Mapping of non-timber forest products using remote sensing and GIS

V.K. SRIVASTAVA[1] & D. ANITHA[2*]

[1]National Remote Sensing Centre, ISRO, Hyderabad 500 037, India
[2]Space Applications Centre, ISRO, Ahmedabad 380 015, India

Abstract: Non-timber forest products (NTFP) form a very important source of livelihood to communities living in the vicinity. However, no systematic attempt has been made so far to map these resources. This study attempts to develop methodology to map NTFP using satellite remote sensing and GIS. The satellite data were used to generate a forest type map, forest density map, non-timber forest (NTF) map and a map showing total economic value (TEV) of trees in Pune District, Maharastra, India. Since, the utilization of forest depends on the total economic value of trees, these maps were integrated in GIS to generate a NTFP map. The results indicated that non-timber trees having moderate to high TEV dominated the western subtropical broadleaf hill forest located in difficult terrain and away from human settlements. The dry deciduous forest found in the close proximity of human settlements contained large number of non-timber trees having moderate TEV.

Resumen: Los productos forestales no maderables (PFNM) conforman una fuente muy importante de subsistencia para las comunidades que viven en las cercanías. No obstante, no se ha hecho un intento sistemático para cartografiar estos recursos. Este estudio intenta desarrollar una metodología para cartografiar a los PFNM usando percepción remota satelital y SIG. Los datos de satélite fueron usados para generar un mapa de tipo de bosque, un mapa de densidad del bosque, un mapa de bosque no maderable y un mapa que muestra el valor económico total (TEV, sigla en inglés) de los árboles en el Distrito Pune, Maharastra, India. Ya que la utilización del bosque depende del valor económico total de los árboles, estos mapas se integraron en el SIG para producir un mapa de los RFNM. Los resultados indican que los árboles no maderables que tenían dese un TEV moderado a alto eran dominantes en bosque latifoliado subtropical de colinas del occidente, localizado en terrenos difíciles y lejos de los asentamientos humanos. El bosque seco caducifolio encontrado en la cercanía de los asentamientos humanos contuvo una gran número de árboles no maderables con un TEV moderado.

Resumo: Os produtos florestais não lenhosos (NTFP) são uma fonte muito importante dos meios de subsistência para as comunidades que vivem na vizinhança da floresta. Contudo, nenhuma tentativa sistemática foi entretanto feita para mapear estes recursos. Este estudo tenta desenvolver metodologia para mapear os NTFP, usando detecção remota de satélite e SIG. Os dados de satélite foram usados para gerar um mapa de tipos florestais, o mapa da densidade da floresta, o mapa de florestas não lenhosos (NTF) e um mapa que mostra o valor económico total das árvores (TEV) no distrito de Pune, Maharastra, Índia. Dado que a utilização da floresta depende do valor económico total das árvores, estes mapas foram integrados num SIG para gerar um mapa de NTFP. Os resultados indicaram que as árvores de interesse não-madeireiro, tendo um TEV moderado a alto dominavam a floresta subtropical de folhas largas das colinas de difícil acesso, longe dos povoamentos humanos. A floresta seca caducifólia encontrada na proximidade dos povoamentos humanos possuía um número elevado de árvores de interesse não-madeireiro tendo um TEV moderado.

* Corresponding Author; e-mail: anithaisro@gmail.com

Introduction

Forests are the repositories of natural wealth in terms of flora and fauna. The economic value of same has long been recognized. The stock inventories have been an integral part of forest resources assessment although these inventories account primarily for timber species. The forest species that provide a variety of non-timber products (known as non-timber forest species (NTF)) are often not recorded. Though there are many terms that define the non-timber forest products, the abbreviation NTFP is most commonly used for non-timber forest products (Wong 2000). In India, forest management has so far focused on the production of commercial timber from the forests. The new National Forest Policy (1988) bans clear felling of forests. The forest working plans often do not take into account the sustainable NTFP management (Giri *et al.* 2005). The policy envisages conservation and increased development of non-timber forest products including medicinal plants. It empowers the people living in and around the forest to collect the NTFP, which play a key role in their economy (Paloti & Hiremath 2005). Ojha *et al.* (2005) emphasized the significance of non-timber forest assessment for increasing subsistence and commercial use of NTFP by local community. The importance of NTFP contribution to food security and financial well being is gaining increasing recognition day-by-day. A study in Zimbabwe revealed that small-scale NTFP-based enterprises employed 237,000 people compared to only 16,000 employed in conventional forest industry (FAO 1995). Wilkinson & Elevitch (2005) opined that steps should be taken to understand and inventory an area's non-timber resources prior to the preparation of the forest management plan. Peterson (2005) attempted to map non-timber forests in parts of Cambodia using aerial photographs. In this study, an attempt was made to map the non-timber forest and NTFP in the Pune Forest Division of Maharashtra using satellite imagery, GIS and field inventory.

Materials and methods

Study area

The study was conducted in Pune Forest Division of Maharashtra (Fig. 1). The district, located between 17° 54′ - 19° 24′ N and 73° 19′ - 75° 10′ E, covers an area of ca. 15643 km². About 18% of the district is covered with forests. The population density in the district is 354 persons km^{-2}. About half of the population lives in the urban areas and the remaining in 1844 villages. The mean monthly temperature and annual rainfall are 25 °C and 715 mm, respectively. There is considerable variation in the rainfall within the district. The rainfall decreases from west to east. Based on the rainfall, the district may be divided in three distinct regions: the extreme western region with highest rainfall (>3000 mm), the central region with moderate rainfall (3000 to 2000 mm) and the eastern region with lower rainfall (<2000 mm).

Methods

The forest was visited in February and March 2005 for phytosociological data collection. Thirty four 25 m x 25 m sample plots were laid randomly in the forests. The geographical co-ordinates of each sample plot were recorded using a GPS receiver. All tree species present in each sample plot were listed (Table 1). Various flora (Singh & Karthikeyan 2001; Cooke 1967; Santapau 1967; Santapau & Henri 1973) and literature on economic botany (Singh *et al.* 1983) were used to ascertain the economic value of each species.

The trees found in the area were assessed for commercial and non-commercial timber, medicinal, human consumption, fuel, packaging, ornamental, wooden articles, dyeing and tanning, animal food, fiber, shelter/support to other plants, soap/detergent, perfume, manure, religious, polish, flavor/spice and condiment, paper and gum utility. The proportion of tree species having non-timber utility in each sample plot was estimated. The
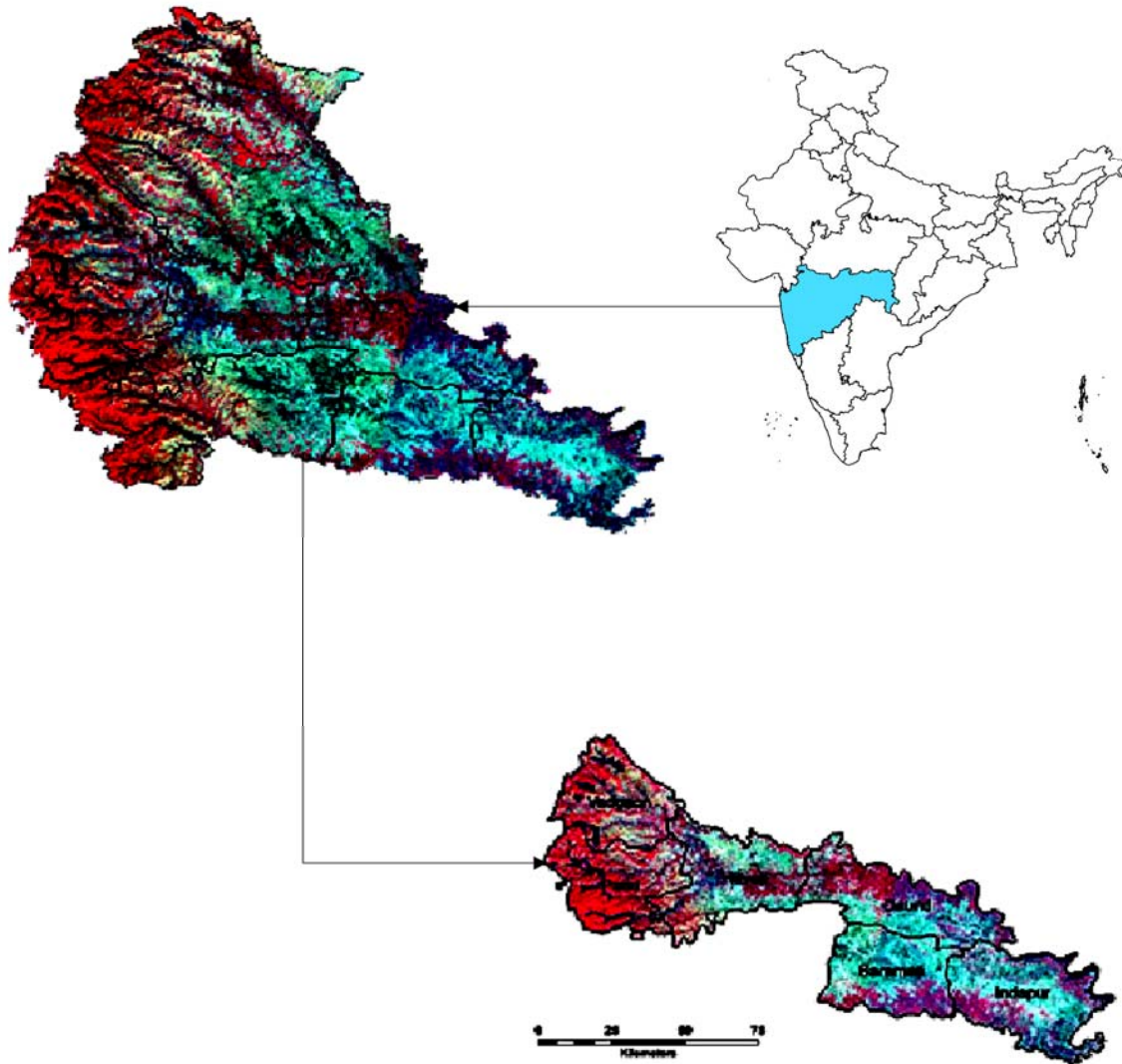
Fig. 1. Location of the study area.

sample plots were grouped in three categories based on per cent NTF. A NTF value up to 33% was defined as low NTF class; 33 to 66% as moderate NTF class and >66% as high NTF class.

All tree species were given an economic importance rating between 1 to 10 for each of the twenty use categories mentioned above. Commercial timber species were assigned a value of 0 indicating no potential non-timber use. The commercial value of the NTFP was determined based on the price tag for each product in local market. The sum of the economic importance values (TEV) for all uses of a species was expressed as relative percentage of the maximum possible score (Belal & Springuel 1996):

$$TEV(\%) = \frac{U1 + U2 + \ldots\ldots\ldots U20 * 100}{\text{Total number of uses} * 10}$$

where, U = importance value for each use

Average TEV of each sample was determined by adding REV of each non-timber species and dividing by the number of non-timber species present in the sample. The average TEV was

Table 1. List of tree species recorded in the study area.

Species name	Species name
Acacia Arabica J.L.Stewart	*Holoptelea integrifolia* Roxb.
Acacia catechu L.	*Ixora brachiata* Roxb.
Actinodaphne hookeri Meissn.	*Jasminum arborescens* Roxb.
Actinospermum cephalotus	*Lagerstroemia lanceolata* Wight.
Adina cordifolia Roxb.	*Lagerstroemia parviflora* Roxb.
Ailanthus excelsa Roxb.	*Lansium anamallayanum* Bedd.
Albizia lebbeck L.	*Lasiosiphon eriocephalus* Decne.
Albizia stipulate Roxb.	*Leucaena leucocephala* Lamk.
Gesan*	*Macaranga tomentosa* Wight.
Artemisia nilagerica Clarke	*Madhuca indica* J.F.Gmel
Bambax malabaricum Roxb.	*Mangifera indica* L.
Bauhinia malabarica Lamk.	*Meyna laxiflora* Robsyn.
Bauhinia racemosa Lamk.	*Memecylon umbellatum* Burm. f.
Bauhinia variegate L.	*Mitragyna parviflora* Roxb.
Bixa orellana L.	*Mussaendra frondosa* L.
Bombax ceiba L.	*Olea dioica* Roxb.
Bridelia retusa Spreng.	*Oroxylum indicum* L.
Butea monosperma Lamk.	*Pterocarpus marsupium* Roxb.
Carallia integerrima DC.	*Randia dumetorium* (Retz.)Poir.
Careya arborea Roxb.	*Schrebera swietenoides* Roxb.
Carissa carandas L.	*Securinega virosa* (Roxb.ex Willd)Baill.
Caryota urens L.	*Smilax zeylanica* L.
Cassia siamea Lamk.	*Stephegyne parvifolia* Korth.
Dalbergia sissoo Roxb.	*Stereospermum chelonoides* (L.f.) DC.
Diospyros buxifolia Hiern.	*Syzigium cumini* L.
Diospyros melanoxylon Roxb.	*Syzigium heyneanum* (Duttie)Wall.exGam.
Diospyros ebenum Koen.exRetz.	*Tectona grandis* L.
Diospyros Montana Roxb.	*Terminalia bellerica* Gaertn.
Emblica officinalis Gaertn.	*Terminalia chebula* Retz.
Erythrina indica Lamk.	*Terminalia paniculata* Roth.
Eucalyptus sps.	*Terminalia tomentosa* Wught & Arn.
Euphorbia lingularia Roxb.	*Trema orientalis* L.
Ficus glomarata Roxb.	*Vangueria spinosa* Roxb.
Flacourtia latifolia Hook.	*Woodfordia floribunda* Salisb.
Glochidion hohenackeri Bedd.	*Wrightia tinctoria* R.Br.
Gnetum scandens Roxb.	*Xantolis tomentosa* Roxb.
Grewia tiliaefolia Vahl.	*Xylia dolabriformis* Bt.
Hardwickia binata Roxb.	Pipran*
Hetrepharma quadriculaorae Roxb.	Kinbai*
Holarrhena antidysentrica L.	Yetha*

* Botanical name could not be ascertained.

considered as a measure of NTFP. The NTFP (TEV) values ranged from 3 to 8% in all the samples. The NTFP value up to 5% was considered as low NTFP class. Four out of 34 samples belonged to this class. The moderate NTFP class consisted of samples having NTFP between 5 and 7% and included 21 samples. NTFP values for the remaining 9 samples were higher than 7% and were classified as high NTFP class.

Analysis of satellite data

Four cloud-free IRS-ID LISS-III scenes with 23.5 m x 23.5 m spatial resolution and covering the study area (path/row: 95/59, 95/60 dated 15th December, 2003 and 94/59 and 94/60 dated 5th January, 2005) were procured. The scenes were radiometrically and geometrically corrected. The corrected scenes were mosaiced. The district boundary mask was overlaid on the FCC mosaic to extract the study area. The satellite data was classified using maximum likelihood classifier to generate thematic maps. Thematic maps were subsequently used in *ARC/INFO* for further

analysis. A classified image of the satellite data over the study area was generated using *ERDAS Imagine* software showing the different types of forest and general land use/cover classes found in the district. The classifier was trained for forest types using ground samples. In addition, the satellite data were also classified by training the classifier with NTF and TEV values ascertained for each sample. In order to assess the distribution of TEV classes within each NTF class, the NTF and TEV maps were intersected using in GIS.

Validation

Attempts were made to validate the methodology developed in the present study. Care was taken to insure that the samples were drawn at random for validation. Repetivity of methodology was ensured by using a different set of satellite data (LISS-IV) over the study area. All the four maps (*i.e.* forest type map, forest density map, NTF map and TEV map) were generated using IRS P6 LISS-IV data (spatial resolution   5.8 m x 5.8 m) for the month of February, 2007.
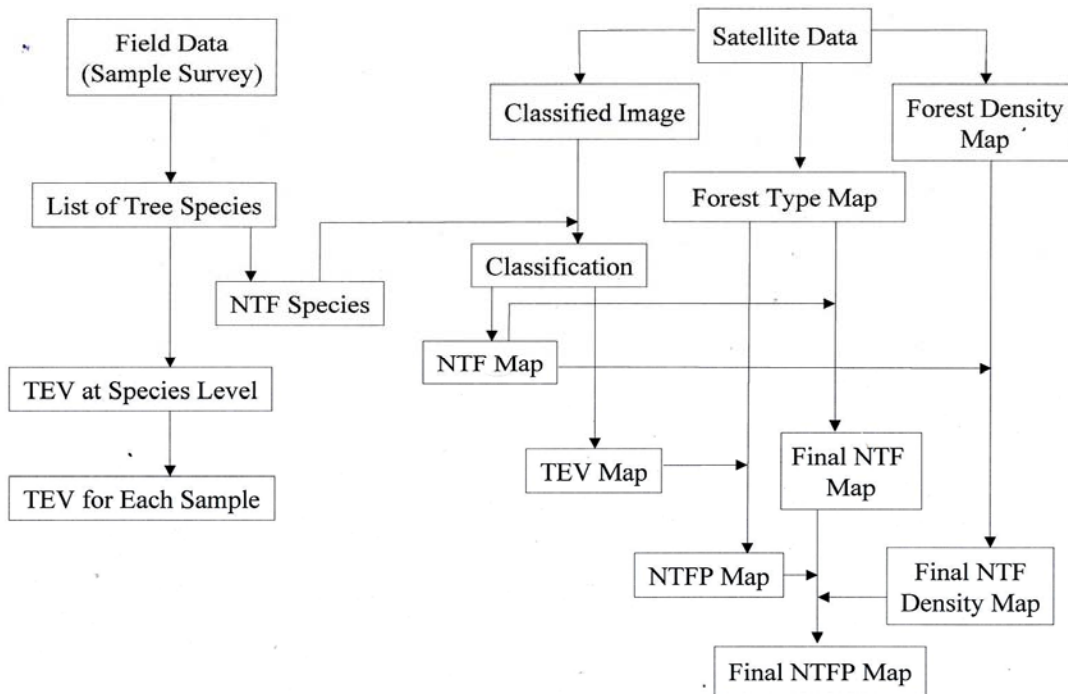

Fig. 2. Methodology to generate TEV map.

The maps were integrated using union function in GIS and final NTFP map was generated. Fig. 2 shows the overall methodology.

Results and discussion

Forest type map

Eight different land use/land cover types were identified within the district using imagery, which included five forest types, covering 18.2% of the area (Srivastava *et al.* 2004) (Table 2). These forests types were:

Western subtropical broadleaf hill forest (8A/C2): This forest covered 1.2% of the area. This forest lies in the heavy rainfall tract in the west, occupying the higher elevations of the Sahyadri's main ridge and extending to some distance on the outlying spurs of the eastern flanks. *Mangifera indica* L.*, Syzigium cumini* L.*, Memecylon umbellatum* Burm. F.*,* and *Terminalia chebula* Retz. were some of the important NTFP tree species found in this type of forest.

Southern moist deciduous forest (3B/C2): This forest covered an area of ca. 6.2% of the district's area and was found as a narrow belt along lower slopes of Sahyadri range, having moderate rainfall. This forest attained its best form where the anthropogenic influences were negligible. Some of the dominant tree species in this type were *Terminalia tomentosa* (Roxb. exDC) Wright & Arn., *Bombax ceiba* L., *Grewia tiliaefolia* Vahl., and *Lannea coromendelica* Houtt. Some evergreen tree species were found mixed with other species in this type.

Southern dry deciduous forest (5A/C3): Ten per cent of the total area was covered with this type of forest, found in much of the western part of the district. Though *Tectona grandis L.* was the principal tree species in this type of forest, its proportion with other species varied from place to place. *Anogeissus latifolia* DC., *Diospyros melano-xylon* Roxb., *Mitragyna parviflora* Roxb. and *Madhuca indica* J.F. Gmel. were some of the common trees found in this forest.

Scrub (6A/C1): This type of forest included the thorn forest found in the eastern part of the district and also the highly degraded forest found elsewhere in the district. Thus, it covered ca. 0.6 % of the district's geographical area. It was found almost in all barren areas that were surrounded by revenue villages and subjected to excessive grazing and browsing. The vegetation was characterized by sparse stunted growth of tree species.

Table 2. Distribution of land use/cover classes in the district.

Land use/cover	Area (ha)	Area (%)
Western sub-tropical broadleaf hill forest	9,952	1.2
Southern moist deciduous forest	49,285	6.2
Southern dry deciduous forest	80,691	10.0
Scrub forest	4,977	0.6
Babul forest	1,541	0.2
Water bodies	24,191	3.0
Agriculture	209,776	26.0
Barren land/ Habitation	416,956	52.0
Total	797,369	-

Table 3. Distribution of forest density classes in different forest types.

Forest type	Forest density class (ha)				
	Dense	Closed	Open	Degraded	Total
Western subtropical broad leaf hill forest	6,616	456	2,873	7	9,952
Southern moist deciduous forest	33,583	14,601	1,099	2	49,285
Southern dry deciduous forest	1,760	14,715	64,016	200	80,691

Babul (Acacia nilotica (L.) Willd. ex Del.*) forest* (5/E3): This forest was found in small patches, covering 0.2% of the district's geographical area. This forest was located on the rich alluvial deposits along the river banks. They remain green in an otherwise open tract.

The three major forests in the division were the western subtropical broadleaf hill forest, southern moist deciduous forest and southern dry deciduous forest. These forests together constituted ca. 17.5% of the district's geographical area. Out of the three forest types, southern dry deciduous forest constituted 58% of the forest area; southern moist deciduous forest constituted ca. 35% while the remaining 7% was covered by western subtropical broadleaf hill forest. NTFP analysis was carried out in these forests only.

Forest density map

Growth of the trees depends upon the site quality and anthropogenic pressure. As a result, the forest density based on crown closure varies from place to place and from type to type. The forest density, therefore, was categorized in four classes. Class 1 is the dense type where the canopy closure was > 0.7; class 2, closed forest where the canopy closure ranged between 0.4 and 0.7, class 3, open forest where canopy closure ranged between 0.2 and 0.4 and class 4 as degraded forest where canopy closure was less than 0.2. The satellite data was classified to generate the forest density map. The classifier was trained using intensity of color and ground information. About 49% of the forest belonged to open forest and ca. 30% to dense class. Only ca. 0.1% of the forest was degraded while the remaining 21% was closed forest. It may be concluded that the forests in the district are generally in good condition (ca. 50% of the forest area was under dense and closed forest density class). The anthropogenic impact on the existing forest was also very low as only ca. 0.1 % of the forest area was degraded.

The forest density map was integrated with the forest type map in ARC/INFO to estimate the density classes in each forest type (Table 3). Most of the area under dense forest was found in southern moist deciduous forest (80%). It was less commonly found in the remaining two types of forests (16% in western subtropical broadleaf hill forest and 4% in southern dry deciduous forest). Closed forest was equally distributed between southern moist deciduous and dry deciduous forests (49% each). It was negligible (1.5%) in western subtropical broadleaf hill forest. Open forest was most common in southern dry deciduous forest (94%) whereas it was 4% in western subtropical broadleaf hill forest and 2% in southern moist deciduous forest.

It was observed that the anthropogenic effects were more pronounced in the Southern dry deciduous forest, leading to much more area under open category. This type of forest is closer to habitation and easily accessible to local populations. Southern moist deciduous forest is not easily accessible to local people; hence, most of this forest is in good condition and is closed forest.

Non-Timber Forest Produce (NTFP) Map

The NTFP map was generated by integrating the forest type, forest density, NTF and TEV maps of the study area and shows the distribution of non-timber species having potential economic uses in different types of forests found in the study area (Fig. 3). The distribution of NTF and TEV classes in each forest type and density class were as follows:

NTFP in Western subtropical broadleaf hill forest: Out of 9,952 ha of this forest, more than two-thirds (68%) of the forest belonged to the dense class, ca. 30% to closed density class and the remaining 2% to open and degraded forest. About 71% of dense forest belonged to high NTF class; ca. 15% to moderate NTF class and the remaining to low NTF class. About 75% of the high and moderate NTF classes contained high TEV class and the remaining was distributed into moderate and low TEV classes and the remaining was distributed into moderate and low TEV classes. Most of the low NTF forest (ca. 67%) belonged to low TEV class. More than 96% of the closed forest belonged to moderate NTF class and the remaining to high NTF class. Low NTF class was almost absent in this density class. About two thirds of the closed forest belonging to moderate NTF class, contain trees with high TEV values and the remaining to moderate and low TEV classes. More than 70% of the open forest belonged to the moderate NTF class and the remaining was equally distributed in the remaining two NTF classes. About three-fourths of the forest falling in the moderate NTF class contained trees having moderate TEV values. However, a large part of the forest (73%) falling under high NTF class belonged to high TEV class (Table 4).

NTFP in Southern moist deciduous forest: Out of the 49,285 ha of this forest, more than 66%

belonged to dense forest followed by open forest (ca. 29%) and closed forest (ca. 4.6%). Degraded forest was found in only 54ha area in this forest type. The dense and closed forests were distributed in high and moderate NTF classes. In case of dense forest, more than 60% of the forest area belonged to high NTF class and ca. 38% to moderate NTF class. More than half of the high NTF forest belonged to high TEV class and the remaining to moderate TEV class. However, almost all the forest under moderate NTF class contained trees with high TEV values. More than 79% of the closed forest category belonged to moderate NTF class and the remaining to high NTF class. Most of the trees in these two NTF classes had high TEV values. The other two TEV classes (moderate and low) were almost absent. About 89% of the open forest was recorded in moderate NTF class; 10% in high NTF class and the remaining 1% to low NTF class. Trees present in high and moderate NTF classes, in general, had high TIV values.

NTFP in Southern dry deciduous forest: More than 79% of this type of forest belonged to the open category, 18% to closed forest, 2% to dense forest, and ca. 0.3% to degraded forest. Though all three NTF classes were found in open forest, ca. 98% belonged to moderate NTF class. High and low NTF were distributed in the remaining 2% of the open forest. About 74% of the moderate NTF class belonged to high TEV class and the remaining to moderate TEV class. However, in the high NTF class, ca. 89% of the forest area belonged to high TEV class and the remaining to moderate and low TEV classes. About 97% of the closed forest area was found to belong to moderate NTF class, ca. 2.8% to high NTF class and the remaining to low NTF class. About 66% of the moderate NTF forest belonged to high TEV class and 33% to moderate TEV class. But in case of high NTF class, ca. 88% of this forest belonged to high TEV class and the remaining to moderate TEV class. The high NTF class in dense forest was found in more than 53% of this forest. The remaining 47% dense forest belonged to moderate NTF class. Almost all the trees found in high NTF class had high TEV values as 96% of the forest area belong to high TEV class. The distribution of high TEV class, in moderate NTF class was 51%; 44% to moderate TEV class and the remaining 5% to low TEV class. The remaining area was found to contain moderate and low TEV values (Fig. 3)

LISS-IV data, during validation, covered only three forest types *viz*. Western Subtropical broadleaf hill forest, Southern Moist Deciduous forest and Southern Dry Deciduous forest. These types are in conformity with the LISS-III data derived forest type map. The overall accuracy was found to be 81% (significant at 90% significance level). This indicated that the methodology developed for mapping NTFP at sample level can be replicated using satellite data of varying spatial resolutions.
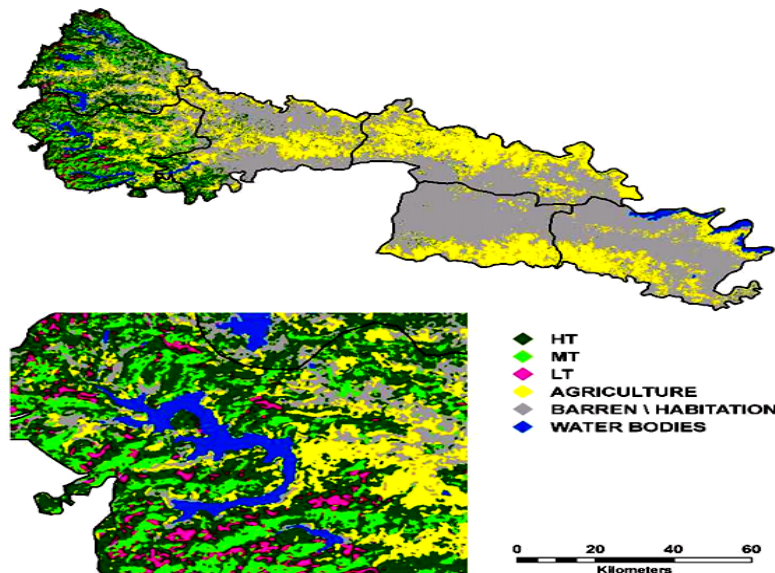

Fig. 3. TEV map of the study area.

Table 4. Distribution (ha) of NTFP in different forest types found in the study area.

Forest Type	Crown density class	NTFP (TEV) Class		
		High	Moderate	Low
Western subtropical broad leaf hill forest	Dense	6,604	2	-
	Closed	348	8	-
	Open	2,854	19	-
	Degraded	6	-	-
Southern moist deciduous forest	Dense	21,646	3,406	7,431
	Closed	10,402	2,870	327
	Open	304	725	27
	Degraded	2	-	52
Southern dry deciduous forest	Dense	1,327	413	51
	Closed	9,457	4,741	47
	Open	47,431	16,443	99
	Degraded	174	-	26

Conclusions

The distribution of tree species depends not only on the ecology of area, but also on anthropogenic pressure. Forests that were far away from the human settlements and on difficult terrain contained large areas under dense and closed forest. In such areas, moderate to high non-timber forest dominated and the trees found in such areas had moderate to high economic values. This is evident from the analysis of NTFP found in the western subtropical broadleaf hill forest. The forest found in close proximity of human settlements and on relatively moderate terrain contained large areas under open forest dominated by trees belonging to moderate NTF class and having moderate TEV values. Southern moist deciduous forest was the intermediate type between the above-mentioned two types. This forest is dense. Tree species constituting this type contributed only to moderate NTF class and had moderate economic values. The study presented above demonstrates the utility of satellite remote sensing data and GIS in generating the NTFP map at sample level. Such maps will have wide utility in management of forest resources and in conservation and rehabilitation of floral diversity. It may also be useful to improve sustainable NTFP use by local communities.

Acknowledgements

References

Belal, AE. & I. Springuel. 1996. Economic value of plant diversity in arid environment. *Nature & Environment* **32**: 33-39.

Cooke, T. 1967. *Flora of Presidency of Bombay*. Botanical Survey of India, Kolkata.

F.A.O. 1995. *Non-wood Forest Products 7*: *Non-wood Forest Products for Rural Income and Sustainable Forestry*. FAO, Rome.

Giri, T.K., A. Mazumdar & S.C. Santra. 2005. Major NTF items and their marketing poten-tials in Hazaribagh forest area in Jharkhand - A Case study. *Indian Forester* **131**: 425-436.

MoEF. 1988. *National Forest Policy 1988*. Resol-ution No. 3.1/86-F.P., Ministry of Environment and Forests, Govt. of India, New Delhi.

Ojha, H.R., B.P. Subedi & S.P. Dangal. 2005. Assessment and sustainable harvesting of non-timber forest products: Some initiatives in community forestry in the hills of Nepal. *http://www.mtnforum.org/resources/library/ojhax 01a.htm*.

Paloti, L.M. & U.S. Hiremath. 2005. Role of NTFPs in economic empowerment of rural women. *Indian Forester* **131**: 925-929.

Peterson, G. 2005. NTFP Project. www. eastwestcenter.org/environment/ethics/NTFP%20 Profile.htm.

Santapau, H. 1967. Flora of Khandala on the Western Ghats of India. *Records BSI* **16**: 1-372.

Santapau, H. & A.N. Henri. 1973. *A Dictionary of Flowering Plants of India*. CSIR, New Delhi.

Singh, N.P. & S. Karthikeyan. 2001. *Flora of Maharashtra State, Dicotyledons. Vol-2. Flora of India Series 2*. Botanical Survey of India, Pune.

Singh, U., A.M. Wadhwani & B.M. Johari. 1983. *Dictionary of Economic Plants in India*. Indian Council of Agricultural Research, New Delhi.

Srivastava, V.K., M. Niphadkar, Neeti, M.K. Kukreja,

S.A. Ravan, M.K. Janarthanam, V.C. Joshi & S. Rajkumar. 2004. *Biodiversity in the Western Ghats districts of Maharashtra and Goa.* SAC/RESIPA/ FLPG/FED/DOS-DBT/SR/02/2004, Space Application Centre, Ahmedabad.

Wilkinson, K. & C. Elevitch. 2005. Non-timber forest products: An introduction. *The Overstory* **53**: 1-9.

Wong, J.L.G. 2000. The biometrics of non-timber forest products resource assessment: a review of current methodology. *Proc. Developing Need-Based Inventory Methods for Non-timber Forest Products-Applications and Development of Current Research to Identify Practical Solutions for Developing Countries*, May 4-5, 2000, Rome, Italy.