Toward Sustainable Use of Forest Resource:

Connecting Forest Ecology to Village Economy

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A NOTE FROM RCDC

Regional Centre for Development Cooperation(RCDC) has been one of the pioneer organizations in India that have taken up research work on the issues and concepts related to climate justice. A preparatory activity on a pilot scale conforming to the overall regime of REDD+ on an experimental basis was a part of this initiative details of which have been made available in a separate report at http://www.rcdcindia.org/PbDocument/d3ea3efa4b8071b-45a2-4ac7-ba45-3751a2387d18Final_RCDC_Brief%20Report_Odisha%20Community%20REDD%20project%20(1).pdf .

A vital component of this project intervention consisted of ecological research. However, an extensive ecological research in the study area was not feasible because of financial limitations and constraints of time. There were some technical limitations too. Despite all these limitations however, noted Ecologist Dr. Debal Deb kindly agreed to take up this research work. We share herewith his report for the access and comments of all concerned stakeholders with a special reference to his claim that the methodology adopted for this study has been adopted for the first time for Odisha forests.

The study could be possible thanks to the facilitation & hard work of a number of persons associated with the project in one way or the other. Notable among them are Mr.S.Palit, IFS (retd.) and CFI Regional Coordinator in India; Mr. Ghasiram Panda, Mr. Milan Pati, Mr. Kulamani Sahu, Mr. Amar Kumar Gouda, and Mr. Raghunath Padhi, retired Ranger.

However, RCDC observes that while the core technical part of this report may have its own justification and relevance, many of the associated/supplementary information are of ambiguity. While one may contact Dr. Deb with comments(if any) or for necessary clarifications at debaldeb01@yahoo.com, RCDC may also entertain a request from competent agencies/individuals for a comprehensive clarity on the matter in deserving cases.

Bikash Rath

Sr. Programme Manager

Toward Sustainable Use of Forest Resource:
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Final Report

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Contents:

1. Introduction

The forest in Balangir district comprises a tract of moist deciduous forest, interspersed with semi-evergreen patches. We have chosen only 5 forest areas, adjacent to villages and , and managed by village protection committees, and comprised by a mix of State Revenue Forest and Reserved Forest tracts. Both types of forest are customarily used by villagers to meet their food and fuel needs, and both are protected to an equal extent under the community management system. In this study, we have sampled equal proportions of Revenue Forest and Reserve Forest, for assessment of the status of forest biodiversity and disturbance regimes. In particular, the Report addresses the following objectives:

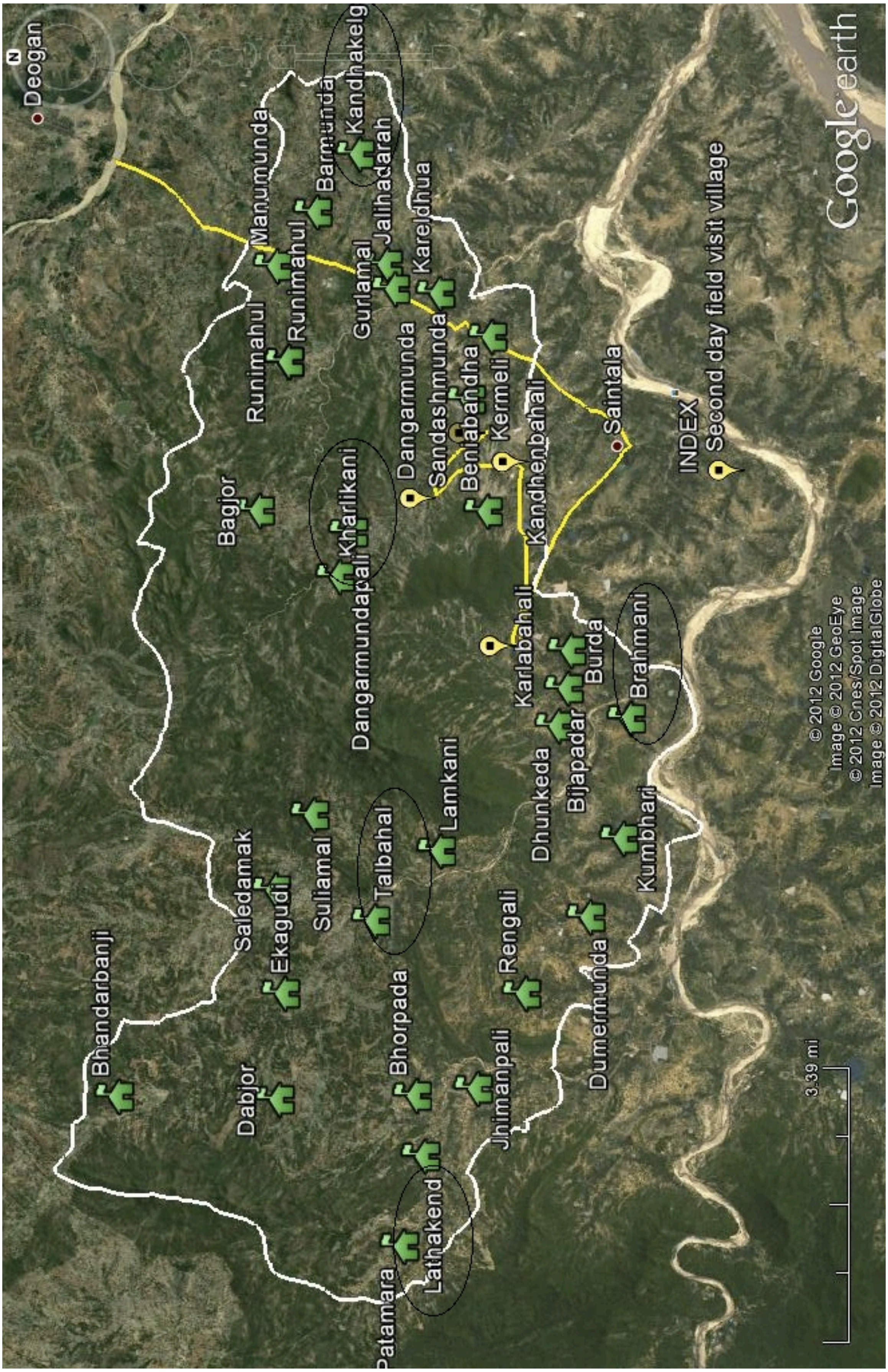
1. *Identifying drivers of deforestation, for developing a mitigation strategy in the REDD+ project area.*
2. *Making a broad estimate of the clumps of bamboos (Dendrocalamus strictus) occurring within the area and suggesting their sustainable harvesting methods and their economic import.*
3. *Preparing an inventory of the Non-Timber Forest Products (NTFP) occurring within the project area mentioned above and suggesting their sustainable harvesting methods for long term benefits to forest village economies.*

In this Report, we have employed forest ecological survey methods, and identified the major drivers of forest decimation and the current trend of forest depletion. This would enable us to draft a mitigation strategy in the FINAL report, based on quantitative data about biomass flow from the forest into the villages.

The ecological implications of the forest species composition, diversity, stem density, crop height and species abundance ranking data are discussed in detail, which will be helpful in devising a long term planning for sustainable forest management. Our on-site data of seedling regeneration, though based on a single season, provides a strong database for indication of the regeneration potential of the forest patches under study.

We have assessed the status of the forest ecosystem – in terms of species diversity and abundances, and their overall contribution to production of biomass that is relevant to the REDD+ objective of carbon sequestration assessment. Based on our empirical estimation of stem biomass, we derived the branch and root biomass, using standard dendrometric procedures. Finally, we have undertaken an additional task of quantifying the total carbon content in the tree wood biomass in the forest areas under study.

This report records the signs and the pattern of biomass removal from the forest, the factors that elicit deforestation, and the management implications of the findings. In the final section we have suggested sustainable methods of harvest for each item of NTFP. The recommendations would likely both enrich the forest species composition and strengthen the CFM regime.



Map 1: Forest Mouzas under RCDC Forest Management Project. The five forest mouzas selected in this study are marked with ellipses.

2. Methods

2.1 *Site selection and Sampling Transects*

The forests in the area used to comprise a continuous tract across the entire district, interspersed with village settlements. With the state's emphasis on revenue generation during British rule, the number of settled agriculturists increased and replaced the traditional hunter-gatherers and shifting cultivators. Expansion of both agriculture and settlement encroached upon the foerst land, resulting in disjointed forest patches (**Map 1**). All these forest patches belong to Balangir Forest Range of the State Forest Department, lying in two adjacent administrative blocks. **Table 1** gives a list of forest villages under the present project of RCDC, which concerns with the forest management patterns and recognition of the community under the Forest Rights Act (FRA) of 2006. Two villages in this list of 31 forest villages observe no rule of management, and their forests are suffering from the tragedy of open access commons. A majority of the forests, numbering 20, are being officially managed by the villagers and the State Forest Department (FD) under the Joint Forest Management (JFM) regime, while 9 forests areas are being managed entirely by the village communities, without any intervention from the FD. The customary management regime of these forests may be categorized as *de facto* Community Forest Management (CFM), in which villagers have framed their own rules governing access and use of the forest resource. With aid from RCDC, a total of 9 villages have claimed their right to ownership of their forests following the FRA guidelines.

We eliminated the 2 villages with no management rules (Saledamak and Manumunda) from our consideration for sampling, and from among the remaining 29 forest areas, selected 5 forest mouzas (17.2% of total number of mouzas in the area), namely, Kandkhelgaon (east), Kharlikani (east central), Brahmani (south), Talbahal (west central), and Lathakend (west). These mouzas were selected for the present study based on the following four aspects:

(a) *Geographical position* (only non-contiguous forest patches, quasi-randomly distributed in the project area – see **Map 1**);

(b) *Management regime*: (3 CFM and 2 JFM villages);

(c) *Number of households*: (villages with small (< 60) to very large (> 300) number of households, in order to reflect the proportionate anthropogenic effects on forest biodiversity and structure in the sample universe).

Table 1: Forest Villages and Forest Management Regimes in the Project Area.

Ser. No.	**Name of Village**	**Total No. of Households**	**Management Regime**	**FRA Status**
1	Patamara	112	JFM	
2	*Lathakend*	91	CFM	
3	Jhimanpali	99	JFM	
4	Rengali bahal	78	JFM	
5	Dabjor	256	CFM	
6	Ekagudi	56	JFM	
7	*Talbahal*	107	JFM	
8	Saledamak	105		
9	Suliamal	43	JFM	
10	*Kharlikani*	57	CFM	Claimed
11	Bagjor	65	JFM	
12	Runimahul	63	JFM	
13	Manumunda	24		
14	Badmunda	65	CFM	
15	*Kandhkelgaon*	333	CFM	
16	Jaliadarah	166	JFM	
17	Gurlamal	35	CFM	
18	Dangarpara	36	JFM	Claimed
19	Junanimal	24	JFM	Claimed
20	Sandasmunda	106	JFM	Claimed
21	Kermeli	86	CFM	Claimed
22	Karlabahali	18	JFM	Claimed
23	Burda	221	CFM	
24	Bijapadar	38	CFM	Claimed
25	Dhunkeda	85	JFM	
26	Lamkani	89	JFM	
27	Dumermunda	164	JFM	
28	Kumbhari		JFM	
29	Kareldhua	72	JFM	Claimed
30	Saintala	124	JFM	Claimed
31	*Bramhani*	294	JFM	

Note: The highlighted villages were selected for sampling

(d) *Area of forest cover*: The total area of the selected five mouzas is 509.7 ha, comprising 25.8% of the total area of 1978.65 ha under forest in the area.

In each of the selected 5 forest mouzas (Talbahal, Lathakend, Kharlikani, Kandkhelgaon, and Brahmani), a limited number (≥ 4) of belt transects were laid in order to conduct a rapid ecological assessment (**Table 2**). Each transect measured 100 m x 10 m, laid in north-south direction. The total sampled area (22,000 m^2) constituted about 0.32% of the total forest area in these 5 mouzas.

Table 2. List of Forest Mouzas Selected for Study

Ser. No.	Forest Mouza Name	Code Used in Report	Revenue Forest (VF) Area (ha)	Reserve Forest (RF) Area (ha)	No. of Transects Laid	Sampled Area (m^2)
1	**Talbahal**	TBL	30.075	93.98	4	4000
2	**Latakend**	LTK	101.504	150.37	4	4000
3	**Brahmani**	BMN	0	187.96	4	4000
4	**Kharlikani**	KLK	88.346	0	4	4000
5	**Kandkel Gaon**	KKG	45.113	0	6	6000
	Total		*265.038*	*432.31*	*22*	*22000*

2.2 *Sampling Method*

The number of tree species enumerated in each belt transect was plotted against the number of sample transects. The resulting species effort curves[*] for the forest patches (**Fig. 1**) appear to indicate near-saturation of sampling of tree species. However, the species effort curve for all trees above 15 cm GBH seem to indicate sampling adequacy.

When the pooled species sampling is considered, the saturation of species numbers reaches at or beyond 4 transects, and addition of new species seems to

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[*] Species effort curves depict the cumulative number of species in successive samples. The saturation of species indicates adequacy of sample numbers, and obviates the need of adding an indefinite number and time for sampling (Soberón and Llorente 1993).

cease. The trend of saturation of species sampling suggests that excepting LTK, the sampled forest sites require no further sampling with additional transects. The cumulative species number also reaches an asymptote, which indicates sampling adequacy for our rapid ecological assessment, based on which a robust understanding of the forest ecological dynamics seems possible.

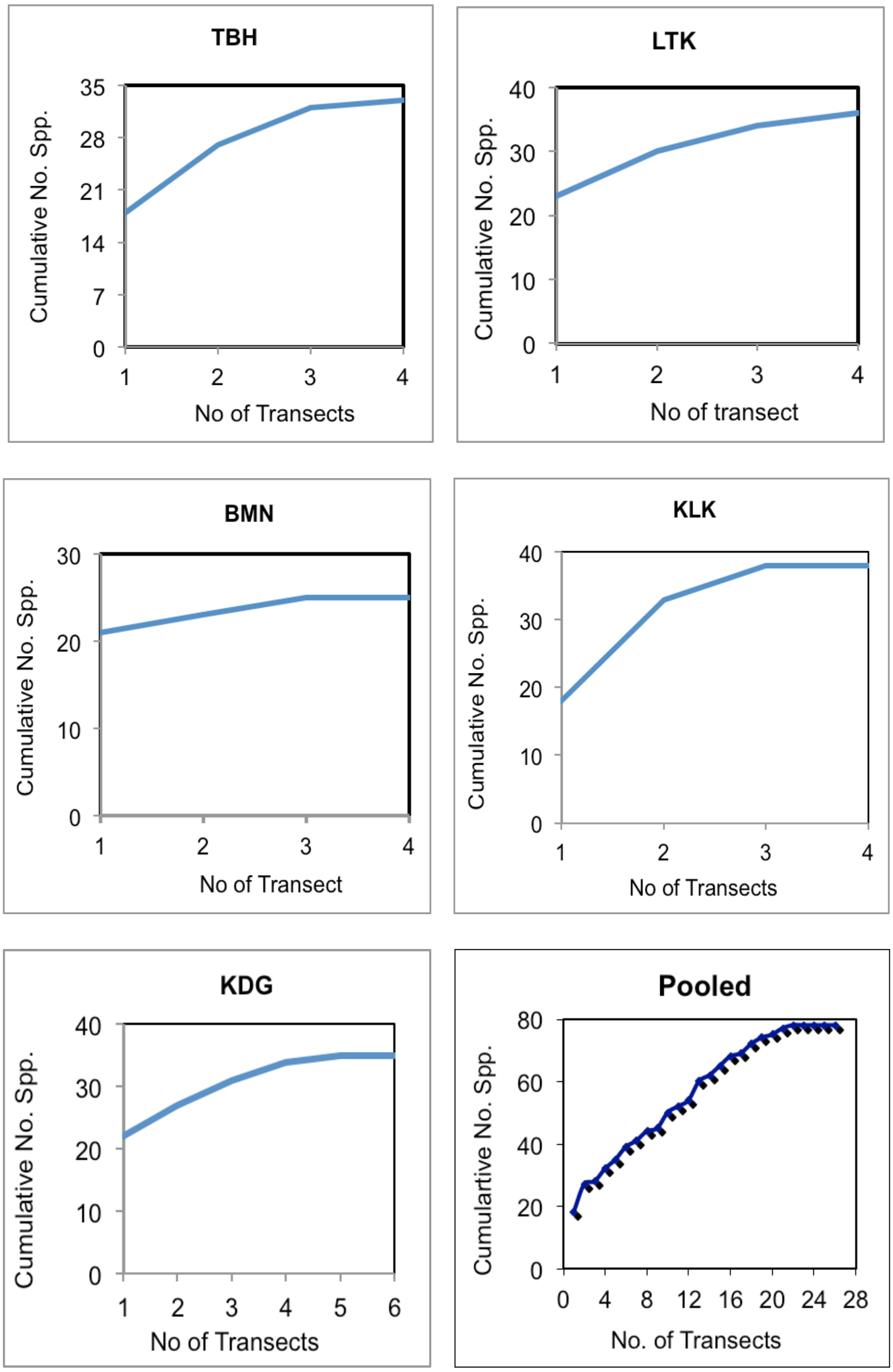

Fig. 1: Species Effort Curves of Five Forest Plots, for Trees with >15 cm GBH.

2.2 *Stem Density and Basal Area*

Stem density was estimated from the mean number of trees in all the transects laid in each forest plot, and expressed as numbers per hectare, using the formula:

$$\text{Stem Density} = 10000 \times [\text{Total No. of trees}/(m \times A)], \qquad \text{eqn. (1)}$$

where m = No. of transects in a plot, and A =1000 m^2 – the area of each transect.

For density estimation, trees of two girth classes were counted - more than 10 cm girth at breast height (GBH), and more than 15 cm at GBH. From the GBH counts of the trees, the basal area (BA) in each plot was calculated as

$$BA = GBH/4\pi \qquad \text{eqn. (2)}$$

An advantage of estimating stand density for two girth classes is that the differences in the densities would indicate the possible external factors for the size-selective mortality of different species occurring at the same habitat (Deb 2009).

2.3 *Tree Volume and Biomass*

While calculating the above-ground wood volume, the shape of the tree is assumed to be uniformly cylindrical, so that its volume is calculated as a product of the tree basal area (BA) and tree height. The total stem volume (TSV) in a forest site is calculated as:

$$TSV\ (m^3/ha) = [10000\ h \sum BA]/\ TA \qquad \text{eqn. (3)}$$

where h = mean crop height, TA = the total area of all transects (in m^2) , and the $\sum BA$ is the sum total of BA of all trees sampled in all transects in a forest site.

The total above-ground wood biomass was calculated based on TSV of each forest site, using the mean wood density of Odisha forest trees, as recorded in Haripriya (2000) and Kaul (2009). This value of wood density D_1 = **0.72** Mgm^{-3}, and the estimated wood biomass figures from forests of the State of Odisha and of India (Table **3**) were used as the reference for this study.

Table 3: Estimated Forest Biomass Parameters from Odisha and India.*

Region	**Mean Wood Density** (Mg m^{-3})	**Wood Biomass** (Mg ha^{-1})		**Ratio of Belowground to Aboveground Biomass**	**Mean Aboveground Biomass Growth** (Mg dm ha^{-1} yr^{-1})
		1992	2002		
India	0.72	98.09	93.27	0.36	1.89
Odisha	0.72	69.48	80.10	0.27	2.45

* *Source:* Kaul (2009)

Table 4: Wood Density of Tree Species Recorded in Forest Areas Under Study.

Tree Species	**Wood Density** (Mg/cu.m.)*	**Tree Species**	**Wood Density** (Mg/cu.m.)*
Adina cordifolia	0.59	*Holoptelea integrifolia*	0.50
Aegle marmelos	0.88	*Ixora parviflora*	0.96
Alangium salvifolium	0.80	*Lagerstroemia parviflora*	0.62
Albizzia lebbek	0.80	*Madhuca (=Bassia) latifolia*	0.99
Albizzia procera	0.64	*Mangifera indica*	0.68
Anogeissus sp.	0.88	*Morinda sp.*	0.72
Artocarpus lacoocha	0.68	*Nyctanthes arbor-tristis*	0.88
Boswellia serrata	0.50	*Pterocarpus marsupium*	0.96
Buchanania lanzan	0.46	*Schleischera oleosa*	1.08
Butea monosperma	0.56	*Shorea robusta*	0.73
Carfeya arborea	0.80	*Soymida fabrifuga*	0.96
Casaria tomentosa	0.64	*Sterblus asper*	0.72
Cassia fistula	0.96	*Symplocos racemosa*	0.44
Dalbergia paniculata	0.80	*Syzygium cumini*	0.76
Dalbergia sissoo	0.76	*Tamarindus indica*	1.28
Diospyros melanoxylon	0.68	*Terminalia belerica*	0.76
Gmelina arborea	0.56	*Terminalia chebula*	0.88
Grewia tiliafolia	0.65	Others	0.652
Holarrhena antidysenterica	0.64	**MEAN**	**0.754**

* Source: Zanne et al. (2009)

However, the actual forest composition of the study sites was taken into consideration for a benchmark estimation of the mean wood density for the forest sites under this study (**Table 4**). The mean wood density of all forest trees enumerated in this survey was estimated from the arithmetic mean of wood densities of all species, as given in the Global Wood Density Database (Zanne et al. 2009). Any tree species that was not found in the database, was assigned the mean density value for the "Others" category. The mean of all wood densities was estimated to be D_2 = **0.754** Mg m^{-3} which is used here as a benchmark value.

The stem biomass (M_s) of forest trees was then calculated as the product of TSV and mean wood density, in two ways:

M_{S1} = TSV. D_1 [density estimation after Kaul et al. 2009) eqn. (4a)

M_{S2} = TSV. D_2 [density estimation after Zanne et al. 2009] eqn. (4b)

Following Moura-Costa (1996), the branch wood biomass (M_B) was calculated as

$M_{B1} = 0.136\ (M_{S1})^{1.07}$ eqn. (5a)

$M_{B2} = 0.136\ (M_{S2})^{1.07}$ eqn. (5b)

Finally, following Chan (1982), the below-ground wood biomass (M_R) (= root biomass) was calculated as

$M_{R1} = 0.25\ (M_{S1} + M_{B1})$ eqn. (6a)

$M_{R2} = 0.25\ (M_{S2} + M_{B2})$ eqn. (6b)

Thus, the total wood biomass (TWM) was calculated as the sum total of the aboveground and belowground wood biomass:

$TWM_1 = M_{S1} + M_{B1} + M_{R1}$ eqn. (7a)

$TWM_2 = M_{S2} + M_{B2} + M_{R2}$ eqn. (7b)

2.4 *Species Diversity*

Species richness was estimated by the total number of species (S) identified at a given site. The species richness is counted regardless of abundances of any of the component species, and represents Hill's N_1.

Abundances and species diversity was measured as Hill's (1973) N_1, which is the exponential of Shannon-Wiener index:

$$N_1 = \exp(H') \qquad \text{eqn. (8)}$$

where $H' = -\sum p_i \ln(p_i)$, and p_i = proportion of the i^{th} species.

We have chosen Hill's N_1 over other diversity indices because (a) it normalizes Shannon-Wiener index by converting logarithmic fractions into more wieldy real numbers; (b) it portrays moderate species dominance (Caballero-Vázquez and Vega-Cendejas 2012), and (c) it is a convex function of the proportions of species throughout the range of proportions, and is expressed in units of species numbers, and therefore more easily interpretable than other indices (Gadagkar 1989). An added advantage of using N_1 is that it reflects the evenness of species distribution, with evenness increasing with the value of N_1. The need to use a separate evenness index is thus obviated.

2.5 *Recruitment Ratio*

As a measure of the normal rate of recruitment from a younger to older age group (equivalently, lower girth class to higher girth class), we define recruitment ratio (RR) as

$$\text{RR} = N_j / N_{j-1} \qquad \text{eqn. (9)}$$

where N_j stands for the number of trees in the j^{th} girth class, and N_{j-1} is the number of trees in the previous girth class. In this study we have defined j = GBH >15 cm, and $j-1$ is GBH above 10 cm but below 15 cm. In a tropical hardwood forest, the ideal recruitment from 10 cm GBH to 15 cm GBH (assuming zero mortality) is 100% (RR = 1). A ratio of RR < 1 would indicate a reduction in the number of older trees, whereas RR > 2 would imply higher mortality/harvest of younger than older trees.

2.6 *Carbon Stock Estimation*

The total wood biomass (TWM) was determined from the wood volume and overall wood density of forest trees (see **Sec. 2.3**). The carbon density (CD)was estimated, using the estimation by Sharma et al. (2000) based on Indian mixed deciduous forests, as:

$$CD_1 = TWM_1 \times C\% \qquad \text{eqn. (10a)}$$

$$CD_2 = TWM_2 \times C\% \qquad \text{eqn. (10b)}$$

where TWM_i is the total (aboveground + belowground) wood biomass (eqn. 7a and 7b), and C% is the mean of carbon fraction, which is estimated at 46% for Indian forest trees (Sharma et al. 2010). The total C stock of the forest tree biomass estimated using eqn. (10) is presented here as the approximate quantity of total stock of forest carbon.

2.7 *Statistical Analyses*

(a) Relationships between parameter sets were ascertained using standard statistical tests like Pearson's correlation (*r*) and linear regression. Non-linear relationships were examined using log-transformed data.

(b) Jack-knifed index of diversity was calculated following Magurran (2004), using a computer program written in QBASIC.

(c) MS Windows Excel® was used to perform regression analyses, with all intercepts set at 0. Student's *t* test was performed for assessing statistical significance of (i) the difference between means and relationships, and (ii) correlations between pairs of data points.

3. SALIENT FINDINGS

3.1 *Floral Species composition*

The studied region has 109 species of vascular plants, belonging in 33 Families (**Table 5**). Anacardiaceae, Ceasalpineae and Moraceae have the highest numbers of member species in the forest sites (**Fig. 2**). The presence of a large number of tree species is an indicator of the mixed nature of this forest ecosystem. The forest has numerous lichens both on tree barks as well as on rocks indicating very low levels of air pollution. We did not enumerate the diversity of lichens and bryophytes because the required taxonomic expertise was not available.

Table-5: Inventory of Vascular Plant Species Rawghat

Serial No.	Local Name	Botanical Name	Family
1	Anchee	*Morinda angustifolia*	*Rubiaceae*
2	Amba	*Mangifera indica*	*Anacardiaceae*
3	Ainla	*Emblica officinalis*	*Euphorbiaceae*
4	Bahada	*Terminalia belerica*	*Combretaceae*
5	Bara	*Ficus benghalensis*	*Moraceae*
6	Bandhana	*Desmodium* (=*Ougenia*) *oojenensis*	*Papilionaceae*
7	Baranga	*Crateva religiosa*	*Capparidaceae*
8	Bela	*Aegle marmelos*	*Rutaceae*
9	Bendi	*Naringi crenulata*	*Rutaceae*
10	Bheru	*Chloroxylon sweitenia*	*Meliaceae*
11	Beuti Laha	*Nyctanthes arbor-tristis*	*Rutaceae*
12	Bhalia	*Semelcarpus anacardiale*	*Anacardiaceae*
13	Bija	*Pterocarpus marsupiym*	*Papilionaceae*
14	Budel	*Ixora parviflora*	*Oleaceae*
15	Chakunda	*Cassea siamea*	*Caesalpineae*
16	Chaar	*Buchanania lanzan*	*Anacardiaceae*
17	Chauldhua	*Glycosmis pentaphylla*	*Rutaceae*
18	Cheena	*Lagertroemia parviflora*	*Lythraceae*
19	Dangar kure	*Bridelia squamosa*	*Euphorbiaceae*
20	Dhamana	*Grewia tilafolia*	*Tiliaceae*

Table 5, contd.

Serial No.	Local Name	Botanical Name	Family
21	Dhaura	*Anogeissus latifolia*	*Combretaceae*
22	Dhatuk	*Woodfordia fruticosa*	*Lythraceae*
23	Gambhari	*Gmelina arborea*	*Verbenaceae*
24	Dhuben	*Dalbergia paniculata*	*Papilionaceae*
25	Gad khair	*Albizzia odoratissima*	*Mimosaceae*
26	Gambhari	*Gmelina arborea*	*Buxaceae*
27	Ghato	*Artocarpus lacoocha*	*Moraceae*
28	Halan	*Adina cordifolia*	*Rubiaceae*
29	Harida	*Terminalia chebula*	*Combretaceae*
30	Jamu	*Syzygium cumini*	*Myrtaceae*
31	Jamurla	*?*	*Myrtaceae*
32	Karla	*Cleistanthes collinus*	*Euphorbiaceae*
33	Kathal	*Artocarpus integrifolia*	*Moraceae*
34	Kendu	*Diospyros melanoxylon*	*Ebenaceae*
35	Keunti	*Strychnos nux-vomica*	*Loganiaceae*
36	Khair	*Acacia catechu*	*Mimosaceae*
37	Khaish	*Casearia elliptica*	*Samydaceae*
38	Kini maja	*Cassine glauca*	*Euphorbiaceae*
39	Kiharal	*Ceriscoides turgida*	*Rubiaceae*
40	Kharsel	*Xylla xylocarpa*	*Mimosiaceae*
41	Kum	*Careya arborea*	*Myrtaceae*
42	Kurdu	*Gardenia gummifera*	*Rubiaceae*
43	Kurei	*Holarrhena antidysenterica*	*Apocynaceae*
44	Kusuma	*Schleischera oleosa*	*Sapindaceae*
45	Madei	*Lannea coromandelica*	*Anacardiaceae*
46	Mahula	*Madhuca latifolia*	*Sapotaceae*
47	Mal dhara	*Albizzia procera*	*Mimosaceae*
48	Mundi	*Mytragyna parvifolia*	*Rubiaceae*
49	Manj	*Mitragyna parviflora*	*Rubiaceae*
50	Mid	*Lagerstroemia parviflora*	*Lythraceae*
51	Padhel	*Butea monosperma*	*Papilionaceae*
52	Panikusum	*Aphanamixis polystachia*	*Meliaceae*
53	Patua	*Stereospermum chelonoides*	*Bignoniaceae*
54	Ping	*Celastrus paniculata*	*Rubiaceae*
55	Pipal	*Ficus religiosa*	*Moraceae*

Table 5, contd.

Serial No.	Local Name	Botanical Name	Family
56	Rohen	*Soymida fabrifuga*	*Meliaceae*
57	Sabun	*Streblus asper*	*Moraceae*
58	Sahaja	*Terminalia tomentosa*	*Combretaceae*
59	Sal	*Shorea roibusta*	*Diptercarpaceae*
60	Salap	*Caryota urens*	*Palmae*
61	Salei	*Boswellia serrata*	*Burseraceae*
62	Salingbanji	*Dendrocalamus strictus*	*Gramineae*
63	Simli	*Bombax malabarica*	*Malvaceae*
64	Sisu	*Dalbergia sissoo*	*Papilionaceae*
65	Sunari	*Cassia fistula*	Caesalpiniaceae
66	Tangen	*Albizzia procera*	*Verbenaceae*
67	Telkuari	*Symplocos racemosa*	*Styraceae*
68	Tentuli	*Tamarindus indica*	*Caesalpiniaceae*
68	Thelko	*Wendlandia tinctoria*	*Rubiaceae*
69	Um	*Holoptelea integrifolia*	*Meliaceae*

3.2 *Site-specific features*

In each of the sites 100m x 10m transacts were laid, all in North-South direction. On an average each hectare of forest has 90 cut off stumps (11% only) out of 820 standing trees with GBH > 15 cm. This indicates that the extent of extractive perturbation is likely to be below the forest regeneration rate. As mentioned earlier, the vegetation type is of *Terminalia spp – Anogeissus latifolia – Cleistanthus collinus* Series (Puri, 1989) but a lot of variation in the vegetation type is visible in different sites. This variation is mostly due to microclimatic variations and successional history shaped by both the local and official management regimes.

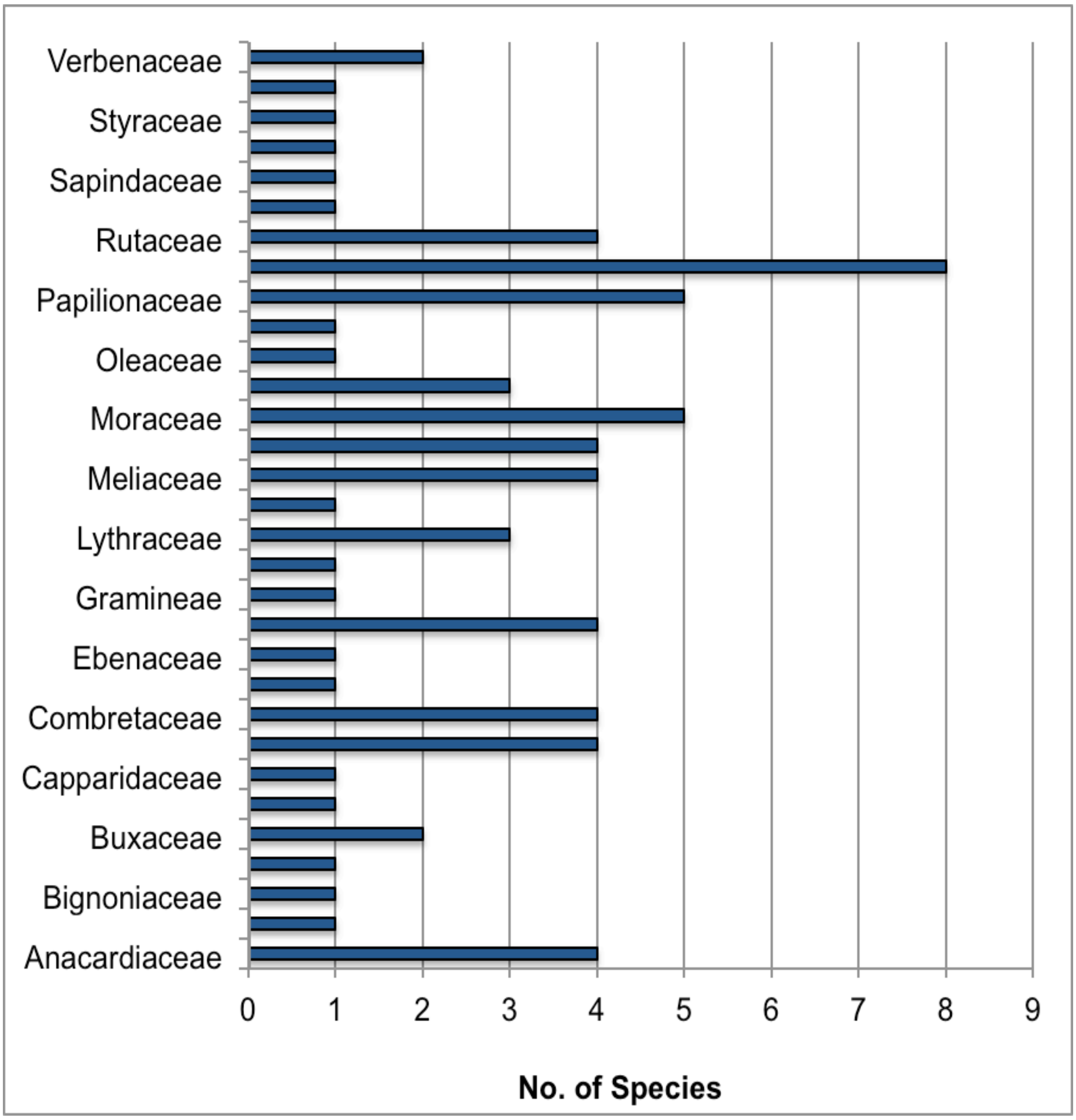

Fig. 2: Overall Representation of Plant Families in the Study Sites.

The individual sites showed considerable variations in tree species diversity (**Fig. 3**). All the sites contained above 40% of the species pool of the entire forest tract, while most of the tree species diversity was present in two of the sites, namely TMP and UBP. The general features of the sites are as follows.

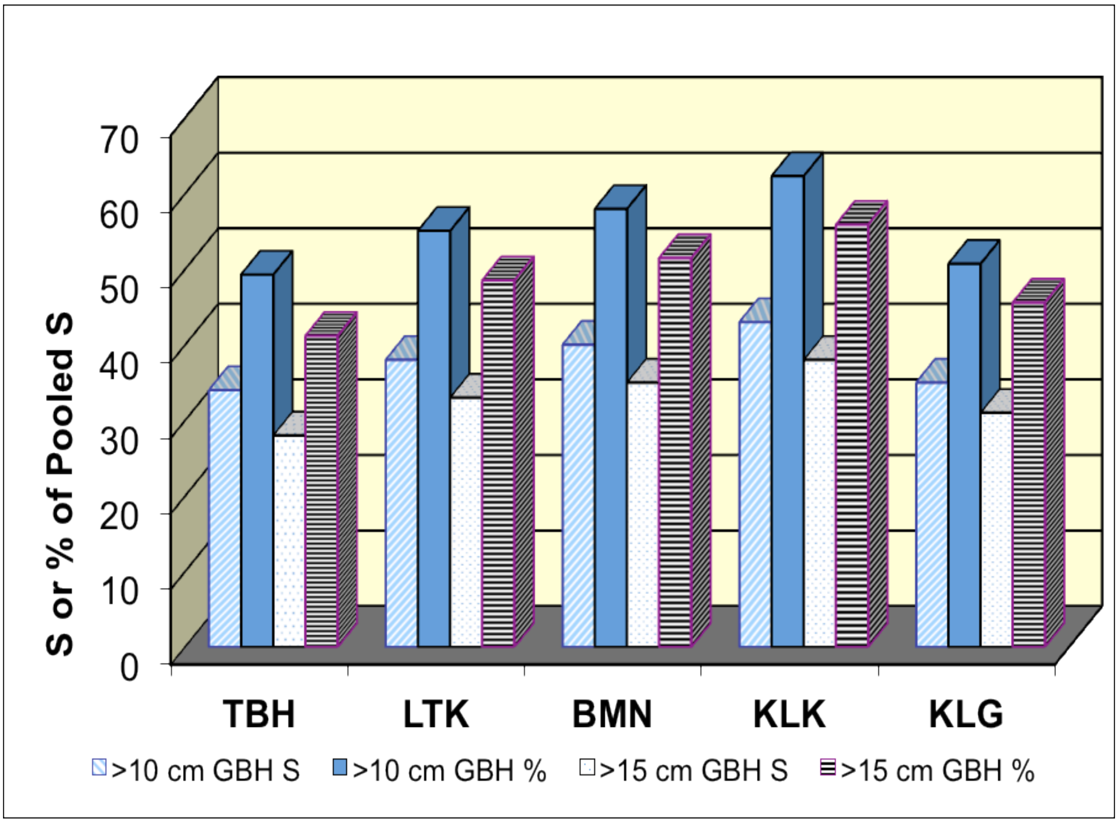

Fig. 3: Tree Species Richness (*S*) and Proportion (%) of Species Count in 5 Forest Sites, for Two Girth Classes.

3.2.1. Species Diversity

Our sampling methodology enumerated all floral species at both tree girth classes (GBH >10 cm and GBH > 15 cm). Thus, the species diversity (*S*) was discretely counted for two girth classes. The patterns of tree species diversity in the forest plots are given in **Table 6**. Clearly, the species are not evenly distributed in the forest sites. Sites TBH and BMN seem to resemble in the evenness of species distribution for trees with GBH >10 cm, but widely dissimilar when trees with GBH >15 cm are considered. The overall N_1 for all sites pooled together is the mean of 22.77 (for trees with GBH > 10 cm) and 21.35 (for trees with GBH > 15 cm). However, these pooled figures in fact do not reflect the true beta diversity. Jack-knifed N_1 for all 5 Sites, is 22.06.

Compared to the jack-knifed diversity value, the sites KLK is the only site where species distribution of trees with GBH >15 cm seems to be least influenced by exogenous factors, including anthropogenic disturbance. However, in the same site, N_1 is far higher (66.05) than the Jack-knifed index.

Table 6: Diversity of Tree Species at Study Sites

Forest Patch Name	**Code Used in Report**	**GBH >10 cm**		**GBH >15 cm**	
		S	N_1	***S***	N_1
Talbahal	TBH	34	53.56	28	13.69
Lathakend	LTK	38	38.23	33	15.92
Brahmani	BMN	40	55.08	35	15.78
Kharlikani	KLK	43	66.05	38	20.97
Kandkhel Gaon	KDG	35	21.67	31	11.84
Pooled		*69*	*22.77*	*68*	*21.35*

3.2.2 Species Abundance Patterns

Relative abundances of the tree species in each forest site were estimated for >10 cm and >15 cm GBH classes. The rank-abundance plots (Whittaker plots) for all sample sites, and for both girth classes of trees, highlight differences in evenness amongst species assemblages, and depict gentle slopes (**Fig. 4**), depicting considerable evenness of distribution (Magurran 2004). The only site showing single species dominance is KDG, where sal (*Shorea robusta*) comprises 25% (for GBH >10 cm) and 32% (for GBH >15 cm) of species abundances. The single species dominance is also observed in site TBH, albeit only for GBH >15 cm, indicating a more pronounced regenration of sub-dominant species.

At the sites TBH and KDG, *Shorea robusta* is the dominant species, seconded only by kendu (*Diospyros melanoxylon*), especially for the larger (>15 cm) girth class. In contrast, at other sites, the co-dominant species are comprised by sal, karla (*Cleistanthus collinus*), dhaura (*Anogeissus latifolia*), chaar (*Buchanania lanzan*) and sahaja (*Terminalia tomentosa*).

The species of low mean abundances (<10/ha) include bheru (*Chloroxylon sweitenia*), dhuben (*Dalbergia paniculata*), chauldhua (*Glycosmis pentaphylla*), kharal (*Ceriscoides turgida*), manj (*Mytragyna parviflora*), kirimala (unidentified), mid (unidentified) and patua (unidentified). The overall species distribution features in the different sample sites are described below.

Site-TBH

The site has 34 tree species and density of 996 trees of >15 cm GBH per ha. The density of trees with >10 cm GBH is 1943/ha. The species composition represents 49.3% of the total species pool of 69. The tree community here is found to be dominated by *Shorea robusta*, *Diospyros* melanoxylon, and *Terminalia tomentosa*. The evenness of species distribution is considerably high, with N_1 = 53.56 (**Table 6**).

Site-LTK

The site has 38 tree species, accounting for 55% of the total species pool. Stand density was estimated at 1435/ha for larger (>15 cm) girth class, and 2072/ha for GBH >10 cm. The tree community here is found to be codominated by *Diospyros melanoxylon, Anogeissus latifolia*, *Cleistanthus collinus*, and *Acacia catechu*. Moderate evenness of distribution is indicated by N_1 = 38.23.

Site-BMN

The site has 40 tree species (58% of the overall spcies pool), with a stand density of 1312/ha for all trees above 10 cm GBH. The density of trees with wider girth (>15 cm) is 802.5/ha. The tree community here is found to be dominated by *Buchanania lanzan*, *Woodfordia fruticosa*, *Shorea robusta* and *Anogeissus latifolia*. High evenness of distribution is indicated by N_1 = 55.08.

Site-KLK

The site has 43 tree species and density of 943 trees of >15 cm GBH per ha. The density of trees with >10 cm GBH is 1523/ha. The species composition represents 62.3% of the total species pool of 69. The tree community here is found to be dominated by *Shorea robusta*, *Terminalia tomentosa* and *Anogeissus* *latifolia*. The distribution is high, as indicated by N_1 = 66.05 (Table 3).

Site-KDG

The site has 35 tree species and density of 3030 per ha for all trees of >10 cm GBH. The density of trees of wider (>15 cm) girth class is 2425/ha. The species composition represents 50.7% of the total species pool of 69. The tree community here is found to be dominated by Sal (*Shorea robusta*) alone, accounting for 32% of tree abundances. Poor evenness of distribution is indicated by N_1 = 21.67.

3.3 Pooled Analysis of All Sites

The overall species richness, distribution and abundance pattern of the sampled forest area were estimated by pooling all discrete site data pertaining to species richness and structural parameters like stem density and basal area.

3.3.1 *Species Richness*

The overall species pool across all 5 sites is 69, with the overall numerical dominance of *Shorea robusta*, *Cleistanthes collinus*, *Buchanania lanzan*, *Anogeissus latifolia*, with lower abundances of *Terminalia* spp. - characteristic of the mixed moist deciduous forest of the region. The poor abundance of sal (*Shorea robusta*) in 3 sample sites indicates that the forest in this tract is not exclusiveluy managed for timber yield.

The forest tract houses several species of low abundance, yet evince good growth features (e.g. >15 cm GBH) – *Chloroxylon sweitenia*, *Dalbergia paniculata*, *Glycosmis pentaphylla*, *Ceriscoides turgida*, *Ougenia oojenensis*, *Mytragyna parviflora*, kirimala, mid, and patua.

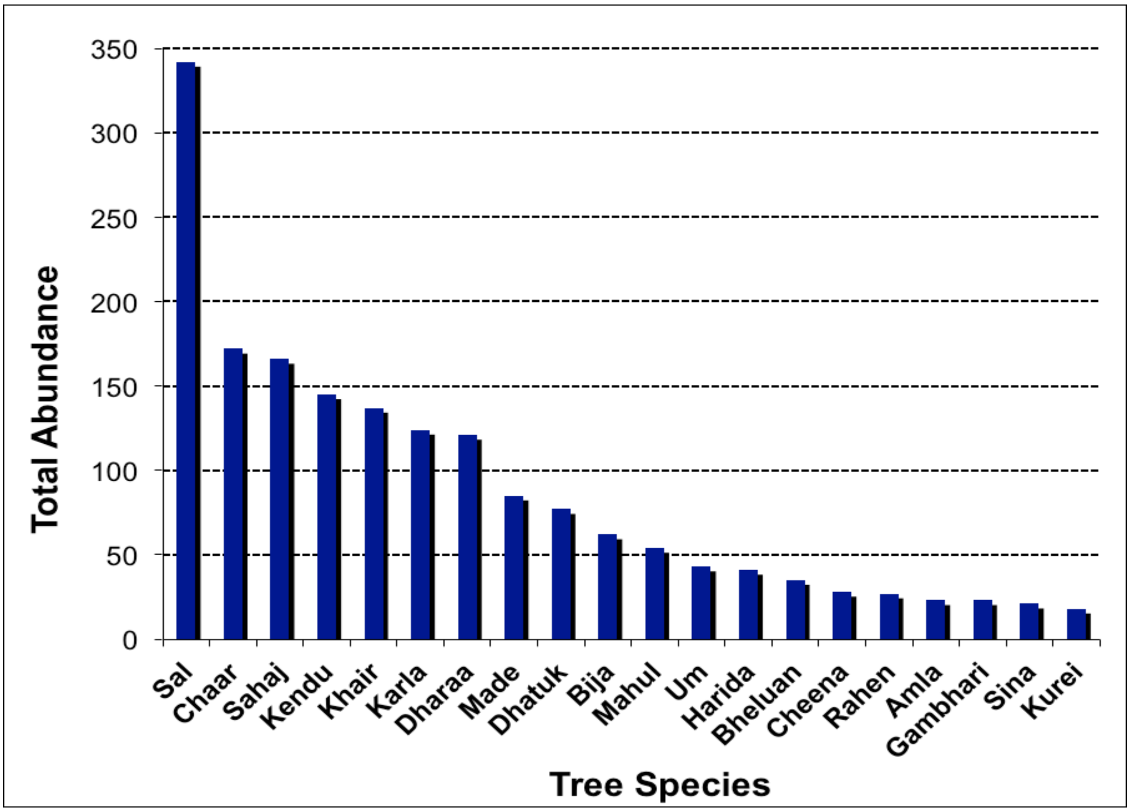

Fig. 4: Pooled Species Densities of First 20 Abundance Ranks of Trees with >15 cm GBH Across All Sample Sites.

The population of the bamboo *Dendrocalamus stricta* demised after its flowering in the forest area some 25 years ago. New clumps of the bamboo have regenerated from the forest floor seed bank, although the abundance of the bamboo clumps is very poor at all sites. A majority of the bamboo clumps occur at the site BMN. The overall abundance of the bamboo comprises only 0.52% of the total arborescent flora (**Fig. 5**).

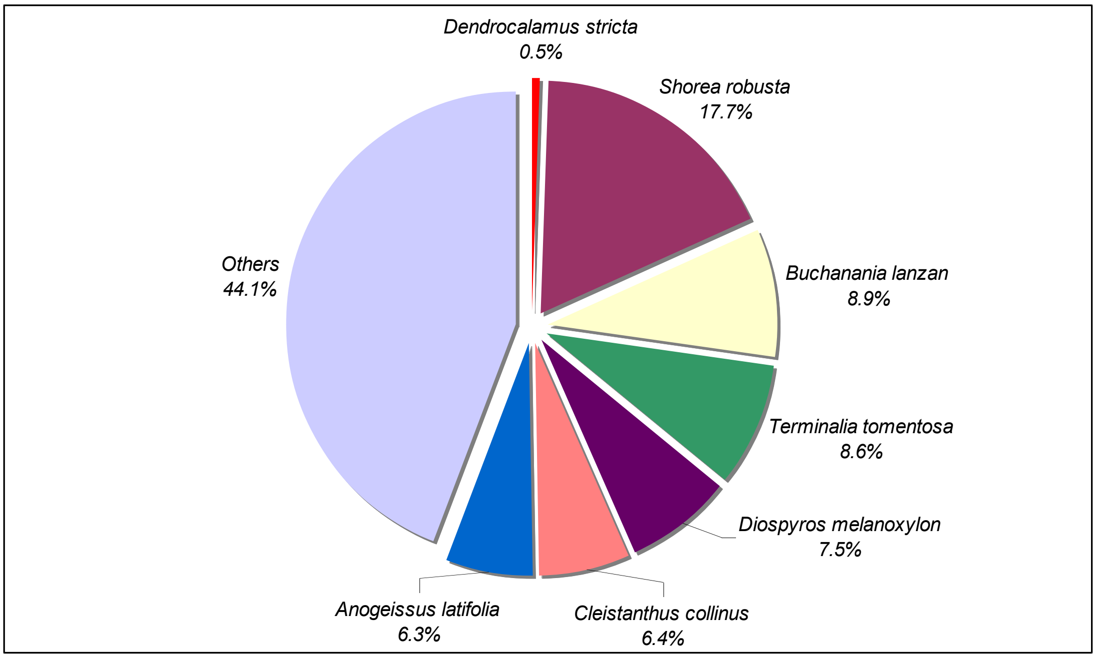

Fig. 5: Overall Forest Composition: Major Flora, Compared to Bamboo.

3.2 **Forest Structure**

The physical or temporal distribution of trees and other plants is impacted by a number of characteristics including species composition, crown volume, topography, and tree age (Oliver and Larson 1996). Generally, as trees grow they require more space; therefore, distances between mature trees are larger than distances between young trees. Such trends can be seen in the spatial pattern of trees; the spatial patterns of individual tree allow us to infer age and therefore forest structure (Nelson et al. 2002). In what follows we describe the forest architecture in terms of the relationships among nearest neighbour distances, basal area (BA), stem density (*d*) and species diversity and dominance.

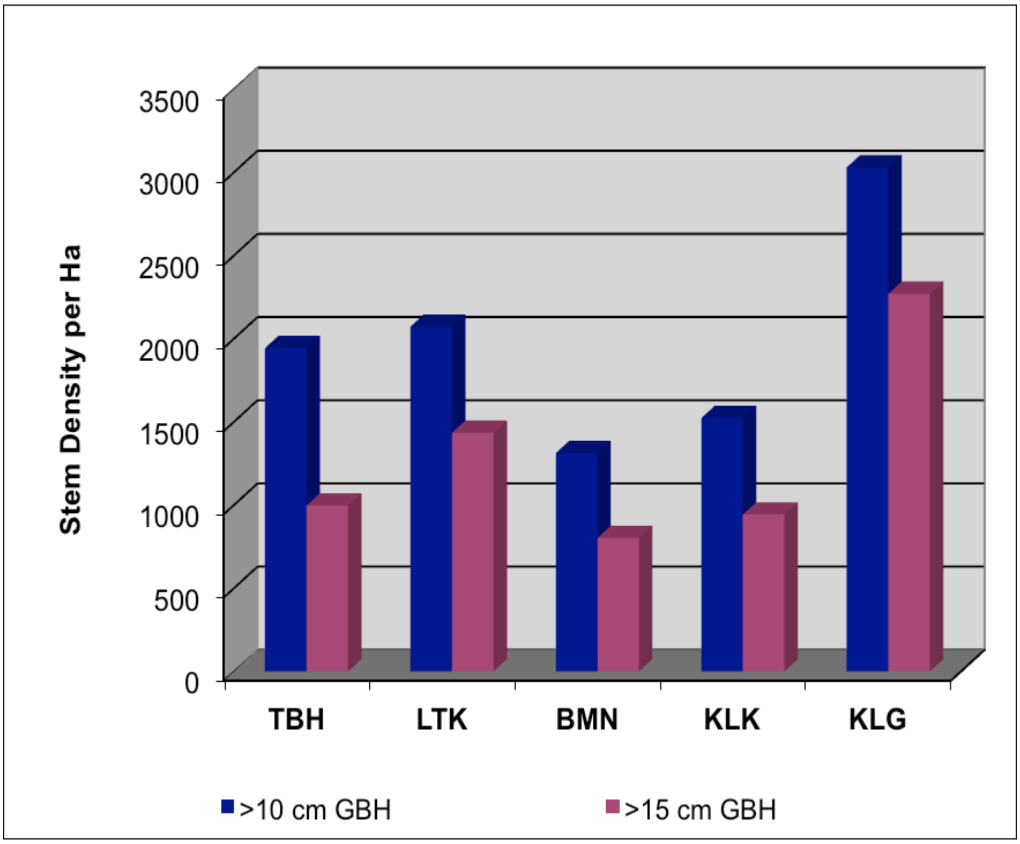

Fig. 6: Tree Density at 5 Selected Forest Sites.

3.3.1 *Stem Density*

Stem density (d) for the 5 sampled sites are shown in **Fig. 6**, which shows that site KDG has the highest d (3032/ha for GBH >10 cm and 2270/ha for GBH >15 cm) among the sampled sites, while BMN has the least density (1312/ha for GBH >10 cm and 802/ha for GBH >15 cm). However, d is a function of competition between different plant species and environmental (including anthropogenic) influences. Because interspecific competition determines the species dominance pattern, stronger competition between neighbours would result in lower density of a few dominant species. Thus, the proportion of dominant species within a forest patch is likely to be inversely related with overall stem density (d). This is evidenced in **Fig. 7**, showing a strong ($P < 0.01$) inverse correlation between Hill's $N1$ and d. The regression for both girth classes (GBH > 10 cm and >15 cm) is strongly negative, indicating that the relationship between species dominance and d is not affected by tree age.

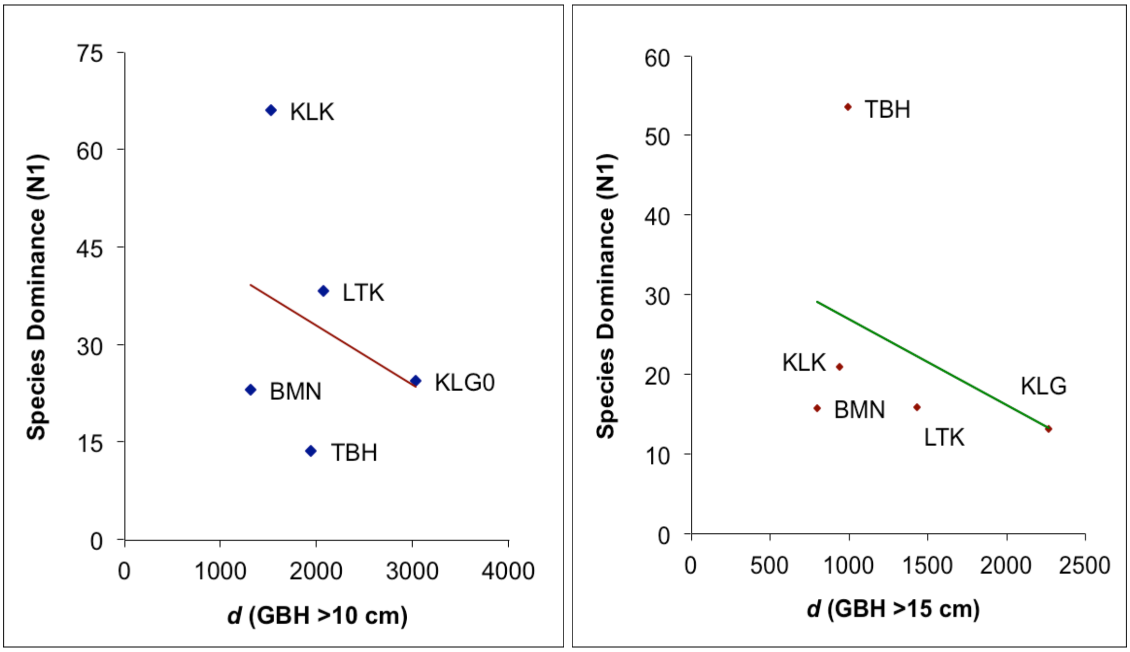

Fig. 7: Relationship between Tree Species Dominance (Hill's *N1*) and Stem Density per Hectare (*d*). Regression slope *b* = –0.009 for GBH >10 cm (left panel) and *b* = –0.011 for GBH >15 cm (right panel).

3.3.2. *Basal Area*

The average tree basal area increases with the trunk diameters, which is a function of tree age. Thus, the total basal area (BA) of a forest stand tends to increase as the relative number of older trees increase in the stand. However, this pattern is violated in patches where many trees are removed from the stand. As anticipated, older trees with larger stem diameters imply greater basal area. This should imply an inverse relationship between tree age and basal area, because in the tropical forest, larger trees with bigger girth and canopy would be widely separated (Oliver and Larson 1996). Indeed, basal area is a conjugate function of the stem density and the trunk diameter. Therefore, lower stem density is associated with mature trees with greater GBH, but if there is selective removal of trees, greater stem density may not imply greater aggregate basal area. An inverse correlation between BA and stem density holds apparently because

(a) there are large spaces between a few old mature trees with huge girths (stem density very low, but BA high), as observed at site BMN;

(b) conversely, there are a large number of young trees, each with relatively small GBH (*d* very high but BA small), as at site KDG.

Nevertheless, the relationship is not statistically significant in our samples. The regression slope is not significantly different from zero ($R^2 = 0.15$), as shown in **Fig. 8**. The relatively large BA for high stem density (as in site LTK), and conversely, small BA and low density (as in KLK) suggest removal of a large proportion of older trees from these sites. It is likely that the relationship will appear more prominent when more sample plots will be examined in the next phase of the study.

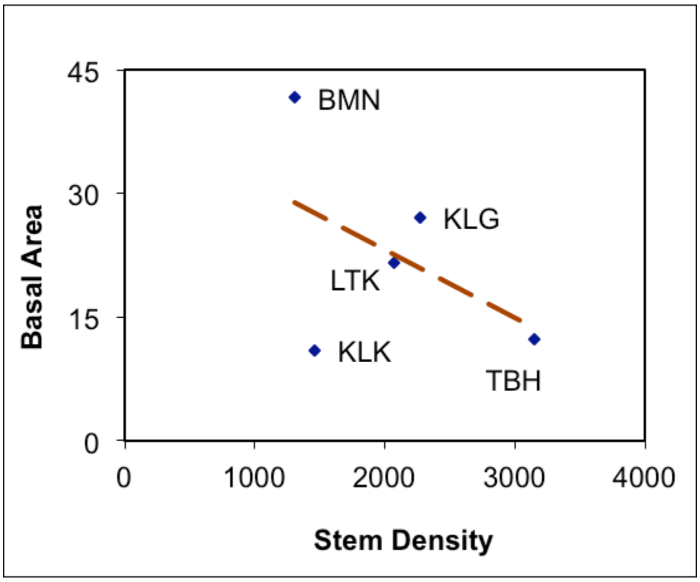

Fig. 8: Relationship of Basal Area (in sq.m.) with Stem Density (*d*) of Trees with >10 cm GBH per Hectare. $R^2 = 0.147$.

From the total basal area of all trees above 10 cm GBH and the mean crop height measured in each transect area, the wood volume of each forest patch was calculated. As the mean crop heights at different forest sites are similar (ranging between 4.6 m and 6.5 m), the pattern of relationship of the estimated wood volume with stem density (**Fig. 9**) is equivalent to that of BA and stem density (**Fig. 8**).

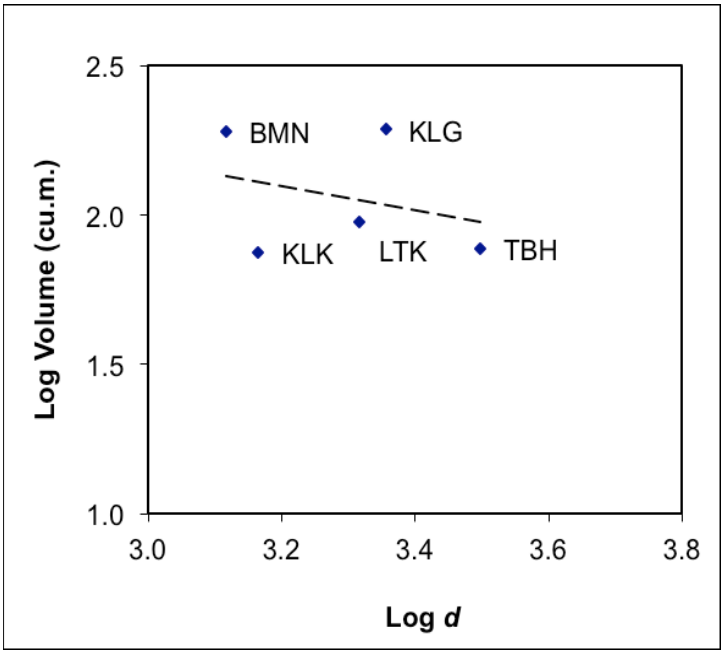

Fig. 9: Regression of log-Transformed Wood Volume against log-Transformed Stem Density (*d*) of Trees with >10 cm GBH per Hectare.

Different tree species have different wood density, and therefore the wood biomass of forest sites are likely to vary according to the species composition and their relative abundances. A precise estimation of the total wood volume from a given forest site should consider the wood volume of different component species proportionate to their respective composition in the forest site, and their respective specific gravities. However, in the absence of specific gravity records for the wood of most of the tree species enumerated in the study sites, we adopted a rapid estimation of wood biomass by taking an average wood density (D_1 = 0.72 Mg m^{-3}) for Odisha forest trees (Kaul 2009) as reference value, and the mean of all wood density (D_2 = 0.754 Mg m^{-3}) estimated in our study as a new benchmark (see **Sec. 2.3**).

The mean wood density for Odisha forest trees, as well as for all forests across India is 0.72 Mg m^{-3} (*see* **Table 3** in Sec. **2.3**). However, we have recalculated the mean wood density, on the basis of species abundance and distribution in the forest sites under this study, using the density of each species available in the forest (see Sec. **2.6**). The overall wood density for Odisha forests (*D*1) is used here as reference, while the density calculated from the actual species composition of forest sites under our study (*D*2) is used as the benchmark value (**Table 4** in **Sec. 2.3**), for calculating the total wood biomass (**Table 7** below).

From this estimation, BMN seems to contain the greatest amount of wood biomass, while KLK contains the least biomass, despite the fact that tree density is considerably lower at site BMN than in site KLK. The total C stock of a forest patch has a power function ($f = 0.472$) relationship with the overall BA of tree stands (**Fig. 10A**). The site KDG, with the highest stem density, contains the second largest amount of wood biomass carbon in the forest. However, when per hectare estimates are considered, the site LTK appears to contain the greatest stock of C, and KLK has the poorest stock of C. The regression of per ha C stock on per ha BA (**Fig. 10B**) is strongly positive ($b = 3.03$).

Table 7: Estimation of Wood Volume, Biomass and Carbon Stock of the Forest Area Under Study.

Parameters	Forest Area					
	TBH	**LTK**	**BMN**	**KLK**	**KDG**	**TOTAL**
AREA (ha)	**81.398**	**34.31**	**65.04**	**44.67**	**103.82**	**329.238**
Overall BA (sq.m.)	1079.59	1761.76	2711.13	695.95	1879.61	8128.04
Crop Ht (m)	7.30	6.40	4.80	5.70	6.20	
Stem Wood Volume (cu.m.)	7905.47	11287.86	13034.19	3969.98	11682.26	47879.77
Mean Wood Density D_1 (Mg/cu.m)$^{(1)}$	0.72	0.72	0.72	0.72	0.72	0.72
Mean Wood Density D_2 (Mg/cu.m)$^{(2)}$	*0.754*	*0.754*	*0.754*	*0.754*	*0.754*	*0.754*
Stem Biomass M_{S1} (Mg)$^{(3)}$	5691.94	8123.81	9378.15	2858.39	8411.23	34463.52
Stem Biomass M_{S2} (Mg)$^{(4)}$	5691.94	8123.81	9378.15	2858.39	8411.23	34463.52
Branch Biomass M_{B1}(Mg)$^{(5)}$	1417.97	2074.83	2419.38	678.56	2153.47	8744.21
Branch Biomass M_{B2} (Mg)$^{(6)}$	1489.73	2179.83	2541.83	712.90	2262.46	9186.75
Root Biomass M_{R1} (Mg)$^{(7)}$	1771.90	2547.87	2946.67	883.54	2634.60	10784.58
Root Biomass M_{R2} (Mg)$^{(8)}$	1777.48	2549.66	2949.38	884.24	2641.17	10801.93
Total Biomass TWM_1 (Mg)$^{(9)}$	8887.39	12748.30	14746.91	4421.18	13205.87	54009.66
Total Biomass TWM_2 (Mg)$^{(10)}$	9313.07	13359.09	15453.54	4632.84	13838.60	56597.14
Total C Stock TC_1 (Mg)$^{(11)}$	**4088.20**	**5866.74**	**6788.32**	**2033.75**	**6074.70**	**24851.71**
Total C Stock TC_2 (Mg)$^{(12)}$	**4284.01**	**6147.83**	**7113.60**	**2131.10**	**6365.76**	**26042.30**

(1) See **Table 3**; (2) see **Table 4**; (3) eqn. 4a; (4) eqn. 4B; (5) eqn. 5a; (6) eqn. 5b; (7) eqn. 6a; (8) eqn. 6b; (9) eqn. 7a; (10) eqn. 7b; (11) eqn. 10a; (12) eqn. 10b.

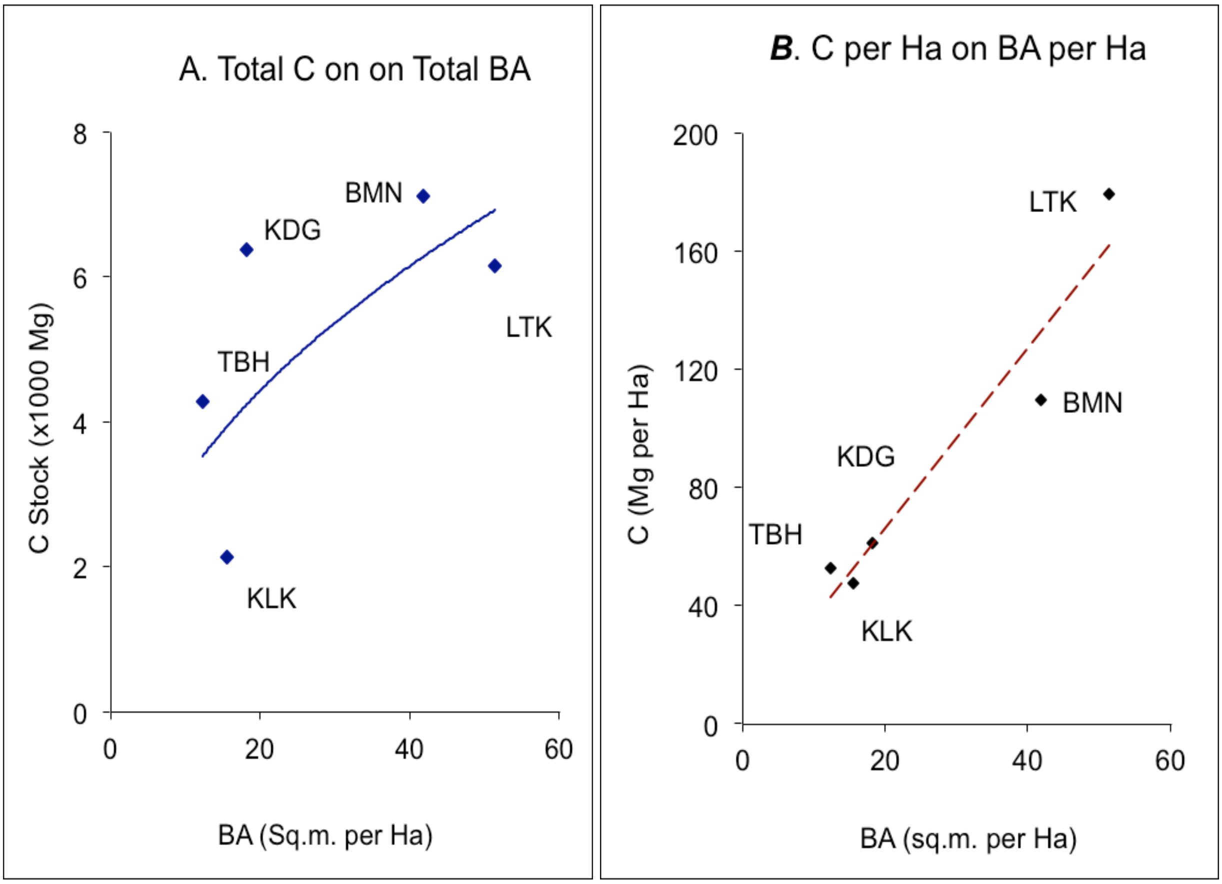

Fig. 10: Relationship of Forest C Stock with Total BA (***A***), and C Stock per ha with BA per Ha (***B***)

Our method of estimation of the C estimation of the forest area under study can be employed to assess the total C stock of the entire Sate forest. The precision of forest carbon stock assessment will vary in accord with the tree species composition of different forest types in the State. Combined with the seedling regeneration and species recruitment profiles, it would also be practicable to detect the trend of C stock change, which is beyond the scope of this Report.

4. BIOMASS EXTRACTION AND DEFORESTATION PATTERN

4.1 *Harvest of NTFP*

Although the forest patches are under various degrees of community

protection, villagers regularly harvest non-timber forest produce (NTFP) to meet their subsistence needs. While leaves of kendu (*Diospyros melanoxylon*), sal (*Shorea robusta*) and siali (*Bauhinia vahlii*) are the principal NTFP for commercial use, fuelwood constitutes the largest volume of NTFP flow. Major NTFP items harvested for direct consumption and sale as food include wild mushrooms, wild tubers (*Dioscorea* spp.), flowers of mahua, fruits of mango, mahua, jamu, bela, kathal, char, kendu, ainla, kusuma, char seeds, and the sago palm (*Caryota urens*) sap. NTFP items harvested for culinary uses include neem leaves, shatamuli (*Asparagus racemosa*) roots, mango and mahua fruits, kusuma oil, and shoots and rhizomes of bamboo (*Dendrocalamus stricta*).

Participant observation indicates that villlagers mostly collect brushwood and dead logs for fuelwood, but felling of trees is not uncommon. Timber trees are also felled in order to collect wood for construction and implements like the ploughshare and cart wheels. The species mostly harvested for structural purposes are sal, dhaura (*Anogeissus latifolia*), sahaja (*Terminalis tomentosa*), gambhari (*Gmelina arborea*), dhuben (*Dalbergia paniculata*), and sisu (*Dalbergia sissoo*). Brushwood from all trees is harvested for fuelwood, the major species being sal, karla (*Cleistanthus collinus*), dhatuk (*Woodfordia fruticosa*), and dhamana (*Grewia tiliafolia*).

Owing to the rapid regeneration rate of bamboo, pewriodic and systematic harvest of bamboo can be conducive to sustained yield of bamboo. However, in the study area, only bamboo shoots and rhizomes are harvesed for food, but rarely for structural uses. Culms of bamboo are cut only from the accessible outer parts of the clump, leaving the interior of the clump to entangle. This mode of bamboo harvest is prohibitive of vigorous growth.

The forest sites house a large number of plants, parts of which are harvested for indigenous medicinal uses. Major medicinal plants include mahua, sal, bahada, harida, ainla, kinimaja, kurei and patua trees, and herbs and climbers such as satabari (*Asparagus racemosus*), suam noi (*Ichnocarpus frutescens*), asadhua (*Capparis zeylanica*), pokosunga (*Ageratum conyzoides*), mutri (*Smilax zeylanica*), gila (*entada phoceoloides*), brahmi buti (*Centella asiatica*) and chireita (*Andrographis paniculata*).

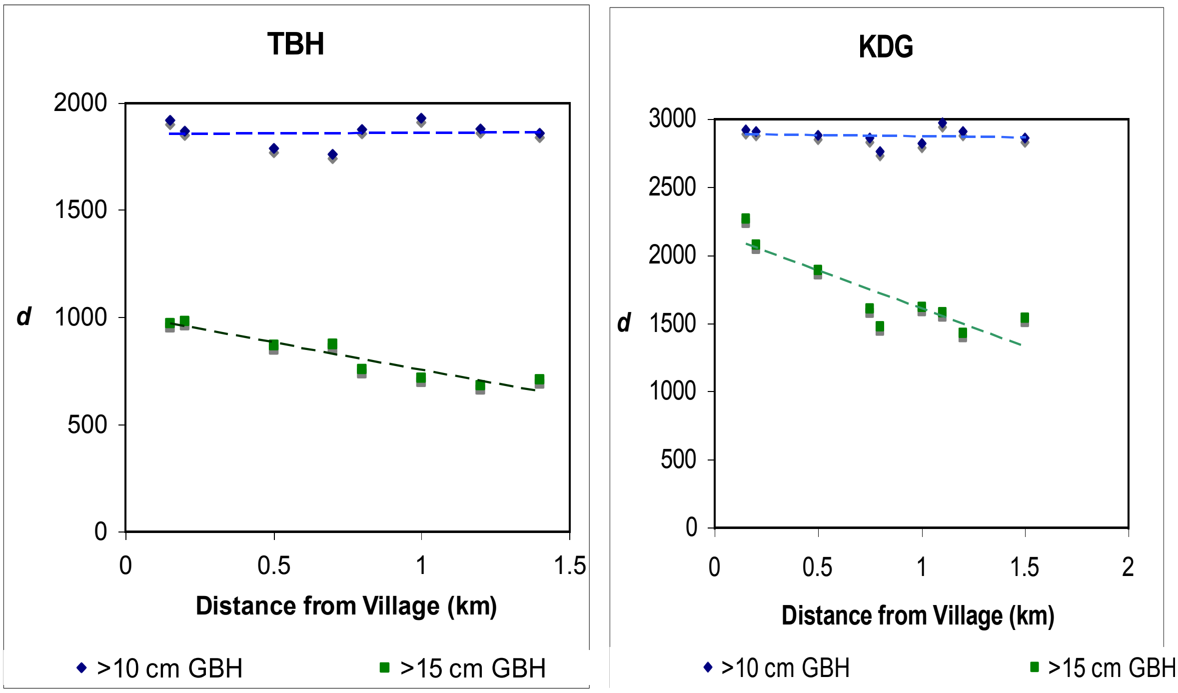

Fig. 11: The Effect of Distance of Forest Patch from Village on Stem Density (*d*) in TBH for Trees of Two Girth Classes. Data from TBH and KDG Sites.

4.2 *Pattern of Forest Damage from Wood Harvest*

Cut stumps of trees were found in all the forest patches under study. We estimated the density of stumps and measured the girths, and measured the linear distance to the spot from the nearby village. The distance (*D*) from the forest in each sample transect area was found to be negatively correlated (R^2 = 0.922, $p < 0.01$) with the density of trees with > 15 cm GBH (**Fig. 11**), although the density of trees with GBH of >10 cm shows no significant trend (R^2 = 0.000). It seems plausible that villagers tend to spare more trees below 15 cm GBH than those above that girth.

The desnity of stumps (> 15 cm) is strongly postively correlated with *D,* up to a certain distance. **Fig. 12** presents data from two village forests to reveal the effect of linear distance from the village on the stump density. It appears that the villagers tend to protect the forest patches that are proximate to their respective villages, but travel to distant forest patches for collecting NTFP and wood. However, the stump density declines beyond a certain distance, presumably because the forest patch is guarded by another villager committe on the fringes of the forest.

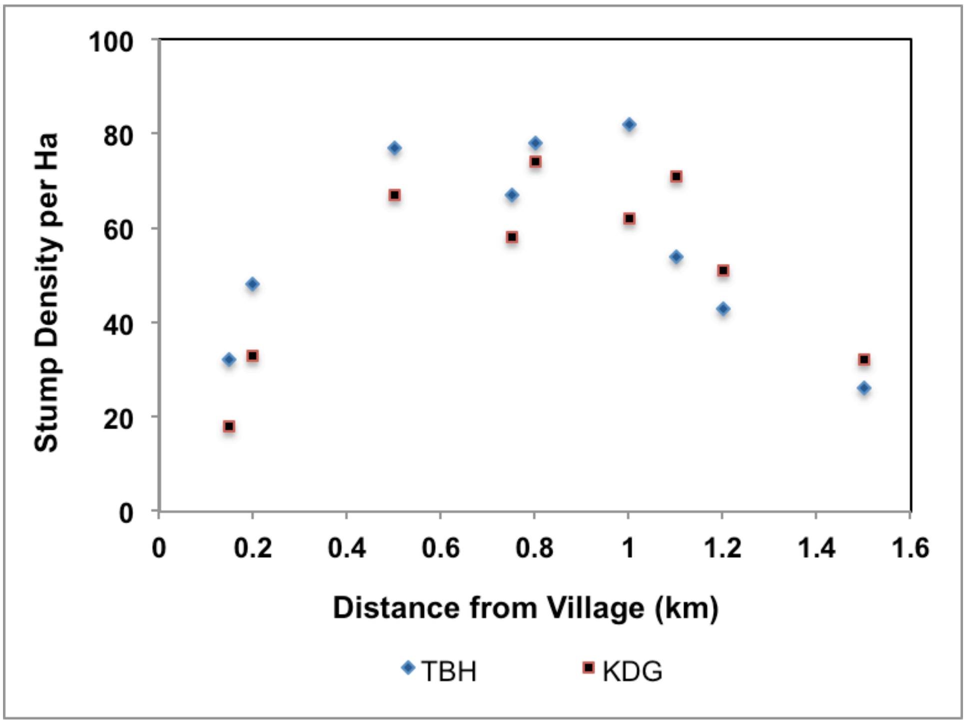

Fig. 12: Effect of Distance of a Forest Patch from Village on Stump Density

Kendu leaves constitute an important item of NTFP for cash earning for the villagers. In order to maintain a steady supply of young (marketable) leaves, villagers regularly prune the kendu trees and keep them short in stature. Pruning drastically truncates the growth of wood tissue and prevents fruiting as a trade-off. However, the harvest of leaves from kendu and sal does not perceptibly reduce survivorship of these species, and the practice may be considered to be economically sustainable as long as the trees are not cleared. However, this will derange the natural structure of the forest, and inhibit fruit production of the species, thereby damaging its ecological functions.

In the absence of quantitative data of NTFP flow and seedling regeneration profiles (which are forthcoming), we are unable to assess the sustainability of wood harvest. However, we made a preliminary estimation of extraction of selected species stocks that are unlikely to get replenished in the near future through recruitment of seedlings. **Table 8** presents the abundances of mature tree species and the extent of their extraction (measured as the number of cut stumps in a unit area). Such stem removal adversely affects the rate of maturation of younger trees. The extent of depletion of tree stock from lower to higher girth class is indicated by the recruitment ratio, RR (*see* **eqn. 6**). It appears that at all sites except KLK, older dhaura (*A. latifolia*) trees are removed at a rate faster than the recruitment from younger trees. The proportion of younger dhaura trees that have been felled is especially high at site TBH, obviating their recruitment and maturation into the next girth class. For sal trees the selection of the girth class for harvest is reverse – younger trees are felled in large numbers, so the recruitment into the higher girth class is curtailed. Much of the forest plots at TBH lies by the side of a roadway, making it vulnerable to wood theft.

Some of the forest patches at TBH and LTK are considerably far from the respective villages, and the distal boundaries of the forest are on the roadside. As a result, forest protection by the community is weaker at those plots. Villagers of TBH and LTK report that *thengapally* (guarding the forest with sticks) is ineffective for the distant roadside patches, because it is difficult to keep guard by the road round the clock. A relatively weaker level of protection at these sites accounts for the greater densities of cut stumps on the sample transects (**Table 8**).

At site KDG, RR > 16 for sal indicates a drastic reduction in the numbers of younger sal trees, making any harvest of sal poles unsustainable. However, at this same site KDG, the recruitment from the younger dhaura trees is proportionate with the number of older trees (RR = 1.03). At site LTK, the numbers of older sahaja, sal and karla trees are disproportionately greater than the number of younger trees (between 10 cm and 15 cm GBH). From the density of stumps at this site, it appears that removal of sal and sahaja poles at a higher frequency has resulted in this age class distribution.

Table 8: Harvesting Profile of Selected Tree Species in Forest Sites.

Site	Species	Density (No./Ha) of Trees with GBH >10 cm	Density (No./Ha) of Trees with GBH >15 cm	Recruitment Ratio	Seedling Density (No./Ha)	Density* (No./Ha) of Stumps
TBH *	Dhaura	65	12	0.23	820.0	3
	Madei	24	17	2.43	1132.5	1
	Sahaja	51	33	1.83	182.5	2
	Sal	109	80	2.76	2280.0	3
LTK *	Dhaura	101	42	0.71	382.5	2
	Sahaja	82	55	2.04	332.5	1
	Sal	49	44	8.80	2087.5	3
	Karla	123	84	2.15	647.5	1
BMN	Dhaura	76	17	0.29	712.5	2
	Sina	20	17	5.67	535.0	0
	Sal	44	34	3.40	620.0	1
	Sahaj	24	18	3.00	365.0	0
KLK	Dhaura	58	26	0.81	145.0	2
	Sahaj	54	31	1.35	135.0	2
	Sal	44	39	7.80	585.0	1
	Bija	31	19	1.58	647.5	1
	Karla	24	14	1.40	542.5	1
KDG	Dhaura	47	24	1.04	533.3	1
	Sahaj	50	29	1.38	196.6	2
	Sal	154	145	16.11	663.3	1

* Data from forest patches within 1 km from Village

Although many of the tree species can grow from coppice, the trunks are chopped down at a level higher than 0.5 m about ground, thereby preventing coppicious growth. At sites where younger trees are extracted from the forest, the stand age structure will shift toward old trees with little regeneration. Conversely, at other sites with RR < 0.5 the stand age distribution will have disproportionately fewer older trees. In both cases, carbon sequestration service of the forest will be severely disrupted.

4.3 *Forest Damage Due to Fire*

Forest fire is common at all sites during the dry summer months. Villagers often put fire to the undergrowth in the belief that fire woul facilitate kendu leaf harvest after the monsoon rains. However, this practice is severely damaging to the undergrowth, destroying most of the saplings of a maority of trees and herbs. This artificial elimination of seedlings prevents regeneration of the forest flora. As a result, a large number of plants and animal species will be eliminated eventually. The forest species diversity will thus be reduced, and the tree species dispersion will be more clustered.

While there is no available data to show the impact of forest fire on the species diversity and distribution in the forest area, it is evident that a large number of species growing at the understroty of the forest are burnt out. Several herbs and climbers like *Andrographis paniculatai, Asaparagus racemosusi, Ichnocarpus frutescens*, and all wild tubers. In particular, young saplings of *Entada spicata*, and *Ventilago madras-patana* are almost nowhere recorded in the forest patches under study. One of the major NTFP item, siali (*Bauhinia vahlii*) saplings cannot survive the fire. Therefore the possibility of a sustained harvest of siali leaves in the future is obviated.

4.4 *Forest Damage from Grazing*

During the period from July to November, when cereals are grown on farm fields, all cattle from the villages graze in the forest is common. In spite of the absence of quantitative data, it can be seen that the cattle and goats releaed in the forest graze on the forest floor, eliminating a large number of regenerating saplings, which appear after the monsoon rain.

Table 9: NTFP Species Vulnerable to Grazing by Village Livestock

Habit	Common Name	Botanical name	Use
Tree	Ainla	*Emblica officinalis*	Food
	Amba	*Mangifera indica*	Food
	Bahada	*Terminalis belerica*	Food
	Bela	*Aegle marmelos*	Food
	Kinimaja	*Cassine glauca*	Medicinal
	Kathal	*Artocarpus integrifolia*	Food
	Kusum	*Schleischera oleosa*	Food
	Madei	*Lannea coromandelica*	Structural
	Mahua	*Bassia latifolia*	Food
	Char	*Buchanania lanzan*	Food
	Panikusum	*Aphanamixis polystachia*	Medicinal
	Patua	*Stereospermum chelonoides*	Medicinal
	Salingbanji	*Dendrocalamus stricta*	Food, Structural
Shrub	Khirkoli	*Manilkara hexandra*	Food
	Gurudu	*Gardenia gummifera*	Food, Fodder
	Begunia	*Vitex negundo*	Medicinal
	Bela	*Aegle marmelos*	Food, Medicinal
	Pokosunga	*Ageratum conyzoides*	Medicinal
Herb & Climber	Mutri	*Smilax zeylanica*	Medicinal
	Asadhua	*Capparis zeylanica*	Medicinal
	Karba alu	*Dioscorea pentaphylla*	Food
	Kosa alu	*Dioscorea anguina*	Food
	Pani alu	*Dioscorea oppositifolia*	Food
	Tunga alu	*Dioscorea wallichii*	Food
	Satabari	*Asparagus racemosus*	Food, Medicinal
	Siali	*Bauhinia vahlii*	Structural
	Suam noi	*Ichnocarpus frutescens*	Medicinal

Except for the thorny shrubs, such as *Zizyphus* spp. and *Bridelia retusa*, most of the plants at the herb and shrub layers are grazed down. This obviously decimates the species diversity and prevents regeneration and recruitment of many species. Species of economic importance to teh as NTFP importance that are vulnerable to grazing by cattle and goats are listed in **Table 9**.

Grazing of cattle and goats on young bamboo shoots is also common. Given the scant abundance of bamboo in the forest (as a consequence of the flowering episode about 25 years ago), unregulated grazing is an important threat to the growth of the bamboo population in the region.

4.5 *Laxity of Community Commitment to Forest Protection*

Owing to an increasing awareness of the importance of forests and the rising demand for reinstatement of indigenous land rights in the recent decade, self-initiated community forest management in Odisha have regenerated and restocked degraded forests in different districts (Conroy et al. 2002). However, the heterogeneous composition of the community in the study area often elicits varied levels of commitment of different community members to protecting their forests. Consequently, different members of the community perform their respective duties of *thengapalli* differently, and the level of protection also vary among the villages.

The condition of the forest sites TBH and KLK is relatively dilapidated owing to the laxity of protection by the committees of Talbahal and Kharlikani villages, respectively. Roadside forest patches at sites KLK and LTK are the least protected, where deforestation is prominent. In many villages outside our study area, especially at Runimahul, trees are regularly cut and carried off on bicycles by by people from distant villages. In contrast, Brahmani and Khandkelgaon villages afford considerably better protection, which is reflected in the better forest structure, species abundances and stand density at sites BMN and KDG.

5. SPECIES REGENERATION AND RECRUITMENT

After 15 days of the onset of the monsoon rain (in late July), enumeration of germinating seedlings was conducted in the belt transects at each study site. The number and location of the transects were the same as those laid for estimation of stem density and girth class. The density of each species was estimated from the mean abundances over all transects, and the species were ranked according their relative abundances at each site. **Table 10** gives a summary of 10 most abundant species at seedling stage.

Table 10: First 15 Species* in Seedling Abundance Ranking at the Study Sites

Abundance Rank	**TBH**	**LTK**	**BMN**	**KLK**	**KLG**	**All Sites**
1	Sal	Sal	Kendu	Bija	Kendu	Kendu
2	Bija	Khair	Karla	Madei	Sal	Sal
3	Madei	Karla	Dhatuk	Kurei	Char	Char
4	Kendu	Kendu	Kurei	Sal	Dhaura	Bija
5	Char	Bija	Char	Kendu	Kurei	Karla
6	Um	Char	Dhaura	Karla	Mahula	Khair
7	Dhaura	Kharal	Kharal	Dhatuk	Karla	Kurei
8	Khair	Dhuben	Sal	Baranga	Khair	Madei
9	Kurei	Kurdu	Mahula	Khair	Bija	Dhaura
10	Harda	Kurei	Sina	Char	Harda	Mahul
11	Dhaura	Badichang	Dhaura	Karla	Bahada	Sahaj
12	Sahaj	Um	Kharal	Semel	Sahaj	Kendu
13	Sina	Madei	Maldhaura	Kharal	Bhader	Harda
14	Padhel	Sahaj	Baldhia	Sunari	Sina	Kharal
15	Rahen	Gindul	Tilei	Mahul	Telkuari	Telkuari

* For botanical nomenclature, see **Table 5**.

The species that show the least germination frequency at all sites include: Ainla (*Emblica officinalis*), Arjun (*Terminalia arjuna*), Bandhan (*Oogenia oogenensis*), Baranga (*Crateva religiosa*), Bela (*Aegle marmelos*), Kanthal (*Artocarpus integrifolia*), Rohen (*Soymida fabrifuga*), Ghoto (*Artocarpus lacoocha*), Chauldhua

(*Glycosmis pentaphylla*) and Dhuben (*Dalbergia paniculata*).

Table 11: Abundance Ranks of Numerically Dominant Species Seedlings, Compared to Ranks of Mature Trees.

Species	Abundance Rank	
	Seedlings	Mature Trees
Kendu (*D. melanoxylon*)	1	4
Sal (*S. robusta*)	2	1
Char (*B. lanzan*)	3	2
Bija (*P. marsupium*)	4	10
Karla (*C. collinus*)	5	6
Khair (*A. catechu*)	6	5
Kurei (*H. antidysenterica*)	7	20
Madei (*L. coromandelica*)	8	8
Dhaura (*A. latifolia*)	9	27
Mahul (*M. latifolia*)	10	11
Sahaj (*T. tomentosa*)	11	3
Sina (*L. parviflora*)	12	19
Harda (*T. chebula*)	13	13
Kharal (*C. turgida*)	14	62
Telkuari (*S. racemosa*)	15	30
Dhuben (*D. paniculata*)	16	34
Um (*H. integrifolia*)	17	12
Anchi (*M. angustifolia*)	18	23

When compared to the relative density of mature (GBH >15 cm) trees (**Fig. 4**), the regeneration profile of the most abundant species (**Table 11**) indicate that the current extraction rate is unsustainable for most species. The species that indicate likely persistence in the near future are: **1. Kendu, 2. Sal, 3. Char, 4. Karla, 5. Kurei, 6. Madei, and 7. Mahul.** The extraction rate of these 7 species seem to be adequately balanced by the annual recruitment of seedlings. However, this prediction of persistence is made on the assumption of no effect of forest fire. If the seedlings cannot recuperate following an incident of forest fire, the populations of Char, Karla, Madei, Kurei and Mahul are unlikely to be stable in the near future.

6. Discussion

The forest under study constitutes is rich in floral diversity, most of which are Class A and Class B timber trees. **About 30% of the foerst is well-stocked,** frequently with old growth trees and old lianas, which indicate s relatively low levels of perturbation in these patches. **The overall density of trees above 15 cm GBH marks the forest patches to be moderately dense, interspersed with low density patches, where removal and slow regenration of trees are noticed.** Trees are frequently harvested for meeting the needs of village households. A majority of the trees are below 40 cm GBH.

In a limited number of degraded patches, there exist plantations of exotics (*Eucalyptus tereticornis*, *E. citriodora*, and *Acacia auriculiformes*), raised by the State Forest Department. The absence of moncultures, low emphasis of conventional silvicultural practices (e.g. multiple shoot cutting, coppicing, thinning), and customary protection of the forest account for the mixed nature of the forest, and a high density of the shrub layer. Nevertheless, **poor abundances of trees above 40 cm GBH indicate a considerable extent of harvest of reproductively mature trees**, leading to significant changes in phytodemographic composition in different patches.

Anthropogenic disturbance like selective tree removals or other kinds of site damages also change the tree species composition and distribution within a given patch. In particular, preferential extraction of certain tree species for construction, fuelwood, or industrial needs creates an unknown degree of intervention in the dispersion of tree species, and impacts on the rates of their seed dispersal and germination. This will have adverse consequences on the flow of ecosystem services to the forest villagers.

Tree density and basal area was found to be inversely correlated with the distance from the village to the forest locations. The density of stumps was positively correlated with distance. This finding corroborates the conclusion of Kao and Lida (2006) and Hoang et al. (2011) that tree density and basal area are negatively correlated with human impact, but the positive correlation between the stump density and distance from the village found in our study is in opposition to theirs. In Hoang et al. (2011) study, people's gathering of NTFP was more intense in locations that are closer to the village, and there was no community regulation to protect the forest from gratuitous harvest. By contrast, in our study villages, the number of stumps found in each plot abruptly increased over 0.7 km away from the villages (**Figure 12**). This is plausibly because the villagers customarily protect the forest patches adjacent to their villages, while going deeper into the forest for collecting NTFP. People from distant villages from the other end of the forest also visit the same patches to collect fuelwood from bordering locations. However, there was no place in these forest sites with zero abundance of stumps.

Despite the large impact of disturbance on tree densities and basal area, the density of cut sumps and the distance from the village had no significant correlation with tree species richness (S). This indicates that **human disturbance, although it affected species composition, does not seem to affect species richness in the forests under study.** This finds support from recent tropical forest studies by Slik et al. (2002), Davies (2005) and Hoang et al. (2011). Nevertheless, size-selective removal of species does affect the overall species composition of the forest. Removal of trees of larger girth size has led in the study sites to a decline of species diversity compared to that of trees of smaller girth (**Table 6** and **Fig. 7**).

The analysis of the current status of the forest architecture and floral composition does not indicate any proximate threat to the forest biodiversity. There is uniform dispersion of trees for both girth classes, with the excpetion of TBH (for GBH >10 cm), LTK (for both girth classes), and KLK (for GBH >15 cm). At sites LTK and KLK, older trees are disproportionately fewer than expected from the recruitment of younger mature trees, while at site TBH, the younger trees seem to be fewer than expected. This indication is further consolidated by the strong inverse relationship between N_1 and d for trees of both girth classes (**Fig. 7)** which indicates prevalence of co-dominance among older trees. However, the weak ($R^2 = 0.041$) power function relationship between BA and *d* indicates that the dispersion of tree age classes departs from what is expected in a purely undisturbed forest. **Especially at site LTK (high *d* and high BA) and site KLK (low *d* and low BA), dispersion of old trees are distorted by selected tree species removal, which took place in the past, and possibly also continuing.** At site TBH, mature trees (with >10 cm GBH) are removed from the locations adjacent to a roadway. The felling and removal of trees is also indicated from the higher frequency of stumps at those sites (**Table 8**).

Bamboos in the forest are almost exclusively comprised by saling-banji (*Dendrocalmus stricta*). Interviews with villagers and the local Forest Department staff revealed that this species had flowered some 25 years ago, following which all culms of this species disappeared form the forest. The distribution of the existing bamboo clumps is scattered, occurring in considerable numbers in only a few sample plots, while absent from most other plots. The bamboo clumps were encountered in 3 transects at site Brahmani at a density of 10/ha, and only in 1 transect laid at site KDG (6/ha). **The bamboo contributes to 0.52% of the total floral composition of the sampled forest tract** (**Fig. 5**).

The culms of the saling-banji bamboos are seldom used for construction. Although it is often used in fences around homestead land, the primary reason the villagers extract the bamboo is to procure the rhizomes and shoots for food. In order to harvest the chosen culm, villagers extract a few culms from the clump. **Cut stumps in the clumps show that culms are harvested from around 1 m above ground, and culms occurring in the interior of the clumps are not harvested**. Although both the frequency of bamboo extraction and the quantity of the culms removed are ver low, the villagers' method of harvesting the culms from the exterior part of the clump, and hacking from 1 m above ground do not promote bamboo growth in the forest. Because the interior culms are not thinned out, most of the culms are congested, thus suppressing the growth and multiplication of the clump (Palit 1999).

The total size of all the forest plots that we surveyed is relatively small (1.7 ha). Since many tropical tree species were rare, and as most species were represented by only a few individuals, this might have resulted in random statistical noise. The sampling limitations notwithstanding, we are confident that the phytoecological patterns in the forest, as described in this report, will be further highlighted in the final report, in which we shall include additional data from analyses of more transects for sampling. This pattern will lead us to devise an informed management plan, in sharing with the local villagers, for a sustainable forest use and conservation of both biodiversity and people's livelihoods.

Sal *(Shorea robusta*), kendu (*Diospyros melanoxlon*), siali (*Bauhinia vahlii*), char (*Buchanania lanzan*), sahaja (*Terminalia tomentosa*), karla (*Cleistanthus collinus*), ainla (*Emblica officinalis*), mahul (*Madhuca indica*), bel (*Aegle marmelos*), kusum (*Schleischera oleosa*) and salingbanji (*Dendrocalamus stricta*) are the major NTFP species. All these species are harvested for fuelwood, but sal, siali and kendu leaves constitute the most important commercial items, sold on market. Fruits of kusum, bel, ainla and char are important food items, which are seasonally harvested for consumption within the village, and also sold on market. Karla leaves are traditionally used as an important agricultural input, though its use is much reduced after the advent of chemical agriculture. Bamboo shoots and rhizomes are harvested for food. It appears that **the harvesting of sal, kendu, and karla leaves do not pose any perceptible threat to the species' survival**, because customary harvesting of leaves does not entail tree mortality. Rather, the pruning of leaves serves to enhance vegetative growth. Furthermore, the harvesting of leaves of these species during the growth period (e.g. rainy season), allows for a quick recovery (Keystone Foundation 2005). However, **the cutting of branches for harvesting leaves, and the cutting of trees for fuel, construction, and for illegal commerce cause forest depletion**, which ought to be regulated. In this respect, siali leaf harvest seems to involve over-harvest of leaves and certain degree of careless damage to the plant, and therefore unsustainable.

7. HIGHLIGHTS OF THE STUDY AND ECOLOGICAL IMPLICATIONS

(i) We selected 5 forest sites for sampling of the forest area in the district of Rayagada. At least 3 transects of 1000 sq.m. size were laid in all selected sites.

(ii) The preliminary study indicates non-saturation of species sampling, indicating the need of adding more transects to the sample number (**Fig. 1**).

(iii) A total of 69 tree species of 29 Families were recorded from the 5 sample sites (**Table 5**). Varying proportions of this species pool exist in different sites, ranging from 49% at site TBH to 62% at site KLK (**Fig. 3**).

(iv) Species diversity and dominance across all 5 sites indicate heterogeneous distribution of species. At all sites, selective removal of larger trees have reduced S for trees with >15 cm GBH, such that it is always less than S for all trees with >10 cm GBH (**Fig. 3**).

(v) A large number of species appear to be rare, represented by < 5 individuals per ha (**Fig. 4**). While this apparent rarity may be an artefact of the small sample size, it is likely that a few species actually have a very low abundance in the entire forest tract, regardless of the sampling effort. Such species include *Chloroxylon swietenia*, *Ceriscoides turgida* and *Stereospermum chelonoides*.

(vi) The dominance of species distribution is considerably low at site KDG. At all other sites, the species composition is considerably even, with high values of N_1, ranging from 21.7 to 66 for trees with >10 cm GBH (**Table 6**). For the larger girth class (>15 cm), N_1 ranges between 11.8 and 20.9, implying that the evenness of species distribution is relatively disrupted for the older/ larger trees by selective removal.

(vii) Trees with wider basal area tend to have lesser density per unit area of forest sites than trees with smaller basal area. There are large spaces between a few old mature trees with large girths (stem density very low, but BA high), as observed at site LTK; conversely, there are a large number of young trees, with a relativelhy small aggregate BA (stem density very high but BA small), as at site KLK. However, the correlation between BA and stem density is statistically weak (R^2 = 0.041, **Fig. 8**).

(viii) The relationship between species dominance and *d* is not affected by tree age in the sampled forest sites (**Fig. 7**). This implies that the anthropogenic perturbations (through harvest of tree stems) are not sufficiently high to significantly change the species dominance pattern across the girth classes.

(ix) At the sites KLK and LTK, a high rate of removal of older trees is a major driver of deforestation, while at site TBH, a high frequency of removal of younger trees is a principal factor of forest destruction, which ought to be checked by means of improved protection.

(xi) Only one species of bamboo, *Dendrocalamus stricta,* is available in sizeable quantities from the forest, with most of the sampled bamboo clumps dispersed in clusters. This species is slowly growing back after its flowering about 25 years ago.

(xii) Villagers extract the bamboo primarily for food, and for use in fences. The conventional method of easy extraction of culms only from the exterior allows the remaining culms to tangle, which suppresses growth and multiplication of the culms. It would be necessary to train the villagers in sustainable bamboo harvesting methods, in order to ensure long-term availability of the material.

(xiii) Because older trees tend to be sparsely distributed, the dendrometric volumes of standing trees above 10 cm GBH indicates that wood volume is inversely related with stem density at the forest sites (**Fig. 9**). With a similar range of crop height at all forest sites, the volume is predominantly determined by basal area, which is also inversely related with stem density (**Fig. 8**).

(xiv) A rapid estimation of the total biomass of forest trees (over 10 cm GBH) per ha of each forest site indicates that site KLG has the greatest biomass while KLK has the lowest amount of biomass (**Fig. 10**). The biomass content seems to be unrelated to the respective stem density at the sites.

(xv) The quantity of tree biomass removal from a forest patch seems to be proportional to the distance of the patch from the nearest village (**Fig. 11**), and tends to increase with the distance within a limit (**Fig. 12**). Tree biomass removal is discouraged under strong protection (such as at site BMN), but is more visible at sites adjacent to roads. At site KLK and TBH, roadside patches show signs of felling of older trees, indicating a weak protection regime under the community management.

(xvi) At several sites other than the five sites under study, removal of old trees (with GBH > 15 cm) is frequent. People from neighbouring villages frequently visit the forest site Runimahul to steal poles on bicycles. The headmen of Runimahul village protection committee connive at the entry of outsiders, with the result that the forest is severly depleted of older trees. This is in contrast with the committee of Kandkhelgaon (site KLG), where the villagers are aware of the crop height and abundances of all older trees at every forest patch under their jurisdiction. The committee of this village are more active in protecting their forest “for the benefit of the current as well as future generations”.

(xvii) Traditionally, villagers used to remain cautious to avoid causing incidental damages to plants while harvesting the NTFP. However, with disintegration of the traditional ecological ethos, the customary care to prohibit gratuitous damage to the resources is disappearing from the harvester’s behaviour during gathering expeditions. Village forest protection committees need to monitor the mode of harvest of NTFP and the impact of the gathering behaviour on the future availability of the items harvested.

(xviii) In contrast to the overall wood density of 0.72 as surmised by Haripriya (2000) and Kaul et al. (2009) for Odisha forest, the mean wood density of tree species comprising the forest in the study region is estimated at 0.754. Using this mean density value of the trees actually enumerated in this study, the total wood biomass over the entire forest area at 5 sites is estimated at 57387.42 Mg. This amount is composed of stem, branches (aboveground) and root (belowground) biomass of all trees.

(xix) Following the conversion equation given in Sharma et al. (2010), the amount of carbon stored in the forest wood biomass is estimated at approximately 26042.30 Mg over the entire forest area, comprised by the five study sites. Continuation of the prevailing process of wood removal and deceleration of the natural rate of regeneration will invariably lead to a gross deficit in the environmental carbon sequestration.

Limitations of the Study:

1. Sampling of more transects, and an examination of the regeneration data in combination with NTFP flow will enable us to offer robust suggestions about a strategy for sustainable harvest of NTFP biomass from the forest. Furthermore, canopy cover estimation was not undertaken in this study. A future investigation using a canopy meter meter would enable us to match the ground level data of forest cover with the satellite imagery data.

2. In the absence of time series data and *in situ* quantification of primary productivity of forest patches, the rate of change in carbon sequestration in wood biomass cannot be predicted.

3. Despite limitations, this study indicates that the overall forest cover seems to be good, with considerably high stand densities, interspersed with low-density stands, where older trees are removed with low level of proteciton afforded by the community. This study has identified the forest sites where deforestation is continuing , and suggested reinvigoration of the community to protect their resource base, with possible intervention by the State forest department.

8. SUSTAINABLE NTFP HARVESTING METHODS: RECOMMENDATIONS

In view of the fact that apart from a few dominant species, most of the species are harvested in unsustaiable manner, a few thumb rules for sustainable harvest of NTFP are in order.

The most **general thumb rule** is that *harvest of all biomass should be made from high-density patches only, leaving the low-density patches to recuperate.* In particular, care ought to be taken while harvesting the following items of forest produce:

(a) **Tubers**: While harvesting of tubers, the whole plant (usually climbers) must not be uprooted.

(b) **Leaves:** At the time of harvesting of leaves, care must be taken to prohibit incidental and gratuitous damage to the tree branches, trunks, and the herb layer of the forest.

(c) **Timber/ poles:** CFM must involve a community regulation on harvest of poles and boles, such that each household will not exceed its quota of harvest, such as 2 poles per year. Cutting of big trees (GBH > 10 cm) must be restricted to occasional uses in house building, and never to be used for fencing or making agricultural implements.

(d) **Fruits:** Harvest of mango, jackfruits, mahua, char and other fruits of household consumption generally tend to be limited. However, when the same fruits are extracted for commercial purposes, the harvest often exceeds the sustainable proportions, and involves gratuitous damage to the trees. In particular, over-harvest of char results in depletion of the seed bank for regeneration of the species. Village committees must obviate any harvest of unripe fruits, and delimit the harvesting quotas for each household.

(e) **Mahua flower:** Mahua flower, used mainly for brewing *mahua* spirit, is harvested and stored in almost all tribal households, and only the are collected from the grounds when shed from the tree. Therefore the harvest is sustainable, and need not any regulation.

(f) **Bamboo**: Villagers almost always extract bamboo culms from the exterior part of the clump, and hack the thineer portions from 1 m above ground. As the interior culms are not thinned out, most of the culms become congested, thus suppressing the growth and regeneration of the clump (Palit 1999). This unssutainable mode of bamboo extraction must be changed, and extraction of the culms from the entangled interior encouraged.

This unsustainable mode of bamboo extraction also entails an unnecessary pressure on forest trees. Thinner portions of bamboo, harvested from 1 m above the ground, are too weak for construction. Therefore, villagers extract tree poles, instead of bamboos, for construction of houses and implements, even for fencing. Thicker bamboos, cut from the basal nodes and from the interior of clumps, would be more useful for the structural purposes, and will alleviate the pressure on trees.

(e) **Siali leaves**: Leaves of siali is an important item of NTFP that is used by all households, and also sold on market. In some villages, siali leaves are economically more important than sal leaves. The harvest of siali leaves appears to be *ad libitum*, and most of the leaves are plucked out. Furthermore, there seems to be a inchoate perception among villagers that the stock of Siali plants is unlimited, so grauitous damage to the climber is very frequent. Protection Committees must restrain this wasteful mode of leaf harvest. This is particularly important in view of the fact that almost no seedling of siali was found in any of the forest patches during the monsoon survey. In the absence of any noticeable regeneration, siali population is likely to disappear before long.

(g) **Peer Monitoring**: Peer groups within the Committee should monitor the harvesting methods and prevent any gratuitous damage to seedlings and trees. Results of the monitoring data should be shared with the villagers so as to improve the method of harvest subsequently.

(i) **Re-stocking of forest wealth**: The forest patches need to be re-stocked by plantation of (1) useful species that are harvested in large quantities, and (2) rare species, regardless of their direct use value. This plantation drive need to be participatory, involving the Forest Department personnel whenever necessary.

(j) **Awareness building**: It is necessary to build awareness among villagers about regulated harvest of NTFP, based on their perception of over-harvest and destructive mode of resource extraction.

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