Chapter 6

Why Forest Plantations Are Disputed? An Assessment of Locally Important Ecosystem Services from the *Cryptomeria japonica* Plantations in the Darjeeling Hills, India

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Abstract

This study explored locally important forest products generated from different plantation forests. A comparison was made between monoculture and mixed stands in terms of understory plant species richness and number of forest products collected by local communities in the Darjeeling Hills of India. The results showed that forest-dependent communities collect an array of forest products from mixed stands compared to the monoculture stands but understory plant species richness was not significantly different between these two types of forest plantations. This study suggests that a single management strategy alone (e.g., mixed species plantations), could not produce an array of forest products expected by local communities, which requires a mixture of different types of strategies. Limited plantation management activities that were confined during the first 3 years after plantation were the major determinants of such homogeneity in the Darjeeling hills.

Keywords: monocultures, mixed stands, plantations, ecosystem services

1. Introduction

1.1. Forest plantations and ecosystem services

Forest plantations, particularly the plantations of exotic conifers, are one of the contentious issues when considering bio-diversity conservation and supply of ecosystem services. Usually, the large-scale monocultures, particularly those established by replacing natural forests, are the concerns of environmental lobbies [1]. In agrarian communities in which forest products are considered as an important input of farm-household production functions, monocultures are likely to receive negative responses. This is because monocultures tend to have the least positive consequences for bio-diversity [2]. An increasing abundance of single planted species literally decreases the availability of other native species. Plant species richness and ecosystem services are so intricately linked that a change in the state of one of these variables can be expected to have an impact on the other [3].

It is likely that the establishment of a species-poor forest (i.e., a monoculture plantation) affects the interaction of local forest dependent communities and the forest in a negative way even though silvicultural options to enhance biodiversity in forest plantations do exist [4]. Even if silvicultural options are applied, they may never reach the levels of biodiversity that a native forest holds.

There are sufficient plantation management options available to manipulate attributes of the planted landscape [5, 6]. These forest management activities can enhance the production of multiple ecosystem services. These services are direct or indirect benefits that ecosystems provide to people [7]. Compared to monocultures, mixed plantation systems of native species are widely acknowledged to provide a wide range of benefits such as increasing production and stability, bio-diversity conservation and rehabilitation of degraded ecosystems [4, 8, 9].

Generally, local communities have the perception that the benefit derived from forest plantations relies on the species composition [10], and forest managers can expect positive responses by transforming forest plantations from monocultures to a mixture of species. However, having a single strategy of a mixed-species plantation may not address all social and environmental issues that arise due to monocultures. In this context, a broader understanding of complex plantation forestry practices and purposes may significantly increase the benefits society derives from plantations and may help to balance some of the shortages in resources that mankind will face in the decades to come [5].

Accordingly, this study will assess the role of plantations in the Darjeeling Hills of India and in so doing will answer two research questions. First: do mixed species plantations enhance plant species richness? Second: is there any improvement in the supply of locally important forest products after a change in forest management strategy from monocultures to mixed plantations?

2. Materials and methods

2.1. The case of *Cryptomeria japonica* plantations in the Darjeeling Hills, India

During British rule in the Darjeeling Hills of India, Japanese cedar (*Cryptomeria japonica*) plantations were extensively established to produce the timber required for railway construction and the tea industry, but at the expense of native forests [11]. *Cryptomeria japonica* locally known as *Dhupi* in the hills is endemic to Japan and Southern China. Today, these plantations of *Cryptomeria japonica* account for one-third of the total area of the Darjeeling Hill Council followed by tea plantations which cover 22% of the total area [12]. It is obvious that such a change in land use, especially when it affects large areas, can cause a significant change in community composition and is very likely to have a negative impact on biodiversity from the stand to the landscape level [1, 13, 14].

These plantations are occasionally portrayed as environmentally negative as they are not suitable for the production of the wide variety of locally important forest products including fuelwood and fodder [15]. For instance, rural people require fuelwood for cooking and heating; and fodder for livestock to maintain their daily livelihoods. Therefore, in rural areas local livelihoods depend highly on the diversity of the native forests and locals can experience much dissatisfaction with commercially introduced plantations. In the Himalayan region reported cases exist where this dissatisfaction has led local people to deliberately damage conifer plantations [16]. However, the magnitude and direction of forest plantations are associated with the objectives of the plantation management and the integration of socioeconomic value into the plantation system [17].

After much public debate in the early 1990s, these plantations have undergone a paradigm shift from monocultures to mixed-species plantations where an allotment of planted conifers is prohibited from being more than one-fifth of the total planted trees [12]. In 1996 following a verdict of the Supreme Court of India, a felling ban in the hill regions was imposed [18]. Consequently, forestry operations were limited to rehabilitation of the degraded areas and nurturing of the planted crops until their establishment. This period generally lasts 3 years [12]. The hill people are allowed to collect forest products (fuelwood and fodder) only from the undergrowth for their subsistence needs. However, this provision seems contradictory with one of the objectives envisaged by the National Forest Policy of 1988 [19] and the Joint Forest Management (JFM) program, which were designed to meet the demand for forest products required in forest dwellers' daily life. Collecting forest products only from the undergrowth may not fulfill the demand for forest products particularly fuelwood and small timber.

For this study, plantation blocks within the Takadah Range of the Darjeeling Forest Division, west Bengal, India, were selected. The pre-requisites to select the pool of potential plantation blocks were (1) outside of the protected areas, (2) managed under the JFM program and (3) both monocultures and mixed stands in the same landscape (aspect and altitude between 1650 and 2140 msl) with different ages of stands. Most of the sites were dominated by *Cryptomeria japonica* monocultures established between 1922 and 1981. Additionally, planting mixed species (*Cryptomeria japonica* with other broadleaved species) was in practice after 1991. All of the hills had south-facing slopes.

The selected forest blocks are being protected by local people under the JFM program. Local people are organized into Forest Protection Committees (FPCs) to protect a particular plantation block. Three FPCs including the Tinchule, the Upper Humbasti and the Takadah are protecting the selected stands. The Tinchule FPC has both forest villages and revenue villages, while other FPCs have only revenue villages. A forest village is a colony of plantation workers established by the forest department on public land, and in the revenue village land are owned by individuals.

We adopted two different methods for each research question, respectively. The first method addressed the effects of plantation management regimes on plant species richness. Plantation management regimes mean the different stand structures that result from the species mixture and tree spacing at the time of establishment and the subsequent management by local people. Silvicultural management was not carried out by the forest department. We performed an inventory where we assessed the plantations composition and structure with special focus on the main understory. The second method consisted of focus group discussions with local communities to access information on the ecosystem services (ES) extracted by them from the inventoried stands.

2.2. Plantation inventory

We applied a stratified systematic sampling method for the plantation inventory. The plantations were divided into two groups: monocultures and mixed stands. Based on the working plan for the Darjeeling forest division [12], monocultures were defined as stands with more than 90% of *Cryptomeria japonica* trees. All other stands were classified as mixed stands. Each group was further stratified into four age classes: under 20 years, 20-40 years, 40-60 years and more than 60 years. This classification was based on the suitability of the particular age-class to produce locally important forest products as preliminary discussions with key persons from the Forest Department and local NGOs including Darjeeling Earth Group, Friends of Trees Forum, WWF Darjeeling, ATREE, and Prerana RCDC. For instance, stands under 20 years old are suitable for fodder and fuel wood, 20 to <40 year-old stands are used for poles, 40 to <60 year-old trees are considered mature, and > 60 years is the harvesting age for timber. A preliminary field visit and interaction with members of the FPC and the Forest Department Range Offices were carried out to select the stands resulting in a total of 17 plantation stands of different age classes that were inventoried (**Table 1**).

As all plantation stands are homogenous in terms of their age, we considered a sampling size of 2% as sufficient for forest inventory. We used a nested plot design with two different plot sizes. In circular plots of 200 m^2 (main plot) to increase the replication by increasing number of plots. We measured the height and diameter at breast height (dbh) of each tree with a dbh of 10 cm or more and recorded the species type. In each main plot we nested three sub-plots of 9 m^2 (square shape) to measure the understory vegetation [20]. In these plots we estimated the total cover of the understory vegetation in percent of the total sub-plot, the cover of different growth forms (i.e., herb, shrub, climber and trees) as well as the cover of each species that covered at least 5% of the sub-plot area. We also estimated the cover of different life forms and

Stand type	Plantation type	Age group	Area (ha)	No. of main plots
Mixed	Mixed	<20 years	26.30	27
Young	Monocultures	20 to <40 years	23.40	25
Mature	Monocultures	40 to <60 years	10.12	12
Old	Monocultures	≥60 years	16.19	18

Table 1. Plantation types, age groups, area (ha), and number of main plots.

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species with a cover of >5%. The understory vegetation here (i.e., trees with a dbh <10 cm) were counted and also included in the cover estimates with shrubs, climbers, and herbs.

A total of 82 main plots were laid systematically at intervals of 100 m along parallel transects that resulted in one main plot per hectare. If there was more than one transect required, when forest area is not sufficient for defined intervals, the distance between the two consecutive transects was 40 m. During the inventory, we involved local inhabitants and forest guards who helped us to identify the plants and for triangulation. We collected a herbarium of the plants that were confused and verified with local experts.

2.3. Focus group discussions

Focus group discussions (FGDs) were carried out with members of the executive committee and general members of FPCs including former plantation workers to identify the services derived from the investigated forest types. To ensure that there was a consensus about the stands, each site was visited twice with the participants before and after the FGDs. These visits (i.e., discussion walks) mainly focused on forest products collected from the particular stand as these are the ecosystem services predominantly derived from the plantations by local people for their livelihoods. A list of ecosystem services was prepared with the participants during the discussion walks and the FGD for each selected stand. Discussion walks with focus group participants also helped to reconfirm to them about the plantation stands they were talking about. Participants were asked to rank the most important ecosystem services for their livelihoods and to indicate the five most preferred species using a majority voting system for each product that they obtain from the forest. In addition to the FGDs and discussion walks, interviews were conducted with 14 local experts from divisional forest offices (6), environmental NGOs (5), and local experts (3). Key person interviews were carried out to get information on the present status of forest management, ongoing conflicts and suggestions for future improvement.

2.4. Statistical analysis

Results from the forest inventory were analyzed with a one-way analysis of variance (ANOVA). Stata 14 software was used for data analysis. The effects of species composition on undergrowth and a variety of forest products were the main interest. The plant species diversity was described by the Shannon Index [21]. The index is a quantitative measure of species diversity in a given community based on the number of species present and their abundance. It is calculated as follows:

$$H' = -\Sigma Pi \times \log\ Pi \tag{1}$$

where H′ is the Shannon diversity index. P_i is the fraction of the entire population made up of species i.

Knowing the structure and diversity of the different plantation types as well as how these types are utilized for locally important ecosystem services, we wanted to know if and to what extent the different stand variables influence the availability of these ecosystem services. We

Variables	Description	Notation
Trees per ha	Number of trees (≥10 cm dbh)	T
Diversity index of undergrowth	Shannon diversity index of vegetation measured in sub-plots	H′u
Diversity index of main plots	Shannon diversity index of vegetation measured in main plots	H′m
Stand age	Age of the plantation stands, which was estimated based on the plantation record	A
Plantation type	Types of plantations, value as 1 for monocultures and 0 for mixed stands	PT

Table 2. Stand characteristics included in the analysis.

therefore performed a multiple regression analysis to identify the determinants of locally important ecosystem services. We selected tree density, diversity of canopy and understory vegetation, stand age and plantation type as independent variables as these are important determinants of provisioning for multiple ecosystem services [4, 22–24].

In general, the quantity of ecosystem services depends on the intensity of forest management while the variety of ecosystem services depends mainly on structural features of the stand [22, 25]. Hence, we considered the number of locally important forest products as a dependent variable. The stand characteristics tested are listed in **Table 2**.

The multiple regression was based on the following model:

$$ES = \alpha + \beta_1 T + \beta_2 H'u + \beta_3 A + \beta_4 H'm + \beta_5 PT \quad (2)$$

where ES is the number of forest products, how many types of forest products, local people were harvesting from each plantation stand, α is the constant term. β_1 to β_5 are the vectors of coefficients associated with the tested stand characteristics (**Table 2**).

3. Results

3.1. Structure and diversity of *Cryptomeria japonica* plantation types

3.1.1. Differences in the upper canopy among plantation types

A total of 54 species were recorded both in main plots and nested plots of all studied plantations. Of the total, 34 species were trees, 9 herbs, 9 shrubs, and 2 climbers. Among them, 17 species occurred in the upper canopy, which are planted as plantations were followed by clear felling. The basal area and average number of trees per ha reported in **Table 3** indicates that the stands are dense according to Takahashi et al. [26]. In the monocultures, two native broadleaved species—*Magnolia lanuginosa* and *Castanopsis tribuloides*—were observed sparsely throughout the stands. As per focus group participants, these broadleaved trees were left by the forest workers during tending operations in the past and grew profoundly and regenerated naturally. In the mixed stands, a total of 16 species were found while *Exbucklandia*

Stand type	Basal area ($m^2\ ha^{-1}$)	Tree per ha	Ratio conifers/broadleaved	Average H′m	Average H′u
Mixed	19.3	1344	24/76	1.08	2.15
Young	54.3	772	100/0	0.16	1.93
Mature	58.7	412	92/8	0.28	1.92
Old	60.6	344	99/1	0.06	1.71

Table 3. Characteristics of the upper canopy (trees >10 cm DBH).

populnea was within 60% of all tree individuals of the main planted species followed by *Cryptomeria japonica* (22%).

3.1.2. Differences in undergrowth vegetation among plantation types

The highest number of regenerated species (36 species) was recorded in mixed stands and young monocultures. Among the monoculture stands, the number of regenerating species decreased further with the age of the stands, i.e. 30 and 26 species in mature and old monocultures, respectively. Very few species were dominant in the understory vegetation. Approximately, three-fourths of the total number of species was recorded in only less than 10% of the total sub-plots. Common herbaceous species where *Dryopteris cochleata, Rumex nepalensis,* and *Eupatorium adenophorum*, which were found in 99% of the total sub-plots, however these species were not used by local people. Other common species were *Porteresia coarctata, Eragrostis tenella,* and *Equisetum debile* (92% of the total sub-plots). *Eurya acuminata* was the highest occurring regenerating tree species and was reported in 60% of the total sub-plots.

Mixed stands showed the highest value for the Shannon Diversity Index. Among the monocultures this value decreases with the age of stands however, they were not statistically significant within monoculture stand types.

3.2. Supply and preferences for ecosystem services by local communities

3.2.1. Forest products from different plantation types

The 12th Working Plan (1997/1998–2017/1918) for the Darjeeling Division states that the main aim of forest plantations was the production of timber and small-timber. However, local people were collecting several products such as fuel wood, fodder, bedding materials, and leaf litter in these plantations (**Table 4**). Among them, the respondents ranked fuel wood, fodder, and poles as the main collected products. Likewise, *Cryptomeria japonica* needles were used for decoration and the local Buddhist community used the needles for incense. Bamboo and Rattan are used by local artisans to produce toys, furniture, and household articles.

In the mixed stands, people collected different types of forest products from both the canopy vegetation and the understory. Bedding materials and fodder in particular were being collected from the understory. In the case of monocultures, *Cryptomeria japonica* trees from young monocultures were suitable for poles and needles, whilst *Cryptomeria japonica* trees from mature monocultures were only useful for the needles. Most of the forest products collected

Stand type	Locally important ES
Mixed	Fuel wood, Fodder, Poles, Leaf litter, Bedding materials, Support to vegetables
Young monoculture	Fuel wood, Fodder, Leaf litter, Decorative, Medicinal herbs
Mature monoculture	Poles, Fuel wood, Fodder, Decorative
Old monoculture	Fodder, Bamboo & Rattan, Vegetables

Table 4. NTFPs collected from different stand types.

in the monocultures was from the understory. However, it was observed that local people were collecting *Cryptomeria japonica* branches for fuel wood.

Obviously, mixed plantations supplied more number of forest products than other stand type.

Shannon diversity index of upper canopy vegetation has a strong correlation with the number of provisioning products ($r = 0.994$, $P = 0.006$).

3.2.2. *Preferred plant species for different forest products*

Native broadleaved species were highly preferred as fuel wood and fodder, while *Cryptomeria japonica* was the first choice for pole production (**Table 5**). Local people concerned about crop raiding by wild animals in their agriculture fields stated that an increase in fruit bearing species like *Castanopsis* spp., *Machilus edulis*, and *Elaeocarpus lanceaefolius* in forest plantations would help to create a suitable habitat for wildlife and reduce animal raids on their agricultural fields.

3.3. Variables determining ecosystem services availability

The results of the multiple regression analysis to identify the determinants of ecosystem services are reported in **Table 6**. The value of R-square indicates that the Model is a good fit. There are a number of significant variables (e.g., the age of the stands, Shannon Index of the undergrowth and the upper canopy, stand type, and number of trees per plot) that determine the variety of forest products from the plantation stands.

The regression analysis showed that the number of trees per ha and the Shannon diversity index of the upper canopy have a positive association with the supply of diverse forest products. On the other hand, the variety of forest products decreases with the understory diversity index and age of the stands, particularly if the stands are monocultures.

Locally important ES	Five most preferred species
Fuel wood	*Quercus* spp., *Acer campbellii*, *Symplocos* spp., *Eurya acuminate*, *Macaranga* spp.
Fodder	*Ficus nemoralis*, *Maesa* spp., *Garuga pinnata*, *Quercus* spp., *Prunus nepalensis*
Pole	*C. japonica*, *Schima wallichii*, *Exbucklandia populnea*, *Symplocos* spp., *Mallotus nepalensis*

Table 5. The five most preferred species by the focus group participants locally important ecosystem services.

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Variables	Coefficients[a]
Constant	5.96 (1.160)***
Age	−0.043(0.008)***
Diversity Index Undergrowth	−0.133(0.055)**
Diversity Index Main plot	1.140 (0.630)*
Plantation type	−2.083(0.627)***
Trees per ha	0.016 (0.005)**
R-square 0.879	Adjusted R-square 0.624

[a]Standard errors in parentheses.
*, ** and *** denote significant at 10, 5 and 1% levels respectively.

Table 6. Variables that influence a variety of forest products availability.

4. Discussion

The first question our research addressed was whether mixed species plantations enhanced plant species richness. Regarding the upper canopy this question can be answered, positively. Mixed plantations showed the highest diversity index in both the upper canopy and in the understory. This can lead to a variety of benefits for plantation managers, such as the creation of structural diversity, better utilization of nutrients leading to faster growth and a higher volume of trees [27] and reducing the risk of pest outbreaks [4]. A balanced mix of native and exotic species therefore seems to be a good option when addressing the multiple demands of forest products by rural communities. For instance, native species are suitable for the production of minor forest products including fuelwood, bedding materials and fodder, and exotic species are more suited for timber and small wood including pole and veneer [25].

Understory plant communities is widely heralded as forest ecosystem drivers as they are shown to significantly contribute toward enhancing species diversity and providing habitats for wild-animals [23, 28]. In this study area, we have seen that understory plants have a significant contribution to rural livelihoods as they are the only source of daily important forest products after the felling ban. In general, the species mixture in plantations enhances undergrowth plant diversity, but it is only partially true in our study [29, 30]. As expected, the mixed stands have with a value of 2.15 (the highest Shannon index), but the difference with monocultures is not statistically significant. This might be the result of the absence of forest management activities in this study area as silvicultural treatments focusing on maintaining spatial and temporal diversity of environments usually have positive effects on species diversity of naturally regenerated plants [31–33].

Our second question addressed whether increased diversity in forest plantations will also benefit local communities in the Darjeeling Hills. First, we must state that ecosystem services other than timber were derived from all plantations types, even from those which had almost no diversity in structure and plant species (**Tables 3** and **4**). This opposes the perception that forest mono species plantations in general, and *Cryptomeria japonica* plantations of Darjeeling in particular, are of no use for the diverse requirements of local forest dwellers [6, 34].

Second, we found that higher diversity of the upper canopy is correlated with a higher number of tangible ecosystem services derived from the stands. As these mixed plantation stands have not faced any structured management since being planted the increased supply of ecosystem services can be seen from the forest department's perspective as undesirable and at best being somehow directed by the local user supporting species that are important to them. As mixed stands are seen to have a great potential for producing a wide variety of forest products [22, 35], a structured and intentional management of these plantations with the enhancement of the supply of ecosystem services seems to bear a much greater potential than currently utilized. This is especially true for the enhancement of the understory diversity which seems not to depend on the grade of tree species and structural diversity in the upper canopy.

The focus group members did not perceive *Cryptomeria japonica* plantations as negative as had been generally presumed [15]. Besides timber production, the rural farmers acknowledged the use of *Cryptomeria japonica* for pole production and its potential for commercial products such as decoration and incense. Typically, rural communities evaluate the plant species based on how their economic needs are influenced by the species regardless of the origin of species [36].

If *Cryptomeria japonica* plantations in the Darjeeling Hills can contribute to local livelihoods, why is their use disputed? We see two reasons why *Cryptomeria japonica* plantations were not able to gain public support. First, the felling ban imposed in the hills enforced monocultures to become over-matured and over-stocked. Second, plantation management in the hills follows an assumption that *Cryptomeria japonica* stands do not respond to thinning and can grow equally in un-thinned stands [12]. As a consequence of both, *Cryptomeria japonica* monocultures, whether mature or young, are dense. These dense stands create a dark understory environment resulting in low plant species richness [37, 38]. This dark understory reduces the availability of forest products.

Following the imposition of the felling ban it has been almost impossible to implement forest management systems. The ban has constrained the supply of locally important forest products thereby influencing regeneration. As a result, the collection of locally important forest products became unsystematic and local people have been collecting those products from whatever was available. In addition, the mixed-species plantations are dominated by limited species and these species do not represent local preferences (**Table 5**). This shows that without considering local preferences, the plantations, whether mixed-species or monocultures, cannot satisfy the local needs. Since there are a number of ways that plantation management can be manipulated for greater diversity in structure and species composition [4], it needs to be assessed at the local level.

5. Conclusions

The study concludes that options to enhance the supply of tangible forest products from forest plantations for rural communities in the Darjeeling hills are far from being fully utilized. There is a need for a mixture of different options based on local assessments with moderate management activities [39]. However, it is almost impossible to apply any silviculture options in the Darjeeling hills due to the felling ban. This study calls for further discussions on whether the felling ban was imposed to support the existing practice of absolute protection or to allow for an improvement in forest operations. The answer to this question would provide valuable information to assist in designing an appropriate strategy to optimize the socioeconomic benefits from plantations. If the answer supports the continuation of the existing practice of absolute protection, then further investigation is called for to examine the future prospects of the plantations, particularly in the matured monocultures.

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