Analysis of the effects of anthropogenic interferences on tree species composition in the forests of Dadra and Nagar Haveli, India

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The composition, dominance and diversity of trees species as analysed during an extensive vegetation survey of the forests of Dadra and Nagar Haveli in 2005, conducted for the revision of the Working Plan, were compared with the results of surveys conducted in 1984–85 for the preparation of the last Working Plan of this division. The study reveals the nature of changes effected on the character and composition of the forests as a result of increasing human interference and simultaneous changes in microclimate. The study may help forest managers in taking suitable corrective measures to ameliorate the present condition.

Keywords: Anthropogenic pressure, deforestation, diversity, dominance, tree species composition.

THE impact of human activities like commercial logging[1], establishment of pastures by clearing forests and shifting agriculture on biodiversity is reflected in the depleting forest cover on the one hand, and changes in the quality and composition of the forest community on the other. Any discussion on deforestation and its effects has to dwell on these two issues.

The unabated degradation of forests in India[2] has caused the forest cover area to decline from 71.8 mha in 1951 to around 67.8 mha in 2003. The per capita availability of forestland had declined steadily from 1.2 ha in 1951 to a meagre 0.0747 ha in 2001, as against 0.2 ha in the Asia-Pacific region[3]. Although the total forest area of the country is recorded to be around 774, 740 km^2, the extent of illegal encroachment is estimated[4] to be as much as 9860 km^2. Increased human activities in the forested areas have not only led to depletion of forests, but have also affected the quality of the forest ecosystem. In just two years between 2001 and 2003, India has lost about 7% of its dense forests[5] (with canopy cover of 10% or more). Factors like trampling and destruction of seedlings by feral cattle and scalding of the forest floors by man-made fires affect the regeneration of the forests, jeopardizing the future of the forest crop. Untreated sludge discharged by industrial units into streams flowing through forests, and dust and smoke from traffic on roads passing through forests also contribute to the degradation of the forests and affect the livelihoods of people dependent on them.

Study area

The Union Territory of Dadra and Nagar Haveli (DNH) is a hilly and forested tract nestled between Maharashtra and Gujarat, on the western coast of India. This tribal-dominated territory lies on the northern fringes of the Western Ghats between 20–20°25′N lat. and 72°50′E–73°15′E long., spread over an area of 491 km^2 (Figure 1). The forest is scattered over the whole territory and constitutes 45% of its total area. The terrain is hilly and undulating with elevation between 40 and 600 m amsl. The territory is criss-crossed by numerous seasonal streams originating in the Western Ghats and meandering through the forest towards the Arabian Sea. The principal river of this area is the Damanganga.

The geological strata of the area are of Deccan Trap Formation, principally basaltic volcanic rocks. The soil is

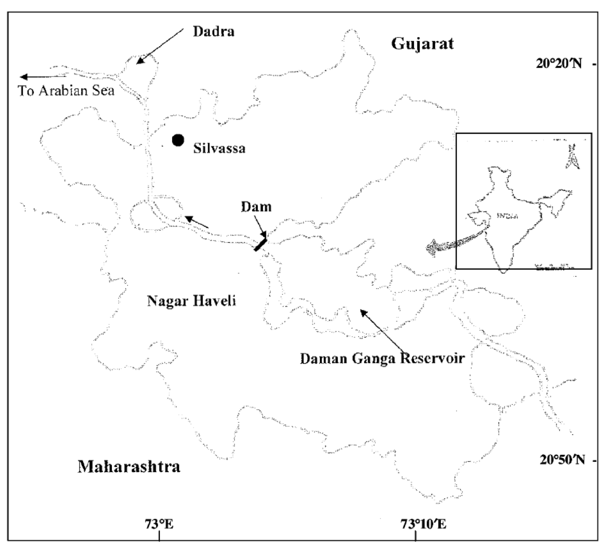

Figure 1. The study area.

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generally lateritic and shallow[6]. Soil in the forest areas is conspicuous by the absence of humus, attributable to the burning of litter (rab burning) on the forest floor by tribals for raising crops. The water-holding capacity of the soil is low and rain water drains away rapidly. Thus although the area gets abundant rainfall (190–250 cm annually) between June and September, much of the area remains dry during the remainder of the year. The climate is warm, humid and equitable due to its proximity to the Arabian Sea.

Once an isolated Portugese territory inhabitated by tribes like Varli, Dhodia and Dubla, Kokna, DNH and its neighbouring areas such as Vapi in Gujarat and Dahanu in Maharashtra have witnessed considerable industrialization in the last decade. This, coupled with its vicinity to the Mumbai and Ahmedabad industrial belt, has led to rapid urbanization, transformation of the rural lifestyle, disruption of the traditional way of life and increasing anthropogenic pressure on the forests. The population has nearly trebled from 74,170 in 1971 to the present 220,451 (2001 census), as a large migrant workforce and people from different professions linked to its fledgling industries have settled here. The indigenous people have also become marginalized, constituting only about 62% of the total population, down from 87% in 1971.

The composition of the forests is largely determined by anthropogenic factors such as livestock pressure, illicit felling, encroachment, industrialization, etc. The forests in the north and southern parts of DNH differ on account of crop composition, moisture condition, history of exploitation, etc. There is an intimate mixture of deciduous and evergreen species, usually 20–25 m high. Most of the dominant trees are deciduous and the evergreen species thrive in the lower storey of the forest. Undergrowth is greatly influenced by fires. The forests in the northern part of the territory are of $3B/C_2$ type, i.e. South Indian moist mixed deciduous forest[7], while those in the south are basically teak-bearing ($3B/C_{1b}$ type). Due to rampant felling, few teak trees remain and the present dominant tree species is *Terminalia tomentosa*. Bamboo undergrowth is common, though locally absent, where evergreens are dominant. Absence of new recruitment is marked and is ascribable to grazing pressure and fire.

As everywhere else, the brunt of development and industrialization has been borne by the forests. The once lush teak forests have been degraded due to overexploitation and illicit felling. The forests of Dadra and Nagar Haveli have become honeycombed, with each village or settlement being a focus of clearing of the forests. The increasing fragmentation of the forests has rendered them virtually unviable for supporting any significant wildlife population. Fragmentation has also led to enhanced degradation along the edges of the patches as it is not possible for the Forest Department to ensure protection to such disjunct patches. Continued exploitation, overgrazing and accelerated erosion along hill slopes have changed the original character of the forests. This article analyses the changes in the composition of forest tree species over the last two decades.

Methodology

The enumeration results of the last Working Plan of the Dadra and Nagar Haveli Forest Division were analysed to obtain the vegetation structure, dominance and abundance of tree species in the forests of Nagar Haveli during 1984–85, when the last extensive enumeration of forests was done before the present survey.

The methodology of the Forest Survey of India (FSI), Dehradun[8] for forest inventory preparation was followed during field survey for the revision of the Working Plan of this Forest Division. The forest cover map of DNH of 1 : 50,000 scale was divided into 144 equal grids. The forest area in each grid was noted and thirty grids were found to have Reserve Forest area. Sample plots were located in each grid in such a manner that the survey covered the whole of the Reserved Forest area. The sampling intensity was about 0.7%. However, taking field conditions into account, the area of sample plots for trees was increased to 0.25 ha, i.e. sample plots were made 50 m × 50 m instead of 0.1 ha as mentioned in the *FSI Manual*. Data regarding regeneration were collected from four square plots of 3 m × 3 m, one at each corner of the sample plot for trees. Ninety sample plots were laid spread over the whole forest area and the sites were recorded by GPS for future verification.

The vegetation data were quantitatively analysed for abundance and density. Species diversity for the two time periods of the forest was determined using the Shannon–Weiner index[9]. Concentration of dominance (C)[10] was measured as follows:

$$C = -\sum (ni/N)^2,$$

where ni is the total number of individuals of species i and N is the total number of individuals of all the species in that vegetation type.

The state of regeneration of some of the important species was assessed based on the following categories: (a) 'good', if seedlings > saplings > adult; (b) 'fair', if seedlings > saplings ≤ adult; (c) 'poor', if a species survives in only sapling stage but not as seedling (though saplings may be less, more or equal to adults; (d) 'none', if a species is absent both in sapling and seedling stage but present as adults[11].

Results and discussion

Changes in tree species composition

The present survey revealed 46 tree species belonging to 21 families (Table 1). Leguminaceae was the most diverse

Table 1. Comparative figures of family-wise tree species, relative density and relative dominance in the previous and present survey

	No. of tree species recorded		Relative density		Relative dominance	
Family	1985	2005	1985	2005	1985	2005
Anacardiaceae	2	2	0.031	0.029	0.035	0.031
Anonaceae	2	2	0.01	0.042	0.011	0.045
Apocynaceae	2	1	0.11	0.04	0.04	0.024
Boraginaceae	1	–	0.006	–	0.005	–
Burseraceae	1	2	0.08	0.014	0.095	0.015
Combretaceae	4	4	0.22	0.322	0.2	0.327
Ebanaceae	1	1	0.011	0.02	0.009	0.014
Euphorbiaceae	2	2	0.032	0.025	0.04	0.025
Flacourthaceae	1	2	0.02	0.006	0.01	0.003
Leguminaceae	15	13	0.13	0.15	0.1	0.168
Lytharaceae	2	1	0.026	0.03	0.04	0.02
Moraceae	2	2	0.027	0.017	0.03	0.015
Myrtaceae	1	2	0.004	0.013	0.003	0.01
Rubiaceae	3	3	0.077	0.061	0.12	0.05
Rutaceae	1	2	0.009	0.045	0.01	0.040
Sapotaceae	1	1	0.018	0.092	0.04	0.145
Ulmaceae	2	1	0.002	0.006	0.003	0.004
Verbenaceae	2	1	0.17	0.075	0.19	0.048
Others (four families)	4	4	0.017	0.013	0.019	0.016

family with 13 species and Combretaceae was the most dominant family followed by Leguminaceae and Sapotaceae. In the previous study, 49 different tree species belonging to 22 families were recorded. While Leguminaceae was the most diverse with 15 species, Combretaceae was the most dominant. The other two most dominant families were Verbenaceae and Leguminaceae. One of the two tree species belonging to Verbenaceae, *Gmelina arborea* and *Trema orientalis* belonging to Ulmaceae, could not be found during the present survey. Similarly, no species of Boraginaceae could be found though it was reported during the previous study.

The percentage cumulative abundance values[12] (*k*-dominance) of the different families reflecting the intrinsic tree species diversity of the forest show that Combretaceae is the most dominant family, i.e. its dominance has increased from 21.6% to more than 34% in last two decades (Table 2). This indicates relative decline in the number of individuals of other families relative to Combretaceae. The dominance of the tree species of the Verbenaceae family has come down from 17% to only about 7%.

The tree species diversity (Shannon–Weiner index) varies from 1.263 to 1.018 in the different girth classes (Table 3). The highest diversity was found in the 60–90 cm girth class. Similarly, the dominance index varies from 0.0809 to 0.174 (Figure 2 *a* and *b*). Diversity (Shannon–Weiner index) varied from 1.315 to 1.185. Dominance varied from 0.078 to 0.104. Shannon–Weiner diversity index and dominance values stand quite far apart.

Anthropogenic intervention has resulted in definitive changes in composition of the forest. The composition of teak-bearing deciduous forests now resembles mixed deciduous forests. The percentage cumulative abundance value (*k*-dominance) of the family Verbenaceae has declined from about 17 to less than 9 in the last two decades, mainly due to elimination of most of the teak by illicit felling. As a result of elimination of teak, the associate species of teak, mainly *Terminalia* sp. have become relatively abundant.

The ecological effects of deforestation like increased run-offs and accelerated erosion have also affected the edaphic and moisture conditions of the forest, which is also reflected in the changes in the composition of forest crop. Increased run-off and erosion of topsoil has decreased infiltration and consequent decline in available soil moisture, resulting in water stress. In such conditions only those species which are adapted to drier conditions, like *Butea monosperma*, *Sterculia urens*, *Writhia tomentosa*, *Aegle marmelos*, etc. are able to survive successfully. Thus the forest is gradually shifting from a moist deciduous type to a dry deciduous one resembling the dry mixed deciduous forest type (5A/C_3), characteristic of many parts of this region[13]. One of the indicators in this regard is the relatively significant presence of *Boswellia serrata* observed during the present survey, but not reported in the last survey or other ethnobotanical studies[14,15], possibly due to the rarity of its occurrence. The increasing presence of *Boswellia* sp., which is a characteristic species of dry deciduous forests in India, indicates the increasing moisture deficiency in these forests. This can be further confirmed by the contrasting moisture conditions prevailing in most of the forest areas which are subject to anthropogenic pressure and small patches of forests which

Table 2. *k*-dominance of different families in the forests of DNH according to the two surveys

k-dominance			
Present survey (2005)		1984–85	
Family	Cumulative dominance score	Family	Cumulative dominance score
Combretaceae	34.15	Combretaceae	21.65
Leguminaceae	48.83	Verbenaceae	38.55
Sapotaceae	58.90	Leguminaceae	51.28
Verbenaceae	66.10	Apocynaceae	62.32
Rubiaceae	72.55	Burseraceae	70.60
Anonaceae	77.13	Rubiaceae	78.30
Apocynaceae	81.15	Euphorbiaceae	81.45
Lytharaceae	84.35	Anacardiaceae	84.53
Anacardiaceae	87.22	Moraceae	87.23
Euphorbiaceae	89.75	Lytharaceae	89.85
Ebanaceae	92.21	Flacourthatceae	91.85
Moraceae	94.00	Sapotaceae	93.65
Bursusaceae	95.51	Ebanaceae	94.74
Myrtaceae	96.69	Tiliaceae	95.82
Others (seven families)	100	Anonaceae	96.80
		Others (seven families)	100

Table 3. Diameter-class wise dominance and diversity indices

		Girth classes				
Diversity/dominance index	Year	30–60	60–90	90–120	120–150	150 and above
Shannon–Weiner index	1985	1.326	1.334	1.315	1.273	1.105
	2005	1.263	1.301	1.275	1.208	1.118
Dominance	1985	0.07	0.068	0.078	0.087	0.104
	2005	0.081	0.071	0.087	0.101	0.129

have escaped disturbances till now thanks to ethnic religious beliefs of local people. In these forest patches, the original moist character of the crop is retained. The trends in changes of forest type in this region as the climatic climax forest community is displaced by the different anthropogenic activities discussed earlier can be traced as follows:

Southern tropical moist teak-bearing deciduous forest ($3B/C_{1b}$ type)
(*Tectona grandis*, *Terminalia tomentosa*, *Dalbergia latifolia*, *Madhuca indica*, etc.)
or
Southern tropical moist mixed deciduous forest ($3B/C_2$ type)
(*T. tomentosa*, *M. indica*, *Adina cordifolia*, *T. bellerica*, etc.)
↓
Southern secondary moist deciduous forest ($3B/2S_1$ type)
(*T. tomentosa*, *D. latifolia*, *M. indica*, *A. cordifolia*, etc.)
↓
Southern dry mixed deciduous forest ($5A/C_3$ type)
(*T. tomentosa*, *Boswellia serrata*, *Sterculia urens*, *Diospyros melanoxylon*, etc.)

Species distribution, density and basal area

The earlier study showed that most of the tree species, irrespective of family, had aggregated distribution. However, the current survey reveals that though the dominant tree species still show an aggregated distribution, many of the rarer species have become randomly distributed within the study area.

The average stand density is 58.7 ha^{-1} and the mean basal area is 19.36 $m^2 ha^{-1}$ for individuals above 10 cm dbh (Table 4). In contrast, the average stand density and mean basal area in 1985 were found to be 144.75 ha^{-1} and 26.4 $m^2 ha^{-1}$ (> 30 cm gbh) respectively (Figure 4). This indicates that the stand density per hectare in the different diameter classes has changed significantly over the last two decades ($t = 2.54$, df = 8, $P > 0.05$). However, the basal area per hectare in the different diameter classes has not changed significantly over this period of time ($t = 0.80$, df = 8, $P > 0.05$).

The percentage of the growing stock composed of individuals of lower girth classes (30–60 and 60–90 cm) has decreased from 56 in 1985 to only about 25 now, principally due to declining recruitment. Diversity indices

Table 4. Diameter-class wise comparison of stand density and basal area in 1985 and 2005

	Stand density (ha^{-1})		Basal area ($m^2\ ha^{-1}$)	
Girth class (in cm)	1985	2005	1985	2005
30–60	71.05	15.2	5.02	1.07
60–90	49.6	19.21	9.73	3.77
90–120	18.53	15.16	7.13	5.83
120–150	3.6	7.0	2.3	4.44
150 and above	1.97	2.09	2.23	4.26
Total	144.75	58.6	26.41	19.37

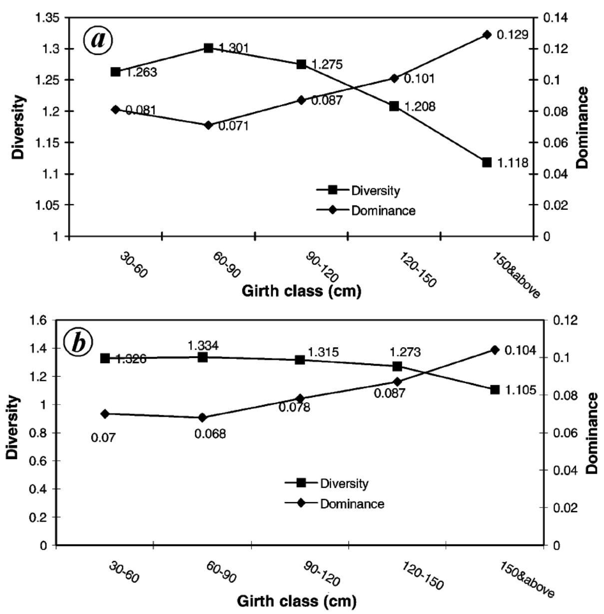

Figure 2. Diameter-class wise dominance and diversity indices. ***a***, Present survey and ***b***, 1985 survey.

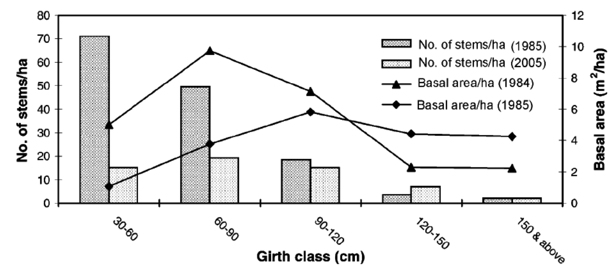

Figure 3. Comparison of tree density and basal area of the forests in 1985 and 2005.

also indicate a fall in the number of species in the lower-diameter classes. The stem density of the tree species in different diameter classes indicates a distorted, involuted graph instead of the typical *j*-shaped pattern observed in healthy natural vegetation. This raises the question of long-term sustainability of the standing crop. The increasing concentration of individuals in higher girth classes implies declining growth rate of the standing crop, as young individuals with high growth vigour are being replaced by mature and old trees with negligible increment and stagnating growth. This also explains the fact that basal area per hectare has not declined significantly, whereas the number of individual trees has declined by nearly 60% in the last two decades. The increasingly random distribution of tree species indicates growing discontinuity and isolation of the different forest patches.

The mean tree density (above 30 cm gbh) of 58 stems ha^{-1} compares poorly with that of similar forests in Maharashtra and Karnataka. It is far lower than tropical deciduous forests in areas such as the Andamans (Table 5). However, it is higher than degraded forests such as Sholapur in Maharashtra, where regressive succession has resulted in thorn forests with average tree density of 22/ha. To put the extent of deforestation into perspective, the average tree density/ha (above 30 cm gbh) of tropical forests ranges from about 245 to about 1000 in the forests of the Andamans and South East Asia[16].

Comparison of average stem density and basal area of some important tree species in the different diameter classes as estimated during the present study and in 1985 is detailed in Table 6. In the case of species like *Dalbergia latifolia* and *Terminalia bellerica*, the basal area per hectare has increased despite the fact that the density has decreased. This can be attributed to the increasing concentration of individuals of these species in higher girth classes as a result of declining recruitment. The gradual elimination of the dominant species like *T. tomentosa* and *T. grandis* has led to the increased proportion of the co-dominant species, which have not been significantly affected by anthropogenic activities.

T. tomentosa (density, 12.23 ha^{-1}; basal area, 3.73 $m^2\ ha^{-1}$) has emerged as the most dominant species (Table 5) in Nagar Haveli forests, replacing *T. grandis* (density, 3.95 ha^{-1}; basal area, 0.88 $m^2\ ha^{-1}$). This is not only due to the fact that it has so far not been overexploited like

Table 5. Comparison of tree species diversity and abundance in various tropical forests

Locality	Forest type	Stem density (ha^{-1}, above 30 cm gbh)	Basal area (m^2 ha^{-1})	Shannon–Weiner index	Dominant tree family*
DNH	South Indian tropical moist deciduous forest	58	19.36	1.263	Combretaceae Leguminaceae Verbenaceae
DNH (1985)[7]	South Indian tropical moist deciduous forest	148	26.4	1.315	Combretaceae Verbenaceae Rubiaceae
Mangalore FD, Karnataka[21]	South Indian tropical moist deciduous forest	234	9.63	–	Combretaceae Leguminaceae Bombacaceae
Mahananda WLS, West Bengal[11]	Sal-bearing northern moist mixed deciduous forest	484	26.3	3.53	Combretaceae Dilleniaceae Meliaceae
Andamans[16]	Andaman tropical moist deciduous forest	946	28.6	1.9	Leguminaceae Combretaceae Rubiaceae
Navegaon National Park, Bhandara, Maharashtra[22]	Southern tropical dry deciduous forest	729–914 (trees for all girth classes)	14.15–17.21	– –	Anacardiaceae Combretaceae Leguminaceae
Sholapur FD[23]	Tropical thorn forest	22		–	Leguminaceae Meliaceae

*Families in order of dominance. FD, Forest Division; WLS, Wildlife Sanctuary.

teak, but also for its adaptability to adverse conditions and biotic pressure. *T. tomentosa* is adapted to a wide range of geological conditions. It is a strong light-demander and germination is successful in bare ground in the rainy season[17]. This is ironic, as in well-protected forests the germination of *T. tomentosa* is suppressed by dense vegetation, whereas in disturbed and degraded forest areas where large blank spaces have opened up, this species finds favourable conditions to regenerate. The species shows better natural regeneration than most other species under similar conditions. The seedlings are tolerant to dry conditions due to their deep root system. The young seedlings also escape grazing injury during the fodder-deficient summer months, as they remain leafless during this period and are among the last of the tree species to acquire foliage in the hot season. Thus different species respond to an external factor, in this case anthropogenic pressure, in diverse ways depending upon their nature and adaptability. Due to the complexity of the forest ecosystem, it is thus difficult to predict a unidirectional change caused by a single external factor.

Status of regeneration

Among the 45 tree species found to be regenerating, only 16 showed good regeneration status, while 19 regenerated poorly. The rest of the species showed fair regeneration (Table 7).

The two most important factors which determine the sustenance of a forest crop are regeneration and adequate growth of the standing crop. The conditions prevailing in these forests, like overgrazing, trampling, soil erosion etc., do not offer a conducive environment for the regeneration of most tree species. Except for the most tenacious species, the rest have failed to regenerate significantly in these extreme conditions. The most extensive regeneration is seen in case of *Ixora parviflora* and *W. tomentosa*, which grow gregariously throughout the territory. Species adapted to drier habitats like *T. tomentosa*, *B. monosperma* and *Trewia nudiflora* also show good regeneration. Coppice regeneration of teak has also managed to survive grazing and lopping. The most disconcerting scenario from a biodiversity point of view is the virtual absence of viable regeneration of the less abundant tree species. Even as the mature individuals of species belonging to 13 of the 21 families constitute only about 10% of the total abundance, viable regeneration of most of the tree species of these families is conspicuous by their rarity. The less abundant species seems unable to regenerate under the stressful conditions. Among the economically importantly species, *Madhuca indica* shows poor regeneration. This is because local people sweep the forest floor to collect the seeds of Mahua for extraction of oil and not enough viable seeds remain for significant regeneration.

One of the major constraints of regeneration in these forests is identified to be rab burning, in which all the vegetation on the forest floor is burnt before sowing of seeds for cultivation. Rab burning is done just before the onset of the monsoon, whereby most of the viable seeds of tree species on the forest floor and young saplings are

Table 6. Comparison of density and basal area of some important species in the 1985 and 2005 surveys

Tree species	Family	Density (ha^{-1})		Basal area ($m^2\ ha^{-1}$)	
		1985	2005	1985	2005
Acacia catechu Willd.	Leguminaceae	3.32	2.14	0.8	0.73
Adina cordifolia (Roxb.) Hook. f. ex Brandis	Rubiaceae	6.67	2.23	1.63	0.61
Anogeissus latifolia Roxb. ex DC	Combretaceae	4.50	3.16	0.94	0.79
Bridelia retusa L. Spr	Euphorbiaceae	3.83	1.30	0.73	0.43
Butea monosperma (Lam.) Taub.	Leguminaceae	5.50	1.11	0.67	0.25
Casearia tomentosa Roxb.	Flacourthaceae	4.12	0.14	0.61	0.02
Dalbergia latifolia Roxb.	Leguminaceae	3.27	2.23	0.63	0.67
Garuga pinnata Roxb.	Bursuraceae	12.05	0.84	2.3	0.28
Lagestromia parviflora Roxb.	Lytharaceae	3.15	1.77	0.6	0.38
Lannea coromandelica (Houtf) Merril	Anacardiaceae	3.80	1.60	0.75	0.58
Madhuca latifolia Macb.	Sapotaceae	2.62	5.54	1.03	3.17
Tectona grandis L.f.	Verbenaceae	24.25	3.95	4.55	0.88
Terminalia bellerica (Gaertn.) Roxb.	Combretaceae	3.70	3.35	0.6	1.24
Terminalia tomentosa Roxb.	Combretaceae	23.14	12.23	4.61	3.73
Writhia tomentosa Roem. & Schult.	Apocynaceae	14.45	2.28	1.30	0.47
Others (31 species in the present survey and 34 in 1985)		26.40	14.73	4.66	5.14
	Total	144.75	58.6	26.41	19.37

Table 7. Status of regeneration of different tree species

Good	Fair	Poor
Bauhinia racemosa Linn.	*Acacia catechu* Willd.	*Adina cordifolia* (Roxb.) Hook. f. ex Brandis
Butea monosperma (Lam.) Taub.	*Acacia ferruginea* DC.	*Aegle marmelos* (L.) Corr.
Cassia fistula Linn.	*Annona squamosa* Linn.	*Albizia lebbeck* (L.) Bth
Dalbergia latifolia Roxb.	*Bridelia retusa* (L.) Spr	*Albizia procera* (Roxb.) Bth
Dyospiros melanoxylon Roxb.	*Holoptelia integrifolia* (Roxb.) Planch.	*Anogeissus latifolia* Roxb. ex DC.
Emblica officinalis Gaertn.	*Lagerstroemia parviflora* Roxb.	*Artocarpus heterophyllus* Lam.
Erythrina variegate Linn.	*Pterocarpus marsupium* Roxb.	*Bauhinia purpuria* Linn.
Ficus glomerulata Roxb.	*Sterculia urens* Roxb.	*Bombax ceiba* Linn.
Ixora parviflora Vahl.	*Syzigium cumini* Linn. Skeels	*Careya arborea* Roxb.
Milliusa tomentosa Roxb. Sinclair	*Tamarindus indica* Linn.	*Casearia tomentosa* Roxb.
Tectona grandis Linn.		*Dalbegia sissoo* Roxb.
Terminalia bellerica (Gaertn.) Roxb.		*Garuga pinnata* Roxb.
Terminalia tomentosa Roxb.		*Lannea coromandelica* (Houtf) Merril
Trewia nudiflora Linn.		*Madhuca latifolia* Macb.
Wrightia tomentosa Roem. & Schult.		*Magnifera indica* Linn.
Zyziphus mauritiana Lam.		*Mitragyna parviflora* (Roxb.) Korth.
		Oogenia oogenesis Roxb. Hoch.
		Schleichera oleosa (Lour.) Oken
		Woodfordia fruticosa Kurz.

destroyed. This practice also removes humus from the forest floor, which severely hampers regeneration and makes the soil almost sterile.

Changes in abundance of some key livelihood species

Although the forest as a whole is under severe biotic stress, the species valued for their timber and non-timber products have borne the major brunt (Figure 4). *T. grandis*, which is the most valuable timber species, has almost been eliminated mainly as a result of illicit felling. The growing stock of teak has decreased from an average 8.63 cum ha^{-1} to as low as 1.13 cum ha^{-1} (Table 8). The growing stock of other important timber species like *T. tomentosa* and *Anogeissus latifolia* has decreased due to their relentless exploitation. Both *Acacia catechu*, which is valued for its kutha and *Diospyros melanoxylon*, the leaves of which are used to make bidis are subjected to exploitation. The only species that has escaped destructive exploitation is the Mahua (*M. indica*), as the tribals revere it as holy for its usefulness. Ironically, the regeneration of this species is poor due to the practice of sweeping of the forest floor under the trees for its seeds. Most importantly, the quantitative figures of the growing stock betray the fact that the quality of the crop is of infe-

Table 8. Comparison of standing volume of some important tree species in 1985 and 2005

Species	Local volume equations used[24]	Standing volume (cum/ha) 1985	2005
Tectona grandis Linn.	$\sqrt{V} = -0.405890 + 1.98158D + 0.987373\sqrt{D}$	8.63	1.13
Terminalia tomentosa Roxb.	$\sqrt{V} = -0.203947 + 3.159215D$	15.99	7.77
Terminalia bellerica (Gaertn.) Roxb.	$V = 0.074706 - 1.430082D + 10.181971D^2$	2.75	2.38
Acacia catechu Willd.	$V = -0.048108 + 5.873169D^2$	1.96	1.2
Lannea coromandelica (Houtf) Merril	$\sqrt{V} = 0.357373 + 2.430449D + 0.794626\sqrt{D}$	3.04	1.92
Anogeissus latifolia Roxb. ex DC.	$V = 0.099 - 1.119D + 8.2D^2$	2.47	2.28
Dalbergia latifolia Roxb.	$\sqrt{V} = -0.144504 + 2.943115D$	2.67	1.77

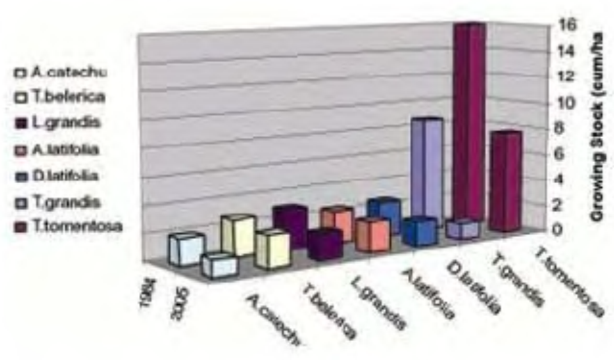

Figure 4. Comparison of growing stock of some important tree species.

rior nature as the superior individuals have already been removed.

The condition of the contiguous forest areas in neighbouring states

It will be a gross oversight to view the alarming rate of deforestation in Nagar Haveli in isolation from the other forested tracts of this region. The phenomenon is taking place in the entire zone of the northern scarps of the Western Ghats falling in south Gujarat and northwestern Maharashtra. The affected area runs parallel to the Mumbai–Ahmedabad industrial belt, which is the most rapidly expanding urban sprawl in India. Rapid urbanization has resulted in a population explosion and exponential rise in demand for forest products, which is taking a toll on the health of the forests. Widespread encroachment, over-grazing, illicit felling, shifting cultivation and destructive methods of non-timber forest products collection have the cumulative effect of threatening the very survival of the plants and dependent fauna, even in the protected areas of the region[18]. The forests are receding at a rapid pace and the rate of depletion is the fastest on the periphery of the forests. Forests have been cleared for mining activities and wastes from such operations are being dumped in the adjoining well-vegetated valleys, thus adversely affecting the vegetation[19].

Coupled with increasing anthropogenic pressure, the forests are also affected by short-sighted forest management practices in some areas. In such cases, it has been observed that forest degradation is more a result of over-estimation of potential out-turn and the consequent over-exploitation by authorized agencies than due to illicit felling[20]. Submergence of forests and diversion of forest land for construction of large dams in the region and the subsequent inadequate compensatory afforestation measures have also been responsible for degradation of forests.

In DNH, despite well-conceived afforestation schemes of the Forest Department, most of the measures have not given the desired result due to lack of follow-up action of the department and absence of coordination with the beneficiaries. Lack of maintenance and protection has led to the failure of most of the afforestation measures. However, plantations have been remarkably successful in localities where local people have actively participated in their protection. The alarming depletion of forests as a result of anthropogenic pressure has not only endangered the existence of the diverse flora and fauna of this region, but is also threatening the livelihood of people dependent on them. The future requires solutions based on effective forest management measures as well as improvement in the living conditions of the poor people dependent on the forests for their livelihood.

1. Revington, J., World Rainforest Report, NSW, Australia, 1992.
2. Ghosh, S., National Forum of Forest People and Forest Workers, World Rainforest Movement Bulletin No. 98, September 2005.
3. Anon, State of Forest Report, Forest Survey of India, Dehradun, Ministry of Environment and Forests, Government of India, 2001.
4. Anon, Forest Statistics India, Indian Council of Forestry Research and Education, Dehradun, Ministry of Environment and Forests, Government of India, 2003.
5. Anon, State of Forest Report, Forest Survey of India, Dehradun, Ministry of Environment and Forests, Government of India, 2003.
6. Chella, O. and Pandey, R. J., *Soils of Dadra & Nagar Haveli*, National Bureau of Soil Survey & Land Use Planning, ICAR, Nagpur, 1989.
7. Pandey, C. N., Ladwa, Y. R. and Joshi, R. R., Working Plan of Dadra and Nagar Haveli Forest Division (1986–87 to 1995–96), 1986.
8. Anon, *Forest Inventory Manual*, Forest Survey of India, Dehradun, Ministry of Environment and Forests, Government of India, 2004.

9. Shannon, C. E. and Weiner, W., *The Mathematical Theory of Communication*, University of Illinois Press, Urbana, USA, 1963.
10. Simpson, E. H., Measurement of diversity. *Nature*, 1949, **163**, 688.
11. Shankar, U., A case of high tree diversity in a sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Curr. Sci.*, 2001, **81**, 776–786.
12. Lambshead, P. J. D., Platt, H. M. and Shaw, K. M., Detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. *J. Nat. Hist.*, 1983, **17**, 859–874.
13. Champion, H. G. and Seth, S. K., *A Revised Survey of Forest Types in India*, The Manager of Publications, Government of India, Delhi, 1968.
14. Sabnis, S. D. and Bedi, S. J., Ethnobotanical studies in Dadra–Nagar Haveli. *Indian J. For.*, 1983, **6**, 65–69.
15. Bennet, S. S. R., Ethnobotanical studies in Dadra–Nagar Haveli – Some interesting native drugs. *Indian For.*, 1978, **104**, 676–680.
16. Padalia, H., Chauhan, N., Porwal, M. C. and Roy, P. S., Phytosociological observations on trees species diversity of Andaman Islands, India. *Curr. Sci.*, 2004, **87**, 799–806.
17. Troup, R. S., *Troup's Silviculture of Indian Trees* (Revised and enlarged by H. B. Joshi in 1984), Controller of Publications, Government of India, New Delhi, 1921, vol. 5.
18. Pradeepkumar, G. and Parthapasenan, G., Tree species diversity of Shoolpaneshwar Wildlife Sanctuary in Gujarat. *Indian For.*, 2001, **127**, 1207–1214.
19. Sharma, D. and Sunderraj, S. F. W., Species selection for improving disturbed habitat in Western India. *Curr. Sci.*, 2005, **88**, 462–467.
20. Verma, A. K., Degradation of forests due to fallacious yield regulation and harvesting: A case study from Vyara Forest Division in Gujarat, India. *Indian For.*, 2002, **128**, 835–845.
21. Gowda, R., Working Plan of Mangalore Forest Division (2002–03 to 2011–12), Working Plan & Survey, Chikmagalur, Government of Karnataka, 2002.
22. Ilorkar, V. M. and Khatri, P. K., Phytosociological study of Navegaon National Park (Maharashtra). *Indian For.*, 2003, **129**, 377–387.
23. Bhangre, A. B., Working Plan of Solapur Forest Division (1995–96 to 2004–05), Working Plan Division, Pune, Government of Maharashtra, 1995.
24. Anon, Volume equations for forests of India, Nepal and Bhutan. Forest Survey of India, Dehradun, Ministry of Environment and Forests, Government of India, 1996.

ACKNOWLEDGEMENTS. We thank M. Z. Singson, DCF, NWFP Division, FRI, Dehradun for his guidance during the survey. Dadra and Nagar Haveli Forest Department provided all the necessary logistical support during the field-work.

Received 15 June 2007; revised accepted 29 April 2008