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Effects of Different Management Practices on Stand Composition and Species Diversity in Subtropical Forests in Nepal: Implications of Community Participation in Biodiversity Conservation

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In this article, we compared the structure, composition, and diversity of trees, shrubs and saplings, seedlings and herbaceous species of community- and government-managed forests in the lowlands of eastern Nepal. Results suggest that among the trees, the community forest was dominated by a single species, Shorea robusta. *However,* Shorea robusta *and* Terminalia myriocarpa *were codominant in the government forest. Tree density and basal area were higher in the government forest, but shrub/sapling density and basal area were higher in the community forest, suggesting a positive effect of community management on tree regeneration. Overstory species assemblages showed an obvious compositional difference between the forests, but understory species assemblages were less obvious. Plot-level tree and shrub/sapling species richness was higher in the government forest than the community forest. However, seedling-herbaceous species richness was higher in the community forest. The dominance of* Shorea robusta *trees in the community forest suggests that people involved in managing forests may be more interested in a limited number of economically valuable species while removing less important trees. Such preferential management practices may increase resource heterogeneity*

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within a forest and maintain species diversity in the understory. Thus, community participation in forest management should be encouraged, with guided management techniques and exercises, to achieve maximum forest recovery, provide sustainable ecosystem services, and maintain forest diversity.

KEYWORDS community forest, government forest, forest management, forest structure, Shorea robusta*, species richness*

INTRODUCTION

Forest ecosystems harbor a wealth of global biodiversity and offer important ecosystem services (Myers, 1997; Louman et al., 2009; Joshi & Negi, 2011; Thompson et al., 2011). However, diminution of global forest cover from its historical expanse has become a major economic and environmental problem throughout the world (Myers, 1997; Foley et al., 2007; Zhai, Cannon, Dai, Zhang, & Xu, 2015). Significant loss of forests around the world, especially in developing countries, has been attributed to increasing fuel demand, human settlements, and conversion of forests to agriculture (Allen & Barnes, 1985; Barbier, 2004; Pandey, Cockfield, & Maraseni, 2013). In particular, changes in demography, urbanization, political instability, conflicts, and sectoral inequality are causing a significant loss of forest resources in several developing countries (Ehrhardt-Martinez, 1998; Bouda, Savadogo, Tiveau, & Ouedraogo, 2011; Laurent-Lucchetti & Santugini, 2012), including Nepal (Eckholm, 1975; Ives, 2006). To address the burgeoning problems with forest degradation and deforestation, different forest management strategies have been adopted in different parts of the world (Malla, 1997; Paillet et al., 2010; Rawat, Tewar, & Rawat, 2011; Måren, Bhattarai, & Chaudhary, 2014). Nevertheless, the survival of many species that depend on natural forest habitat remains compromised (Bengtsson, Nilsson, Franc, & Menozzi, 2000; Acharya, 2004; Shrestha, Shrestha, & Shrestha, 2010).

In recent decades, substantial investments have been made to initiate forest management through community participation, called community forestry (Brown, Malla, Schreckenberg, & Springate-Baginski, 2002; Blaikie, 2006; Charnley & Poe, 2007; Bowler et al., 2011; Soltani & Eid, 2013; Pinyopusarerk, Tran, & Tran, 2014). In the process, a dramatic shift from state-centric toward participatory, people-centric natural resource management has occurred (Bray et al., 2003). Because of increased community participation in forest management and conservation, deforestation rates have not only slowed in some parts of the world since the 1990s (Charnley & Poe, 2007; Porter-Bolland et al., 2012), but the forest cover has also increased in some regions (Varughese & Ostrom, 2001; Gautam, Shivakoti, & Webb, 2004). Yet, there is still a debate over the ecological effects of participatory forest management, for example, on forest structure and diversity (Paillet et al., 2010; Rawat et al., 2011; Måren et al., 2014). In this study, we examined whether the participatory forest management (community forestry) in Nepal is resulting in ecologically healthier forests (i.e., increased tree density, basal area, and diversity) relative to the forests managed through the country's government agencies.

Community forestry in Nepal is one of the highly successful stories among developing nations in terms of improving forest cover and rural livelihoods and empowering the local community (Acharya, 2002; Springate-Baginski, Dev, Yadav, & Soussan, 2003; Thoms, 2008; Gurung et al., 2013; Adhikari, Kingi, & Ganesh, 2014; Birch et al., 2014). Since the initiation of the Community Forestry Act of 1979 and subsequent revision in 1993, forest cover has increased in different parts of the country (e.g., Varughese & Ostrom, 2001; Gautam, Shivakoti, & Webb, 2004; Niraula, Gilani, Pokharel, & Qamer, 2013). Positive effects on forest cover and ecosystem services have also been reported through qualitative studies from middle mountains of the country (Carter & Gilmour, 1989; Gautam, Webb, & Eiumnoh, 2002; Niraula, Gilani, Pokharel, & Qamer, 2013). For instance, Carter and Gilmour (1989) compared tree cover in 1964 (using air photographs) and again in 1988 (using a ground survey) on private and community forests across two hilly districts in central Nepal and found a two- to threefold increase in tree cover over the 24-yr period. A recent study in the mid-hills of Nepal also verifies the success of community-based forest management in increasing forest cover (Niraula et al., 2013). However, systematic and quantitative studies that evaluate the effects of participatory forest-management practices on forest stand structure and diversity are limited (Poudel, Fuwa, & Otsuka, 2014). In addition, the findings about the forest structure and composition are not consistent. For instance, species richness in community-managed forests may be higher or lower than government-managed forests for various reasons (Roberts & Gilliam, 1995; Måren et al., 2014).

Evaluation of existing ecological parameters is one of the best methods to investigate the effects of different management practices on the composition and diversity of forest vegetation (Barbour, Fernau, Benayas, Jurjavcic, & Royce, 1998; Rawat et al., 2011; Måren et al., 2014). Additionally, comparing forest stands that are in proximity and share similar topographic factors provide the ideal conditions for assessing the effects of different management practices on forest structure and diversity (Sitzia et al., 2012). Understanding the impacts of different management systems on forest composition and diversity may offer evidence to support management decisions that will eventually improve the ecological health of the forests, increase the flow of ecosystem services, and support livelihoods in rural societies that are dependent on forest resources. A healthy forest is likely to have increased carbon sequestration and resilient to the climate change (Pearce, 2001; Malhi et al., 2008).

Here, by sampling the overstory (trees, shrubs and saplings, and woody climbers) and understory (herbs and woody seedlings) of a community-managed forest and a government-managed forest from a lowland plain ("Terai") of eastern Nepal, we asked the following question: Does a people-centric management system with the regulated use of resources result in more diverse forest than a government-managed forest? To answer this question, we performed a quantitative investigation of the plant community composition and species diversity within these forests and compared some ecological parameters between them. Specific objectives were to (a) measure the current patterns of forest vegetation structure and diversity within community- and government-managed forests; (b) investigate any differences in structure and diversity between the forests; and (c) evaluate the utility of community participation in forest-biodiversity conservation.

METHODS

Study Site

The study was carried out in the Udayapur District of eastern Nepal (26° 39'–27° 11' N, 86° 9'–87° 10' E; Figure 1). Climate is subtropical with a maximum average temperature reaching up to 32.5°C in the summer (June to August) and the minimum average temperature falling to 12.1°C in February (Government of Nepal, 2010). Mean annual precipitation is 1,600 mm yr^{-1}; and precipitation is mainly concentrated during the monsoon season (mid-June to mid-September; Government of Nepal, 2010). The soils are nonsticky sandy loam, typical of the low-lying Terai region (Paudel & Sah, 2003).

Two neighboring forests, a community-managed forest (hereafter, community forest) and a government-managed forest (hereafter, government forest), were selected for this study (Figure 1). The two forest stands are in the altitudinal range of 210 m to 250 m asl (above sea level) and lie in more or less plain areas with an average slope of 10°. In 1993, some patches of natural forest were handed over to the local community to be managed by forest user groups and utilized in a restricted manner. The two selected forests are in close proximity and share comparable topographic, edaphic, and climate conditions. Thus, we assumed that only the management regimes are different between the forests. The government forest has been managed by the District Forest Office with few to no restrictions on local communities regarding the exploitation of forest resources such as collection of fodder, firewood, and cattle grazing. However, the District Forest Office regulates and monitors the illegal logging and timber harvest in the forest. Forest user groups are allowed to utilize forest resources from the community forest through selective harvest that is limited to biannual 1-week periods. Such harvests primarily come through thinning, pruning, weeding,

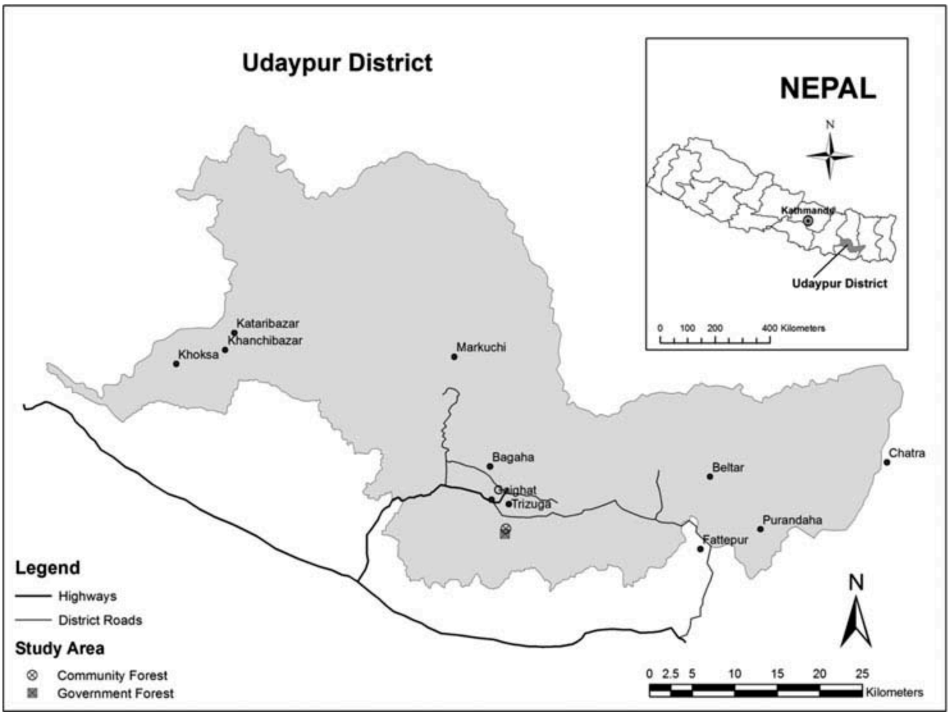

FIGURE 1 Map showing Udaypur District and the location of the study area.

and selective logging. Meanwhile, local people tend to rely on the government forest for their daily needs (e.g., fodder, firewood, hay, timber, and others). The overstory forest vegetation of the study area was dominated by the *Shorea robusta* Geartn.f., a typical hardwood and economically important tree species, which regenerates naturally in the Terai, Nepal (Stainton, 1972).

Vegetation Sampling

Vegetation data were collected in 30 randomly selected sampling units within each forest stand following the methods described in the International Forestry Resources and Institutions (IFRI) Research Program, Indiana University (IFRI, 1996). Each sampling unit was composed of three concentric circular plots of 10-m, 3-m, and 1-m radius, respectively. Ten-meter radius plots were used to sample all trees and woody climbers—diameter at breast height (DBH) $\geq$ 10 cm; hereafter, tree layer. Three-meter radius plots were used to sample shrubs, saplings, and woody climbers (DBH $\geq$ 2.5 and $<$ 10 cm; hereafter, shrub layer). In each of these circular plots, we recorded presence of species, number of individuals of each species, and DBH of each individual using diameter tape. Count of trees, shrubs, saplings, and woody climbers and DBH data were used to calculate density and basal area per hectare, respectively. In each 1-m radius plot, we recorded the presence, number of individuals and percent cover of all woody seedling species (DBH < 2.5 cm), and presence and percent cover of herbaceous species (hereafter, woody seedlings and herbs are referred to as ground layer). All plant species were identified in the field following Polunin and Stainton (1984). Species not identified in the field were taken to the National Herbarium and Tribhuvan University Central Herbarium (TUCH), Kathmandu, Nepal and identified to species. Species nomenclature follows Press, Shrestha, and Sutton (2000) and The Plant List (2010).

Vegetation sampling was carried out in the spring of 1999. While a snapshot in time, this study gathered the important data from community- and government-managed forests of eastern Nepal. Thus, the findings and conclusions of this study should be broadly applicable to other places with similar management schemes.

Data Analysis

Nonmetric multidimensional scaling (NMDS) ordination based on the Bray–Curtis dissimilarity index was used to assess the differences in overstory (trees, shrubs and saplings, and woody climbers, combined together) and understory (ground layer) species composition between community and government forests. NMDS is a nonparametric multivariate ordination technique, which does not assume multivariate normality and is robust to the data sets with a large number of zero values (Minchin, 1987). Using permutational analysis of multivariate dispersion (PERMDISP; Anderson, 2006), we measured a degree of dispersion of sampling points within an ordination space in each forest as mean distance from an individual sampling unit to the group centroid. Differences in the overall community composition between two forests for each category (overstory and understory) were examined statistically using analysis of similarities (ANOSIM). ANOSIM is a nonparametric procedure based on rank-similarities among all sites that operates directly on a dissimilarity matrix, and a significance test is performed by permutations. ANOSIM gives the test statistic R value (between 0 and 1) and is an absolute measure of how separate the groups are from each other. To determine the most dominant species within the tree layer in each forest type, we calculated proportional distribution of species as: number of individuals of a species within the community/total number of individuals of all species in a community.

Species diversity (Shannon's diversity index), species differentiation or compositional turnover between plots (Whittaker's β-diversity), evenness, and community species richness (gamma [γ] diversity) for three different categories (tree, shrub, and ground layers) in each forest type were determined. We also estimated the number of species within a plot (alpha [α] diversity) in each category and compared the mean plot values between two forests using a two-sample t-test. Beta diversity was calculated as:

$$\beta = (\gamma/\bar{\alpha})$$

We also compared Shannon's species diversity, stem density, and basal area at the plot scale between two forests using a *t*-test.

Except Shannon's diversity index and evenness, which were determined using EstimateS (Colwell, 2013), all statistical analyses were performed using R software packages (R Development Core Team, 2008). NMDS ordination was performed using the "MASS" package (Oksanen, 2013). The function "adonis" in the package "vegan" (Oksanen, 2013) was used to perform ANOSIM.

RESULTS

Forest Community and Stand Structure

In total in both forests, 46 species were identified in the overstory; 63 species were identified in the understory. While *Shorea robusta* alone was the most abundant and dominant species within the tree layer in the community forest (Figure 2a), both *Shorea robusta* and *Terminalia myriocarpa* Van Heurck & Mull. Arg. were codominant in the government forest (Figure 2b).

Overall, total tree density was greater in the government forest (243 stems/ha) than in the community forest (227 stems/ha). Likewise, plot level tree density also was relatively high in the government forest (Table 1),

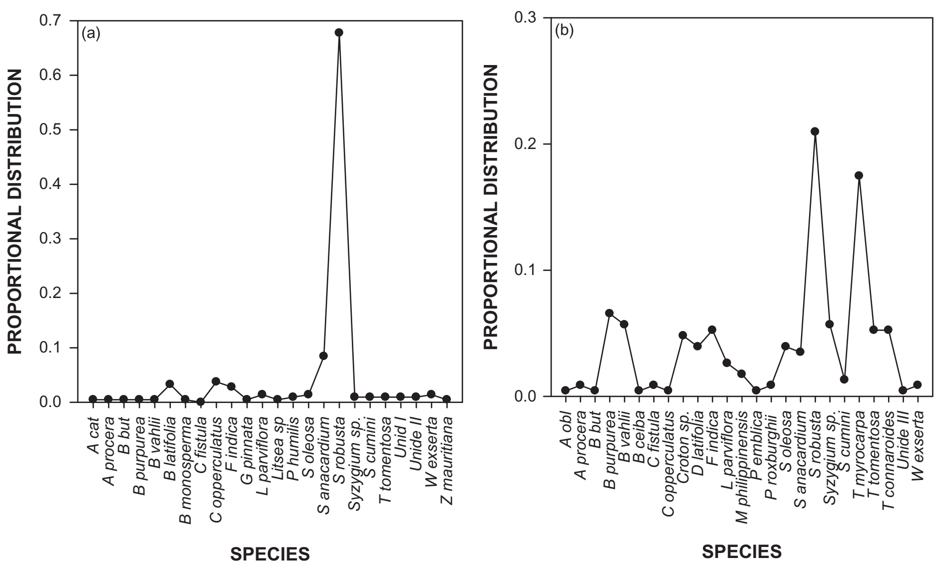

FIGURE 2 Proportional distribution of trees in two types of forests: community managed (a) and government managed (b).

TABLE 1 Forest Structural Parameters (Trees, Shrub, and Ground Layers) of Two Types of Forests

	Tree layer		Shrub layer		Ground (seedling) layer	
Parameters	Community forest	Government forest	Community forest	Government forest	Community forest	Government forest
Community species richness	21	25	40	30	50	41
Community: Shannon's index (*H′*)	1.23	2.47	2.92	2.95	2.00	1.98
Evenness	0.40	0.76	0.79	0.86	0.51	0.53
Community: Beta diversity (Whittaker's)	7.50	4.77	5.02	3.21	6.32	5.30
Mean (± *SD*) stem density (stem/plot)	7.13 (± 0.82)	7.63 (± 0.36)	38.43 (± 2.55)	32.43 (± 1.67)	25.3 (± 0.38)	18.4 (± 0.24)
Mean (± *SD*) stem density (stem/hectare)	227.17 (± 26.27)	243.09 (± 11.36)	13,599.91 (± 902.6)	11,476.76 (± 586.6)	80,573.25 (± 11,981.7)	58,598.73 (± 7,429.6)
Mean (± *SD*) basal area (m^2/ha)	34.89 (± 1.92)	50.49 (± 2.49)	15.31 (± 0.37)	14.6 (± 0.32)		

but the difference between the two forest types was not statistically significant ($p > .05$). The tree layer in the community forest was dominated by a single species, *Shorea robusta*, which contributed 68% of the total stem density (153.0 stems/ha). In contrast, in the government forest, *S. robusta*, with a density of 51.0 stems/ha (Table A1), contributes only 21% of the total density, followed by *T. myriocarpa*, contributing 18% (42.5 stems/ha; Table A1). The government forest also had a higher tree basal area (50.5 m^2/ha) relative to the community forest (34.9 m^2/ha; Table 1). Within the shrub layer, the community forest had greater total and plot level stem density relative to the government forest (Table 1), and *S. robusta* had the highest plot level stem density in both the community (15.6 stems/plot) and government (10.9 stems/plot) forests followed by *Phoenix humilis* Royle ex Becc. & Hook. f. (10 and 3.8 stems/plot, respectively; Table A2). Size class distributions among trees, shrubs and saplings, and seedlings suggest that the community forest harbors a higher number of seedlings (DBH < 2.5 cm; Figure 3) than the government forest. In contrast, a greater number of large-sized individual trees (DBH > 30 cm) are present in the government forest (Figure 3).

Differences in pattern of dispersion of sampling units in both the forests and for both overstory and understory are depicted in the NMDS ordination (stress = 0.17, Figure 4a; and stress = 0.19, Figure 4b, respectively). Results suggest that community dispersion was higher in the community

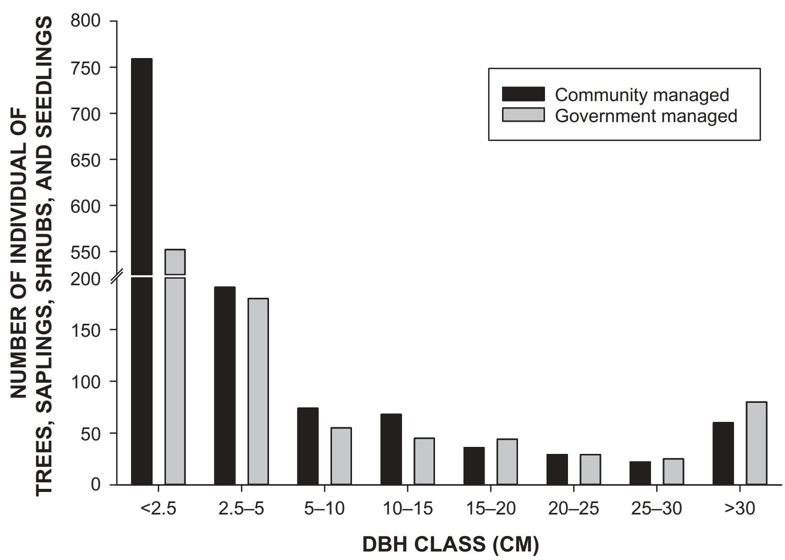

FIGURE 3 Number of trees and shrub-saplings of the two types of forests (community managed and government managed) in different DBH classes.

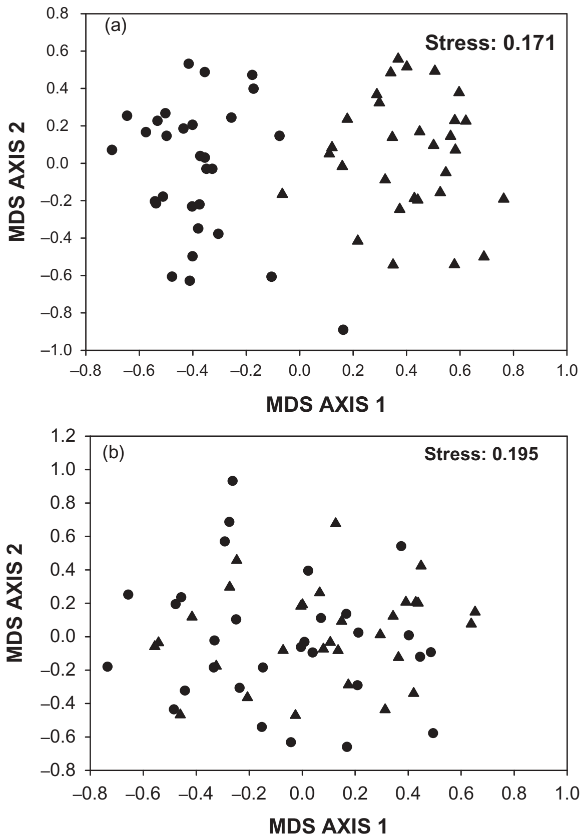

FIGURE 4 Three-dimensional NMDS ordinations depicting plant assemblages in the overstory—trees and shrub-saplings (a) and understory—herbs and seedlings (b). Each point represents the composition of a community (filled circles: community-managed forest; filled triangles: government-managed plots) in multidimensional space. For clarity, only Axes 1 and 2 in ordination space are shown.

forest for both overstory and understory (mean distance to the group centroid of sampling unit: 0.47 and 0.55, respectively) than in the government forest (mean distance to the group centroid of sampling unit: 0.44 and 0.45, respectively). Overstory plant assemblages showed a clear separation in the community forest with the government forest, while the separation was less evident for understory plant assemblages (ANOSIM: $R^2 = .24$, $p = .001$, Figure 4a; and ANOSIM: $R^2 = .091$, $p = .01$, Figure 4b, respectively).

Species Richness and Diversity

The tree layer plant community was much more diverse in the government forest than in the community forest. Both the gamma diversity and Shannon's species diversity were higher in the government forest than in the community

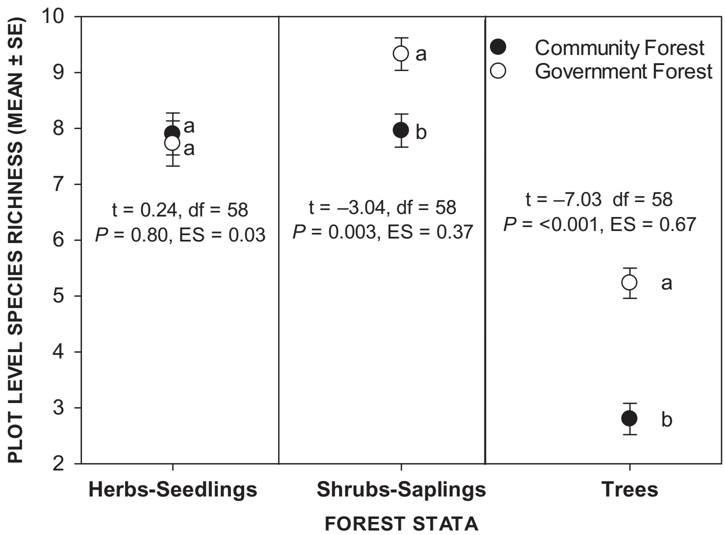

FIGURE 5 Plot-level species richness for herbs-seedlings, shrubs-saplings, and trees of the two types of forests (community managed and government managed). Means accompanied by different letter were different from one another (α = .05). Note: ES value represents the effect-size.

forest (Table 1). Meanwhile, community level species richness in both the shrub and ground-layer vegetation was relatively high in the community forest (Table 1). Alpha diversity in both tree and shrub layers was significantly higher in the government forest than in the community forest (Figure 5). However, no significant difference was found in seedlings and herbaceous species richness between the two forests (Figure 5). Tree and shrub and sapling species evenness was higher for the government forest. However, seedlings and herb species evenness was not different between the two forests (Table 1).

DISCUSSION

Comparative studies of forest vegetation under different management practices provide insights into the relative importance of different management practices that influence forest stand structure and diversity (Roberts & Gilliam, 1995; Rawat et al., 2011; Måren et al., 2014; Poudel et al., 2014). The forest communities we studied here exhibit the differential effects of two kinds of management practices. While the community-based forest management produced positive effects on some structural parameters (i.e., improved regeneration of tree seedlings and higher community species richness for the shrub and herb layers), the government forest nevertheless maintained greater tree density, basal area, and plot-level species richness.

This is an important finding because community- and government-managed forests in developing countries, including Nepal, are lacking quantitative assessment of plant community responses to different management systems. Previous studies that mainly compared the forest structure and species diversity between managed (clear-cut, selective logging, or plantation) versus natural or untouched forest stands documented the conflicting results regarding how management influences the plant species composition and diversity (Battles, Shlisky, Barrett, Heald, & Allen-Diaz, 2001; Paillet et al., 2010; Shahabuddin & Rao, 2010; Måren et al., 2014). It has been suggested that the active management might decrease plant species diversity because the historic (natural) disturbance regime required to uphold maximum diversity may not be maintained under guided management practices (Roberts & Gilliam, 1995). Alternatively, local communities involved in managing forest resources may be more interested in a few sets of multipurpose, fast-growing, and economically important species (e.g., timber species), permitting them to grow while removing slow growing nontimber tree species through pruning, weeding, and selective thinning (Saha, 2003; Shrestha, Shrestha, & Shrestha, 2010; Pandey, Maraseni, Cockfield, & Gerhard, 2014; Poudel et al., 2014). In this study, the complex suites of differing management actions have differential effects on the forest structure and composition in these two forests.

Species Composition and Stand Structure

We found a significant difference in vegetation composition between the two forests, specifically for overstory layer. Species composition was relatively more heterogeneous—i.e., community dispersion is greater—in the community forest than in the government forest. This can be explained by either higher habitat heterogeneity in managed forests that produce more diverse plant assemblages compared to the government forest (Siitonen, 2001) or the homogenization effect of anthropogenic disturbance in the government forest (Mouquet & Loreau, 2003). Since both the forests possess relatively similar environmental conditions, and the soil parameters were not different between these forests (Paudel & Sah, 2003), differential management practices might have a greater influence on overstory compositional differences. Some level of disturbances in the government forest may increase the dispersal resulting in homogeneity within forest plots (low community dispersion). Conversely, within the community forest, selective thinning and pruning might increase the heterogeneity in microenvironmental conditions such as differences in the availability of light (Decocq et al., 2004) may increase the compositional dissimilarity among forest plots (Kouba, Martínez-García, de Frutos, & Alados, 2014; Paudel & Vetaas, 2014).

Researchers have suggested that the community attributes such as higher basal area and tree density are indicative of a mature forest (Saha, 2003;

Banda, Schwartz, & Caro, 2006; Timilsina, Ross, & Heinen, 2007). Based on this statement, our results show that the government forest is relatively more mature than the community forest, a situation that persists despite the utilization pressure from nearby human settlements. Total basal area recorded for the government and community forests are within the range recorded for community forests and natural forest (37.2–59.6 m^2 ha^{-1}), dominated by *Shorea robusta*, in the Siwalik region of central Nepal (Shrestha, Karmacharya, & Jha, 2000). However, some other studies have reported much lower basal area compared to ours (e.g., Timilsina et al., 2007; Sapkota, Tigabu, & Odén, 2009). The higher basal area reported in our study is likely resulted from a good number of mid- to large-sized trees (Figure 3). In particular, the higher basal area observed in the government forest compared to the community forest is due to the presence of a greater number of large-sized trees (> 30 cm DBH; Figure 3) in the former. Our results also suggest that the community forest enjoys recently improved regeneration, resulting in a substantially higher number of seedlings with DBH < 2.5 cm (Figure 3). Prior to handing over the management responsibilities to the forest user groups (here local community), the community forest was in a much more degraded state compared to the government forest (the authors' personal communication with local forest user groups). The community forest is located close to the human settlements (≈ 500 m) and was used extensively by new settlers who had moved into the area from hilly regions in late 1970s. The proximity to the settlement has been an important driver of forest degradation in Nepal (Måren et al., 2014). Illegal cut down of towering sal (*Shorea robusta*) forest in the inner Terai like Udayapur by migrants from the hills was common throughout the country after 1960 until conservation efforts were started in the early 1990s (Subedi, 1991). This implies that the community forest may still be in a successional stage and individual trees have not had enough time to reach maturity. Additionally, the dominance of the *S. robusta* tree in the community forest and codominance of *S. robusta* and *T. myriocarpa* in the government forest may also produce a compositional difference between the forests. The preferential thinning in favor of *S. robusta* may have caused the dominance of this species in the community forest. We argued that the historical state of the two forests in combination with the citizens' preference for particular species within the community forest, and other unrecorded abiotic and biotic conditions may be responsible for the observed compositional differences between community and government forests. Nonetheless, we recognized that additional studies covering multiple forests from multiple regions may be helpful to identify potential factors that drive community composition in the forests growing under different management systems.

Species Richness and Diversity

Our results support the findings of Økland, Rydgren, Økland, Storaunet, & Rolstad (2003), suggesting that active forest management may not necessarily decrease overall diversity and species richness of all ecological and functional groups in the forest. Also, forest-management practices are likely to have differential effects on different functional and ecological groups (Paillet et al., 2010), and active management may provide opportunities for diverse species assemblages to coexist and increase overall community species richness. Relatively high community species richness (except for the tree layer) and beta diversity reported in the community forest suggest that people-centric forest management plays a crucial role in both increasing habitat heterogeneity and biodiversity conservation (Bruner, Gullison, Rice, & Da Fonseca, 2001; Bajracharya, Furley, & Newton, 2005). Researchers have reported a significantly higher species diversity in conserved/managed areas relative to outside neighboring unmanaged areas (Bajracharya et al., 2005; Måren et al., 2014). These results can be related to the patterns of forest resources used by local communities, management regulations imposed by local conservation agencies and forest user groups, and selective thinning and pruning process in the community forests (Acharya, Goutam, Acharya, & Gautam, 2006). Especially selection filtering from the species pools that potentially replace nontimber species with timber species may widen the gaps within forests, increase resource opportunities, and provide a unique opportunity to grow a variety of species (Saha, 2003). This may result in an increase in the community-level species richness and beta diversity. Very recently, Boch et al. (2013) suggested that the disturbances by management may increase plant species richness. These argument are supported by the greater community-level species richness for shrub and herb layers and the higher beta diversity in the community forest reported in this study.

Higher plot-level species richness (alpha diversity), Shannon's diversity index, and evenness for trees and shrubs and saplings in the government forest compared to the community forest suggest the complex effects of forest management practices on species richness and diversity at plot to stand levels (Decocq et al., 2004). For example, selective thinning and pruning in the community forest may increase the heterogeneity in habitats, enhance accessibility to resources (e.g., light, soil moisture, and nutrients), and subsequently support a greater number of understory species (Decocq et al., 2004). On the other hand, the thinning and weeding process might have resulted in removing some of undesired (nontimber) species from the plot, subsequently reducing the plot-level species richness. For instance, among trees and shrubs and saplings, the community forest has 67% of individual plants belonging to important timber species, *S. robusta*. The replacement of nontimber tree species by one or two preferred timber tree species during forest management practices may facilitate recruitment of the unique suite of rare species, thus decrease evenness (Saha, 2003). Conversely, a moderate level of disturbance in the government forest in the form of cattle grazing, fodder collection, and anthropogenic and animal movements likely increase the plot-level species richness (Hobbs & Huenneke, 1992). Since we sampled forests with contrasting management practices from one specific location, additional studies are needed to show whether differences in vegetation composition, species richness, and diversity between community-managed forests and the forests administered by federal agencies may serve as indicators of the impacts of people-centric management practices on forest structure in different climatic and social settings across the developing world.

MANAGEMENT IMPLICATIONS

The improved regeneration and greater community-level species richness for shrub and herb layers suggests that active management may preserve the diversity and richness of understory species while fulfilling the needs of local communities. Thus, community participation may be an important factor in forest management and conservation. However, active management sometime produces negative effects on tree stand density and basal area because of forest users' preference in a few sets of economically important species, such as *Shorea robusta* in our case. This underscores the need for better management schemes, education in forest management, and shifts in prevalent passive forest management strategy (Acharya, 2004; Acharya et al., 2006; Shrestha, Shrestha, & Shrestha, 2010). Discouraging the development of monoculture and promoting the recruitment of multiple tree species possibly maintain a sustainable forestry and conserve forest biodiversity (Pandey, Maraseni, et al., 2014). Although development of a monoculture can have economic advantages (for example, *S. robusta* is one of the most important timber species in Nepal), such monocultures do not necessarily ensure sustainability (Carnus et al., 2006). Thus, while encouraging community participation in forest management, certain regulations (e.g., maintain multiple species during thinning and pruning processes; see, Acharya, 2004; Acharya et al., 2006) and awareness programs should be placed, which would provide a regeneration ground for a multiple species and maintain the diversity in community-managed forests. Managers need to pay more attention to forest biodiversity issues supported by sound scientific studies that indicate that forest biodiversity can improve ecosystem functioning and support livelihoods. Improved regeneration, increased forest productivity, and enhanced forest diversity increase the carbon sink that is necessary to tackle burgeoning carbon emissions from both the industrialized and the fast-developing world.

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APPENDIX

TABLE A1 Trees and Woody Climbers (DBH ≥10 cm) Species with Stem Density from the Community Forests (CF) and the Government Forests (GF)

Species	CF Stems/ha	GF Stems/ha
Tree layer		
Acacia catecheu (L.F.) Willd.	1.1	—
Acer blongum Wall. ex Dc.	—	1.1
Albizia procera (Roxb.) Benth.	1.1	2.1
Bassia butyracea Roxb.	1.1	1.1
Bauhinia purpurea L.	1.1	15.9
Bauhinia vahlii Wight & Arn.	1.1	13.8
Bombax ceiba L.	—	1.1
Buchnania latifolia Roxb.	7.4	—
Butea monosperma (Lam.) Kuntz	1.1	—
Cassia fistula L.	—	2.1
Cleistocalyx opperculatus (Roxb.) Merr. & Perry	8.5	1.1
Croton sp. L.	—	11.7
Dalbergia latifolia Roxb.	—	9.6
Flacourtia indica (Burm.f) Merr.	6.4	12.7
Garuga pinnata Roxb.	1.1	—
Lagerstroemia parviflora Roxb.	3.2	6.4
Litsea sp. Lam. (nom.cons.)	1.1	—
Mallotus philippinensis (Lam.) Muell.-Arg.	—	4.2
Phyllanthus emblica L.	—	1.1
Phoenix humilis Royle, nom.	2.1	—
Putranjiva roxburghii Wall.	—	2.1
Schleichera oleosa (Lour.) Oken	3.2	9.6
Semecarpus anacardium L.f.	19.1	8.5
Shorea robusta Geartn.	153.9	51.0
Syzygium sp. Geartn. (nom.cons.)	2.1	13.8
Syzygium cumini L.	2.1	3.2
Terminalia myrocarpa Heurck & Muell-Arg.	—	42.5
Terminalia tomentosa Roxb.	2.1	12.7
Trichilia connaroides (Wight & Arn.) Bentv.	—	12.7
Unidentified I	2.1	—
Unidentified II	2.1	—
Unidentified III	—	1.1
Wendlandia exserta Roxb.	3.2	2.1
Zizyphus mauritiana Lam.	1.1	—

TABLE A2 Shrubs, Saplings, and Woody Climbers (DBH $\geq$ 2.5 and $\leq$ 10 cm) with Stem Density from the Community Forests (CF) and the Government Forests (GF)

Species	CF Stems/ha	GF Stems/ha
Shrub layer		
Acacia catecheu (L.F.) Willd.	11.8	—
Acer oblongum Wall. ex DC.	—	129.7
Albizia procera (Roxb.) Benth.	235.9	94.4
Ardisia solanacea Roxb.	—	235.9
Bassia butyracea Roxb.	11.8	11.8
Bauhinia purpurea L.	118.0	377.4
Bauhinia vahlii Wight & Arn.	35.4	837.5
Bombax ceiba L.	—	11.8
Buchnania latifolia Roxb.	672.3	188.7
Butea monosperma (Lam.) Kuntz	35.4	—
Callicarpa macrophylla Vahl	11.8	—
Careya arborea Roxb.	35.4	—
Cassia fistula L.	23.6	23.6
Celastrus paniculatus Willd.	35.4	—
Cleistocalyx opperculatus (Roxb.) Merr. & Perry	318.5	82.6
Colebrookea oppositifolia Sm.	11.8	—
Cornus oblonga (Wall.) Sojak	283.1	—
Croton sp. L.	212.3	1073.4
Dalbergia latifolia Roxb.	11.8	306.7
Dendrocalamus strictus (Roxb.) Nees	—	141.5
Dillenia pentagyna Roxb.	11.8	—
Flacourtia graveolus	35.4	—
Flacourtia indica (Burm.f) Merr.	129.7	578.0
Garuga pinnata Roxb.	11.8	—
Glycosmis pentaphylla (Retz.) Correa	59.0	—
Lagerstroemia parviflora Roxb.	35.4	389.2
Litsea sp. Lam. (nom.cons.)	82.6	—
Mallotus philippinensis (Lam.) Muell.-Arg.	—	94.4
Melastoma malabathricum L.	59.0	—
Melastoma normale D. Don	188.7	—
Mimosa rubicaulis Lam.	47.2	11.8
Myrsine semiserrata Wall. in Roxb.	70.8	—
Phoenix humilis Royle, nom.	3538.6	1332.9
Phyllanthus emblica L.	330.3	35.4
Putranjiva roxburghii Wall.	—	23.6
Randia tetrasperma (Roxb.) Benth. & Hook. f. ex. Brandis	70.8	47.2
Schleichera oleosa (Lour.) Oken	35.4	118.0
Semecarpus anacardium L.f.	601.6	118.0
Shorea robusta Geartn.	5508.4	3845.2
*Spatholobus parviflorus (*Roxb.) Kuntze	11.8	—
Syzygium cumini. Geartn. (nom.cons.)	401.0	436.4
Terminalia myrocarpa Heurck & Muell-Arg.	—	471.8
Terminalia tomentosa Roxb.	23.6	153.3
Thespesia lampas (Cav.) Dalz. et Gibs.	23.6	—
Trichilia connaroides (Wight & Arn.) Bentv.	—	141.5
Unidentified I	23.6	—
Unidentified II	—	11.8
Unidentified III	23.6	—
Wendlandia exserta Roxb.	153.3	82.6
Woodfordia fruticosa (L.) Kurz	35.4	70.8
Zizyphus mauritiana Lam.	23.6	—