A comparative analysis of regeneration in natural forests and joint forest management plantations in Uttara Kannada district, Western Ghats

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Five villages undertaking joint forest management (JFM) were chosen in Uttara Kannada district, Karnataka for assessing regeneration in plantations and nearby natural forests of the village. Species number, stem density, diversity index, similarity in species composition in less disturbed and disturbed forests and plantations in the village were compared. Stem density was low in all the disturbed forests; however, the species number was low in disturbed forests of three villages and high in two villages. Plantations showed lower diversity values compared to the adjacent natural forests. Regeneration in all less disturbed forests was better compared to the disturbed counterparts. Villages were ranked based on number of landless families, per capita forest available and number of cut stems. Assessment of village forests using ranks indicates that parameters such as per capita availability, cut stems in the forests may determine the success of JFM.

FORESTS, which used to be a major resource in the past, are now not able to meet even the basic needs of the forest-dependent communities. With increase in population, pressure on forest has increased to meet the growing needs of industrialization, urbanization and rural subsistence[1–5]. However, over the years the policy-makers as well as the communities have realized the need to reverse such a process and also conserve what is left of the natural forests. A study on deforestation has concluded that forest policies have contributed significantly in conserving forests in India[6–9]. These include the Forest Conservation Act 1980, the Forest Policy 1988 and the Wildlife Act 1972, which triggered several afforestation programmes such as social forestry and Joint Forest Management (JFM), apart from various other reforestation or afforestation programmes. The JFM programme was primarily initiated to regenerate the degraded lands with the help of the local community, offering them a stake through sharing a portion of the profit from the sales proceeds of timber in the final harvest. Though the social forestry programme had similar objectives to meet the local biomass needs, it has been criticized strongly that the involvement of local community was lacking in the programme and therefore it was unable to achieve the goals[6,9].

JFM in India is a decade-old now, with over 62,000 forest-protection committees covering over 14.4 million ha of forests, accounting for nearly 50% of the open forests in the country[10]. Now 27 states have passed the JFM resolution based on the resolution of the Government of India on JFM. Karnataka is one of the pioneering states to initiate JFM during 1993 with support from external agencies to develop Western Ghat districts, namely Uttara Kannada and Shimoga. In Uttara Kannada district, nearly 7000–9000 ha of forest plantations is raised annually[11]. The reforestation programme was dominated by exotic tree species such as *Acacia auriculiformis*[12]. Large-scale development of plantations was carried out extensively in the district since 1842 (ref. 13). However, during the post-1980 period, the emphasis shifted to raising of plantations on disturbed lands under the social forestry and JFM programmes. Though large-scale afforestation programmes in the district have been undertaken for over two decades, regeneration and furtherance of such plantations have not been assessed, particularly the JFM plantations. There is hardly any report indicating the success factors that contribute to JFM in order to strengthen those areas of expertise. We attempted to elucidate in this article, some parameters that directly affect the livelihoods of the inhabitants in these forests. An attempt has also been made to compare the species composition and diversity of natural forests and JFM plantations and to understand the regenerative capacity of the forests of Uttara Kannada.

Study site

The Western Ghats, which run parallel to the west coast, pass through this district dividing it into two distinct

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zones – a wide upland country along the Ghats at an elevation of 675 m MSL, and a narrow coastal strip. The Uttara Kannada district is richly endowed with forests and about 75% of the total land area of 10,291 km^2 is forested. There are broadly four different categories of forests, viz. tropical evergreen, semi-evergreen, moist deciduous and dry deciduous.

The district receives an average annual rainfall of 2742 mm, mainly from the SW monsoon concentrated during the months of June to September. The district has been divided into five forest divisions, namely Haliyal, Yellapur, Karwar, Honnavar and Sirsi. Table 1 gives details of the area under various forest types in each of the forest divisions. Each of these forest divisions in turn has been subdivided into ranges.

Methods

One village per forest division was selected, where the JFM programme was being implemented. In each of the villages a plot in the JFM plantation, a plot in the nearest or disturbed forest and another in the farthest or less-disturbed forest were selected for vegetation assessment. The forest area which falls within 2-km radius from the village was considered disturbed and those beyond 5 km were considered less-disturbed. It is assumed here that the forests that are closer to a village are more likely to be accessed frequently than those further away. Also, the time available for harvesting or any other activity conducted in the forest will be more in proximal areas than in the farther areas[14]. This categorization of forests was done to enable comparison of various parameters of vegetation, viz. species composition and size class distribution at various levels of disturbance. In the disturbed and less-disturbed areas of each of the five forest divisions, three quadrats, each of dimension 100 m × 100 m (1 ha), and in plantations, three quadrats of 50 m × 50 m (0.25 ha) were laid. All stems with GBH > 30 cm were measured as trees, while those that have GBH between 3 and 30 cm were considered as shrubs. Plots were laid in all the five forest divisions of Uttara Kannada during 1997–98 in forest ranges of Kulgi in Haliyal division, Siddapur in Sirsi division, Gersoppa in Honnavar division, Yellapur in Yellapur division and the Gopishetta in Karwar division. These five ranges capture the variation across forest types and across the rainfall gradient.

Table 1. Area under different forest types (%) in the five forest divisions of Uttara Kannada

Forest division	Evergreen	Semi evergreen	Moist deciduous	Dry deciduous	Total forest area (km^2)
Haliyal	5.37	4.61	48.24	41.78	1442
Yellapur	6.57	13.31	30.09	50.02	1692
Karwar	21.48	38.39	34.75	5.36	2037
Honnavar	18.08	32.13	34.31	5.48	1409
Sirsi	9.20	36.05	25.25	29.47	1713

Data were analysed separately for the three sample stands in all the divisions after pooling the replicates together. Shannon–Wiener diversity index (H') was computed. The Kolmogorov–Smirnov (KS) test was done following Zar[15], and the Morishita–Horn similarity index following Magurran[16]. An index was developed using the forest area available per household, proportion of landless households in the village and number of cut stems found in each of the sample plots from plantation, disturbed and less-disturbed forests. A rank was assigned for each of these parameters and ranks were summed for all the villages over all the parameters. The ranking method is given in Table 2. Lower forest area available per household is expected to have a negative impact on the forest. Thus a higher rank would mean less negative impact on the forest. Higher proportion of landless households in a village indicates greater dependence on the forest, and therefore greater negative impact on the forest. Therefore, it is given a higher rank for lower proportion of landless households in a village. Greater the proportion of cut stems in the forest, greater is the negative impact on the forest. Thus higher rank indicates higher negative impact. Ranks obtained for each parameter were summed over all the villages, and from this sum the proportion was calculated for each village. Proportion of the rank obtained for each of the villages was summed over all the parameters for that village. This rank qualitatively indicates the success of the village for its efforts in JFM.

Village profile

Major features of study villages are given in Table 3. The number of households in the selected villages ranged from 22 in Sabgere with a population of 124 to 340 in Kangod with a population of 1928. In Saralgi, 57% of the households are landless and in Kangod it is 20%. An interesting feature in Sabgere and Kulgi is that all households are landless and most of the people are traders and agricultural labourers. The major occupation in other villages is agriculture (Table 3), with very low proportion of artisan families.

Results

Species number, density and diversity

Highest number of species was found in Kangod (140) followed by Saralgi and Sabgere (Table 4). Total number

Table 2. Assigning rank values for different parameters

Parameter	Rank 1	Rank 2	Rank 3
Forest per household (ha)	< 0.5	0.5–1	> 1
Landless (%)	> 50	25–50	< 25
Cut stem (%)	> 5	1–5	< 1

of individuals was also the highest in Kangod, with a diversity index of 3.96. The species diversity index of Satgere was 3.68 with 4802 individuals and in Saralgi, it was 3.45 with 5472 individuals. Lowest species diversity index of 2.66 was recorded in Kulgi with 63 species. Both species number and number of individuals were low in plantations, when compared to natural forest (i.e. disturbed and less-disturbed forest). Similar pattern was found in Kulgi. In Sabgere, Saralgi and Satgere, the number of species and number of individuals in less-disturbed forests were higher compared to their disturbed counterparts. Plantations of Saralgi and Satgere showed lower species number and stem density compared to the natural forests. Interestingly, in Sabgere, both density and species number were higher in plantations compared to disturbed forests, but lower than less-disturbed forests.

In Kangod, the species number and the number of stems were highest compared to other villages. The lowest number of stems and species diversity index were recorded in Kulgi. The number of stems in the sample plot of disturbed forest was highest in Kulgi followed by Saralgi and Satgere. The lowest number of stems was found in Sabgere. However, the number of species was high in Satgere followed by Saralgi and Kangod. The lowest number of species was found in Sabgere (Table 4). Though the species number in plantations was highest in Sabgere, Shannon–Wiener index of diversity was high in Satgere (2.34) and low in Kangod (1.56). High diversity and stem number per unit area may be due to high area of forest in Kangod and Saralgi village compared to other villages. Higher forest area coupled with higher agricultural area seems to indicate that forests are less disturbed. Villages with no natural forest and less agricultural area seem to suffer greater damage.

Regenerative capacity of forests

Regeneration within a village forest

The difference in cumulative frequency of size-class distribution in Satgere indicates that some size classes are

Table 3. Profile of villages selected for vegetation assessment

Feature	Kangod	Satgere	Sabgere	Saralgi	Kulgi
No. of households	340	32	22	255	59
Population	1928	173	124	1047	342
No. of landless households	75	2	22	145	59
No. of artisans	8	–	–	6	–
Geographic area (ha)	661	123	NA	720	NA
Forest area (ha)	370.6	–	–	500.8	–
Reserve forest	128.0	–	–	306.0	–
Minor forest	243.0	–	–	194.8	–
Other forests	49.6	–	–	108.8	–
Area of cultivated land (ha)	224.4	25.6	–	110.8	–
Livestock	1336	92	–	648	–
Area under JFM (ha)	229	36	25	35.5	15

NA, Not available.

Table 4. Mean and standard deviation of species number and stem density in less-disturbed, disturbed and plantation forests of study villages

	Kangod	Kulgi	Sabgere	Saralgi	Satgere
Overall					
Number of species	140 ± 21.92	63 ± 2.83	113 ± 47.38	126 ± 10.61	110 ± 4.24
Number of stems	5565 ± 2206.88	3548 ± 191	3355 ± 1574.73	5472 ± 1329.36	4802 ± 1033.79
Shannon–Wiener index (*H*′)	3.96	2.66	3.42	3.45	3.68
Disturbed					
Number of species	78 ± 28.84	47 ± 5.03	34 ± 2.52	81 ± 8	83 ± 7.02
Number of stems	1222 ± 343.12	1909 ± 276.52	564 ± 47.34	1796 ± 674	1670 ± 174.78
Shannon–Wiener index (*H*′)	3.50	2.48	2.31	3.27	3.41
Less-disturbed					
Number of species	109 ± 16.97	43 ± 3.51	101 ± 30.15	96 ± 20.22	89 ± 3.51
Number of stems	4343 ± 648.56	1639 ± 119.15	2791 ± 567.19	3676 ± 1011.38	3132 ± 746.14
Shannon–Wiener index (*H*′)	3.75	2.42	3.99	3.28	3.62
Plantation					
Number of species	21 ± 4.03	28 ± 2.08	41 ± 5.65	37 ± 5.13	34 ± 3.21
Number of stems	967 ± 235.68	1132 ± 111.16	743 ± 252.44	762 ± 222.12	1475 ± 401.85
Shannon–Wiener index (*H*′)	1.56	1.70	2.29	2.27	2.34

*Includes all stems in disturbed and less-disturbed forests and does not include stems from plantations.

getting affected in disturbed forests. KS test indicates the maximum difference found in the size-class 10–15 cm DBH, between disturbed and less-disturbed forests (Table 5 and Figure 1). Thus, the class 10–15 cm is getting affected probably due to extraction. In Kulgi, KS test reveals that the difference is greatest in the size-class 15–20 cm and 20–25 cm, indicating that there is probably pressure of extraction on those size classes. As in Satgere, the plantations of Kulgi also have the highest number of stems in the regenerating size class of 1–5 cm. A comparison of disturbed and less-disturbed forests with plantations therefore gives comparable values. Size-class distribution of stems in Saralgi shows that the difference is greatest in 1–5 cm size-class, while in Sabgere, it is highest in 15–20 cm size-class. However, in Kangod the difference is highest in the 5–10 cm size-class. These differences indicate disturbance. A comparison between disturbed and less-disturbed forests with plantations in all villages reveals a great deal of difference that exists between these forest types, primarily because plantations have greater proportion of individuals in the lower size class than in higher size classes.

Regeneration among forests

A comparison of size-class distribution (combining all stems of disturbed and less-disturbed plots) among the villages indicates that there is similarity between the forests of Sabgere and Kangod, and Satgere and Kangod (Table 5). Sabgere and Satgere, although similar to Kangod in the size-class distribution, are different from each other. It was found that the class that had maximum number of individuals was 5–10 cm, except in Kangod. The comparison also indicates that six pairwise comparisons had maximum difference in size-class 5–10 cm, one in 1–5 cm class, one in 10–15 cm class, and one in 15–20 cm class. This pattern indicates that the proportion of individuals present in size-class 5–10 cm determines the difference in size structure in different communities. This may arise from differential recruitment rate from 1–5 cm to 5–10 cm class, or conversely, the differential recruitment rate from 5–10 cm class to higher classes.

Community structure and composition

In Kulgi, the most dominant species was *Tectona grandis*, followed by *Terminalia paniculata*, *Lagerstroemia lanceolatus* and *Xylia xylocarpa*. In Sabgere and Satgere, *Terminalia tomentosa* and *T. paniculata* dominate respectively. *Xylia xylocarpa* and *Careya arborea* are the two other species common to Sabgere and Satgere, among the top-ten dominant species. In Saralgi, *Aporosa lindleyana* dominates, and this is one of the top-ten species in Sabgere and Satgere also. The other dominant species in Saralgi are *Vitex altissima*, *Holarhena antidyssenterica* and *Olea dioica*. *Ervatamia heyneana* is the most dominant species in Kangod. The other species with greater representation are *T. paniculata*, *Loenicera malabarica*, *Diospyros* spp. and *Ixora brachiata*.

Composition of forests within a village: In Satgere, maximum similarity was found between disturbed and less-disturbed forests (Table 6). Plantations shared the least similarity with both disturbed as well as less-disturbed forests. Similar pattern was found in Saralgi. However, there was greater similarity among forest types of Kulgi.

Regeneration in natural forest and plantations: A comparison between species composition of natural forests and regenerating individuals in the plantations[1] (Table 7) indicates that greater similarity exists in Kulgi (76%) and the least in Kangod (7%). In natural forests of Satgere, Sabgere and Kulgi, *Terminalia* species dominate and therefore the same species dominate in the understorey layer in plantations, indicating native species probably would dominate the plantations in future. Kulgi recorded the highest number of species regenerating naturally (19), whereas Satgere and Sabgere recorded 17 and 10 species respectively. However in Kangod only nine species were found regenerating, but none of them were representative of natural forests. Similarly, in Saralgi 16 species were found regenerating and only *I. brachiata*, a native species, was found regenerating in small numbers. The number of species planted in Kangod, Satgere, Sabgere, Saralgi and Kulgi was 11, 10, 14, 21 and 11 respectively, while the number that regenerated naturally was 9, 17, 10, 16 and 19 respectively.

Table 5. Maximum difference values of cumulative frequency of size-class distribution of various forests in the study villages (KS test). Values in parenthesis indicate critical limit

Village	Between disturbed and less-disturbed forests	Between disturbed forest and plantation	Between less-disturbed forest and plantation
Satgere	0.08 (0.04)	0.63 (0.04)	0.67 (0.05)
Kulgi	0.07 (0.05)	0.57 (0.05)	0.59 (0.05)
Saralgi	0.09 (0.04)	0.81 (0.05)	0.90 (0.06)
Sabgere	0.60 (0.14)	0.57 (0.14)	0.82 (0.19)
Kangod	0.15 (0.04)	0.64 (0.14)	0.73 (0.14)
Pooled	0.17 (0.02)	0.62 (0.03)	0.72 (0.03)

Assessment of villages for their efforts towards JFM

Kulgi (0.687) obtained the lowest rank and Satgere the highest (1.252). The ranks obtained here place the villages in the order of their efforts to make the JFM a success, i.e. their efforts towards use of resources in a sustainable manner (Table 8). Satgere obtained higher rank because of higher forest area available per household, lower proportion of landless families in the village and relatively lower proportion of cut stems in the forests. Conversely, the lower rank in Kulgi was primarily because of lower forest area available per household and greater proportion of landless people in the village though the proportion of cut stems found in the forests was low. Similarly, Saralgi got lower ranking mere because of higher proportion of cut stems in the village than because of proportion of landless people in the village. Rank correlation between land per household and percentage of cut stems in plantations indicates negative and strong (– 0.7, $n = 5$) correlation suggesting that landless people in the village would enhance the success in the village. The rank sum values with the percentage landless is also same (– 0.7, $n = 5$), indicating that the landless community in the village would enhance the efforts of JFM in the village.

Discussion

Regeneration in the forests is an indicator of the well being of the forest. Studies relating to the regeneration of

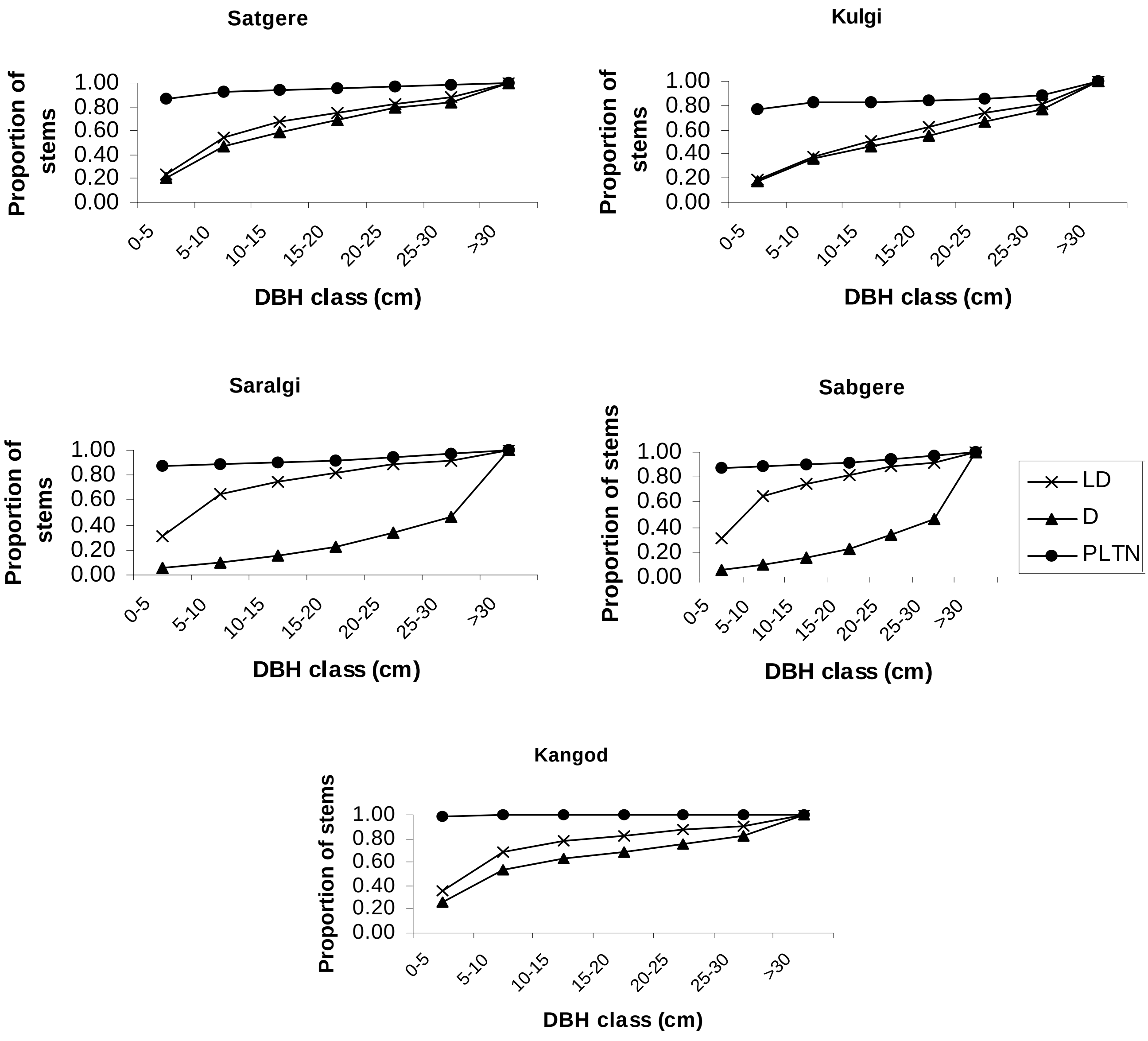

Figure 1. Size-class distribution of species in the study villages. Solid circles indicate the stems in JFM plantation, asterisk indicates stems in less degraded forest and solid triangle indicates stems in degraded forest.

Table 6. Morishita–Horn similarity value (%) in species composition among disturbed, less-disturbed and plantation forests of study villages

Village	Between disturbed and less-disturbed	Between disturbed and plantation	Between less-disturbed and plantation
Satgere	80.9	28.6	21.6
Kulgi	62.7	78.1	57.1
Saralgi	57.4	16.8	7.6
Sabgere	34.1	15.4	6.2
Kangod	38.8	1.4	0.9

Table 7. Comparison between species composition of natural forests of a village with the naturally regenerating saplings in the plantations of the same village

Village	Similarity (%)
Kangod	7
Kulgi	76
Sabgere	43
Saralgi	24
Satgere	43

either specific species or in general, have looked at the factors responsible, i.e. fire or tree-felling or any such anthropogenic pressures. It has been recorded that regeneration of the species was affected by fire[17–19] and logging[20]. In general, the regeneration of species is also affected by natural phenomena such as light gaps[21]. Degradation is argued to reduce species number, stem density and regeneration potential of the forests[14,22–24]. Similar observations are made in this study where four villages show low species diversity (Kangod, Sabgere, Saralgi and Satgere) in disturbed forests compared to the less-disturbed forests. However, in Kulgi, the highest species diversity was recorded in disturbed forests than in less-disturbed forests. This can be partly explained that whenever there is a disturbance, particularly at the intermediate-level, the species number tends to increase[25]. However, Kulgi, a forest with lowest number of species, is deciduous and still exhibits good number of species in the degraded state. The differences may not be statistically significant.

Plantations show lower species diversity. Some studies indicate that natural species have regenerated under the plantations[26–27]. This is an indication that protection accorded by the community in the initial years of plantation may enhance the natural species regeneration in plantations. Later, if protection continued, the plantation may recover into natural forest. Surprisingly, the village Kangod which showed high species diversity in natural forests had less species diversity in plantations. The species fail to regenerate in plantations of Kangod, though it is a species-rich forest. This indicates that the species of this forest may need a particular niche for better regeneration. Conversely, Kulgi, a species-low forest showed highest number of species regenerating in their plantations. The species that are regenerating are mostly of deciduous type, which may require open canopy. Similar pattern was found in Satgere, Saralgi and Sabgere. Thus, it can be concluded that species of evergreen type may fail to regenerate in plantations though the natural forest is close to plantations, indicating high specificity of regeneration niche.

Variation in size-class structure in the study villages is high. Disturbed forests of all villages differ from their less-disturbed counterparts in size structure. Most of the villages differ with respect to the size class in 10–15 cm category. But the regenerating class, i.e. 1–10 cm category does not show any difference among villages with differing levels of degradation. This could be due to lower grazing pressure and frequency of fire. Thus, it may be concluded that regeneration potential is not hampered despite degradation in most forests in these villages. However, some size classes are hampered probably due to harvesting. Thus in these village forests, JFM may prove successful. The plantations differ with respect to the natural forests, disturbed and less-disturbed forests in size class 1–5 cm, indicating that the plantations are young and therefore may represent only lower size class. Further, the difference in the size class 10–15 cm as observed in the natural forests is not found in plantations, i.e. there may not be cutting of poles of that size. This may probably be because of the protection provided by the Forest Department by way of trenches, fencing and a watch-guard.

Ranking and assigning values to JFM villages may be useful in incorporating management or implementing strategies of the programme. In this article we have attempted to understand the indices that have direct relevance on the ecology of the village. Forest available per household seems to be determining the success of JFM, as indicated by the cut stems in the JFM plantations. Though these results are not conclusive as we have taken only five sample villages, this needs to be replicated in many villages of different agro-climatic zones, so that such indices could be developed to understand the other aspects of JFM, such as institutional and economic factors. In this study, Satgere, Sabgere and Kangod obtained high ranks primarily because of the lower disturbances in the forest and higher forest area available for the households. These indices may prove useful in ranking the villages that need to be strengthened. These indices also indicate the areas

Table 8. Weighted sum rank for study villages using forest available per household, landless households in the village and cut stems found in different forests

Village	Forest/household (ha)	Percentage landless	Percentage cut stems in			Weighted sum rank
			Plantation	Disturbed	Less-disturbed	
Satgere	1.13	6.25	0.95	2.69	1.12	1.25
Kulgi	0.25	100.00	0.97	1.15	0.67	0.90
Saralgi	0.14	56.86	3.41	2.62	0.73	0.83
Sabgere	1.14	100.00	0.67	7.27	1.22	0.90
Kangod	0.67	22.06	0.62	6.30	0.37	1.10

that need improvement, and therefore a strategy that could prove useful for a given village could be adopted. Further, these indices may help in guiding the JFM villages to sustain their programme. As mentioned earlier the above-said villages have shown good regeneration, higher tree density and species number, indicating that the impact of village activities on the forests is relatively less. Further, Saralgi, the village with low species diversity and stem density shows lower ranking, indicating that the chances of sustenance of the JFM programme may be less. Such information may help the managers to pay more attention to human and financial efforts and thus assist villages use their resources in a sustainable manner.

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