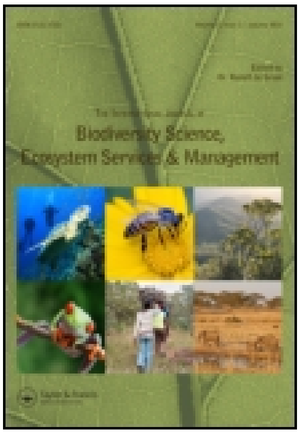

International Journal of Biodiversity Science, Ecosystem Services & Management
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tbsm21

Regeneration of native woody species under plantations in Kudremukh National Park, Western Ghats of South India

B.C. Nagaraja [a] , Niki Maskey [b] & R.K. Somashekara [a]
[a] Department of Environmental Sciences, Bangalore University, Bangalore, India
[b] World Wildlife Fund for Nature (WWF), Kathmandu, Nepal
Published online: 13 Oct 2011.

International Journal of Biodiversity Science, Ecosystem Services & Management
Vol. 7, No. 2, June 2011, 77–83

Taylor & Francis
Taylor & Francis Group

Regeneration of native woody species under plantations in Kudremukh National Park, Western Ghats of South India

B.C. Nagaraja[a]*, Niki Maskey[b] and R.K. Somashekara[a]

[a]*Department of Environmental Sciences, Bangalore University, Bangalore, India;* [b]*World Wildlife Fund for Nature (WWF), Kathmandu, Nepal*

A study was carried out to investigate the potential of monoculture plantations of *Acacia auriculiformis*, *Casuarina equisetifolia* and *Anacardium occidentale* to foster the regeneration of native woody species with respect to proximity to human settlements and natural forest (NF) as the major factors in Kudremukh National Park of South India. A total of 80 plots were laid down in three monoculture plantations in nearby NF and abandoned pasture. A total of 32 naturally regenerated woody species were recorded beneath all plantation stands with a density ranging from 4600 to 17,100/ha. The plantation of *C. equisetifolia* supports more number of species and diversity with more canopy cover (71–87.5%) and also more litter depth (10.8–11.67 cm). Sorenson's index of similarity (IS) values indicated that *C. equisetifolia* and *A. auriculiformis* stands exhibited the highest similarity and the *C. equisetifolia* showed high degree of similarity with NF. The soils of all plantations are acidic in nature with higher nutrients observed in *C. equisetifolia* plantation. This study highlighted the concept of using plantations to foster the regeneration of native woody species, thereby promoting regional biodiversity and also improve the ecosystem services of the region by improving soil nutrients and microclimate.

Keywords: Kudremukh National Park; forest succession; understorey regeneration; species diversity; degraded lands

Introduction

Plantations have been shown to be able to recuperate the productive potential of degraded lands in the tropics (Sanchez et al. 1985; Carnevale and Montagnini 2002; Senbeta et al. 2002). Few studies pertaining to the dynamics of plantation understorey communities (Lugo et al. 1993; Haggar and Richard 1997; Loumeto and Huttel 1997; Oberhauser 1997; Elliott et al. 2003) revealed that substantial regeneration of native species may occur under the canopy of these plantations, and that the capacity of these plantations to develop species-rich understories could make a significant contribution to higher regional biodiversity through catalysing the arrested forest succession (Senbeta and Teketay 2001; Arthur and Ganesan 2009). The rain forest of the Western Ghats mountain range has been the subject of many studies, of which the most comprehensive are those of Pascal (1988). These forests have been unique because of the geographic location, stable geological history, equable climate, heavy rainfall and good soil conditions that support a variety of tropical forest ecosystems. During the last few decades, these forests have been and continue to be subjected to various human pressures contributed by agriculture, construction of hydroelectric project, logging and other development projects culminating in depletion of forest areas significantly to less than 20% of original forest cover (Shankar et al. 2009).

Kudremukh National Park (KNP) is located in the Western Ghats and supports a complex vegetation patterns (Krishnamurthy et al. 2001). Recently, large-scale encroachment of the KNP is combined in the periphery for raising the activities of mining and plantations (coffee and others) attributing more human intervention inside the Park (Hussain 2003) leading to its fragmentation. Several attempts have been made by the Forest Department to raise fast growers like *Acacia auriculiformis*, *Casuarina equisetifolia*, *Grevillea robusta* on degraded lands to meet the ever-increasing fuel and small timber requirements of forest fringe people (Swamy 1999). From the Indian subcontinent, limited studies (Mathur and Soni 1983; Sangha and Jalota 2005; Arthur and Ganesan 2009) are available to show how these fast-growing plantations are helping the native species colonization in the fragmented landscapes. In this regard, our objective is to test the hypothesis whether the fast-growing plantations such as *A. auriculiformis*, *C. equisetifolia* and *An. occidentale* have 'catalytic effect' on the regeneration of woody native species with reference to the human disturbance.

Materials and methods

Study area and plot selection

The study area lies within the KNP, Karnataka state (South India) and the experimental plots lie between 13° 1′ to 13° 29′ N latitude and 75° 0′ to 75° 30′ E longitude. The Kudremukh–Gangamoola belt of the Precambrian Dharwar Schist comprises hornblende schists, amphiboles and thick beds of magnetite–quartzites. The mean annual rainfall ranges from 300 to 400 cm, mostly spread over during June and September, while January to March is relatively dry. The most important river in the area, the Tunga, flows

*Corresponding author. Emails: nagenvi@gmail.com; bcnagaraja@bub.ernet.in

ISSN 2151-3732 print/ISSN 2151-3740 online

http://dx.doi.org/10.1080/21513732.2011.622297
http://www.tandfonline.com

eastwards. The topography of the area ranges from very steep to undulating with outcrops of rocks on local peaks and ridges.

Preliminary information on ecology, biodiversity and afforestation undertaken in the region was collected from the Forest Department records of 1999 to choose the possible plantation sites within the National Park (Karnataka Forest Department 2000). Three plantations plots, namely, *A. auriculiformis*, *C. equisetifolia* and *An. occidentale*, were selected for this study during 2004. All three plantations plots were extending from human settlement to natural forest (NF), each having an area of 20-hectare block was raised before the area was declared as the National Park. The distance from human settlement to NF is around 5 km. The regeneration of woody species in these plots was compared with abandoned pasture (AP) and undisturbed NF located almost nearer to plantations.

Soil sampling and analysis

About 3 kg of soil sample was collected at each site at 20 cm depth of 1 m × 1 m pit and analysed following the standard procedure (Indian Agricultural Research Institute 1971; Soil Conservation Service – United States Department of Agriculture 1972). The pH was determined in a 1:2.5 mix of fresh soil:water using an Elico Digital Mhos pH meter (model PE-133; Bangalore, Karnataka, India). The soil was air dried, grounded and passed through a 2 mm mesh and the coarse sand was weighed and subsequent analysis was made on the 70.50 mm fraction for the estimation of organic carbon (Walkley and Black 1934), total nitrogen (Kjeldahl distillation), potassium and sodium (flame photometry), calcium and magnesium (EDTA titration method) and the available phosphorus was extracted by using 0.03 m ammonium fluoride in 0.025 m hydrochloric acid (Bray and Kurtz 1945). The plantations litter depth has been measured in all the plots using a measuring scale.

Plantation stands and understorey regeneration assessment

To assess understorey regeneration, plantation plots in each stand have been characterized into two categories: Plot 1 (near to human settlement) and Plot 2 (near to NF). In each plot, line transect was deployed to assess the understorey vegetation within the stands. The assessment was undertaken in 10 quadrates of 10 m × 10 m (0.01 ha) plot size at 100 m interval along the line transect in each plot. The plots were laid at least 10 m away from the plantation edge on each transect, which is reliable to record the species biodiversity as per Oberhauser (1997). In each sampling plot, the planted trees and colonized woody species were counted and their diameter at breast height was recorded. The collar diameter of seedlings were also measured. Their crown projections were plotted on the graph to calculate the percentage canopy cover and gap area. The identities of woody species were confirmed by cross-checking with the herbarium available in the southern branch of Botanical Survey of India.

The data on understorey vegetation were analysed for relative frequency, density, dominance and their sum yielded the importance value index (IVI) for various species recorded during this study (Kershaw 1973). The species diversity is calculated using the formula of procedure given by Shannon and Wiener (1963) as follows:

$$H = \left(3.32189 \log_{10} N - \frac{1}{N} \sum_{i-1}^{s} n_i \log_{10} n_i\right)$$

derived from

$$H = -\sum_{i-1}^{s} \left(\frac{n_i}{N}\right) \log_2 \left(\frac{n_i}{N}\right),$$

where H is Shannon index and n_i and N are the IVI of the species and community, respectively.

The index of dominance of the community was calculated by Simpson's index (Simpson 1949) as follows:

$$C = 1 - \sum_{i-1}^{s} \left(\frac{n_i}{N}\right)^2,$$

where C is the Simpson's index of dominance; n_i is the IVI of species 'i'; and N is the IVI of the community.

Floristic compositions of the area were analysed for similarity index using Sorenson's index of similarity (IS). This index measures the ratio of common species (C) to the average number of species occurring in two samples ($A + B$) in percent (Muller-Dombois and Ellenberg 1974):

$$\mathrm{IS} = 2\left(\frac{C}{A+B}\right) 100.$$

Determination of stand quality

Species recorded in these plantations were categorized into three groups, and each group was assigned with a numerical value, namely, Pioneer index 1 for the group requiring a small gap for regeneration; Pioneer index 2 for the species whose seedlings established in small gaps but need small-to medium-sized gaps to grow; and Pioneer index 3 for the group of strong light demanders. We adopted the procedures from Whitmore (1989) and Chandreshekhara and Sankar (1998) to indicate the intensity of disturbance:

$$\mathrm{RISQ} = \sum \left(\frac{n_i \times \text{Pioneer index}}{N}\right),$$

where RISQ is the Ramakrishna index of stand quality and n_i and N are the IVI of the species and community, respectively. The RISQ can vary from 1.0 to 3.0, where 3.0 indicates high disturbances.

Results

Soil characteristics

Overall soils of KNP were found to be more acidic in nature (Table 1). However, the plantation plots exhibited a little more acidity than the NF and AP plots. The organic carbon, total nitrogen, available phosphorus, potassium, calcium and magnesium contents recorded in the plantation plots are less than the NF. Among different plantations, *C. equisetifolia* plot exhibited higher values for organic carbon (4.30%), available phosphorus (8.27 mg/g), potassium (0.53 mg/g), calcium (4.46 mg/g) and magnesium (2.4 mg/g). *A. auriculiformis* plot showed slightly higher nitrogen (0.57%) than the other two plantations.

Plantation stands and understorey regeneration assessment

The plantation stand characteristics (Table 2) reveal that the stand density in Plot 2 of *An. occidentale* plantation is more (17,100 stems/ha) contributing 32.9% of total stands, followed by *C. equisetifolia* (12,900 stems/ha) with 24.85% of total stands and *A. auriculiformis* (4600 stems/ha) with 8.8% of total stands. Generally, the plots of *C. equisetifolia* and *An. occidentale* closer to the NF have harboured more stand density than the plots near to human settlement. In general, more canopy cover (71–87.5%) and the amount of litter depth (10.8–11.67 cm) were seen in *C. equisetifolia* plantation than in *A. auriculiformis* and *An. Occidentale* plantations. In addition, the plots nearer the NF showed higher canopy cover than those situated near human settlements.

A total of 32 woody species were recorded from the 6 plots, among these *Syzygium caryophyllatum* have highest IVI (129.79) in the *C. equisetifolia* plots nearer to NFs (Table 3), which also supported the highest number of woody species (22) (Table 4). The numbers of tree and shrub species recorded were less in *An. occidentale* plots contributing just 25% of the total species in Plot 1 and 18.75% of the total species in Plot 2. The Plot 2 of the *C. equisetifolia* plantation supported higher number of species with 68.75% of the total species. The common trees in *C. equisetifolia* plots 1 and 2 are *Syzygium cumini*, *Rapania striata*, *Glochidion zeylanicum*, *Symplocos racemosa*, *Aporosa lindlyana*, *Olea dioica*, *Ervatamia heyneana*, *Litsea floribunda* and *Litsea ghatica*. In addition *C. equisetifolia* Plot 2 also supported the NF species that were absent in other plantations and AP. *Glochidion zeylanicum* is dominant in *An. occidentale* plantation. Plantation stands supported the same species that existed in NF and AP understories. However, some species like *Hopea parviflora* are restricted to pastureland, whereas shrubs like *Bridelia scandens* and herbs like *Zingiber montanum*, *Elephantopus scaber* and *Mallastoma malabaricum* were widely spread in plantations. In contrast, 45% of species found in forest plots were not found either in other plantations or savanna plots. The value of Shannon index of diversity was more in *C. equisetifolia* (3.1–3.31) plots located nearer to NF and was less in

Table 1. Comparison of soil chemical properties in the five different land use plots in Kudremukh National Park (KNP), South India.

Plots	pH	Organic carbon (%)	Total N (%)	Average P (mg/g)	K (meq 100 g)	Ca (meq 100 g)	Mg (meq 100 g)
Acacia auriculiformis	4.9 ± 0.09	3.16 ± 0.17	0.57 ± 0.01	6.00 ± 0.07	0.42 ± 0.27	4.06 ± 0.53	1.9 ± 0.04
Casuarina equisetifolia	5.18 ± 0.19	4.3 ± 0.04	0.56 ± 0.03	8.27 ± 0.34	0.53 ± 0.31	4.46 ± 0.24	2.4 ± 0.24
Anacardium occidentale	5.26 ± 0.05	4.06 ± 0.08	0.52 ± 0.00	7.9 ± 0.21	0.47 ± 0.05	4.25 ± 0.04	2.15 ± 0.07
Abandoned pasture (AP)	5.7 ± 0.04	4.65 ± 0.45	0.35 ± 0.04	5.2 ± 0.08	0.62 ± 0.02	3.5 ± 0.04	2.4 ± 0.06
Natural forest (NF)	5.54 ± 0.12	9.18 ± 0.05	0.65 ± 0.09	9.63 ± 0.62	0.55 ± 0.08	11.52 ± 0.05	3.04 ± 0.06

Notes: N, nitrogen; P, phosphorus; K, potassium; Ca, calcium; Mg, magnesium.

Table 2. Characteristics of monoculture plantations in Kudremukh National Park (KNP), South India.

Sampling plots	Age (years)	Density (stems/ha)	Basal area (m^2/ha)	Litter depth (cm)	Canopy cover (%)
Ac Plot 1	20	4600	2.1146	6.57	51.5
Ac Plot 2	20	3600	0.3052	7.37	56.25
An Plot 1	18	6700	0.7998	4.3	51.75
An Plot 2	18	17,100	0.286	5.17	6.25
Ca Plot 1	22	7000	1.926	10.8	71
Ca Plot 2	22	12,900	2.792	11.67	88.75

Notes: Plot 1 refers to plantation near to human settlements and Plot 2 refers to plantation near to natural forest (NF). Ac, *Acacia auriculiformis*; An, *Anacardium occidentale*; Ca, *Casuarina equisetifolia.*

An. occidentale plantation (1.82–2.38) situated near the NF (Table 4). Simpson index confirmed higher values for *An. occidentale* plantation (0.24–0.36) situated near the NF. The percentage contribution of late secondary species to density was greatest in the case of *Casuarina* plots (86.05%) nearer to NF followed by *Anacardium* plots (73.1%) nearer to human settlements (Table 5). The percentage contribution of early secondary species to basal area was greatest in *Acacia* plots (70.3%) nearer to human settlements followed by primary species (52.0%) in *Casuarina* plots nearer to human settlements.

Sorenson's IS values ranged from 12 to 45 among plots (Table 6). Plot 2 of *C. equisetifolia* (22 years old) and *A. auriculiformis* (20 years old) stands exhibited the highest similarity index (IS = 45) and the least degree of similarity is exhibited between Plot 2 of *C. equisetifolia* (22 years old) of NF and Plot 1 of *An. occidentale* (IS = 12). Interestingly, Plot 2 of *C. equisetifolia* (22 years old) showed high degree of similarity with NF (IS = 43), followed by *A. auriculiformis* Plot 1 with AP (IS = 40).

Stand quality

Acacia auriculiformis plots nearer to human settlements recorded 2.31 RISQ values, which is highest among the six plots studied, followed by *An. occidentale* (2.17) and *C. equisetifolia* (1.94) plots near to human settlements (Table 4). The lower RISQ values were observed for *A. auriculiformis* (1.84) plots situated near to plantations followed by *C. equisetifolia* and *An. occidentale* plots near to plantations.

Discussion

The experiment reveals that the monoculture plantations of *C. equisetifolia*, *An. occidentale* and *A. auriculiformis* did not inhibit the colonization of naturally regenerating native woody species, which was supported by the findings of Nagaraja et al. (2001) and Arthur and Ganesan (2009) in Western Ghats region of India. The higher density of regeneration that occurred in the plantations of *An. occidentale* and *C. equisetifolia* may be attributed to the seedbanks in topsoil that germinate and colonize under the condition of more light availability (Bellairs and Bell 1993; Arthur and Ganesan 2009) and its vicinity to the NF (Senbeta and Teketay 2001), which experience less disturbance; high dispersal of seeds and the nature of dispersal agents attributed well to the higher density in the area. The less density of regenerated woody species found in the *A. auriculiformis* stand may be due to the slow decomposition of leaf litter Feyera and Demel (2001). In general, weed like *Chromolaena odorata* occupied a bigger niche in *A. auriculiformis* and *An. occidentale* plantations closer to human settlements, which hampered the regeneration of many native species. A similar situation was noticed in South African Fynbos shrublands where mono-dominant *Acacia salinga* contributed to substantial reduction in local species (Holmes and Cowling 1997).

The pH value was seen in decreasing proportion with other cations in the plantation sites as compared with NFs. Similar observation was reported by Nagaraja and Somashekar (2004) in nearby plantations. However, as per Nagaraja and Somashekar (2004), the plantation sites require potassium and magnesium contents to support tree species growth in the region. The rapid decomposition of litter may directly help more number of primary forest species such as *Calophyllum apetalum*, *Syzygium caryophyllatum* and *Symplocos racemosa* to germinate and establish. Brown and Lugo (1990) suggested that plantations accumulate species as rapidly as secondary forests, implying a similarity in ecological functions. The low values of IS for the plots located nearby human settlements signify human disturbances contributing to reduction in regeneration of native species. Moreover, proximity to NF stand is another factor that favoured floristic diversity culminating in the development of native secondary forest.

This study indicates that a high similarity of woody species composition exists between the NF and *Casuarina* plots located near to NF. This can be attributed to the available species pool in the surrounding forest and the presence of more litter. The finding of this study is contrary to the results of some studies conducted in Ethiopia (Feyera et al. 2002), which reported low similarity among different plantations and the adjacent NF.

RISQ values for *A. auriculiformis* plots nearer to NF are higher than the plots nearer the human settlements indicating greater extent of human disturbance. Higher RISQ values for seedlings and saplings indicate repeated disturbance, which hinders the colonization of shade-loving primary forest species (Chandrashekhara and Sankar 1998). This study revealed that tree plantations can be useful to forest natural regeneration of native woody species, particularly on abandoned sites. Ewel (1983) opined that

Table 3. PI and IVI of species recorded in plantations in Kudremukh National Park (KNP), South India.

		Plots near to human settlements			Plots near to natural forest (NF)		
Species	PI	Ac Plot1	An Plot 1	Ca Plot 1	Ac Plot 2	An Plot 2	Ca Plot 2
Alstonia scholaris (L.) R. Br.	2	5.56	NF	NF	NF	11.51	NF
Aporosa lindlyana (et.) Baill.	2	13.59	5.51	18.26	NF	NF	31.99
Artocarpus hirsutus Lamk.	2	NF	NF	7.71	NF	NF	3.36
Callicarpa tomentosa (L.) Murray	3	NF	6.76	NF	NF	NF	NF
Calophyllum apetalum Willd.	1	NF	NF	NF	NF	NF	2.36
Canthium dioica (Gaertn.)	3	5.03	11.61	NF	NF	NF	NF
Carallia brachiata (Lour.) Merr.	2	NF	NF	NF	NF	NF	9.09
Careya arborea	3	35.57	25.86	45.31	12.29	39.08	NF
Caryota urenes	2	NF	NF	NF	NF	NF	11.28
Chionanthus malabarica (Wall. ex G.Don) Bedd.	2	10.21	NF	8.63	NF	NF	NF
Dillinia pentagyna Roxb.	3	NF	13.22	NF	NF	NF	NF
Dimocarpus longan Lour.	2	NF	NF	NF	NF	NF	2.31
Elaeocarpus serratus L.	1	NF	NF	NF	NF	NF	2.6
Ervatamia heyneana (Wall.) Cooler	3	NF	NF	11.78	42.3	NF	3.06
Floucourtia montana Grah.	2	NF	NF	NF	NF	NF	4.16
Glochidion zeylanicum (Gaertn) A. Juss	2	NF	114.8	10.85	7.87	161.31	11.88
Holigarna arnotiana Hk f.	1	NF	NF	NF	NF	NF	2.4
Ligustrium gamblei Ramam.	3	NF	NF	3.87	NF	NF	NF
Litsea floribunda (Bl.) Gamble	2	10.25	NF	8.9	41.35	NF	2.4
Litsea ghatica Saldanha	2	5.12	NF	NF	NF	NF	NF
Memecylon umbellatum Burm.f.	2	NF	NF	5.55	7.87	11.18	7.1
Meyna latifolia Robyns	3	12.56	56.74	5.84	7.35	NF	NF
Olea dioica Roxb.	2	NF	NF	9.22	17.23	NF	12.47
Psidium guajava L.	3	NF	NF	NF	10.64	NF	5.39
Rapania striata Mez.	2	12.74	NF	51.71	17.07	NF	10.15
Symplocos racemosa Roxb.	2	NF	NF	13.13	16.38	5.45	31.51
Syzygium caryophyllatum (L.) Alston	2	NF	NF	2.82	NF	NF	129.79
Syzygium cumini (L.) Skeels	1	75.76	65.09	83.83	119.59	71.12	11.93
Syzygium gardeneri (Thw.) Bedd	1	NF	NF	11.49	NF	NF	NF
Terminalia bellerica (Gaertn.) Roxb.	3	NF	NF	NF	NF	NF	4.76
Trichilia conizoidis (Wt. & Arn.) Benth.	3	7.35	NF	NF	NF	NF	NF
Wendlandia sp.	3	106.21	NF	NF	NF	NF	NF

Notes: PI, pioneer index; IVI, importance value index; NF, not found in the plot.

Table 4. Characteristics of woody species regenerating in the plantations in Kudremukh National Park (KNP), South India.

Sampling plots	Number of species	Density (stems/ha)	Basal area (m^2/ha)	Frequency	Shannon index (*H*)	Simpson index (*D*)	RISQ
Ac Plot 1	12	4,600	2.11	140	1.91	0.21	2.31
Ac Plot 2	11	3,600	0.31	96	1.94	0.21	1.84
An Plot 1	8	6,700	0.80	108	1.64	0.24	2.17
An Plot 2	6	17,100	0.29	84	1.26	0.36	1.89
Ca Plot 1	16	7,000	1.93	172	2.29	0.14	1.94
Ca Plot 2	22	12,900	2.80	268	2.13	0.22	1.86

Notes: Plot 1 refers to plantation near to human settlements and Plot 2 refers to plantation near to natural forest (NF). RISQ, Ramakrishna index of stand quality; Ac, *Acacia auriculiformis*; An, *Anacardium occidentale*; Ca, *Casuarina equisetifolia*.

Table 5. Percentage contribution of primary, late secondary and early secondary regenerating species to density and basal area in Kudremukh National Park (KNP), South India.

	Contribution to density			Contribution to basal area		
Sampling plots	Primary species	Late secondary species	Early secondary species	Primary species	Late secondary species	Early secondary species
Ac Plot 1	28.26	23.90	47.82	24.66	5.00	70.34
Ac Plot 2	38.88	38.88	22.23	47.42	31.42	21.21
An Plot 1	17.93	53.71	28.36	21.27	48.16	30.57
An Plot 2	21.52	73.10	5.87	21.53	59.24	18.97
Ca Plot 1	20.10	44.32	35.72	52.07	35.42	12.55
Ca Plot 2	9.02	86.05	4.66	3.97	44.92	0.94

Notes: Primary species – require a small gap for regeneration; early secondary species – seedlings can become established in small gaps but need small- to medium-sized gaps to grow; late secondary species – strong light demanders. Plot 1 refers to plantation near to human settlements and Plot 2 refers to plantation near to natural forest (NF). Ac, *Acacia auriculiformis*; An, *Anacardium occidentale*; Ca, *Casuarina equisetifolia*.

Table 6. Sorenson's IS for all woody species Kudremukh National Park (KNP), South India.

Ac Plot 2	21						
An Plot 1	33	41					
An Plot 2	13	36	17				
Ca Plot 1	34	36	31	21			
Ca Plot 2	15	45	12	44	36		
NF	21	25	12	13	25	43	
AP	40	26	34	25	35	16	18
	Ac Plot 1	Ac Plot 2	An Plot 1	An Plot 2	Ca Plot 1	Ca Plot 2	NF

Notes: Plot 1 refers to plantation near to human settlements and Plot 2 refers to plantation near to NF. IS, index of similarity; Ac, *Acacia auriculiformis*; An, *Anacardium occidentale*; Ca, *Casuarina equisetifolia*; NF, natural forest; AP, abandoned pasture.

the high net productivity among successional ecosystems supports large animal populations. Life forms, seed dispersal strategies and vegetative reproduction abilities are important factors influencing understorey establishment (McIntyre et al. 1995). Apart from animals and birds, wind also plays an important role in seed dispersal of many of herbs and shrubs, such as Achenes (*Vernonina*) or capsules as in *Chromolaena*. The persistence of *Syzygium cumini*, *Syzygium caryophyllatum*, *Careya arborea* and *Ap. lindlyana* is helping more of their progeny to colonize, thereby enriching the endemism and supporting biodiversity of the region.

Conclusion

Overall, the findings indicated that raising plantations on degraded lands, particularly where seedbanks of native forest species are lacking, initiates the process of forest succession with nurse effect for woody native species regeneration. The plantations of *A. auriculiformis* and *C. equisetifolia* in this area would have been thinned out on a rotational basis to facilitate native species establishment. The numbers of vascular plant species in the plantation plots were much higher than the AP fields, indicating that reforestation of severely disturbed areas with *C. equisetifolia* or *A. auriculiformis* might indeed speed up the recolonization of some native flora through their influence on understorey microclimate and soil fertility improvement, suppression of dominant grasses and provision of habitats for seed-dispersing animals. It is evident from our study that plantations raised in Western Ghats region could make a significant contribution to higher regional biodiversity and ecosystem improvement.

Acknowledgements

The authors thank the Karnataka Forest Department for granting permission to carry out work in KNP and their invaluable help in site selection and field data collection. The valuable comments and suggestions from anonymous reviewers are gratefully acknowledged.

References

Arthur SM, Ganesan R. 2009. Evaluating the potential role of *Eucalyptus* plantations in the regeneration of native trees in southern Western Ghats, India. Trop Ecol. 50(1): 175–191.

Bellairs SM, Bell DT. 1993. Seed stores for restoration of species rich shrublands vegetation following mining in Western Australia. Rest Ecol. 1(4):231–240.

Bray RH, Kurtz LT. 1945. Determination of total, organic, and available forms of phosphorus in soils. Soil Sci. 59(2): 39–45.

Brown S, Lugo AE. 1990. Tropical secondary forestry. J Trop Ecol. 6(1):1–32.

Carnevale N, Montagnini F. 2002. Facilitating regeneration of secondary forests with the use of mixed and pure plantations of indigenous tree species. For Ecol Manage. 163(1–3): 217–227.

Chandrashekhara UM, Sankar S. 1998. Ecology and management of scared groves in Kerala, India. For Ecol Manage. 112(1–2):165–177.

Elliott S, Navakitbumrung P, Kuarak C, Zangkum S, Anusarnsunthorn V, Blakesley D. 2003. Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. For Ecol Manage. 184(1–3):177–191.

Ewel J. 1983. Succession. In: Golley FB, editor. Tropical rain forest ecosystems, structure and function. Amsterdam (The Netherlands): Elsevier. p. 217–223.

Feyera S, Demel T. 2001. Regeneration of indigenous woody species under the canopy of tree plantations in central Ethiopia. Trop Ecol. 42(2):175–185.

Feyera S, Demel T, Bertake N. 2002. Native woody species regeneration in exotic tree plantations at Munessa-Shashemene forest, Southern Ethiopia. New For. 24(2):131–145.

Haggar W, Richard F. 1997. The potential of plantations to foster woody regeneration within a deforested landscape in lowland Costa Rica. For Ecol Manage. 99(1–2):55–64.

Holmes PM, Cowling RM. 1997. Effects of invasion by *Acacia saligna* on the guild structure and regeneration of capabilities of fynbos shrublands. J Appl Ecol. 34(2):317–332.

Hussain SA. 2003. Kudremukh national park, Karnataka: a profile and a strategy for the future. J Bombay Nat Hist Soc. 100 (2–3):202–213.

Indian Agricultural Research Institute. 1971. Soil survey manual. New Delhi (India): All India Soil and Landuse Survey Organization.

Karnataka Forest Department. 2000. Koppa divisional working plan. Karnataka (India): Government of Karnataka.

Kershaw KA. 1973. Quantitative and dynamic plant ecology. London (UK): Edward Arnold.

Krishnamurthy SV, Reddy AHM, Gururaja KV. 2001. A new species of frog in the genus *Nyctibatrachus* (Anura: Ranidae) from Western Ghats, India. Curr Sci. 80(7):887–891.

Loumeto JJ, Huttel C. 1997. Understory vegetation in fast growing tree plantations on savanna soils in Congo. For Ecol Manage. 99(1–2):95–81.

Lugo AE, Parrotta JA, Brown S. 1993. Loss in species caused by tropical deforestation and their recovery through management. Ambio. 22(2–3):106–109.

Mathur HN, Soni P. 1983. Comparative account of undergrowth under Eucalyptus and Sal in three different localities of Doon valley. Indian For. 109(12):882–890.

McIntyre S, Lavorel S, Tremont RM. 1995. Plant life history attributes: their relation to disturbance response in herbaceous vegetation. J Ecol. 83(1):31–44.

Muller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. New York (NY): Wiley.

Nagaraja BC, Somashekar RK. 2004. Changes in soil characteristics of natural forests upon replacement with monoculture plantations in Sringeri area of the Western Ghats, South India. Ecol Environ Conserv. 10(4):391–397.

Nagaraja BC, Somashekar RK, Ramachandra Swamy H. 2001. Uses of Australian *Acacia auriculiformis* A.Cunn. (Ex.Benth) for the establishment of native species in Sringeri area of Western Ghats, Karnataka, India. For TreesLivelihood. 11(4):369–372.

Oberhauser U. 1997. Secondary forest regeneration beneath pine (*Pinus kesiya*) plantations in the northern Thai highlands: a chronosequence study. For Ecol Manage. 99(1–2):171–183.

Pascal JP. 1988. Wet evergreen forest of the Western Ghats of India. Pondicherry (India): French Institute.

Sanchez PA, Palm CA, Davey CB, Scott LT, Russel CE. 1985. Trees as soil improvers in the humid tropics? In: Cannel MGR, Jackson JE, editors. Attributes of trees as crop plants. Huntingdon (UK): Institute of Terrestrial Ecology. p. 327–358.

Sangha KK, Jalota RK. 2005. Value of ecological services of exotic *Eucalyptus tereticornis* and native *Dalbergia sissoo* tree plantations of north-western India. Conserv Soc. 3(1):92–109.

Senbeta F, Teketay D. 2001. Regeneration of indigenous woody species under the canopies of tree plantations in Central Ethiopia. Trop Ecol. 42(2):175–185.

Senbeta F, Teketay D, Nästlund BA. 2002. Native woody species regeneration in exotic tree plantations at Munessa–Shashemene forest, Southern Ethiopia. New For. 2(2):131–145.

Shankar TR, Divya M, Kapoor V. 2009. Restoring rainforest fragments: survival of mixed-native species seedlings under contrasting site conditions in the Western Ghats, India. Rest Ecol. 17(1):137–147.

Shannon CE, Wiener W. 1963. The mathematical theory of communication. Urbane (IL): University of Illinois Press. p. 320–322.

Simpson EH. 1949. Measurement of diversity. Nature. 163(April):163–168.

Soil Conservation Service – United States Department of Agriculture. 1972. Soil survey laboratory methods and procedures for collecting soil samples. Soil investigation report – 1. Washington (DC): United States Department of Agriculture.

Swamy HR. 1999. Investigation of plant genetic wealth, its dynamics and nutrient status of *Soppina betta* forests in comparison with natural forests in Sringeri area of the Western Ghats. Report to Department of Sciences and Technology. New Delhi (India): Department of Sciences and Technology.

Walkley A, Black IA. 1934. An examination of Degtjareff method for determining organic carbon in soils: effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63(2):251–263.

Whitmore TC. 1989. Changes over twenty-one years in the Kolombangara rain forests. J Ecol. 77(2):469–483.