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Forest resource use and perception of farmers on conservation of a usufruct forest (Soppinabetta) of Western Ghats, India

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ABSTRACT

The negative impact of anthropogenic activity on tropical forests is well documented, but the underlying factors, including socioeconomic conditions, government policy, and agricultural practices, that influence forest degradation in developing countries are poorly understood. For centuries, Soppinabetta forests (SBFs) in the Western Ghats of India have provided essential habitat for wildlife and vital organic resources (leaf litter, green foliage) for the cultivation of betel nut palms (*Areca catechu*) and rice paddy (*Oryza sativa*). Historically, betel nut farmers carefully managed resource extraction in SBFs, but recent changes in land use policy allow for unmitigated resource extraction by site dwellers, which may imperil the traditional sustainable management of SBFs. Site dwellers live on government allotted sites and primarily derive their income through the sale of forest-based products. We used SBFs as a model system to investigate the factors governing: (i) forest resource extraction, (ii) the effect of changing agricultural practices on the rate of resource extraction, and (iii) farmers' perception of SBFs conservation in response to changes in governmental land use policy. Results from surveys of 90 households (57 farmers and 33 site-dwellers) and the forest department indicate individual farmers collected an average of 31.09 (range 0–125) metric tons of leaf litter and 19.11 metric tons (range 0–120) of green foliage per year. Organic resource harvesting by farmers was positively correlated with the size of betel nut plantations, size of SBFs, and number of livestock owned per household. Betel nut plantations require six times more compost than food grains cultivated in field paddies. In past one decade, 33% of field paddies have been converted into betel nut plantations, increasing the strain on SBFs for forest resources. Farmers believe that when they lose provisional ownership of SBFs, site dwellers unsustainably harvest resources and severely damage SBFs. We suggest that an inclusive, local-level, farmer-driven protection be implemented to preserve the SBF heritage system of Western Ghats.

Introduction

Conversion of tropical forests to agrosystems is the dominant anthropogenic process underlying the accelerating rate of primary habitat loss in tropical developing countries (Perfecto and Vandermeer, 2010). The widespread loss of primary habitat has increased interest in human-influenced forest landscapes that are traditionally managed and modified for a range of purposes, including agriculture, agroforestry, and plantations for biodiversity conservation (Bawa et al., 2004). Recognizing the relevance of local communities' involvement in the conservation of natural habitats, more forests are globally being devolved to local communities (Bray et al., 2003) and increased level of local enforcement for conservation of habitats is appealed (Chhatre and Agarwal, 2008; Lele et al., 2010).

The Western Ghats biodiversity hotspot has a long history of managing natural resources and forests in the form of sacred forests, homegardens, and Soppinabetta forests (Nagendra and Gokhale, 2008). Sacred forests are generally off limits to anthropogenic modification and have historically contributed to forest conservation (Nagendra and Gokhale, 2008). Homegardens are sustainable and diversified niches shaped by a close interaction between nature and human cultures (Kumar and Nair, 2006, Galluzi et al., 2010). Soppinabetta forests are managed forests that are allocated to farmers of betel nut, the primary economic crop, to harvest green foliage and leaf litter used in compost production (Lele, 1993). Hence, Soppinabetta forests are the foundation of the local economy. Despite more than 2000 years of continuous cultivation, a culture of sustainable agriculture has maintained significant forest cover and consistent economic output in the Western Ghats (Gadgil, 1987).

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Fig. 1. A closer look of Soppinabetta forest of Sringeri in the Western Ghats.

Fig. 2. A degraded reserve forest in Sringeri area of the Western Ghats due to site-dweller encroachment.

To better understand the role socioeconomic factors and cultural traditions play in the success of conservation strategies of Soppinabetta forests of Western Ghats, our study examined forest organic resource harvesting, the effect of changing agricultural practices on the rate of organic resource harvesting, and farmers' perception on conservation of Soppinabetta forests in the context of recent changes in government land use policy (Guillerme et al., 2011). This study occurred along a gradient of tropical land use transition in Sringeri area of the 160,000 km^2 contiguous belt of the Western Ghats biodiversity hotspot (Myers et al., 2000). The study area has all the essential habitat stages that characterize tropical land use transition, ranging from natural forest reserves, community-managed Soppinabetta forests, small-scale agriculture, and monoculture acacia plantations (*Acacia auriculiformis*).

Materials and methods

Study area

Sringeri (442.84 km^2; 12°55′–13°54′N and 75°01′–75°22′E; 750 m asl) is the lowest population dense (83 individuals per km^2, 4507 households) *taluk* (=sub-district) of the Chickmagalur District of Karnataka State in Southern India (Anonymous). Peoples of Sringeri are educationally and economically forward, but, predominantly are agriculturists (betel nut growers) (Anonymous). Over the past 2000 years, farmers of Sringeri have sustainably managed forest resources, and limited large-scale logging and non timber resource harvesting (Nayak et al., 2000). Forest cover in Sringeri is 73.4% and over 25% of the forests are Soppinabetta forests (SBFs). To access forest resources, farmers are provisionally allotted 3.24 ha of secondary wet evergreen forests for each 0.405 ha of betel nut plantation that is designated as Soppinabetta forest (Buchanan, 1870). For more than a century, Soppinabetta forests have been sustainably managed by betel nut (*Areca catechu*) growers, although the forest department is the legal custodian of the forests (Lele, 1993). The designation allows farmers to restrict access and forest resource harvesting in their allotted SBF fragments. Soppinabetta forests (Fig. 1) are species rich, including a diversity of trees that exceed 220 species (Swamy, 1999; Sinu, 2008). Soppinabetta forests are similar to scientifically planned protected areas of the region in terms of plant species diversity (Sinu et al., in reviewed).

The two dominant forms of agriculture in Sringeri are multistoried betel nut plantations, with cardamom (*Elettaria cardamomum*) and coffee (*Coffea arabica* and *C. robusta*) grown in the understory, and rice (*Oryza sativa*) grown in paddy fields. Both forms of agriculture require large amounts of either compost or chemical fertilizer application. Betel nut plantations are the fastest expanding and most intensively managed agricultural systems in Sringeri *taluk*. These plantations produce 4368 metric tons of betel nut – worth 14.56 million US$$^{-year}$ – and account for 12% of the total land area (pers. commn.). Paddy fields produce about 7688 metric tons of food grain and account for 10% of the total land area in Sringeri (pers. commn.).

Forest dwelling communities are composed of farmers and site-dwellers. Farmers are 87.5% of the total population of Sringeri *taluk*. Conventional betel nut farming is the primary source of household income of 72.3% farmers in Sringeri. To acquire materials necessary for compost production, farmers collect leaf litter and green foliage from their provisionally owned SBF. Site dwellers are landless peoples do not own property, typically have an income that falls below the poverty line (less than US$ 1.25^{-day}), and live in government allotted sites. Economic opportunities for site dwellers are limited, primarily they are employed as day laborers, maintain livestock, or harvest non-timber forest products (NTFP). To sustainably manage SBF and limit overharvesting, farmers have historically restricted access of site-dwellers to SBFs. The unmanaged harvest of timber and other NTFP by site dwellers may imperil the ecological health of Soppinabetta forests (Fig. 2).

Compost production

To fertilize betel nut palms and rice paddy, farmers apply compost to each crop. Forest resources, leaf litter and green foliage, are the main ingredients used to make compost that is applied to paddy fields and betel nut palms, respectively (Fig. 3). Betel nut plantations are divided into three equal areas and each betel nut palm traditionally receives 90 kg (= 3 baskets) of compost amendment once every four years. On an annual basis, leaf litter compost is randomly placed in small heaps (1 basket = approximately 30 kg) in paddy fields several days before the fields are ploughed (Fig. 3). During the shortage of green foliage compost, farmers use leaf litter compost too to fertilize betel nut palms; in such a scenario, paddy fields would be given less priority for organic matter addition.

Farmers collect leaf litter during the dry season (December–May) and green foliage during the rainy season (June–November) (Figs. 4 and 5). Leaf litter is collected in bamboo baskets that hold 25 kg of leaf litter. Green foliage is collected in bundles; one bundle of green foliage weighs approximately 40 kg. To collect green foliage, farmers have traditionally removed entire trees and branches (Fig. 6). Because there has been a steady decline of adult trees in recent years, green foliage is currently collected

Fig. 3. Compost is being applied in a paddy field of Sringeri in the backdrop of Soppinabetta forests of the Western Ghats.

from understory shrubs and saplings of SBFs and degraded lands (personal observation).

To produce compost, green foliage is spread on cattle shed floors, mixed with cattle urine and dung, and after several weeks transferred to a dung pit. Leaf litter is not spread on cattle shed floor, but directly added to a dung pit. To transport compost, a locally made basket is used and can carry approximately 30 kg of compost. Unless otherwise noted, all weights are reported in metric tons.

Fig. 4. Leaf litter is being collected by laborers to make compost during dry period in Sringeri area of the Western Ghats.

Fig. 5. Green foliage is being collected by a laborer to make compost during wet period in Sringeri area of the Western Ghats.

Household and government surveys

Between 2006 and 2009, we surveyed 90 households (57 farmers and 33 site-dwellers) and forest department (FD) to characterize socioeconomic traits and land usage. The survey was designed to collect data for each individual household on the number of livestock, land area of SBF, area of betel nut plantations and paddy fields, land conversion of paddy field to betel nut plantation in the past 10 years, biomass of leaf litter and green foliage collected, compost production and trade, application of chemical fertilizer, and compost application style. Information on the current status of SBFs of Sringeri, including legality, protection measures, and governmental policies is gathered from Regional and Divisional Forest Department offices at Sringeri and Koppa, respectively. Participants were randomly selected and represented the entire range of social classes and ethnicities of Sringeri. *Brahmin*, *Gowda*, *Naik* and *Rao* are the upper class communities, and *Harijan*, *Kumbara*, *Achar*, *Muslim*, *Pujar* and *Devadika* are the lower class communities of Sringeri. In order to standardize the weight of different products (leaf litter, green foliage, compost) that are transported in similar containers in the entire region, we personally weighed them in selected ($n = 5$) households to account for variability. Since, they do not vary among samples, in the remaining households that were surveyed, quantification of leaf litter and green foliage was estimated through personal interactions with each household. We quantified it in terms of the number of (1) days spent extracting organic matter each year, (2) baskets or bundles of forest materials collected each day and (3) baskets of compost derived and applied to agricultural lands.

Recent changes in governmental land use policy have disrupted longstanding cultural traditions that conserved and sustainably managed SBFs. Because access to SBFs was prevented, site dwellers used reserve forests (RFs) and acacia plantations for organic

Fig. 6. A site-dweller collects green foliages and fuel–wood by cutting trees in a reserve forest of Sringeri area of the Western Ghats.

Table 1
Summarizing household characteristics and Soppinabetta forest dependence by farmers ($n=57$) and site dwellers ($n=33$) of Sringeri area of the Western Ghats.

Variable	Farmer		Site dweller	
	Mean ± SE	Range	Mean ± SE	Range
Forest area (ha)	6.17 ± 1.22	0–34.43	–	–
Betel nut land area (ha)	1.27 ± 0.17	0.08–4.86	0.03 ± 0.01	0–0.41
Rice paddy field area (ha)	1.33 ± 0.12	0.08–3.65	0.02 ± 0.01	0–0.41
Livestock (number)	8.79 ± 0.63	1–21	3.12 ± 0.28	1–8
Leaf litter collected/farmer (tons)	31.09 ± 4.86	0–125	6.99 ± 0.77	1.2–18
Green foliage collected/farmer (tons)	19.11 ± 2.91	0–120	7.15 ± 0.56	0–18.4
Compost made/farmer (tons)	103.04 ± 19.93	0–480	14.91 ± 1.93	2.85–54
Buying compost/farmer (tons)	40.55 ± 7.55	3–150	–	–
Compost input to farm/farmer (tons)	122.96 ± 23.40	6–570	–	–
Selling compost/farmer (tons)	–	–	14.55 ± 2.28	2.85–60
Money spent for compost/farmer (US $)	422.64 ± 78.70	31.27–1563.28	–	–
Income from compost selling/farmer (US $)	–	–	151.38 ± 23.82	29.70–625.31
Household income from compost selling/site seller (%)	–	–	15.16 ± 1.70	3.21–40.56

resource acquisition. Since SBFs were designated as RFs in 2006, farmers were required to remove the fences surrounding SBFs and add RF signage at the perimeter of each SBF fragment. We recorded farmers' and site dwellers' perception on property rights, forest dependence and conservation of SBF. Farmer households between 2 and 22 km (av. 10.27 ± 5.07 SD) and site dweller households between 6 and 17 km (av. 9.8 ± 2.83 SD) from Sringeri town were surveyed. Since Sringeri is dominated by farmers with 0.41–2.5 ha of betel nut land, we included 82% of the households of this size class in the survey. The remaining farmer households were large scale farmers (>2.5 ha of betel nut land) of Sringeri. Household income is only recorded for site dwellers since they depend on forest products for their livelihood.

Statistical analysis

Data on the quantity of bio-resources harvested by farmers and quantity of compost produced or purchased by farmers were analyzed by simple and polynomial regression against agricultural land use and associated variables. To derive the best model that predicts forest and agricultural land use change by farmers, we included the significant variables and interaction effects in a multiple regression analysis. To ordinate the farmers interviews based on their agricultural practices, we used non-metric multidimensional scaling (NMDS) technique using Vegan library of R (Oksanen et al., 2007). To understand which size classes of farmers were crucial for forest dependence, the derived dimensions were correlated with the quantity of leaf litter and green foliage collected by the farmers and with the quantity of compost purchased by farmers. To test the assumption that large-scale farmer depend more on chemical fertilizers, the four classes of farmers were compared by one-way ANOVA against the size of betel nut plantation holding. Means and standard errors of mean (±1 SEM) are used in text and tables. Response variables were either log or square root transformed to achieve normality. Data were analyzed with R program (R Development Core Team, 2007).

Results

Land use patterns and forest resource usage by farmers

In Sringeri, 98% ($n=57$) of farmers cultivate betel nut palms. Mean betel nut land use per farmer was 1.27 ha (±0.17, range 0.08–4.86 ha, $n=56$) (Table 1). The mean number of betel nut palms per plantation is 608.35 ± 81.44 (range 45–3500, $n=56$). Farmers that have more betel nut plantations ($R^2=0.73$, $n=55$, $P=0.000$) are provisionally allotted more forest land to harvest resources compared to farmers that cultivate rice paddy ($R^2=0.17$, $n=55$, $P=0.001$) (Fig. 7). Over the past 10 years, agricultural land use has changed because 33.30% (±3.59, $n=53$, range 0–100) of paddy fields have been converted into betel nut plantations. Paddy fields now account for 46.56% (±3.58, $n=57$, range 0–100) of agricultural land use among the studied farmers.

Each farmer collected an average of 31.09 (±4.86, $n=57$, range 0–125) metric tons of leaf litter and 19.11 metric tons (±2.91, $n=57$, range 0–120) of green foliage per year (Table 1). All farmers applied compost to betel nut palms, but the rate of application varied (Table 2); 84.0% ($n=56$) of farmers applied compost every four

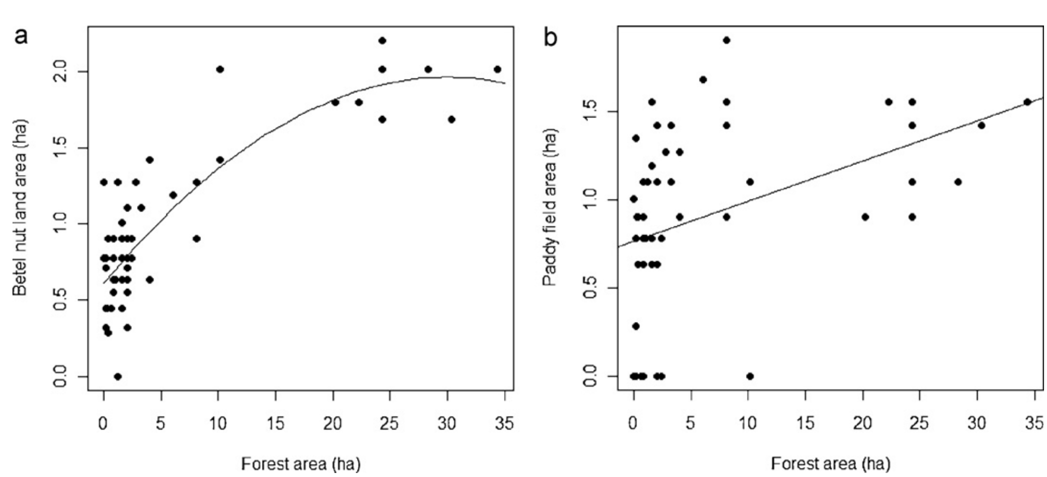

Fig. 7. Regression analysis shows the relationship between Soppinabetta forest holding size and betel nut land area (a; R^2 Polynomial = 0.73, $F_{2,54}=72.29$; $P=0.00001$) and rice paddy field area (b; R^2 Simple = 0.17, $F_{1,55}=11.23$; $P=0.001$) of farmers of Sringeri area of the Western Ghats. *Y*-axes are square root-transformed.

Table 2
Summary of variation in betel nut palm farming practice among farmers ($n = 56$) of Sringeri area of the Western Ghats.

	Farmers (%)		Betel nut plantation (ha)	
			Mean ± SE	Range
Rotation period[a]	3	84	1.31 ± 0.18	0.10–4.86
	2	14.2	1.14 ± 0.17	0.40–4.05
	1	1.8	0.08	
Amount of compost/betel nut palm[b]				
	90	12.5		
	60	57.14		
	30	30.35		

[a] Provided in years.
[b] Provided in kg.

years, 14.2% ($n = 56$) applied every two years, and 1.8% ($n = 56$) applied every year (Table 2). Mean area of land use for betel nut plantations for each class of farmers was 1.31 ha (±0.18, range 0.10–4.86), 1.14 ha (±0.17, range 0.405–4.05) and 0.08 ha. Each betel nut palm received between 30 kg and 90 kg of wet compost (Table 2); 12.5% ($n = 56$) of farmers applied the traditionally suggested quantity of 90 kg, 57.14% ($n = 56$) of farmers applied 60 kg of compost per betel nut palm and 30.35% ($n = 56$) of farmers applied 30 kg of compost per palm (one-way ANOVA, $F_{2,175} = 0.00007$). Compost application is a significant linear function of the area of land used for betel nut palm cultivation ($R^2 = 0.86$; $F_{1,54} = 336.01$, $P = 0.00001$). To fertilize one ha of a betel nut palm plantation, our analysis suggests that 75.61 metric tons of compost is required per year.

A total of 82.1% of farmers applied agrochemical fertilizers (nitrogenous and phosphate) to betel nut palms, 41.1% of farmers added between 250 and 400 g of chemical fertilizers to each betel nut palm during compost application, 21.4% of the farmers added 50–200 g of fertilizer, and 19.6% of the farmers added 500–1500 g of fertilizer to each betel nut palm (Table 3). Although it was expected that only large-scale farmers use chemical fertilizers, there was no relationship between betel nut plantation size and chemical fertilizer application ($R^2 = 0.05$, $F_{1,54} = 3.07$, $P = 0.08$).

Table 3
Comparison of the land holding size of betel nut of the farmers ($n = 56$) who apply chemical fertilizer to betel nut palm in Sringeri area of the Western Ghats.

Chemical fertilizer input/betel nut palm (g)	Farmers (%)	Betel nut plantation (ha)	
		Mean ± SE	Range
0	17.86	0.64 ± 0.12	0.20–1.62
50–200	21.43	0.88 ± 0.27	0.20–3.24
250–400	41.07	1.98 ± 0.33	0.10–4.86
500–1500	19.64	0.77 ± 0.16	0.08–1.62

A majority of farmers (84.0%, $n = 57$) cultivated rice in paddy fields; the amount of land used per farmer was an average of 1.33 ha (±0.12, range 0.08–3.64 ha, $n = 48$) (Table 1). Compost application was positively correlated with the area of land used for paddy cultivation ($R^2 = 0.27$; $F_{1,46} = 17.65$; $P = 0.0001$). One hectare of paddy field received an average of 11.94 metric tons of compost.

Drivers of leaf litter and green foliage collection by farmers

The amount of leaf litter collected by farmers is associated with the area of betel nut plantations ($R^2 = 0.65$, $n = 55$, $P = 0.00001$),

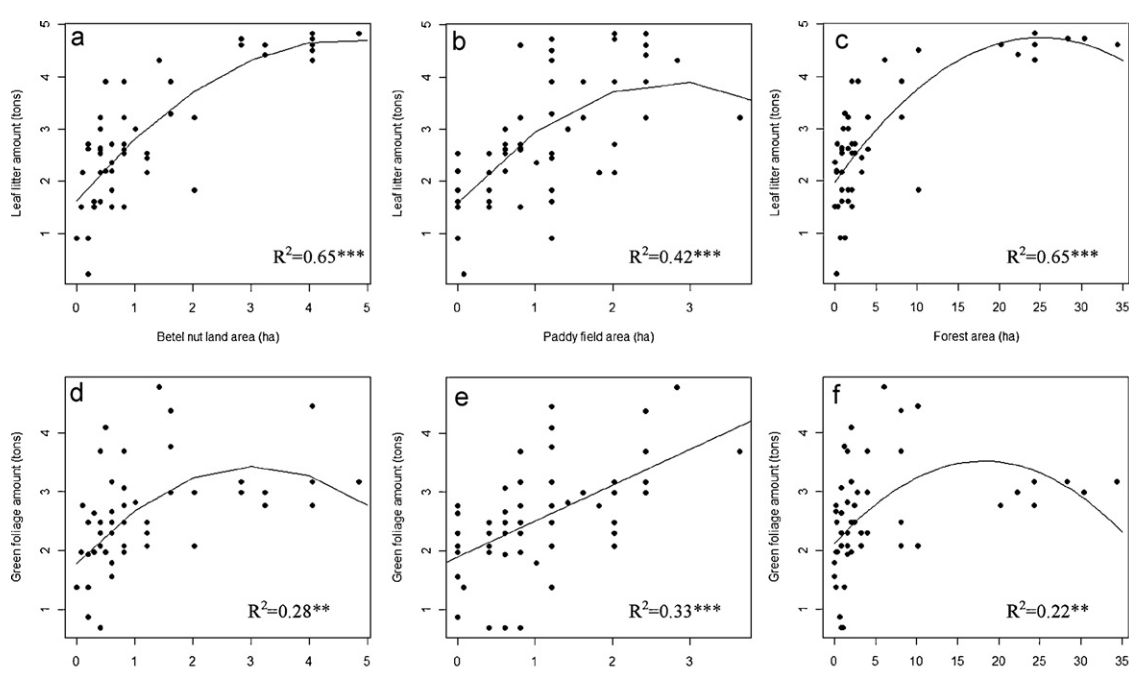

Fig. 8. Leaf litter (a–c) and green foliage (d–f) collection (log transformed) along the land holding size of betel nut, rice paddy and Soppinabetta forest of farmers of Sringeri area of the Western Ghats. Wherever curvature is observed in the relation, R^2 values are calculated on polynomial regression.

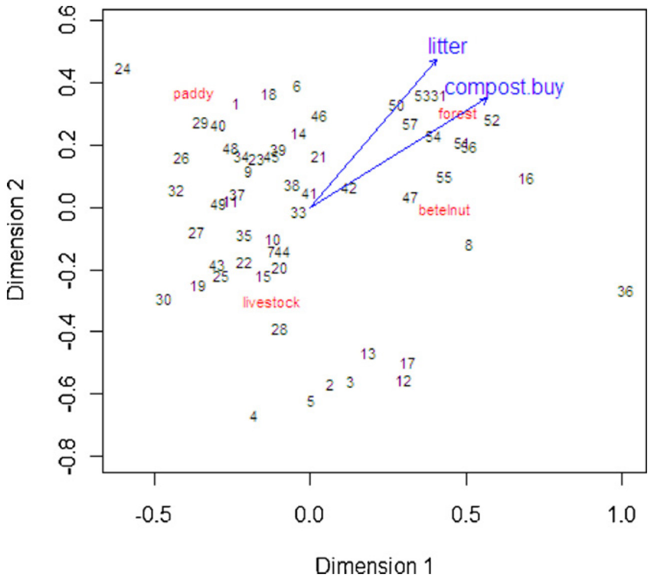

Fig. 9. Farmers of the Sringeri area of the Western Ghats are mapped in the ordination space based on the size of Soppinabetta forest and agricultural land use holdings and livestock numbers using non-metric multidimensional scaling based on Sorensen's dissimilarity values (Stress = 8.93; R^2 = 0.99 for non-metric fit; R^2 = 0.98 for linear fit of ordination distances). Leaf litter collection (R^2 = 0.42; P = 0.001) and compost buying (R^2 = 0.48; P = 0.001) by farmers are significantly related with Dimension 2. Green foliage collection is not related with either of the dimensions.

paddy field (R^2 = 0.42, n = 55, P = 0.00001) and SBF holding (R^2 = 0.65, n = 55, P = 0.00001) (Fig. 8). Multiple regression analysis showed a significant three-way interaction effect that explained 86% ($F_{5,51}$ = 67.33; P = 0.00001) of the total variation in the amount of leaf litter collected by farmers.

Farmers with an intermediate level of betel nut plantation (R^2 = 0.28, n = 55, P = 0.0001) and SBF holding (R^2 = 0.22, n = 55, P = 0.001) had the highest level of green foliage removal. The amount of green foliage harvested also increased with the area of paddy field (R^2 = 0.33, n = 55, P = 0.00001) (Fig. 8). Farmers that are provisionally allotted large SBF and betel nut plantations collected less green foliage compared to historic collections. Farmers that owned more livestock collected more bundles of green foliage (R^2 = 0.25, n = 55, P = 0.0001). The distance farmers lived from Sringeri was positively correlated with green foliage removal (R^2 = 0.10, n = 55, P = 0.01). Overall, betel nut plantation area and paddy field area were the drivers of green foliage extraction (R^2 = 0.45; $F_{4,50}$ = 10.32, P = 0.00005).

A farmer produced an average of 103.04 metric tons (±19.93, n = 57, range 0–480) of compost in a year (Table 1). In addition, site dwellers sold the compost to 49.12% of farmers (n = 57). Farmers purchased an average of 40.55 metric tons (±7.55, n = 28, range 3–150) of compost for US\$ 10.42$^{-\text{ton}}$ in a year (Table 1). To fertilize agriculture lands each year, farmers used an average of 122.96 metric tons (±23.4; n = 57; range 6–570) of compost. The amount of compost purchased by a farmer is driven by the area of betel nut plantations owned by that farmer (R^2 = 0.73; n = 57; $F_{2,54}$ = 74.98, P = 0.00001).

Non-metric multidimensional scaling (NMDS) mapped the farming community on two major categories in the ordination space of the two axes (Fig. 9). The first major group comprises two unequal subsets: a minor subset of farmers that possess large SBFs and large betel nut plantations, and a major subset comprises the majority of the farmers in the region who own small SBFs, betel nut plantations, paddy fields and maintain considerable numbers of livestock. Dimension 2 is positively correlated with leaf litter collection (P = 0.001) and compost purchase (P = 0.001) by farmers. Green foliage collection is not significantly correlated with any of these dimensions (P = 0.09). The second major group is composed of farmers who do not own paddy field (Fig. 9).

Forest dependence of government site dwellers

Site dwellers' primary income is earned by producing and selling compost to and working at nearby farms. Secondary income is earned through livestock husbandry. To obtain firewood, fodder for livestock, and materials used to make compost, site dwellers collected leaf litter and green foliage from nearby RF and acacia plantations. Site dwellers sold compost to large-scale farmers at a cost of US\$ 0.32 per 30 kg (=1 basket). We estimated that, each site dweller collected an average of 6.99 metric tons (±0.77, n = 33, range 1.2–18) of leaf litter and 7.15 metric tons (±0.56, n = 33, range 0–18.4) of green foliage in a year (Table 1). The number of livestock owned by each household of site dwellers predicted the amount of leaf litter (R^2 = 0.43; $F_{1,31}$ = 22.92, P = 0.00003) and green foliage (R^2 = 0.14; $F_{1,31}$ = 5.21, P = 0.02) collected and compost produced (R^2 = 0.33; $F_{1,31}$ = 15.27, P = 0.0004). Site dwellers produced an average of 14.91 metric tons (±1.93, n = 33, range 2.85–54) of compost in a year and 97.6% of compost was sold to farmers (a minority of 12.4% of site dwellers use compost on their own betel nut palms). By selling compost, site dwellers earned a mean of US\$ 151.68 (±23.82, range 29.70–625.31) per household, which amounted to an average of 15.16% (±1.708, n = 33, range 3.21–40.56) of total annual household income (Table 1).

Farmers' perception of Soppinabetta conservation policy

According to farmers, by designating SBFs as RFs, site dwellers were allowed to harvest resources from SBF fragments. Furthermore, farmers believed (100%, n = 57) that the government has chosen short-term unsustainable economic gains and long-term ecological degradation (Fig. 2). Our survey indicated that the majority of the farmers (96.5%, n = 57) believed the conservation of SBFs can only occur if the forests remain under farmer management.

Farmers stated that degradation of SBFs generally happens in two steps. First, the "RF" signage gives site dwellers access to SBFs. This designation allows for unsustainable logging of the trees for fire wood and organic material, boosting canopy clearing and forest degradation (Fig. 2). Second, once the degradation of a SBF plateaus, the government (forest department) will review land use and allocate degraded SBFs for social forestry programs, such as establishing *Acacia* plantations. For these two reasons, many farmers are opted to sell the betel nut land to non-native farmers for cultivating monoculture crop plantations, such as rubber and oil palm.

Discussion

According to our results for the Soppinabetta forests of Sringeri, governmental policy that promotes short term economic gains through establishing monoculture plantation crops at the cost of degraded SBFs and grazing lands and removing restrictions on forest resource harvesting can rapidly dismantle longstanding agricultural traditions that sustainably manage and protect the ecological integrity of tropical forests. In the absence of traditional sustainable management, betel nut plantations and paddy fields may become imperilled because of a decline in the quality and quantity of leaf litter and green foliage used in compost production. Furthermore, such shifts in land use policy governing SBFs may lead to a further reduction in forest products due to intensifying competition for resources between traditional farmers and site dwellers. Overexploitation of resources in these valuable forest systems may lead to widespread forest degradation and end a 2000-year-old tradition of sustainable land use and in the Soppinabetta forest system.

Farmers of Sringeri are increasingly converting paddy fields into betel nut plantations because per ha revenue produced from betel nut is approximately four times higher than per ha revenue produced from paddy fields. Transformation of paddy fields to betel nut can increase the demand for organic material and will likely led to an increase in resource harvesting in SBFs (Fig. 8). An increase in forest resource harvesting may negatively affect the ecological health of SBFs, potentially outweighing the economic benefit obtained from agricultural land transformation. If the number of betel nut plantations continues to increase, Soppinabetta forests in Sringeri could follow the path of ecological degradation observed in SBFs in adjacent districts of Karnataka Western Ghats (Gadgil, 1987).

Agrochemicals are becoming the dominant fertilizer in Sringeri, replacing the longstanding traditional use of compost that is derived from forest products harvested from SBFs. Our results demonstrate that betel nut plantations use six times more compost than paddy fields that are comparable in size. Per capita leaf litter and green foliage extraction is directly related to the number of livestock maintained in a household, as cattle dung is a primary ingredient of compost (Davidar et al., 2008). Compost production has decreased for the following reasons: the size of grazing lands has declined, there has been a 60% reduction in the number of cattle owned per household, the density of day laborers has declined, and the new generation of farmers has a limited interest in traditional agriculture – i.e. compost production and application.

The reserve forest designation eliminated restrictions that prevent site-dwelling individuals from accessing SBFs for forests resources. This change in policy has led to a dramatic increase in population density of site dwellers in SBFs, intensifying conflict between the farming and site dweller community over access to SBF resources. Furthermore, the increased forest resource harvesting by site dwellers, coupled with the increased amount of compost needed for new betel nut plantations, is unsustainable and will likely create a dramatically impoverished tropical forest system in Sringeri.

Recent forest department policy is aimed at increasing monoculture plantations of acacia trees, following a global trend in which governmental planners expect this policy to be an effective afforestation management practice (Bernhard-Reversat, 1999; Poore and Fries, 1985). However, homogeneous exotic plantations do not provide adequate sustainable resources and services needed by impoverished rural communities (Lamb et al., 2005). Acacia plantations provide inadequate resources for compost production because acacia leaves degrade slowly and farmers typically do not buy compost produced from acacia leaves (Dreschel et al., 1991).

The sustainable management of SBF was previously evaluated by calculating production and harvest ratio of tree woody biomass in Uttara Kannada District (Gadgil, 1987; Bhat and Huffaker, 1991; Lele, 1993). Wood extraction by lopping and occasionally entire tree felling is widespread in SBFs of the Uttara Kannada District, but remains limited in Sringeri of the Chickmagalur District. The canopy structure of SBFs in Sringeri is similar to protected wet evergreen forests in the region, as opposed to SBFs in the Uttara Kannada that are similar to savannas (Lele and Hegde, 1997). In turn farmers of Uttara Kannada harvest grass for livestock fodder (Lele, 1993).

As forest policy has changed, many medium to large scale farmers plan to sell agriculture lands in Sringeri area, immigrate to cities, and engage in business activities or purchase small urban agricultural holdings (Guillerme et al., 2011). This phenomenon is similar to other developing tropical countries (Ptaff, 2000; Lamb et al., 2005). Before immigrating to cities, farmers of Sringeri sell agriculture land to migrant farmers from nearby States, primarily Kerala and Andhra Pradesh. New farmers usually convert bio-intensive betel nut plantations that require mandatory manuring for desirable crop yield to cash crop monoculture plantations, primarily rubber (*Hevea brasiliensis*), oil palm (*Elaeis* sp.), and ginger (*Zingiber officinale*) plantations (Steffan-Dewenter et al., 2007; Guillerme et al., 2011). This change in agricultural practice is driven by two interlinked factors: first, heavy monsoon rains (approx. 4600 mm, annual average) frequently leach the soil nutrients in the agricultural lands. Hence, amending soil nutrients and preventative measures to reduce leaching are periodically required. Compost application was an economically viable solution to meet these requirements. Second, it is foreseeable that the organic resources will become increasingly scarce because provisional ownership of SBF tracts by farmers is further eroded by recent governmental policy. Many medium and large scale farmers are reducing the amount of green foliage-cattle dung compost purchased due to its scarcity and poor quality. As an alternative, they have increased chemical fertilizer application to betel nut palms (Table 3), and a minority of the farmers has shifted to using goat dung pellets and rice husks to fertilize agricultural lands, although it costs more.

When the agrarian and rural communities rely on resources derived from the environment they should be involved in conservation programs that limit or prevent access to those resources (Nagendra and Gokhale, 2008; Chaudhry et al., 2011). Conservation of SBFs should be of the utmost priority because this system maintains biodiversity [for example: epiphytic orchids: Sinu et al. (2011); birds: (Sinu, unpublished; Daniels et al., 1990); insects (Sinu, 2004); plants (Swamy, 1999; Sinu, 2008)] that is comparable to protected wet evergreen forests of the region, and act as a natural reservoir of the biotic agents that provide regulating ecosystem services in an agriculture–forest matrix system (Sinu, 2005; Sinu and Shivanna, 2007; Kuriakose et al., 2009). Moreover, it supports small-scale traditional agriculture in the region.

Concluding remarks

Threats to tropical forests are multifaceted, stemming from systemic poverty, exploitation of natural resources to meet the demands of accelerating agricultural activity, and forest policies that focus on economical outcomes as opposed to the ecological integrity of tropical forests (Bawa et al., 2007). It is difficult and challenging to prescribe a management and conservation plan for SBFs of Sringeri region because reconciling farmers' and site dwellers' needs with the integrity of the environment is difficult in the present socioeconomic and political climate. We suggest that (1) to limit the need for widespread organic resources, agricultural land transformation should be avoided, and (2) the forest department should take their effort to reduce agricultural encroachment into the forests. In addition, they should not promote land use practices that convert natural forest and grazing land to monoculture timber-based plantations, such as *Acacia auriculiformis*; but, they should rehabilitate the degraded lands by heterogeneous energy plantations to cater to the needs of impoverished communities. To sustain the SBFs for traditional farming activities, we argue that participation between farmers and the government should occur. In the present scenario, policy makers should value local-level protection in order to conserve Soppinabetta forests, which otherwise are increasingly susceptible to degradation from further encroachment and exploitation.

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