000 Ha	Financial Value Per 1000 Ha (In Rs)
Evergreen zone (in Kgs)				
Artocarpus lakoocha	69855	118387	188242	9686
Acacia sinuata	18	5374650	5374668	637
Bambusa arundinacea (nos)	57671	-	57671	13107
Garcinia indica	144564	991870	1136434	46312
Garcinia cambogea	1353	7380000	7381353	3969
Honey	54	346430	346484	3198
Mangifera indica	1231044	-	1231044	559
Mushrooms	102	-	102	1 020
Sapindus emarginatus	71	18	89	712
TOTAL				**1801 360**
Calamus rotundus (nos)	10379	355	10379	1037
Semi Evergreen zone (in Kgs)				
Artocarpus lakoocha	8958	2084100	2093058	1114
Acacia sinuata	200	11701070	11701270	652
Garcinia indica	1567	1746100	1747667	703
Garcinia cambogea	145608	13120000	13265608	51634
Honey	221	6100500	6100721	3301
Mangifera indica	52409	-	52409	2620
Sapindus emarginatus	5439	5546240	5551679	444
TOTAL				**604 68**

Appendix 6.2 (Continued). Total quantity and value of NTFPs obtained/1000 ha from Forest Department and Household Survey in Uttara Kannada.

NTFP	Per 1000 ha from HH SURVEY	Per 1000 ha from FD data	Total per 1000 ha	Financial value per 1000 ha (in Rs)
Moist Deciduous zone (in Kgs)				
Artocarpus lakoocha	42506	2891850	2934356	3349
Acacia sinuata	42388	13128710	13171098	3389
Bambusa arundinacea (nos)	37372	-	37372	4671
Calamus rotundus (nos)	264	355	264	3326
Garcinia indica	6	2422850	15	316
Honey	1085	8459850	8460935	542
Mushrooms	34850	-	34850	3485
Mangifera indica	30396	-	30396	1520
Sapindus emarginatus	580	4580250	4580830	159
TOTAL				**207 50**
Dry Deciduous zone (in Kgs)				
Bambusa arundinacea (nos)	1649	-	1649	41225
Carissa carandas	58	-	58	174
Honey	7553	6472900	6480453	4714
Emblica officinalis	355	-	355	1420
TOTAL				**797 345**
Anogeissus latifolia	63 478	-	63 478	5078 240

Appendix 6.3a. Flow of NTFPs under Climate Impacted "Moderate" Scenario - 2050 - Uttara Kannada.

Product	Quantity (Kgs) 1000ha	Financial value (Rs)	Baseline quantity in Kgs 108986ha	Baseline financial value ('000 Rs)	Projected 2050 quantity in Kgs 158300ha	Projected 2050 financial value ('000Rs)
Evergreen zone						
Artocarpus lakoocha	70 751	1061 265	7710 868	115 663	11199 883	167 998
Acacia sinuata	61	549	6 648	59	9 656	86
Bambusa arundinacea (nos)	44 726	1 125	4874 507	122	7080 125	178
Garcinia indica	9 760	341 600	1063 703	37 229	1545 008	54 075
Garcinia cambogea	277	13 850	30 189	1 509	43 849	2 192
Honey	92	9 200	10 026	1 002	14 563	1 456
Mangifera indica	124 013	372 039	13515 680	40 547	1963 125	58
Mushrooms	102	1 020	11 116	111	16 146	161
Sapindus emarginatus	89	712	9 699	77	14 088	112
Total		**1801 360**		**196 319**		**226 316**
Semi Evergreen zone						
Artocarpus lakoocha	6 089	91 335	1273 849	19 107	1377 331	20 659
Acacia sinuata	224	2 016	46 861	421	50 668	456
Garcinia indica	218	7 630	45 606	1 596	49 311	1 725
Garcinia cambogea	9 703	485 150	2029 916	101 495	2194 818	10 974
Honey	171	17 100	35 774	3 577	38 680	3 868
Mangifera indica	564	1 692	117 991	353	127 576	382
Sapindus emarginatus	3 708	29 664	775 732	6 205	838 749	6 709
Total		**634 587**		**132 754**		**44 773**

Appendix 6.3a (continued). Flow of NTFPs under Climate Impacted "Moderate" Scenario - 2050 - Uttara Kannada.

Moist deciduous zone						
Product	**Quantity (Kgs) 1000ha.**	**Financial value (Rs)**	**Baseline quantity in kgs 226589ha**	**Baseline financial value ('000 Rs)**	**Projected quantity in 2050 in kgs 177900ha**	**Projected 2050 financial value (Rs)**
Artocarpus lakoocha	37 424	561 360	8479 866	127 198	6657 729	99 865
Acacia sinuata	48 896	440 064	11079 295	99 713	8698 598	78 287
Bambusa arundinacea (nos)	11 432	285 800	2590 365	64 759	2033 752	50 843
Calamus rotundus (nos)	874	11 012	198 038	2 495	155 484	1 959
Garcinia indica	15	525	3 398	118	2 668	93
Honey	976	97 600	221 150	22 115	173 630	17 363
Mangifera indica	415	1 245	94 034	282	73 828	221
Mushrooms	259	2 590	58 686	586	46 076	460
Sapindus emarginatus	485	3 880	109 895	879	86 281	690
Total		**1404 076**		**318 145**		**249 781**
Dry Deciduous zone						
Bamboo(nos)	1619	4 0475	77 428	1 935	48 408	1 210
Carissa carandas	58	174	2 773	8	1 734	5
Honey	7554	755 400	361 270	36 127	225 864	22 586
Emblica officinalis	324	1 296	15 495	61	9 687	38
Total		**797 345**		**38 131**		**23 839**
Anogeissus latifolia	63478	5078 240				

Appendix 6.3b. Flow of NTFPs under Climate Impacted "Moderate" Scenario - 2050 - Nilgiris.

Evergreen Zone						
Product	1 000 ha		58 544 ha		71 425 ha	
	Baseline quantity (t)	Baseline financial value ('000 Rs)	Quantity (t)	Baseline financial value ('000 Rs)	Moderate Scenario projected quantity (t)	Moderate Scenario Projected financial value ('000 Rs)
Acacia sinuata	45	224	2 623	13 114	3 200	15 999
Bambusa arundinacea (nos)	1 602	40	93 787	2 345	114 422	2 861
Curcuma aromatica	6	23	337	1 349	411	1 646
Canarium strictum	73	437	4 268	25 607	5 207	31 241
Cyclea peltata	2	19	111	1 112	136	1 357
Desmodium gangeticum	8	15	445	890	543	1 086
Emblica officianalis	119	357	6 967	20 900	8 500	25 499
Garcinia cambogea	8	76	445	4 449	543	5 428
Honey	3	115	169	6 744	206	8 228
Holostemma annulare	2	95	111	5 562	136	6 785
Hemidesmus indicus	5	43	316	2 529	386	3 086
Kavadi*	2	16	94	937	114	1 143
Mangifera indica	6	30	351	1 756	429	2 143
Nilgirianthus cilata	86	86	5 035	5 035	6 143	6 143
Piper nigrum	0.2	6	11	334	14	407
Piper longum	1	3	47	187	57	229
Sida rhambifolia	16	32	937	1 873	1 143	2 286
Solanum indicum	15	22	861	1 291	1 050	1 575
Sapindus	2	10	111	556	136	679
Terminalia chebula	4	12	244	731	297	891
Yarakasinga*	2	16	94	937	114	1 143
Zingiber zerumbet	1	4	53	211	64	257
		1 681		**98 449**		**120 112**
Moist Deciduous Zone						
	1 000 ha		89 556 ha		113 657 ha	
Acacia sinuata	131	653	11 695	58 476	14 843	74 213
Bambusa arundinacea (nos)	2 984	75	267 234	6 717	339 152	8 524
Curcuma aromatica	22	90	2 014	8 056	2 556	10 224
Curcuma zerumbet	1	6	52	520	66	660
Cinnamom zeylanicum	1	39	117	3 511	149	4 456
Canarium strictum	37	224	3 338	20 027	4 236	25 417

Desmodium gangeticum	31	62	2 765	5 530	3 509	7 018
Emblica officianalis	382	1 146	34 217	102 650	43 425	130 275
Elettaria cardamomum	1	26	77	2 305	98	2 926
Garcinia cambogea	25	255	2 281	22 805	2 894	28 943
Honey	6	251	563	22 511	714	28 569
Honey wax	1	31	70	2 794	89	3 546
Kalikarpa tomentosa	29	73	2 603	6 509	3 304	8 260
Mangifera indica	14	70	1 260	6 298	1 599	7 993
Ocimum canus	0.1	0.3	12	30	15	38
Phoenix sylvestris(bundles)	228	51	20 412	4 567	25 905	5 797
Pseudarthis vascidia	1	6	124	496	157	630
Pseudarthis vascidia	35	71	3 174	6 349	4 029	8 058
Sida rhambifolia	176	351	15 726	31 451	19 958	39 915
Solanum indicum	79	119	7 080	10 620	8 986	13 478
Sapindus	3	14	250	1 250	317	1 586
Tree moss	1	6	88	527	111	669
Terminalia chebula	22	65	1 944	5 832	2 467	7 401
Tamarindus indicus	15	74	1 326	6 632	1 683	8 417
Vateria indica	0.2	0.4	17	35	22	44
Zingiber zerumbet	6	23	526	2 104	668	2 670
		3 780		**338 633**		**429 727**
Dry Deciduous Zone						
	1 000 ha		**162 417 ha**		**103 280 ha**	
Bambusa arundinacea (nos)	133	3	22	540	14	343
Curcuma aromatica	1	3	123	493	78	313
Capcicum fruitisense	2	18	292	2 923	185. 9	1 859
Emblica officianalis	7	20	1 104	3 313	702	2 106
Honey	1	24	97	3 898	62	2 478
Phoenix sylvestris (bundles)	1	30	120	4 801	76	3 053
Tamarindus indicus	1	7	227	1 136	145	722
Zingeber zerumbet	0.3	1	42	168	27	107
		106		**17 272**		**10 981**
Dry Thorn Zone						
	1000ha		**208306ha**		**233947ha**	
Acacia sinuata	0.4	2	83	416	94	467

Bambusa arundinacea(nos)	0.1	2	18	447	20	502
Emblica officianalis	2	5	375	1 124	421	1 263
Honey	0.4	17	90	3 582	101	4 023
Phoenix sylvestris(bundles)	1 119	19	233	3 962	262	4 450
Tamarindus indicus	9	46	1 916	9 582	2 152	10 761
Termenalia chebula	0.03	0.1	7	19	7	22
Zingeber zerumbet	0.2	1	40	158	44	177
		92		19 290		21 665
Montane Zone						
	1000ha		28969.9ha		26833ha	
Bambusa arundinacea	2	53	62	1 544	57	1 430
Honey	6	236	171	6 836	158	6 332
Honey wax	1	47	34	1 367	32	1 266
		336		9 747		9 028

• Local names