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Journal Item

excess growth of water hyacinth. Water quality and climate data show that high pollution supported robust growth of water hyacinth.

The study has shown that the lakes with water hyacinth infestation can be mapped using remote sensing data more accurately than field visits. The fluctuation and changes taking place as well as seasonal variations were detected. These data showed the water hyacinth regions expanding over the years.

Work on water hyacinth parameters would be useful in future, in a wide range of areas, from weed ecology to water-resource management. Monitoring water hyacinth with good accuracy would be useful in aspects concerning the dynamics of the environment.

1. Dunigan, E. P., Phelan, R. A. and Shamsuddin, Z. H., *Hyacinth Control J*., 1975, **13**, 59–61.
2. Dinger, R., *J. Water Pollut. Control Fed*., 1978, **50**, 833–845.
3. Holm, L. C., Weldon, L. W. and Black Burn, R. D., *Res. Dev. Sci.*, 1970, **16**, 576–589.
4. Singh, S. P., Technical Bull. No 1, Project Directorate of Biological Control, 1989, p. 7.
5. Das, R. R., Ph D thesis, Banaras Hindu University, Varanasi, 1968.
6. Vander Weert, R. and Kamerlung, G. E., *J. Hydrol*., 1974, **22**, 201–212.
7. Benton, A. R. Jr., James, W. P. and Rouse, Jr. J. W., *Water Resour. Bull.*, 1978, **14**, 919–930.
8. Hill, M. P., in Proceedings of the First IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, 16–19 November 1998, Zimbabwe, p. 182.
9. Holm, L. G., Plucknett, D. L., Pancho, J. V. and Herberger, J. P., *The World's Worst Weeds: Distribution and Biology*, Honolulu, 1977, p. 606.
10. Verma Rinku, Ph D thesis, Mysore University, 2002, p. 236.
11. Ganesha Raj, K., Padmavathy, A. S. and Kumaran Raju, D., Proceedings of National Symposium On Remote Sensing Applications for Natural Resources: Retrospectives and Perspectives Bangalore, 19–21 January 1999, pp. 338–342.
12. Ganesha Raj, K., Proceedings of 7th International Conference on Lakes Conservation and Management, Buenos Aires, Argentina, 26–31 October 1997.
13. Ben Hardin, *Agric. Res. Mag*., 1999, **47**, 1–11. Also available at http://www.ars.usda.gov/is/AR/archive/jul99/remote0799.htm
14. Jakubauskas Earth Observatory Features (ed. Jesse Allen), http://earthobservatory.nasa.gov/Study/RioGrande/ (2002), NASA.
15. Sahai, Baldev, in Proceedings of the Indo-British Workshop on Remote Sensing of Environment in Mining Field, Dhanbad, Bihar, 1988, pp. 11–25.

ACKNOWLEDGEMENTS. We thank Dr M. A. Paul, ISRO, Bangalore, Dr Sushil Kumar Jalali and Dr Chandish. R. Ballal, PDBC, ICAR, Bangalore for their valuable inputs. We also thank the two referees for useful comments and suggestions.

Received 30 July 2002; revised accepted 25 January 2003

Do informally managed sacred groves have higher richness and regeneration of medicinal plants than state-managed reserve forests?

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Sacred groves are 'traditionally managed' forest patches that functionally link social life and forest management system of a region. It is believed that one of the prime utilities of sacred groves is the protection and occasional supply of medicinal plants. We assessed the regeneration among sacred groves of the central Western Ghats, India, and compared it with the 'state-managed reserve forests'. Overall, nearly 60% of the regenerating species were medicinally important. The density of regenerating medicinal plants among sacred groves was almost twice as that of reserve forests. There were a higher number of seedlings (Class-II), saplings (Class-III) and poles (Class-IV) of medicinally important plants in sacred groves than among reserve forests. Further, we found that nearly 40% of medicinally important species were unique to sacred groves; in contrast, only 11% was unique to reserve forests. However, nearly equal proportions (29 vs 27%) of 'non-medicinal plants' were unique to sacred groves and to reserve forests. These results suggest that informal management systems such as sacred groves have not only conserved useful species, but people have tended to 'discover' medicinal values more often among plants unique to sacred groves, than those found in other landscapes. Perhaps, this typifies one preliminary step in medicinal-plant domestication.

'SACRED groves' are patches of forests that are informally managed as part of a local cultural tradition, without much intervention from State Forest Departments. They represent a functional link between social life and forest management system of a region[1]. The concept of sacred groves is still followed in a few ethnic groups in the world and there are certain micro-sites in India, where such traditional forest management has sustained over the years due to support from native communities[2]. Kodagu district in the central Western Ghats, South India is regarded as the 'global hot spot for sacred groves', because there are over 1200 sacred groves documented in

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this tiny province[3]. Generally, sacred groves are believed to be treasure houses of medicinal, rare/endemic plants, as refugia for relic flora of a region and as centres of seed dispersal[4]. According to Gadgil and Vartak[5], the sacred groves have originated to protect particularly useful species, which had a function; for example, a medicinal plant. However, there are few assessments of regeneration in these landscapes in comparison to large areas of state-managed, formally conserved forest patches[6] (but, see refs 7 and 8). In this communication we provide a comparative assessment of regeneration of medicinal flora among the sacred groves and reserve forests.

The study was conducted among the sacred groves and reserve forests of Kodagu district, in five different localities (12° to 12°11′N; 75°40′ to 75°57′E and 836 to 957 m above msl). Although the sacred groves are protected by social taboos, they are not immune to anthropogenic influences. We assessed the disturbance levels of sacred groves considering the extent of canopy, and categorized them into 'disturbed' and 'conserved' sacred groves[1,9]. The disturbed sacred groves had larger canopy opening, existence of at least one major disturbance and generally were less than 5 ha in size. The conserved sacred groves and reserve forests were larger in extent, with relatively good canopy covering. We selected one disturbed and one conserved sacred grove in each of the five different localities and compared the regeneration with that of a nearby reserve forest of the respective locality (treated as 'control'). In all the localities selected, the sacred groves and reserve forests were within a radius of 10 km and possessed similar vegetational associations, i.e. *Palaquium ellipticum – Mesua ferrea*[10].

Permanent transects (5 m width and a maximum of 100 m length) randomly laid in an earlier study[2,9] were used while assessing the regeneration. In each sacred grove and reserve forest, five regeneration plots (each 2.5 m × 10 m) were laid in randomly selected permanent transects. All individual plants which have less than 30 cm girth at breast height (GBH) were identified to the level of species and classified into four height/girth classes. Using this information, species richness and density per ha were calculated. The species were classified as medicinally important or not, based on authentic publications[11].

More than half, 136 out of 241, species of the regenerating plant species identified in the study were medicinally important. Some of the important medicinal plants that were found regenerating among sacred groves but not among reserve forests were: *Cassine glauca*, *Archidendron monadelphum*, *Chukrasia tabularis*, *Diospyros montana*, *Elaeognus conferta*, *Lobelia nicotinifolia*, *Sida obovata* and *Tabernaemontana heyneana*.

The data pooled over all localities suggested that more medicinally important plant species were found regenerating among disturbed sacred groves than either in conserved sacred groves or in reserve forests (Table 1). In general, among sacred groves, nearly 60% of the regenerating species were medicinally important, while the same was only 50% among reserve forests. As shown in Table 1, the density of regenerating medicinal plants among conserved sacred groves was twice as that of reserve forests (58,280 vs 25,008 per ha). These patterns were similar in most of the localities (Table 2).

The size-class distribution considering data pooled (for tree and shrub species only) over localities revealed that there was a higher number of seedlings (Class-II), saplings (Class-III) and poles (Class-IV) among the disturbed sacred groves than among reserve forests. This trend was generally similar in all the localities studied. The reverse 'J' pattern was more pronounced among sacred groves than among reserve forests, suggesting a healthy regeneration dynamics of medicinal plants (Figure 1). The results further reinforce the notion that sacred groves are important repositories of medicinally important flora and possess a higher success of regeneration compared to reserve forests, and therefore they have a tremendous conservation value. In fact, a mild disturbance is known to increase the species richness and density, further supporting the 'disturbance theory'. For the sacred groves of Himachal Pradesh in northernwest India, Singh *et al.*[12] reported more number of medicinal plants from sacred forests/meadows than other forest ecosystems. Chandrashekhara and Sankar[6] opined that nearly 150 species (accounting for 19% of the total flora) of medicinal plants regenerated in the sacred landscapes of Kerala in southern India.

One of the prime utilities of sacred groves is the protection and occasional supply of life-saving medicinal-

Table 1. Species richness and density of medicinal plant species regenerating in different landscapes of Kodagu. Data pooled over all the locations. Values in parentheses indicate per cent of the total within a landscape

Landscape	No. of medicinally important species	No. of medicinally non-important species	Density of regeneration (no./ha)
Reserve forest	80 (50.0)	80 (50.0)	25,008 ± 14,065
Conserved sacred grove	87 (59.59)	59 (40.41)	58,304 ± 33,215
Disturbed sacred grove	92 (58.97)	64 (41.03)	57,280 ± 15,120
Kruskal–Wallis test criterion	–	–	5.66*

*$P < 0.05$ level.

Goodness of fit test criterion (chi-square) for ratio 1 : 1 of medicinal : non-medicinal species with respect to reserve forests = 0; Non-significant; For conserved sacred groves = 4.51, P level < 0.05 and for disturbed sacred groves = 4.26, P level < 0.05 at one degree of freedom.

Table 2. Location-wise species richness and density of medicinal plants regenerating in reserve forests and sacred groves of Kodagu. Values in parentheses indicate per cent of the total of respective landscapes within a locality

Locality	Landscape	No. of medicinally important species	No. of medicinally non-important species	Density of regeneration (no./ha)
Kuttandi	Reserve forest	49 (71.1)	20 (28.9)	46,880 (69.0)
	Conserved sacred grove	50 (75.8)	16 (24.2)	42,640 (50.8)
	Disturbed sacred grove	57 (69.5)	25 (30.5)	80,320 (78.2)
Heggala	Reserve forest	27 (48.2)	29 (51.2)	10,560 (20.3)
	Conserved sacred grove	36 (56.3)	28 (43.7)	21,440 (49.1)
	Disturbed sacred grove	40 (62.5)	24 (37.5)	48,720 (80.9)
Thora	Reserve forest	29 (46.8)	33 (53.2)	16,880 (42.9)
	Conserved sacred grove	44 (68.8)	20 (31.2)	85,360 (84.0)
	Disturbed sacred grove	44 (67.7)	21 (32.3)	53,360 (84.9)
Theralu	Reserve forest	32 (43.8)	41 (56.2)	30,000 (51.7)
	Conserved sacred grove	47 (67.1)	23 (32.9)	1,00,640 (81.8)
	Disturbed sacred grove	56 (58.3)	11 (41.7)	64,880 (44.9)
Beeruga	Reserve forest	43 (76.8)	13 (23.2)	30,800 (70.8)
	Conserved sacred grove	42 (64.6)	23 (35.4)	41,440 (53.9)
	Disturbed sacred grove	43 (64.2)	24 (35.8)	41,600 (63.4)

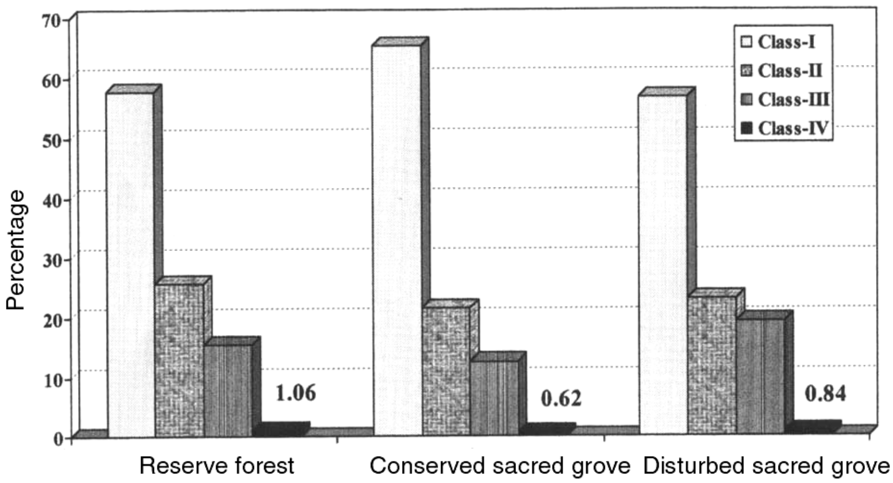

Figure 1. Distribution of regenerating stems of medicinal species into size classes in reserve forest, disturbed and conserved sacred groves in Kodagu. Data pooled over all localities. (Class-I, < 40 cm height; Class-II, 41–100 cm height; Class-III, > 100 cm height, < 10 cm GBH; Class-IV, > 10 cm height, 10–30 cm GBH).

plant species. Our study shows that sacred groves indeed harbour a higher regeneration of medicinal plants than do reserve forests. This is perhaps due to the fact that the former provides an ideal niche for the regeneration in terms of more opened conditions, etc. Further, data on number of species of medicinally important and non-important plants were recast into classes of life form and their occurrence. This was done to test whether more number of shrubs in sacred groves (because of the openness) was contributing to the higher occurrences of medicinally important plants among sacred groves. The data in Table 3 suggest that among the sacred groves, though there was slightly higher number of species in the tree and shrub category, it was not statistically significant. Hence canopy-openness itself cannot be the sole reason for the increased number of medicinally important species among sacred groves. It may also be hypothesized that the old tradition of sacred groves (perhaps 1000 years old) may have predisposed people to discover pharmaceutical properties more often among plant species that are unique to sacred groves, than among plant species that are unique to reserve forests. Since sacred

Table 3. Distribution of number of regenerating species into classes of medicinal importance and life forms in reserve forests and sacred groves of Kodagu. Data pooled over localities; Values in parentheses are expected from a random distribution

	Life form							
	Medicinally important species				Medicinally non-important species			
Landscape	Tree	Shrub	Herb	Climber	Tree	Shrub	Herb	Climber
Reserve forest	62	6	0	13	39	18	9	12
	(57)	(8)	(1)	(14)	(36)	(19)	(10)	(13)
Conserved sacred grove	66	10	2	16	23	12	7	10
	(65)	(8)	(1)	(17)	(23)	(12)	(6)	(9)
Disturbed sacred grove	57	11	2	18	25	17	8	12
	(64)	(11)	(2)	(21)	(29)	(16)	(9)	(11)

Contingency chi-square test criterion:
Medicinally important plants: $c^2 = 5.14$, non-significant at 6 df.
Medicinally non-important plants: $c^2 = 1.89$, non-significant at 6 df.

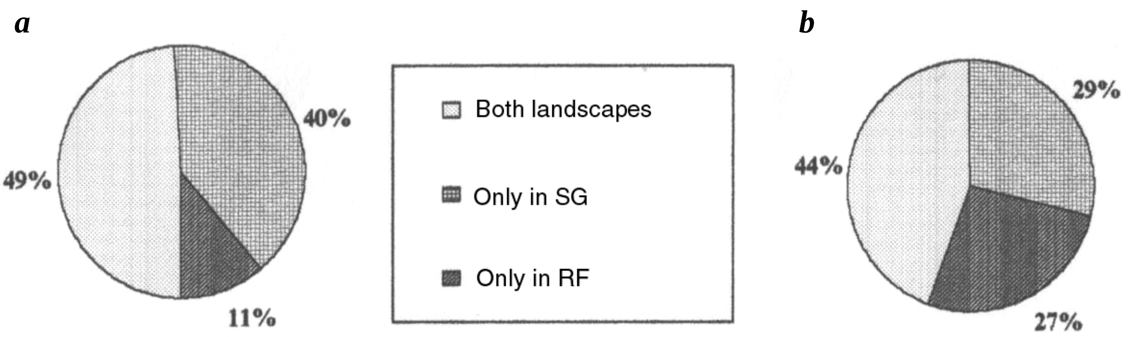

Figure 2. Proportion of species regenerating in reserve forests (RF) alone, in sacred groves (SG) alone and in both the landscapes with respect to (***a***) medicinal ($n = 136$) and (***b***) non-medicinal ($n = 109$) plants.

Table 4. Distribution of number of regenerating species into classes of medicinal importance and uniqueness of their regeneration in Kodagu. Data pooled over landscapes and localities. Values in parentheses are expected values based on random distribution

	Uniqueness of regeneration		
Medicinal importance	Only among sacred groves	Only among reserve forests	In both the landscapes
Medicinal	54 (47)	15 (24)	67 (64)
Non-medicinal	32 (39)	29 (20)	48 (51)

Contingency chi-squared value, $c^2 = 10.01$, P level < 0.05 at two degrees of freedom.

groves are generally nearer to the human settlements (sometimes amidst a cropland) than reserve forests, they are also continuously more accessible.

We tested this hypothesis using the regeneration data. We categorized separately, medicinal and non-medicinal plant species into the following three groups: (a) those regenerating both in reserve forests and sacred groves, (b) those unique to sacred groves, and (c) those unique to reserve forests. Their proportions in each of these categories were computed. It was found that among medicinal plants, nearly 40% was unique to sacred groves and only 11% to reserve forest (Figure 2). The goodness of fit in the case of reserve forests showed significant deviation from the 1 : 1 ratio (54 : 15; chi-square = 22.04, $P < 0.05$) at 1 df). However, interestingly, nearly equal proportions of non-medicinal plants were unique to sacred groves and to reserve forests (29 vs 27%). In this case, the goodness of fit data for number of species did not significantly deviate from the 1 : 1 ratio (32 : 29), suggesting that among non-medicinal species, equal numbers were unique to sacred groves and reserve forests. The contingency chi-square analyses of the data (Table 4) indicated that more number of medicinally important species, than expected from a random distribution, uniquely regenerate among sacred groves. As a consequence, more number of non-medicinal species, than expected from a random distribution, is unique to reserve forests. These findings suggest that the good old tradition of informal management of forests, such as sacred groves, has not only conserved useful species, but also that people have tended to 'discover' medicinal values more often among plants unique to sacred groves than those found in other landscapes. Perhaps, this typifies one preliminary step in medicinal-plant domestication.

1. Boraiah, K. T., Shonil Bhagwat, Kushalappa, C. G. and Vasudeva, R., in *Tropical Ecosystems: Structure, Diversity and Human Welfare* (eds Ganeshaiah, K. N., Uma Shaanker, R. and Bawa, K. S.), Oxford and IBH, New Delhi, 2001, pp. 561–564.
2. Kushalappa, C. G. and Bhagwat, Shonil A., in *Tropical Ecosystems: Structure, Diversity and Human Welfare* (eds Ganeshaiah, K. N., Uma Shaanker, R. and Bawa, K. S.), Oxford and IBH, New Delhi, 2001, pp. 21–29.
3. Bhagwat, S. A. and Kushalappa, C. G., in Proceedings of the National Workshop on Community Strategies on the Management of Natural Resources, Indira Gandhi Rastriya Manav Sangrahalaya, Bhopal, pp. 9–10.
4. Chandran, M. D. S., Gadgil, M. and Hughes, J. D., in *Conserving the Sacred for Biodiversity Management* (eds Ramakrishnan, P. S., Saxena, H. G. and Chandrashekhara, U. M.), Oxford and IBH, New Delhi, 1998, pp. 211–231.
5. Gadgil, M. and Vartak, V. D., *J. Bombay Nat. Hist. Soc*., 1975, **72**, 314–320.
6. Chandrasekhara, U. M. and Sankar, S., *For. Ecol. Manage*., 1998, **112**, 165–177.
7. Bhaskar, V., Nandini, D., Shivaprakash, H. B. and Anjanappa, M., *Myforest*, 2000, **36**, 105–120.
8. Boraiah, K. T., Shonil Bhagwat, Kushalappa, C. G. and Vasudeva, R., *Myforest*, 2002, **38**, 123–128.
9. Boraiah, K. T., M Sc thesis submitted to the Department of Forest Biology, University of Agricultural Sciences, Dharwad, 2001, pp. 1–101.
10. Ramesh, B. R. and Pascal, J. P., *Atlas of Endemics of the Western Ghats* (*India*), French Institute, Pondicherry.
11. Anon, *Amruth*, 1997, **3**, 1–17.
12. Singh, G. S., Rao, K. S. and Saxena, K. G., in *Conserving the Sacred for Biodiversity Management* (eds Ramakrishnan, P. S., Saxena, H. G. and Chandrashekhara, U. M.), Oxford and IBH, New Delhi, 1998, pp. 301–314.

ACKNOWLEDGEMENTS. We thank the Department of Forests for permission to work in the sacred groves of Kodagu. S. D. Bhat provided critical comments on an earlier version. K.T.B. thanks Dr N. Satyanarayana for support during the study. We thank the anonymous referee for useful comments.

Received 26 August 2002; revised accepted 31 December 2002

Spatial patterns of tree and shrub species diversity in Savanadurga State Forest, Karnataka

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A study conducted in Savanadurga State Forest in Karnataka indicates that the spatial variation of trees was high and similarity among the species in the adjacent plots was low, suggesting that the spatial heterogeneity is influencing the pattern of diversity of tree species. The degraded forest, which is considered as shrub and tree savanna of the *Anogeissus–Chloroxylon–Acacia* series is highly diverse, recording over 59 tree and 119 shrub species. Tree species similarity index among quadrats in the forest is less than 0.02, indicating high diversity in tree species within a limited area of the sample. Conversely, the shrub species are far more similar than the tree species when the two plots are compared. The number of stems > 1 cm DBH observed in the sampled plot (7844/ha) is high, further reinforcing that the area is rich in species and stems. Correlation between species diversity of mean and standard deviations of adjacent plots of the focal plot was high, indicating that the species-rich patches in the forests are likely to associate with other species-rich patches. The study is based on 30 quadrats of 25 m × 25 m laid at 1 km interval over the state forest.

SPATIAL variation in species diversity has been documented at a global level, with an observed gradient of increasing diversity from the poles to the equator[1–3]. Further, it is observed that the diversity usually decreases as we move up the slopes of a mountain from the base[4,5]. A number of hypotheses have been invoked to explain the observed patterns in the distribution of biological species diversity. Proponents of the theory of spatial heterogeneity claim that there might be a general increase in environmental complexity as one proceeds towards the tropics. A recent study[6] explains the influence of tectonic activity on biological diversity. In the tropics, it is considered that spatial heterogeneity is high, and therefore species accommodate themselves in a myriad of niches available to them.

Competitive exclusion theory claims that competitions exclude the real niche of the species and therefore more species could be accommodated in a small space[7]. This theory predicts that tropical species will be more highly

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