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Effect of protection on regeneration in some selected village forests under community protection in Uttara Kannada district, Karnataka, India

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Effect of protection on regeneration and species similarity was studied in six village forests under Joint Forest Management in Uttara Kannada district, the Western Ghats. Difference in species number, stem density, basal area of planted and natural species, and shrub density was compared between two observations in all the villages studied. All village forests experienced a decrease in the number of stems after the protection was withdrawn. The decrease in overall density of natural species was more (19.7%) than that of the exotic species (8.2%). This could be because of the utility of native species than the exotic ones. Basal area increased for stems that were planted, while it generally decreased for stems of natural species. The overall basal area, including native and planted species, had increased during the observation period indicating biomass accumulation. Shrub density increased in all villages except in Kadle, where there was no natural vegetation in the village forest. Greater similarity of species was found for planted species within the same village forests before and after protection. The number of cut stems increased significantly when the protection was removed, indicating diversion of pressure. The community did not prefer exotic species that were planted and on the other hand the native species were used to meet various biomass needs. The study indicates that the programme should develop strategies that incorporate various measures to conserve and maintain the village forests.

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ONCE forests used to be a major resource in the past, but with increase in population, pressure on the forests has increased to meet the growing needs of industrialization and urbanization[1–5]. Now the forests are unable to meet even the basic needs of the forest-dependent communities. Continued deforestation has put increasing pressure on the natural resources and on the livelihood patterns of the forest-dependent communities. A study on deforestation has concluded that forest policies have contributed significantly in conserving forests in India[6–10]. The policies include the Wildlife Act 1972, Forest Conservation Act 1980, and the Forest Policy 1988. The last two policy pronouncements triggered several afforestation programmes.

Participatory forestry programme called as Joint Forest Management (JFM) was launched in India during 1990 with a view to enhance regeneration of degraded forests and accord protection through local community. The effort towards community-initiated forest protection has emerged as a movement in India with over 62,000 village communities protecting over 14.4 mha of forests[11]. Though the efforts are largely from the government, the impact of such efforts on the ecology is not properly understood[12,13]. The programme now is over a decade old and no attempt has yet been made to understand the impact of protection towards vegetation recovery, regeneration potential and species composition either at the local, regional or national level[12,14].

In Karnataka, the programme of participatory forestry is called the Joint Forest Planning and Management (JFPM). A guideline was issued in the state to undertake participatory community forestry during 1993 through an order based on the guidelines passed from the Government of India. Plantations under JFPM were raised with a view to supply fuelwood, fodder and other non-timber forest products to the local people living in and around the forests. These plantations were also expected to improve tree cover and allow natural regeneration due to the protection provided jointly by local people and the Forest Department. The implicit assumption in the community protection is to improve regeneration in these forests, as a low cost option and meeting their subsistence biomass requirements. For the first three years of JFPM plantations in Karnataka, protection is offered primarily by the Forest Department through barbed wire fencing, cattle-proof trenches and a watchman[15]. After completion of three years, the fence and services of the watchman will be withdrawn to enable the community to take over the forest for protection. Here we attempt to understand the change in regeneration potential, species number and stem density in these JFPM plantations.

The study was conducted in Uttara Kannada district, Karnataka (lat 13°55′–15°31′N and long 74°9′–75°10′E), where the first experiment on JFPM was undertaken by the Karnataka Forest Department with support from an English donor agency called Department for International Development. The district has of over 330 Village Forest Committees (VFCs) as a part of JFPM programme in the state[16]. The study was conducted in Sirsi block of Uttara Kannada district. The district is hilly terrain with varying depths of soil. Soils are lateritic with gneiss and schist type of rocks underneath and with a pH around 5. Annual average rainfall in the district is 250 cm. June to mid-October is monsoon season, November to January is winter season and February to May is summer season. The study villages were Nidgod, Goranmane, Hallibailu, Illimane, Kadle and Hukli belonging to Sirsi division except Kadle, which belonged to Honnavar division. In all the VFCs, the year of plantation was 1995–96 and observations were made during 1997–98 and 1999–2000.

Data on vegetation parameters were taken twice in all the villages, once before the removal of protection and after one year of removal of protection. In each location, three quadrats of size 40 m × 50 m each were measured. GBH of all the stems was measured for the planted species and for natural species stems above 10 cm girth were measured. Within each quadrat another plot of 10 m × 10 m was laid and all stems measuring > 20 cm height counted and the species to which each stem belongs was recorded. In the subsequent year, i.e. approximately one year later, similar data from the same plot were recorded. Difference in species number, stem density, basal area of planted and natural species, and shrub density was compared between two observations in all the villages studied. In order to know whether the differences are statistically different, Student's *t*-test statistics was computed[17]. Similarity of species composition at two observations was made using Morishita–Horn index as given by Mcgurran[16].

Table 1. Species planted under JFM

Acacia auriculiformis, *Casurina equisetifolia*, *Acacia catechu*, *Phyllanthus emblica*, *Acacia mangium*, *Sapindus emarginata*, *Mangifera indica*, *Anacardium occidentale*, *Terminalia paniculata*, *Artocarpus integrifolia*, *Zanthoxylon retusa*, *Eugenia jambolana*, *Lagerstroemia microcarpa*, *Dalbergia latifolia*, *Mitragyna parviflora*, *Pterocarpus marsupium*, *Terminalia arjuna*, *Terminalia tomentosa*, *Terminalia bellerica*, *Tamarindus indica*, *Syzygium cumini*, *Anthocephalus cadamba*, *Artocarpus hirsute*, *Albizia chinensis*.

All the species found in different villages are given in the Appendix. Species planted under the JFM plantation programme are given in Table 1. Majority of the species planted were exotic, such as *Acacia auriculiformis*, *Casuarina equisetifolia* and *Acacia mangium*. The other important native species planted were *Phyllanthus emblica, Mangifera indica* and *Anacardium occidentale*. All VFCs experienced a decrease in the number of planted stems after protection was withdrawn (Table 2). The highest was in Kadle, with 16.61% stem removal within one year and the least was in Hallibailu with only 4% stem removal. Stand density of natural species also experienced similar pattern of removal. The highest removal was in Nidgod with nearly 60% of stems being extracted and the lowest in Hallibailu with 4.25% of stems cut. No natural species was found in Kadle, as it was a pure plantation. The overall decrease in stem density was highest in Nidgod (18.71%) and lowest in Hallibailu (4.02%). Thus there was a difference among villages in stem density of native and exotic species of village forests. The decrease in overall density of natural species was more (19.7%) than that of the exotic species (8.2%), though the total stem density decrease was more in planted or exotic species. This may be primarily because of the utility of the native species compared with the exotic ones. Exotic species are planted primarily to meet the firewood demand rather than other utilities of the community.

The species that were cut for various purposes are listed in Table 3, which indicates that stems cut by the people were mostly natives and rarely exotics. Though, in terms of absolute values, the exotics may have been harvested more, their percentage harvest is far less. For example, the species *A. auriculiformis* was planted in large numbers, but stems cut were only 2% indicating that disproportionately low utility was found for exotics. Decreased stem number has been reported to be due to human impacts even in national parks and wildlife sanctuaries, where utmost protection is accorded[18,19]. However, villages where the participatory conservation approach has recently been introduced, have yet to take time. Thus these villages also experienced decreased stem number. Perhaps people had no other alternative but to use the natural resources, or it is habituated, or even participatory approach has not been taken up in the proper way. In fact, there are reports where[14] it is noted that participatory approach is improper in this part. It is also interesting to note that the stem numbers of native species have decreased in these forests as against the exotic ones, indicating that even today people use indigenous species than exotics, further reinforcing the idea that participatory planning may not have been initiated during the initial implementation process.

Basal area increased for stems that were planted, while it generally decreased for stems of natural species. The increment in basal area was over 100% in all villages for planted species, while enhancement of basal area for stems of natural species was observed in Illimane and Kadle. There was decreased basal area of stems of natural species

Table 2. Species richness and vegetation parameters in villages of JFPM plantations (before and after indicates the time from removal of protection)

	Planted species		Natural species		Total	
	Before	After	Before	After	Before	After
Stem density						
Nidgod	633 (11)	568 (–10.27) (12)	131 (25)	53 (–59.54) (16)	764	621 (–18.71)
Goranmane	843 (9)	788 (–6.52) (8)	353 (22)	313 (–11.33) (16)	1196	1101 (–7.94)
Hallibailu	873 (5)	838 (–4.00) (2)	47 (11)	45 (–4.25) (11)	920	883 (–4.02)
Illimane	1009 (10)	967 (–4.16) (10)	75 (32)	73 (–2.67) (30)	1084	1040 (–4.02)
Kadle	1180 (10)	984 (–16.61) (10)	0	0	1180	984 (–16.61)
Hukli	956 (9)	897 (–6.17) (8)	166 (29)	136 (–18.07) (25)	1122	1033 (–7.93)
Average	915.67	840.33 (–8.22)	128.67	103.33 (–19.7)	1044.33	973.67 (–6.76)
Basal area (m^2/ha)						
Nidgod	0.803	2.981 (+271)	5.619	5.194 (–7.56)	6.422	8.175 (27.3)
Goranmane	0.776	4.16 (+436)	6.953	6.700 (–3.6)	7.729	10.86 (40.5)
Hallibailu	0.315	2.378 (+655)	0.492	0.538 (+9.3)	0.807	2.916 (261.46)
Illimane	1.380	4.738 (+243)	3.578	3.716 (+3.8)	4.958	8.454 (70.49)
Kadle	2.120	4.950 (+133)			2.120	4.950 (+133)
Hukli	0.810	2.541 (+213)	1.927	1.850 (–3.99)	2.737	4.931 (80.16)
Average	1.034	3.62 (250.6)	3.094	2.99 (–3.47)	4.128	6.71 (62.55)
Shrub density	Before	After				
Nidgod	3216 (23)	3600 (11.94) (25)				
Goranmane	3933 (25)	8250 (109.7) (34)				
Hallibailu	1750 (25)	2700 (54.28) (18)				
Illimane	3350 (32)	4350 (29.85) (28)				
Kadle	37525 (9)	32225 (–14.12) (10)				
Hukli	11383 (45)	11867 (4.25) (39)				
Average	10192.33	10498.67 (–3.0) (63)				
New recruits	Number	Basal area				
Nidgod	0	0				
Goranmane	22	0.0022				
Hallibailu	28	0.0306				
Illimane	53	0.0650				
Kadle	168	0.5060				
Hukli	22	0.0223				
Average	48.33	0.14				

in Nidgod, Goranmane and Hukli, while increased basal area was observed in Hallibailu and Illimane. The overall basal area, including native and planted species, had increased between two observations indicating increased biomass accumulation. Shrub density increased in all villages, except Kadle. Being a village without any natural species, the shrub density was zero at Kadle. Increase in over 100% shrub density was observed in Goranmane. The planted species probably did not promote growth of shrubs under them, and the density of planting in Kadle is relatively higher than at other village plantations that were either mixed plantation model or assisted natural regeneration model. The number of new recruits was high in Kadle (168), while no new recruits were found in Nidgod (Table 2), and therefore the basal area of new recruits was also high in Kadle.

Basal area is a function of radius of the stem, and therefore, if the stem diameter increases linearly, the area increases to the square of linear increment. Although there is loss of stems in the village forests, the basal area and therefore the total biomass have increased. The loss of stems perhaps is much less compared to that of growth of the already existing stems. Thus the regenerating individuals have been lost, keeping the adult individuals. This, though, has a serious consequence for the species in future, but at present has improved the biomass and sequestered carbon.

Species diversity was high in Illimane both before and after removal of protection for planted and natural species, followed by Nidgod. Least species diversity was observed in Hallibailu for planted and natural species as well (Table 4). Greater similarity of stems was found for planted species and natural species at all villages within the same VFC before and after protection. Species diversity for planted and natural species had decreased after removing protection but the shrub species diversity had increased for the same period. This indicates that people have used poles size (in this case with > 10 cm DBH) in the villages. In addition, this pattern could be because of enhanced diversity of new recruits adding to the shrub layer diversity. In all villages the diversity

Table 3. Per cent cut stems of different species in all study villages

Species	Per cent cut stems	Species	Per cent cut stems
Knedia	90.91	*Acacia auriculiformis*	2.10
Ficus aspirima	62.50	*A. catechu*	1.52
Meliaceae sp.	50.00	*Eugenia umbellate*	1.38
Murraya koenigi	50.00	*Terminalia chebula*	1.36
D. latifolia	39.47	*Eugenia jambolana*	1.27
Acacia concinha	33.33	*Ixora braceata*	1.23
Canthium dicoccum	29.41	*Buchanania lanzan*	1.22
Tamarindus indica	25.00	*Ervatamia heyneana*	0.93
Memicelon terminale	19.84	*S. cumini*	0.80
Nothopagia sp.	16.13	*Ziziphus rugosa*	0.78
Santalum osyris	10.99	*Diospyros melanoxylon*	0.77
Sapium insigne	10.53	*Randia spinosa*	0.64
A. mangium	10.00	*Ziziphus xylopyrus*	0.59
A. occidentale	8.078	*Calicopteris floribanda*	0.40
L. microcarpa	7.23	*Pterocarpus marsupium*	0.33
Olea dioca	7.04	*T. paniculata*	0.29
Semicarpus anacardium	6.85	*Bassia latifolia*	0.22
C. equisetifolia	5.51	*Holarrhena antidysenterica*	0.14
S. emarginata	5.31	*Careya arborea*	0.058
Aporosa lindleyana	4.68	*Xylia xylocarpa*	0.03
P. emblica	2.63		

Table 4. Shannon–Weiner diversity index and Morishita–Horn index among the villages studied

	Diversity index									
	Planted species		Natural species		Shrub species		Similarity index			Diversity index of new recruits
	Before	After	Before	After	Before	After	Plantation	Natural	Total	
Nidgod	0.911	0.872	2.649	2.297	2.614	2.841	0.999	0.952	0.991	1.6819
Goranmane	0.720	0.704	2.225	2.212	2.743	2.978	0.999	0.999	0.999	1.4100
Hallibailu	0.062	0.030	1.883	1.930	2.452	2.800	0.999	0.998	0.999	1.4470
Illimane	1.018	1.006	2.958	2.845	2.838	2.914	0.9997	0.978	0.997	Nil
Kadle	0.971	0.955	Nil	Nil	0.187	0.216	0.999	Nil	0.999	Nil
Hukli	0.349	0.292	2.814	2.640	2.729	2.952	0.999	0.988	0.999	1.9250

Table 5. Comparison between vegetation parameters before and after protection across all villages

	Before removal of protection mean ± SD	After removal of protection mean ± SD	t-statistics
Stem density (number/ha)	915.67 ± 182.87	840.5 ± 152.84	0.567
Basal area of planted species (m^2/ha)	0.607 ± 0.27	2.21 ± 0.67	5.4*
Basal area of natural species (m^2/ha)	2.48 ± 2.72	1.58 ± 1.48	0.71
Cut stems (number/ha)	6.83 ± 4.71	81.33 ± 57.3	3.17*
Dead (number/ha)	32.33 ± 29.97	10 ± 5.93	1.7
Density of natural species (number/ha)	128.67 ± 124.76	72.33 ± 111.86	1.03
Species number (natural)	19.83 ± 12.12	16.33 ± 10.56	0.533
Density of shrubs (number/ha)	517 ± 519.34	501.83 ± 448.83	0.05
Shrub species	26.5 ± 11.8	25.67 ± 10.55	0.12

*Indicates significance at $P < 0.01$.

of new recruits was quite substantial, indicating that the protection of three years has improved new species to occupy the niche provided.

In view of limitations on the availability of villages that had no physical barriers (such as trenches, barbed wires and watchman), the comparison of regeneration was not

Appendix. Species present in different villages in the study sites

Species	Goran-mane	Halli-baila	Hukli	Illi-mane	Kadle	Nida-god
Acacia auriculiformis	x	x	x	x	x	x
Acacia catechu					x	
Acacia concinha	x					
Acacia mangium	x					x
Albizia chinensis				x		
Albizia odorotissima		x				
Albizia procera			x			x
Alseodaphne semicarpifolia	x					x
Alstonia scholaris				x		
Anacardium occidentale			x	x	x	
Anthocephalus cadamba						x
Aporosa lindleyana		x	x	x		x
Artocarpus hirsuta		x		x		
Artocarpus integrifolia				x		x
Artocarpus lakoocha				x		
Bahunea sp.				x		
Bassia latifolia	x					x
Breynia	x	x	x			x
Bridelia	x	x	x	x		x
Buchanania lanzan	x	x	x	x	x	x
Butea monosperma		x				
Calicarpa wightiana						x
Calicopteris floribanda	x			x		x
Callophyllum wightiana				x		
Callophylum inophylum				x		
Canthium dicoccum			x	x		
Carallia integerrima	x	x	x		x	
Careya arborea	x	x	x	x	x	x
Carrissa carandas					x	
Cassia fistula			x			
Casuarina equisetifolia	x			x		x
Chukrasia	x		x			
Dalbergia latifolia			x			
Dalbergia simpethetica			x	x		
Dillenia pentagyna	x					
Diospyros candaliana				x		
Diospyros melanoxylon	x					x
Diospyros montana	x		x	x		
Embelia			x			x
Ervatamia heyneana	x		x	x		x
Eugenia jambolana	x		x		x	x
Eugenia umbellata	x	x	x	x	x	x
Ficus aspirima			x			
Ficus benghalensis			x			
Ficus religiosa			x			
Ficus sp.	x		x	x		x
Flacourtia montana			x	x		
Flacourtia sp.	x		x	x	x	
Garcinia indica				x		
Gardenia	x		x			x
Gardenia gummifera		x	x		x	x
Gnedia sp.		x	x			
Gonagalu				x		
Grewia tilifolia		x	x			
Holarrhena antidysenterica	x		x	x		x
Holigarna arnotiana				x		x
Hopea wightiana				x		
Ixora braceata		x	x			x
Ixora cocsinia	x			x	x	x
Jasmine malabaricum	x	x	x	x		x
Knedia			x			
Kydia calycinna			x			
Lagerstomia spp.						x
Lagerstroemia microcarpa	x	x	x	x		x
Leea indica		x	x	x		
Mallotus phillipinesis				x		
Mangifera indica		x	x	x	x	
Memicelon			x	x	x	x
Memicelon terminale			x		x	
Milliaceae sp.				x		
Mimusops elangi			x			
Mitragyna parviflora						x
Murraya koenigi				x		
Musunda sp.		x				
Neolitsea			x	x		
Nothopagia			x			
Olea dioca	x	x	x	x		
P. dalzelli			x			
Phoenix silvestris	x	x	x			x
Phyllanthus emblica	x	x	x	x	x	
Pterocarpus marsupium	x	x	x		x	x
Randia spinosa	x	x	x	x	x	x
Randia uliginosa				x		
Santalum osyris			x			
Sapindaceae	x		x			
Sapindus emarginata				x	x	x
Sapium insigne			x			
Semicarpus anacardium	x					x
Smilex sp.			x			
Stereospermum spp.			x			x
Strychnos nux-vomica	x					
Syzizium cumini			x		x	
Tamarindus indica	x					
Terminalia arjuna					x	
Terminalia bellerica			x	x		
Terminalia chebula	x	x	x	x		x
Terminalia paniculata	x	x	x	x		x
Terminalia tomentosa	x	x		x		x
Unknown			x	x		
Vitex altissima		x		x		
Wendlandia sp.		x	x			x
Xantalis tomentosa			x	x		
Xylia xylocarpa	x					x
Zanthoxylon retusa				x		
Ziziphus oenoplea	x		x	x		x
Ziziphus rugosa	x	x	x	x	x	x
Ziziphus xylopyrus	x	x	x	x		x
Zynthoxylon retusa				x		

possible with 'control' villages. There is significant difference in the protected and protection relieved forest was found for cut stems (Table 5), indicating that people used these stems to meet their needs. The number of cut stems is almost 12 times higher after removal, indicating the necessity of small stems. The other parameters did not show significant statistical difference with respect to number of dead stems, species number, etc. between the same periods.

JFM being a people-oriented programme, should have taken the people's confidence into account prior to initiating the village forest committees. However, in view of the target-oriented programme, the JFM was initiated primarily through enthusiasm of the Forest Department. The present study indicates that many species that are useful for the community have been cut due to removal of physical protection owing to the fact that these resources were not allowed to a part with the community. The community did not use the exotic species that were planted, and on the other hand, native species were used to meet their various biomass needs. The programme should develop measures that build up confidence in the village community before the formation of the forest committee. The social fencing attitude should be developed for their own benefit.

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Mesoscopic ductile shear zones from the Main Central Thrust zone of Bhagirathi Valley, Garhwal Higher Himalaya

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Mesoscopic ductile shear zones are well developed in the crystalline rocks of the Main Central Thrust (MCT) zone of Bhagirathi valley. Ductile and brittle–ductile shear zones are dominantly observed and exhibit both sinistral and dextral sense of sear. Detailed analysis reveals that NE-striking sinistral and NW-striking dextral shear zones form a conjugate pair. The bisectors of preferred orientations of these two sets of shear zones indicate that they developed in response to NNE–SSW horizontal compression synchronous to the translation of the MCT, which took place during the northward movement of the Indian Plate. Strain analysis reveals that the mesoscopic ductile shear zones developed in response to very high strain, in a narrow zone, which even deformed the internal fabrics of the rocks. The study of quartz *c*-axis fabrics in mesoscopic shear zones demonstrates that a single girdle pattern of quartz developed at the shear zone boundary and became prominent in the centre of the shear zone with increase in shear strain.

DUCTILE shear zones are common features in crystalline rocks that have undergone natural deformation at moderate to high temperature[1,2]. They vary in width from millimetre to kilometre and displacements along them may vary from the same order of dimension as the width to several orders of magnitude larger[3–6]. In sections perpendicular to the plane of shear and parallel to the shear direction, they typically display a

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