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Implications of Impacts of Climate Change on Forest Product Flows and Forest Dependent Communities in the Western Ghats, India

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Abstract

The tropical wet evergreen, tropical semi evergreen and moist deciduous forest types are projected to be impacted by climate change. In the Western Ghats region, a biodiversity hotspot, evergreen forests including semi evergreen account for 30% of the forest area and according to climate change impact model projections, nearly a third of these forest types are likely to undergo vegetation type change. Similarly, tropical moist deciduous forests which account for about 28% of the forest area are likely to experience change in about 20% of the area. Thus climate change could adversely impact forest biodiversity and product flow to the forest dependent households and communities in Uttara Kannada district of the Western Ghats. This study analyses the distribution of non-timber forest product yielding tree species through a network of twelve 1-ha permanent plots established in the district. Further, the extent of dependence of communities on forests is ascertained through questionnaire surveys. On an average 21% and 28% of the tree species in evergreen and deciduous forest types, respectively are, non-timber forest product yielding tree species, indicating potential high levels of supply of products to communities. Community dependence on non-timber forest products is significant, and it contributes to Rs. 1199 and Rs. 3561/household in the evergreen and deciduous zones, respectively. Given that the bulk of the forest grids in Uttara Kannada district are projected to undergo change, bulk of the species which provide multiple forest products are projected to experience die back and even mortality. Incorporation of climate change projections and impacts in forest planning and management is necessary to enable forest ecosystems to enhance resilience.

Key Words: climate change, non-timber forest products, yield, tropical forests, Western Ghats

Introduction

Forest ecosystems provide a wide range of provisioning, regulating, supporting and cultural services broadly termed the 'ecosystem services' (MEA 2005). Forests, particularly in the tropics, are subjected to anthropogenic pressures leading to degradation and loss of ecosystem services. Human-induced climate change represents an important additional stress on many natural ecosystems and socio-economic systems which are already affected by increasing re-

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source demands and non-sustainable management practices (IPCC 1996). These climate-induced changes in landscape patterns have important implications for biodiversity (Chapin et al. 2007) and together with existing socio-economic processes such as population growth, forest fragmentation, deforestation, degradation and habitat loss, climate change could lead to significant changes in the delivery of such services (Ravindranath et al. 2006). 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 in India. The secondary impacts on local communities, local economy or regional economy are even less understood.

A preliminary assessment of impact of climate change on forest ecosystems of India showed that 77% and 68% of the forested grids are likely to experience changes in forest types, particularly shifts in the boundary under A2 and B2 scenario, respectively (Ravindranath et al. 2006). Further, the study showed large-scale likely impacts on forest biodiversity and a positive impact on net primary productivity. Thus, the projected impacts of climate change are likely to affect the yield and production of diverse forest products. In the context of this paper forest products refer to Non-Timber Forest Products (NTFPs) including grass, fruits, seeds, flowers, gum, bamboo, honey and medicinal plants. Various studies conducted in different parts of India have shown that there is a large dependence of local communities on these forest products for subsistence as well as commercial purposes (Malhotra et al. 1991; Appasamy 1993; Tewari and Campbell 1995; Ravindranath et al. 1996; Kodandapani et al. 2001; Bhat et al. 2005; Murthy et al. 2005).

Given the significant dependence of local people and economies on forests, there is a need to assess the possible impacts of climate change on forests, the resulting vulnerabilities and develop adaptation measures. It is important to make these assessments at a regional scale, given there are variations in species distribution as well as community dependence across forest types and regions. This study is focused on the Western Ghats, a biodiversity hot spot. A preliminary assessment of the impacts of climate change on ecologically sensitive region such as the Western Ghats is attempted and the study further aims to understand the vulnerability of the forest ecosystems as well as the communities dependent on these ecosystems. In particular, the potential impact of projected climate change on NTFP product supply and their implications as well as adaptation strategies is presented in this paper.

The Study Area

The Western Ghats chain of mountains run parallel and close to the west coast of India (8^{o}N 20^{o}N lat and 73^{o}E 78^{o}E long). It is a tract of high biological diversity, second only to the Eastern Himalayan range in the Indian sub-continent. The Western Ghats have been identified as one of the "hot spots" of global biodiversity. At least 4,050 flowering plants have been identified in the Ghats, of which about 1,600 are endemics (Martin 1999). About 60% of the Western Ghats is located in the state of Karnataka. In the Western Ghats region, Uttara Kannada district in Karnataka is selected for the case study to assess the implications of climate change on forest product flow and livelihoods. Uttara Kannada district in the Western Ghats was selected since forests dominate the geographic area of the district, accounting for 76.3% of the total geographic area.

Uttara Kannada district

Uttara Kannada district topographically can be divided into 3 distinct zones; the narrow coastline, the abruptly rising hills of the Western Ghats, and the flatter, elevated eastern portion that merges with the Deccan Plateau (Fig. 1). 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 eastward. The total geographic area of the district is 1,029,100 ha of which forests account 782,000 ha according to the State of Forest Report 2010, which is about 76% of the total geographic area of the district. Champion and Seth in 1968 have classified the forest on the western slope as tropical evergreen and included the forest of the eastern zone in the category of south Indian moist deciduous type. Based on rainfall and vegetation types, the district can be broadly divided into evergreen/semi-evergreen forest zone and drier secondary/moist deciduous zone.

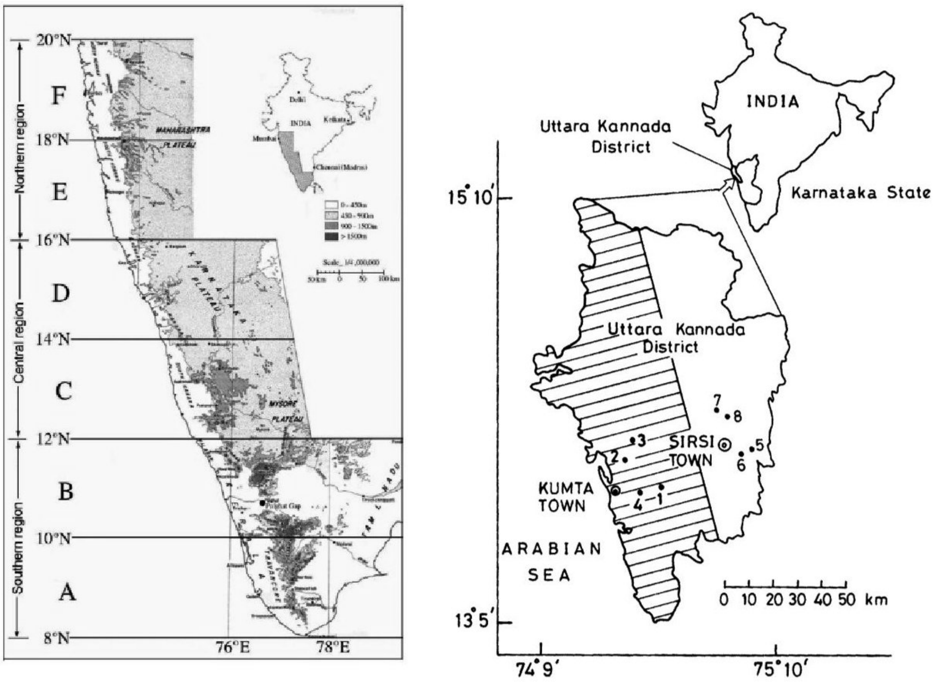

Fig. 1. Map of Southern Western India and Uttara Kannada district showing broad vegetation.

Climate and Vegetation Model and Scenarios

The impacts of climate change on forests in India are assessed based on the changes in area under different forest types, shifts in boundary of forest types and changes in NPP (net primary productivity). This assessment was based on spatial distribution of (i) current climatic variables, (ii) future climate projected by relatively high-resolution regional climate models for SRES A1B emission scenario, and (iii) vegetation types and NPP as simulated by the global dynamic vegetation model IBIS v.2 (Integrated Biosphere Simulator). Detailed information about the methodology and IBIS model used is given in Chaturvedi et al. (2011).

In this study, data from the HadCM3 GCM (Global Circulation Model), downscaled by PRECIS model, a regional climate model for downscaling climate projections is used. Climate change projections were made for monthly mean values of temperature (average, maximum, minimum, monthly mean values of precipitation and at grid-spacing of 0.44250 latitude by 0.44250 longitude. IBIS requires a range of input parameters including climatology as well as soil parameters (Kucharik et al. 2000).

In this study, the future period 2021-2050 under SRES scenario A1B (atmospheric CO_2 concentration of 490 ppm by 2035) is considered. The mid-year for this future period is 2035, and hence we refer to this assessment period as the "2035" scenario.

The model has been well-validated for the Indian region (Chaturvedi et al. 2011). Comparison of simulated vegetation cover with the observed vegetation (Champion and Seth 1968) shows fair agreement. Many important observed vegetation features are simulated by the model, specifically the placement of tropical evergreen forest vegetation in the Western Ghats.

Impact of Climate Change on Forests of Western Ghats

The impact of climate change on the forests of Western Ghats is assessed with respect to potential shift in vegetation types or Plant Functional Types and changes in NPP for the region (Gopalakrishnan et al. 2011). The results are presented only for the forested grids of the region. The entire Western Ghats region is covered by 54 grids, out of which 10 (18%) of them are projected to undergo change. The forests in areas where IBIS predicts vegetation shift are

Table 1. Summary of vulnerable vegetation types for the Western Ghats (Gopalakrishnan et al. 2011)

Champion and Seth type	Number of grids	% of grids as per Champion and Seth classification	Number of grids where vegetation shift is projected	% of grids where vegetation shift is projected
Tropical Wet Evergreen Forest	6	11.11	2	33.33
Tropical Semi Evergreen Forest	10	18.52	3	30.00
Tropical Moist Deciduous Forest	15	27.78	3	20.00
Tropical Thorn Forest	13	24.07	2	15.38
Tropical Dry Deciduous Forest	10	18.52	0	0.00
Total	54	100.00	10	18.52

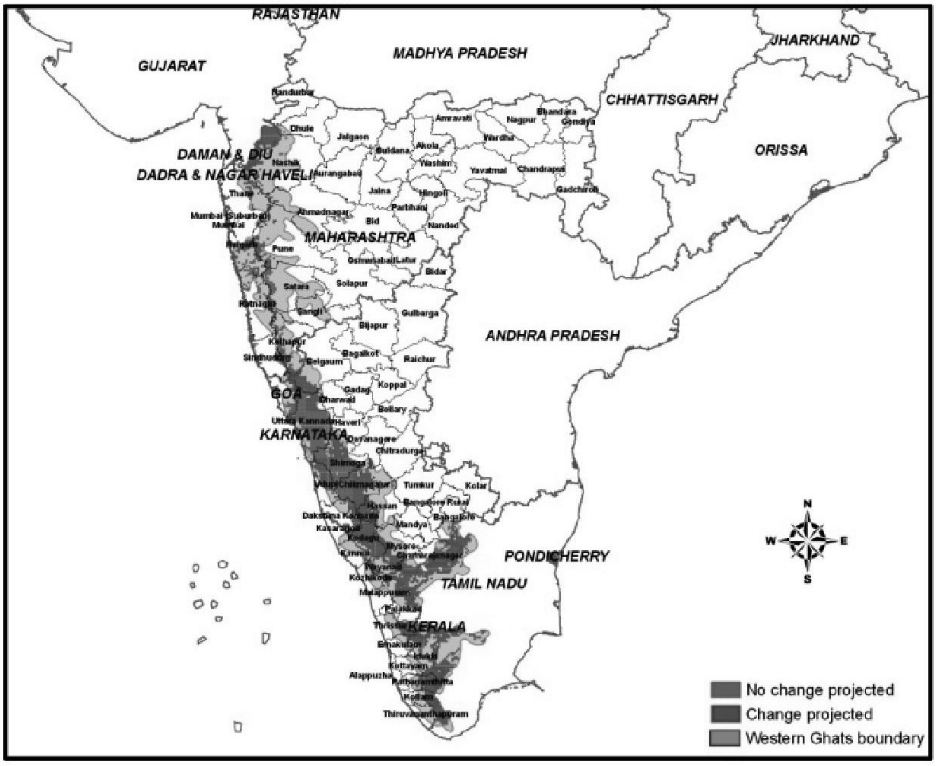

Fig. 2. Vegetation change projected by 2035 under A1B scenario in the Western Ghats.

considered vulnerable to climate change. This is because the future climate may not be optimal to the current vegetation in those places. In other words, 18% of forested grids in the region are projected to be vulnerable to climate change.

The Champion and Seth classification of forest types is used to assess the current vegetation at these vulnerable grids. The salient results are shown in Table 1. Tropical wet evergreen forested grids are most vulnerable to climate change with 2 out of the 6 grids projected to undergo change. Similarly, tropical semi evergreen as well as moist deciduous forests are also projected to be impacted by climate change (Table 1).

It can be observed from Fig. 2 that the case study region of Uttara Kannada district and the neighbouring regions are projected to experience change in the forest or vegetation type compared to, the rest of the Western Ghats region. Uttara Kannada district is dominated by moist deciduous and evergreen forests, which are likely to be impacted by climate change. Thus the forests in Uttara Kannada district seem to be vulnerable to climate change impacts. The projected impact of climate change on forests of Uttara Kannada district is likely to affect the species assemblage, biodiversity, the forest product flows and the local communities depending on the forest product flows, which is analysed in the following sections.

Distribution of Non-Timber Forest Products Yielding Tree Species in The Forests of Uttara Kannada

Forests provide a range of products and services to local communities, the national economy and international trade. These include timber and non-timber forest products, widely referred to as NTFPs. The importance of NTFPs in the economy has always been underplayed because most of the products are largely for subsistence use (FAO 1997).

A network of twelve 1-ha permanent plots have been established in the Uttara Kannada district, across a rainfall gradient in evergreen and deciduous forest types under HSBC - Earthwatch Climate Partnership Programme during 2008-2009. Of these six are evergreen and six are deciduous forest plots. In each location, two 1-ha plots were selected; one close to the settlement and another a little away from the settlements (1 to 2 kms). Plot method was adopted to study the vegetation status. All the trees in the plots were enumerated for species distribution, density and biomass through measurement of girth and height of all stems above 10 cm GBH (Girth at Breast Height) in the tree plots as well as 10 sub-plots of shrubs for every 1-ha tree plot during 2009 and again in 2011-2012. Further, household survey was conducted in the villages in the vicinity of the established plots using a questionnaire to assess the level of dependence of communities on forest products and to identify the end uses of the forest products.

Biodiversity of the evergreen and deciduous forest plots and distribution of non-timber forest product yielding species

Shannon Wiener diversity index was calculated following Krebs 1999. It can be observed from Table 2 that both evergreen and deciduous forest plots are biodiversity rich with high Shannon Wiener diversity index in the range of 2.48 to 3.50 with only one plot having less than 2.0. The number of tree species in the evergreen plots ranged from 56 to 89 and in the deciduous plots it was in the range of 22 to 60 and the number of individuals ranged from 761 to 1822 in evergreen and 342 to 818 in the deciduous plots.

In all the 12 forest plots of evergreen as well as deciduous forest types, tree species yielding NTFPs were ascertained based on literature and household surveys conducted in the adjacent villages. The number of NTFP yielding tree species in 1-ha evergreen plots ranged from 7 to 24 and the highest number of 24 was recorded in the 1-ha plot of Tattikai (Table 2). Similarly among the deciduous plots, 7 to 13 NTFP yielding tree species were recorded. Among the evergreen plots, the highest percentage of NTFP yielding tree species (29%) of the total number of species was recorded in Hosur while among the deciduous plots, the 1-ha plot in Hudelakoppa recorded as high as 59% of the total number of species to be NTFP yielding. On an average 21% and 28% of the tree species in evergreen and deciduous forest types, respectively are NTFP yielding tree species, indicating potential high levels of supply of products to communities (Table 2).

It is evident from Table 3 that the density of NTFP yielding tree species is substantive in all the plots, both evergreen and deciduous. Among the evergreen plots, the density of *Hopea wightiana* is highest followed by *Aporosa lindleyana*, a tree yielding edible fruits and green leaves for manure and *Memecylon umbellatum* and *Aglaia roxburghii* also medicinal tree species.

Among the deciduous forest plots, *Calycopteris floribunda*, *Randia spinosa*, *Aporosa lindleyana*, *Randia uliginosa* and *Macaranga peltata* are the top five species accounting for 69% of the total density of the deciduous plots (Table 3). Of these, *Calycopteris floribunda* and *Aporosa lindleyana* are gathered for their medicinal properties, *Randia uliginosa* yields small timber used as fencing material and the leaves of *Macaranga peltata* are used as manure and *Randia spinosa* fruits are used as fish poison.

It is interesting to note that the density of NTFP yielding tree species accounts for 43% and 38% of the total number of individuals recorded in evergreen and deciduous forest types, respectively. This indicates the presence of large diversity and density of NTFP yielding tree species in the evergreen and deciduous forest types of the Western Ghats. The end uses of the NTFP tree species recorded in the ev-

Table 2. Number of NTFP yielding tree species in 1-ha forest plots

Forest type	Location	Total no. of tree species	Total number of individuals	Diversity index	NTFP species	% NTFP species
Evergreen	Ekkambi	64	761	3.25	7	11
		56	923	3.00	9	16
	Tattikai	74	1,822	3.25	16	22
		89	1,376	3.33	24	27
	Hosur	56	1,685	2.74	13	23
		59	1,183	2.78	17	29
Deciduous	Hudelakoppa	40	342	1.98	13	33
		22	604	2.48	13	59
	Panchavati	52	818	2.90	7	13
		48	774	2.81	10	11
	Togralli	53	682	3.50	12	23
		60	721	3.11	13	22

ergreen and deciduous forest plots are given in Appendix 1. It can be observed that 29 tree species in the sampled villages and forest plots provide NTFPs to local communities. The dominant use of these species is for medicinal purposes - both human as well as livestock, followed by use as food at the household level (Table 3).

Community Dependence on NTFPS

A range of NTFPs are collected and used by the local communities for various purposes - food, fibre, fodder, flavor/fragrance, fatty oils, gums, resins, medicinal herbs, religious rituals, structural material, household articles, agricultural implements, etc. NTFPs are of importance to forest-dependent communities for subsistence and as raw material for handicrafts and for sale to industry. The dependence of communities and industries on forests of Uttara Kannada district has been assessed by Murthy et al. (2005) and Bhat et al. (2005). The flow of forest products was assessed by these studies by sampling households in villages that fall within different forest types, using the questionnaire method. Murthy et al. (2002) report that almost all rural households gather products such as fuelwood, medicinal plants etc., for subsistence use and some households are also involved in the collection of commercially valuable products and in all about 50% of the rural households in the district are involved in NTFP collection. A similar study for understanding the dependence of communities on forests in the villages around the forest monitoring plots was undertaken in all the villages close to the permanent plots in both the evergreen and deciduous regions during the year 2010. The survey was conducted in 6 villages close to the permanent plots; 3 close to the evergreen plots - Ekkambi, Tattikai and Hosur and 3 others close to deciduous plots - Panchavati, Hudelakoppa and Togralli.

Questionnaire survey was conducted to collect information on; i) diversity of NTFPs extracted, the parts of the trees used, their end use as well as the season of collection, and ii) quantity of NTFPs gathered per typical trip and quantity collected in a season. To conduct the study, the households were stratified, based on their land holding as large farmers (>2 ha), medium farmers (1.2 to 2 ha), small farmers (<1.2 ha) and landless. If the number of households was less than 5 in a category, 100% sampling was done; in others, 25% of the households were randomly selected for the survey. There is 100% dependence of all the three land holding categories (large farmer, medium farmer and small farmer) as well as landless for fuelwood in both evergreen and deciduous forest villages and therefore no separate discussion on the same is included. Further, the dependence of communities has been assessed mainly for tree-based NTFPs only and the same is discussed here.

Diversity of NTFPs gathered and end use

Table 4 presents percentage of households collecting NTFPs and end use of the different species is presented in

Table 3. Distribution and density of NTFP yielding tree species in evergreen and deciduous forest plots (where 1 and 2 refer to 1-ha forest plot numbers in each village)

Species name	Evergreen						Deciduous						Total
	Ekkambi		Tattikai		Hosur		Panchavati		Hudelakoppa		Togralli		
	1	2	1	2	1	2	1	2	1	2	1	2	
Aglaia roxburghii			25	8	157	23					12	45	270
Anogeissus latifolia							4			1			5
Aporosa lindleyana	6	129	64	438	11	61			142	3		7	861
Artocarpus hirsutus				11	3	4							18
Artocarpus integrifolia			4	1									5
Artocarpus lakoocha			7	5		1					1		14
Calycopteris floribunda	2	61		13	1		41	141	54	100	65	18	496
Careya arborea				21		2	16	6		20	8		73
Cinnamomum zeylanicum			9	20	2	26					2	23	82
Emblica officinalis		6		2					2	4	1		15
Ervataemia heyneana				25		12	3	24	6		18	18	106
Eugenia jambolana			10	18		3	1	3	5	23	5	12	80
Flacourtia montana	19	14	39	96	8	15						3	194
Garcinia cambogea			75	1	14	34							124
Garcinia indica			13	8									21
Garcinia morella			140	13	26	29							208
Hopea wightiana	2		21	1	48	595							667
Ixora brachiata	12	107	59	25	83	110			1	10		22	429
Macaranga peltata	11	7		1		1			9		60	47	136
Mangifera indica					2	4					3		9
Memecylon umbellatum	1		4	6	257	66						1	335
Murraya koenigii								13	32	28	11	5	89
Myristica beddomei			1		9	32						20	62
Myristica malabarica			1	1									2
Randia spinosa		67	3	39			1	2	130	94			336
Randia uliginosa		8		10				26	72	18		12	146
Sapindus spp.									4		1		5
Terminalia bellerica				2			1	9	3	4			19
Terminalia chebula				1				1		2			4
Ziziphus rugosa		3						10	1	26			40

Appendix 1. Some species such as *Syzigium cuminii*, *Ziziphus rugosa*, *Artocarpus lakoocha*, *Artocarpus integrifolia* and *Mangifera indica* are collected from both evergreen as well as deciduous forest types. However, species such as *Garcinia cambogea* and *Myristica* spp., are gathered only in the evergreen forests. Similarly species such as *Tamarindus indica* and *Flacourtia montana* are gathered only in the deciduous forest type.

Among various products, species with commercial importance such as *Garcinia cambogea* is collected by 26% and 19% of the households respectively in Tattikai and Hosur villages of the evergreen zone. 14% of households in Hosur, an evergreen village collect 2 other NTFPs that are commercially important - *Garcinia indica* and *Myristica* spp (Table 4).

Carissa carandas is collected for its fruits in only one evergreen village (Tattikai) while the same is gathered in all the three deciduous forest villages (4 to 17% households). *Artocarpus lakoocha* is gathered by 48% of the Households in the Hosur, an evergreen forest village. The same is extracted by 3 to 8% of the Householdss in 2 of the 3 deciduous forest villages (Table 4). *Mangifera indica* and

Table 4. Percentage of households collecting tree-based NTFPs from different species

Location (% dependent households) / Species name	Ekkambi (13.4%)	Tattikai (26.3%)	Hosur (47.6%)	Malgi (9.6%)	Hudelakoppa (34.2%)	Togralli (42.3%)
Garcinia cambogea		26.3	19.0			
Syzigium cuminii	1.2	18.5		3.9	20.0	
Carissa carandas		18.5		7.7	17.1	3.9
Ziziphus rugosa	2.4	11.1			2.9	3.9
Garcinia indica	9.8		14.3			38.5
Myristica spp.			14.3			
Artocarpus lakoocha	6.1		47.6		2.9	7.7
Mangifera indica	2.4		14.3		8.6	3.9
Artocarpus intergrifolia	1.2		19.0		11.4	15.4
Tamarindus indica					2.9	
Emblica officinalis	1.2				2.9	
Flacourtia montana						15.4
Poles	42.7	42.7	33.3	50.0	68.6	65.4
Leaf manure						
Green	-	2.2	9.7	-	10.0	2.2
Dry	30.6	15.5	25.8	3.8	20.0	25.8

Table 5. Socio-economic aspects of NTFP collection in the study villages

Forest type	Village name	Percent farmers involved in NTFP collection			
		Large farmer	Medium farmer	Small farmer	Landless
Evergreen	Ekkambi	-	35	43	39
	Tattikai	-	16	9	19
	Hosur	21	21	9	16
	Average	21.0	24.0	20.3	24.7
Deciduous	Hudelakoppa	28	35	21	28
	Malgi	21	21	30	32
	Togralli	26	19	17	17
	Average	25.0	25.0	22.7	25.7

Artocarpus integrifolia are collected in 2 of the evergreen as well as deciduous villages (except Tattikai and Malgi).

Leaves, both green and dry are gathered in all the villages, except Ekkambi and Malgi, as leaf manure to crop fields, and green leaves are also collected for use as fodder (Table 4). The percent dependence of households on green leaves (2.2 to 10%) is comparatively lower than the dependence on dry leaves (about 4 to 31%). The percent dependence of evergreen forest villages on dry leaves is slightly more (24%) than that of the deciduous forest villages (17%). The dependence for poles is highest in the deciduous forest village of Hudelakoppa (68.6%) followed by Togralli (65.4%) and Malgi - both deciduous forest villages. Thus the percent dependence of deciduous forest villages for poles is higher (61%) than that of the evergreen forest villages where the percent dependence is 33% to 43%, with an overall average percent dependence of 40% (Table 4).

Dependence on NTFPs according to land holding size

The percent of households collecting NTFPs according to land holding size is given in Table 5. It can be observed that, households belonging to all land holding categories

Table 6. Percentage of households gathering NTFPs from different tree species, quantities gathered and financial value realized at the household level per annum

Forest type	Species	Percent dependence of gathering households (%)	Quantity gathered (kg/household)	Financial value (Rs./household/year)
Evergreen	*Artocarpus intergrifolia*	3	4	105
	Artocarpus lakoocha	6	15	750
	Garcinia cambogea	6	234	18,680
	Garcinia indica	15	19	772
	Mangifera indica	4	3	98
	Myristica spp	8	10	4,500
	Ziziphus rugosa	2	2	20
Deciduous	*Artocarpus intergrifolia*	10	8	225
	Artocarpus lakoocha	21	31	1,550
	Carissa carandas	7	4	70
	Emblica officinalis	3	15	600
	Flacourtia montana	6	3	60
	Garcinia indica	4	2	80
	Mangifera indica	10	169	5,932
	Syzigium cuminii	3	2	100
	Tamarindus indica	3	3	150
	Ziziphus rugosa	2	0.5	5

and the landless collect NTFPs, with no major difference among the land holding groups (Table 5).

Potential economic value of NTFPs in evergreen and deciduous forest types

It is generally believed that the value of NTFPs gathered from the forests is high. But, very little information is available on the financial value of NTFPs extracted on per hectare basis for the different forest types.

In Table 6, the overall percent dependence of households, the average quantities and financial value of the NTFPs gathered in the evergreen and deciduous forest zones are presented. It can be seen from Table 6 that the percent of households depending on different NTFPs in the evergreen villages ranges from 2% on NTFPs such as *Ziziphus rugosa* primarily used at the household level to 15% dependence on commercially important species such as *Garcinia indica*. The quantity of NTFPs gathered is large for commercially important species such as *Garcinia cambogea* (234 kg) while for others that are primarily used at the household level, quantities range from 2 to 19 kg (Table 6). The financial value of the NTFPs gathered by considering the current market prices indicates that per household income from some of the commercially important NTFPs such as *Garcinia cambogea* and *Myristica* spp., is substantial (Table 6).

In the deciduous forest villages, the percent of households depending on NTFPs varies from 2% on *Ziziphus rugosa*, gathered for household consumption to 21% for *Artocarpus lakoocha*, a commercially important species (Table 6). The quantity of NTFPs gathered is small as compared to the evergreen forest villages. It ranges from less than one kg of *Ziziphus rugosa* to about 169 kg of *Mangifera indica*. The financial value of products gathered is insignificant for some of the NTFPs (Table 6) and substantial for products such as *Artocarpus lakoocha* (Rs. 1550/Households) and *Mangifera indica* (Rs. 5932/Households).

Thus the contribution of NTFPs to household income could be significant in both evergreen and deciduous forest villages. It is estimated that the value of NTFPs realized per household is Rs. 3561/household in the evergreen and Rs. 1199/household in the deciduous zone. A similar study by Murthy et al. (2005) reported Rs 3445 and Rs. 1233/household for the evergreen and deciduous zones (Table 6).

Implications of Climate Change on Forest Products And Livelihoods

In the Western Ghats region, evergreen forests including semi evergreen account for 30% of the forest area and according to model projections, nearly a third of these forest types are likely to undergo change. Similarly, tropical moist deciduous forests which account for about 28% of the forest area is likely to experience change in about 20% of the area. It can be observed from Fig. 2, that bulk of the forest grids consisting of Evergreen and Moist Deciduous forest types in the Uttara Kannada district are projected to undergo change, which means the projected climate by around mid 2030s will not be optimal for the existing vegetation type or species assemblage. This could mean that in the next 30 to 50 years, bulk of the species which provide multiple forest products are projected to experience die back and even mortality. Thus, climate change even for the short term period of 2030s could have adverse impacts on the production and supply of NTFPs in Uttara Kannada district.

The dependence of communities on the forests for livelihoods, nutrition and as a source of raw material for a range of household consumption and commercial purposes is high in the district. The projected impact of climate change on forests in the district is therefore likely to adversely impact the forest product flow to the forest dependent households and communities. Forest-based communities in developing countries are especially vulnerable because of limited adaptability in rural, resource-dependent communities to respond to risk in a proactive manner (Davidson et al. 2003).

Incorporation of climate change projections and impacts in forest planning and management, in particular the forest working plans of the state forest department and development of adaptation strategies and practices is necessary to enhance resilience of forest ecosystem. Potential illustrative adaptation strategies and practices (Murthy et al. 2011) to be incorporated include the following:

- Modification of the forest working plan preparation process, incorporating projected climate change and likely impacts
- Initiation of research on adaptation practices, covering both conservation and forest regeneration practices
- Linking of Protected Areas and forest fragments
- Anticipatory planting of species along the altitudinal and latitudinal gradient, particularly NTFP yielding tree species
- In situ biodiversity conservation
- Adoption and promotion of mixed species forestry in all afforestation programmes
- Incorporation of fire protection and management practices and implementation of advance fire warning systems

Some of the potential adaptation strategies to enhance the resilience of the communities to the projected climate impacts on the forests and forest product flows include the following:

- Promotion of sustainable biomass extraction and grazing practices since degraded forests are more vulnerable to climate change
- Increasing efficiency of use of forest products such as fuelwood through promotion and dissemination of fuel efficient cook stoves as well as biogas
- Promotion of livelihood diversification activities such as agro-forestry
- Promotion of afforestation and reforestation programmes incorporating NTFP yielding tree species that are likely to be tolerant to projected climate change.

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Appendix 1. End use of NTFP yielding tree species

Species	Primary use	Secondary use
Aglaia roxburghii	Green leaves for manure	Small timber
Anogeissus latifolia	Medicine	Timber
Aporosa lindleyana	Edible fruits	Green leaves
Artocarpus hirsutus	Edible fruits	Timber
Artocarpus integrifolia	Edible fruits, Vegetable	Timber
Artocarpus lakoocha	Seeds souring agent	Edible fruits, timber
Calycopteris floribunda	Green leaves for manure	
Careya arborea	Green leaves for manure	Timber
Cinnamomum zeylanicum	Leaves and bark as spice	Medicine
Emblica officinalis	Edible fruits	Pickled
Ervataemia heyneana	Green leaves	Medicine
Eugenia jambolana	Edible fruits	Timber
Flacourtia montana	Edible fruits	Fuelwood
Garcinia cambogea	Edible oil, and pickling	Fat and medicine
Garcinia indica	Edible fruits	Fat and medicine
Garcinia morella	Seeds edible oil	Medicine
Ixora brachiata	Green leaves for manure	Small timber and ornamental
Macaranga peltata	Green leaves for manure	Fuelwood
Mangifera indica	Edible fruits	Pickled
Memecylon umbellatum	Medicine	Fuelwood, Construction
Murraya koenigii	Edible leaves	Medicine
Myristica beddomei	Medicine	
Myristica malabarica	Spice	
Randia spinosa	Fruits/bark fish poison	Medicine
Randia uliginosa	Fencing material	
Sapindus spp.	Fruits cleansing agent	
Terminalia bellerica	Fruits medicine	Green leaves for manure
Terminalia chebula	Fruits medicine, oil	Green leaves for manure
Ziziphus rugosa	Fruits edible	Fencing material