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The vegetation status of regrowth forests in abandoned farmlands in the subtropical forest of Eastern Bhutan Himalaya

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ABSTRACT: Many regrowth forests have occurred in abandoned farmlands all over the world. The regrowth forests of 20–60 years old on abandoned farmlands and old-growth forests in a subtropical forest of Eastern Bhutan Himalaya are studied and their floristic and structural compositions are compared. A total of 64 and 43 plots were sampled in regrowth forests and old-growth forests respectively based on stratified random sampling method. Species richness of woody plants and predominant ground covers in regrowth forests is lower than old-growth forests though few of them show higher species richness in woody stems. Species composition of trees (≥5cm DBH) in younger regrowth forests (<30 yrs.) and older regrowth forests (>30 yrs.) show 10% and 42–51% of Bray Curtis similarity to their adjacent old-growth forests respectively. A total of 53% of trees and 63% of large saplings/shrubs (≤4cm DBH and ≥1m height) are shared species between two forest types. The top dominant species such as *Betula alnoides* Buch.-Ham. ex D.Don, *Lithocarpus fenestratus* (Roxb.) Rehder, *Schima wallichi* Choisy, and *Itoa oreintalis* Hemsl. in regrowth forests make distinct patches different from old-growth forests. Species composition of trees in regrowth forests retains the variation along the elevation gradient like old-growth forests. Land-use history of the regrowth forests has also affected the regeneration of forest. Basal area and density of trees in regrowth forests are close or even higher than old-growth forests. The regrowth forests reveal robust recovery of old-growth species and growth of unique species.

KEY WORDS: Abandoned farmlands, Bhutan Himalaya, old-growth forests, regrowth forests, subtropical forest.

INTRODUCTION

Previous land-use areas or abandoned lands have contributed to the recovery of forest cover by natural regrowth forests in several parts of the world (Aide *et al.*, 2000; Bhat *et al.*, 2001; Martin *et al.*, 2004; Ruiz *et al.*, 2005; Romero-Díaz *et al.*, 2016). Several studies suggested that regrowth forests in the previous land use areas help to restore natural vegetation and promoted the development of native forests (Zhang *et al.*, 2010; Liu *et al.*, 2014; McNamara *et al.*, 2012). The regeneration potential of the disturbed area is contributed by factors such as the presence of old-growth forests nearby (Endress and Chinea, 2001; Martin *et al.*, 2004; Rolim *et al.*, 2017) and soil seed bank (Omomoh *et al.*, 2019). Moreover, the previous land use types and intensity of abandoned lands have influenced the floristic composition and structure of the regrowth forests (Rivera *et al.*, 1999; Pascarella *et al.*, 2000; Colón and Lugo, 2006). Nevertheless, the regrowth forests indicate closer species composition to the old-growth forests gradually towards the older stage of succession along the chronosequence of abandonment of land-use areas (Pascarella *et al.*, 2000; Rivera *et al.*, 2000; Gehring *et al.*, 2005; Ruiz *et al.*, 2005; Sampaio *et al.*, 2007; Baniya *et al.*, 2009).

The rapid socio-economic development, improved agricultural practices and a gradual change in policy on traditional farming systems (slash burn agriculture) in Bhutan have resulted in the abandonment of farmlands, which benefited in the recovery of vegetation (Gilani *et al.*, 2015; Bruggeman *et al.*, 2016; Siebert *et al.*, 2014). The above factor is also claimed to be one of the factors to increase its net forest cover since the 1990s and during the 2000s (Gilani *et al.*, 2015; Bruggeman *et al.*, 2016). Prominent forest recoveries in the abandoned farmlands are mostly observed in remote areas of the sub-tropical zone where traditional farming of slash burn and dryland cultivation had been widely practiced (Ohsawa, 1991; Siebert *et al.*, 2014). Bhutan's forest cover has reached 71% of the total area, which is much higher than her constitutional mandate of maintaining minimum forest cover of 60% for all time (Department of Forest and Park Services, 2016). Generally, abandoned farmlands are smaller in size and scattered due to its small population and geographical features such as steep slopes, cliffs, and high hills. Although slash burn was widely practiced, it was practiced in confined areas in patches preventing to cut whole forested areas due to culturally driven reason, thus it has also created the mosaic of the structure along old-growth forest (Siebert *et al.*, 2014).

Although, significant vegetation development took place after the radical land-use change over the past few decades in Bhutan, the floristic composition, species richness, and structure of the vegetation derived from abandoned farmlands are least studied. The recent studies on regenerations in Bhutan are only focused on post-disturbance of selective logging broad-leaved forests (Covey *et al.*, 2015; Tenzin and Hasenauer, 2016)

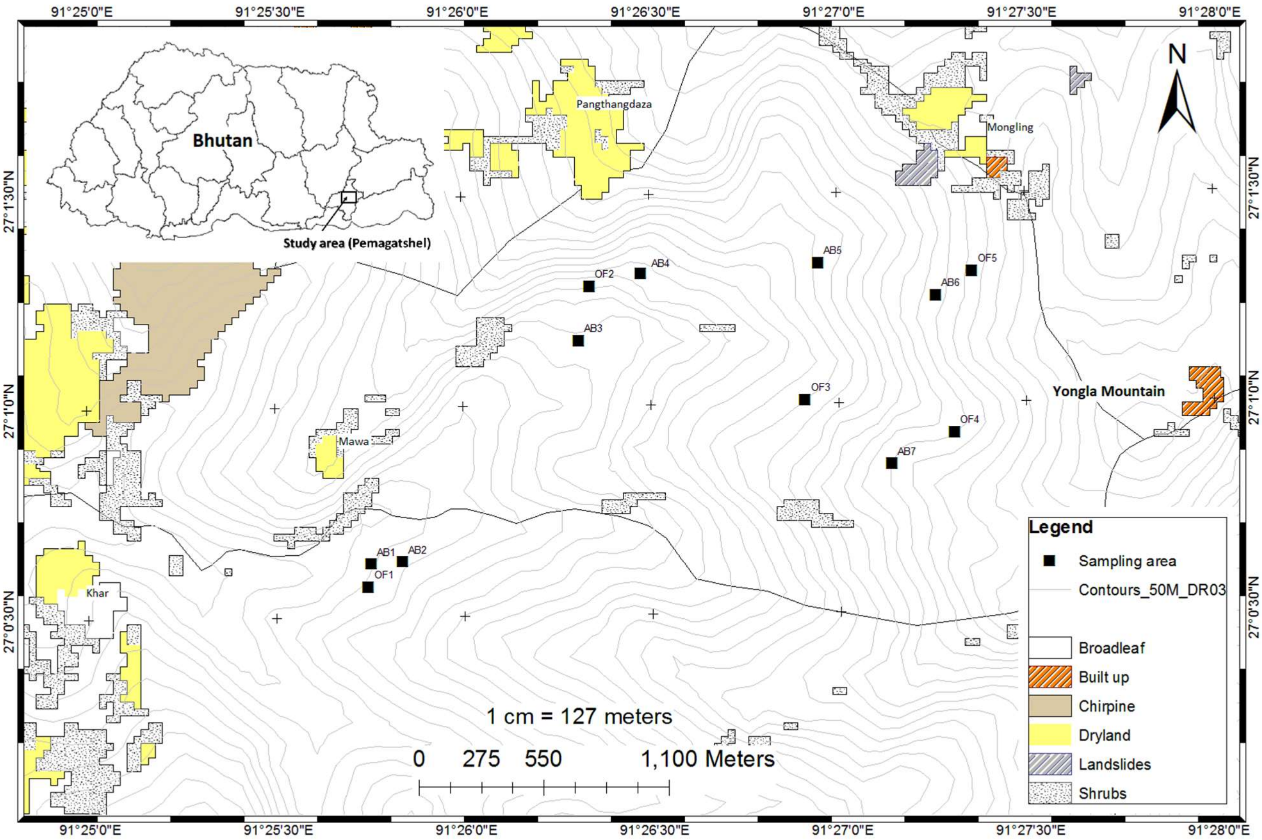

Fig. 1. The study area in the west-facing slope of Yongla Mountain showing the seven abandoned farmlands/regrowth forests: AB1 (1120–1130 m), AB2 (1120–1165 m), AB3 (1315–1329 m), AB4 (1360–1400 m), AB5 (1673–1700 m), AB6 (1970–2000 m), AB7 (1987–2046 m) and five old-growth forests:OF1 (1120–1157 m), OF2 (1329–1380 m), OF3 (1673–1690 m), OF4 (1990–2016 m), OF5 (2020–2055 m). The proportion of the landscapes in the map are based on the land use and land cover of Bhutan by the Ministry of Agriculture and Forestry (2016)

where there is no alteration of soil. Moreover, secluded and undisturbed land-use areas since the abandonment in the vicinity of old-growth forests in the lower montane region are underrepresented in other similar studies. Therefore, the present study focused on the representative of such regrowth forests on abandoned slash burn and dryland cultivations which are approximately 20–60 years since the abandonment. Species composition of these regrowth forests is expected to show fast recovery and high similarity to that of the old-growth forest. Land-use history has likely affected the floristic composition and structure of the regrowth forests beside the elevation gradient. Therefore, the study examines the floristic composition and structure of both the regrowth forests adjacent old-growth forests to answer the following questions: 1) What is the similarity of the floristic and structural composition of regrowth forests and old-growth forests? 2) Are there any species lacking to recovered or found only in regrowth forests? 3) Do the elevation and land-use history (age and type of land use) of regrowth forests affect the floristic and structural composition of regrowth forests? The study might contribute to the knowledge of natural recovery of vegetation and its implication in forest restoration and conservation of biodiversity as well.

MATERIALS AND METHODS

Study area

Bhutan has broadly three zones of vegetation: Alpine (4000m and above), temperate zone (2000–4000m), and subtropical zone (150–2000m). The study area falls in the subtropical zone in Pemagatshel region, Eastern Bhutan. An elevation of the region ranges from 1000-2500m, featured by an average rainfall of 1500mm to 3000mm, and an average temperature of 3°C to 26°C recorded in the last ten years (National Centre for Hydrology and Meteorology, 2018). The study area is in the west-facing hillside of the Yongla mountain (Lat 27°00′30.49″N, Long 91°25′12.06″E), which has an elevation of 1100-2500m, irregular slopes and the lower montane forest with few chir pines stands. Moreover, it is characterized by distinct patches of regrowth forests in the vegetation which had been agricultural lands formerly belonged to the people of nearby villages: Pangthangdaza, Mawa, Khar and Mongling (Fig.1).

Table 1. Site description and number of sampling plots in the abandoned farmlands (regrowth forests) and old-growth forests.

Abandoned farmlands (regrowth forests)						Old-growth forests		
Sampling site code	Elevation (m)	Land-use history	Age (years)	Size (Hectare)	Plot-n	Sampling site code*	Elevation (m)	Plot-n
AB1	1120–1130	Dryland	23–26	1.5	10	OF1	1120–1157	6
AB2	1120–1165	Slash burn	25–28	1.4	7	OF2	1329–1380	9
AB3	1315–1329	Dryland	20–23	0.7	5	OF3	1673–1690	9
AB4	1360–1400	Slash burn	40–42	0.8	7	OF4	1990–2016	8
AB5	1673–1700	Slash burn	30–33	2.5	10	OF5	2020–2055	11
AB6	1970–2000	Slash burn	55–60	2	10			
AB7	1987–2046	Slash burn	36–39	3.5	15			

* OF1(adjacent to AB1 and AB2), OF2 (adjacent to AB3 and AB4), OF3 (adjacent to AB5), OF4 (adjacent to AB6) and OF5 (adjacent to AB7)

Being protected by the Royal Government of Bhutan, no recent disturbance is found in the area since the abandonment. An intervening and alternating land use policy to phase-out the trend of slash burn agriculture at the national and local level took off in this region owing to the high prevalence of such practices (Upadhyay, 1995). The selected study area is suitable for the study due to the availability of key informants (landowners and local people), particularly to acquire information on the history of these regrowth forests. Moreover, the vegetation in the hillside might somewhat represent the vegetation of the region due to its similar elevation range in the region.

Preliminary Survey

Elderly villagers and landowners of the abandoned farmlands were interviewed and checked their old land ownership certificate if available to acquire information on the history of land use and years since abandonment. Most of the abandoned farmlands were areas well-suited for cultivation, while most of the undisturbed areas were steep and rocky. In total, seven patches of regrowth forests on the abandoned farmlands were identified along the slope of a west-facing hillside of Yongla Mountain (Table 1) which could be grouped in four ranges of elevation (i.e., 1120–1265m, 1315–1400m, 1673–1700m, and 1970–2055m). The duration of abandonment varied approximately from 20 years to 60 years, according to the landowners' information and their records (Table 1). Among the seven abandoned farmlands, five were used slash-burn/shifting cultivation, and two were used dryland cultivation (Table 1). Area of the abandoned farmlands that varied across 0.8–3.5ha (Table 1) was measured by walking along the demarcated boundaries with GPS with the landowners' guidance. In the past, major agricultural activities in the region were intensive and rotational farming of staple foods (e.g., maize, potato, chili) in the dryland and slash burn respectively in an average of 1 ha each by a household (Upadhyay, 1995). For comparison, five patches of undisturbed forests/old-growth forests of no land-use history were identified adjacent to abandoned farmlands. They were located within the elevation ranges mentioned above (Table 1). Patches of representative old-growth forest were chosen only in areas of similar topography to adjacent abandoned farmlands. All the areas of dissimilar habitats and slope were avoided to minimize the uncertainty of various environmental factors.

Vegetation Sampling

The field data were collected from April to October 2018. A stratified random sampling method was used in the identified areas. Based on the size of the abandoned farmlands and patches of old-growth forests, the 5–15 (15×15m) plots were randomly sampled excluding groove or eroded areas (Table 1). A total of 107 quadrats was laid: 64 plots in regrowth forests of seven abandoned farmlands and 43 plots in the five adjacent old-growth forests (Table 1). The stems of diameter at breast height/DBH of 5 cm and higher were categorized as trees (Oosterhoorn and Kappelle, 2000; Do *et al.*, 2010), and counted, identified and assessed their DBH values (lianas not included) in each 15×15m quadrat. The smaller woody plants/large saplings (≥4cm DBH and ≤1m height) counted in the nested (5 ×5m) subquadrats. Further, the presence and absence of ground cover occurring predominantly (> 50% coverage) or entirely (Harrelson and Matlack, 2006), were recorded and identified in the same (5×5m) subquadrats. All plants of these categories occurring in the sampling quadrats were collected for validation of identification and Herbarium deposition. Flora of Bhutan (Grierson and Long, 1983, 1984, 1987, 1991, 1999, 2001; Noltie, 1994, 2000), Flora of China ('eFloras, 2008) and the plant collections at National Herbarium, Thimphu, Bhutan had been referred to for identification. The voucher specimens were deposited in the National Herbarium, Thimphu, Bhutan.

Data analysis

The species richness of the trees (≥5 cm DBH) of the two forest types are calculated and drawn the species accumulation by using function “specaccum”, randomizing for plot order (Gotelli and Colwell 2001). Plot ordination of all 107 plots with the trees abundance data is performed by detrended correspondence analysis (DCA) by using function “decorana” in package vegan (Oksanen *et al.*, 2019) to determine the assemblage of plots or pattern of tree community composition of both the forest types along the elevation gradient. The

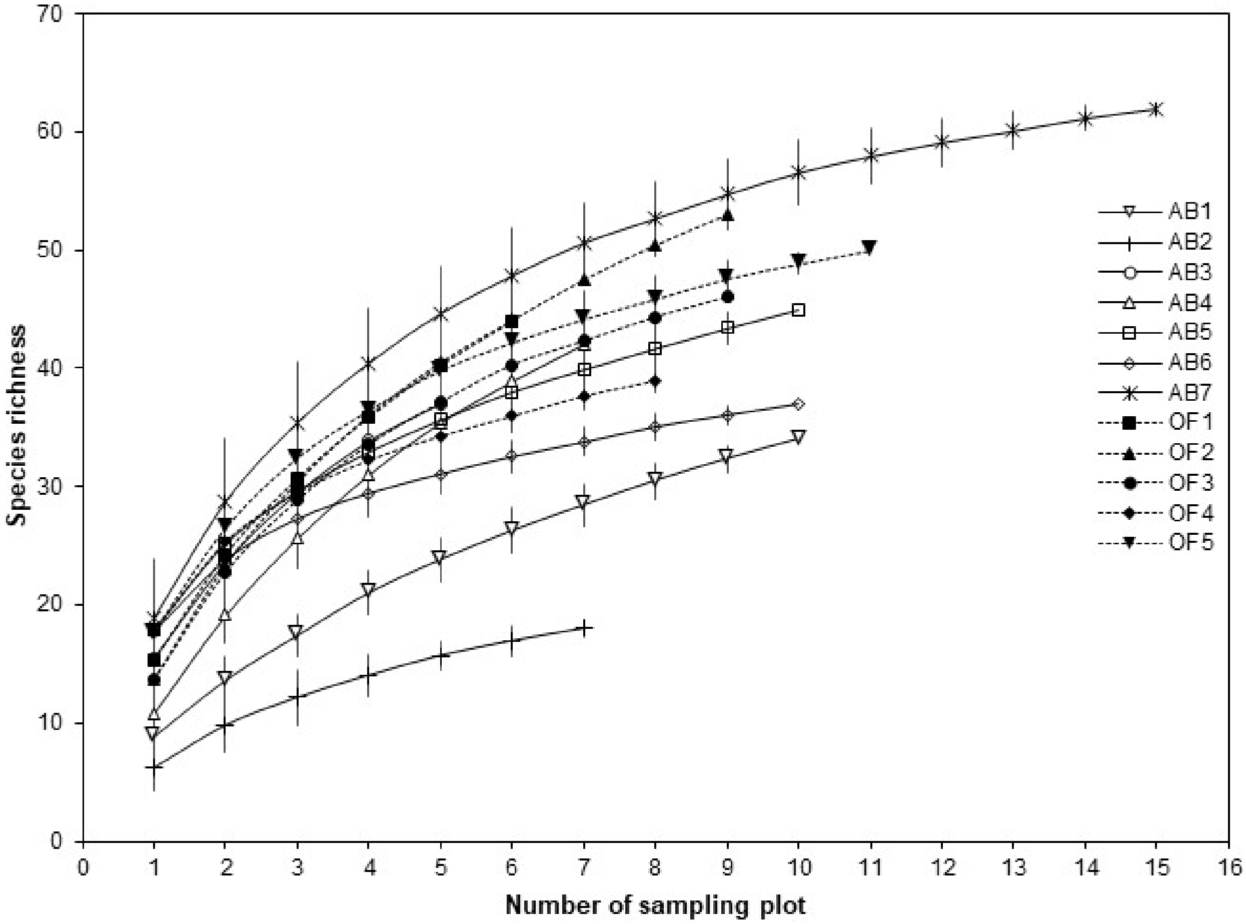

Fig. 2. Species accumulation curves for the seven abandoned farmlands/regrowth forests (AB1–AB7) and five old-growth forests (OF1–OF5).

percentage of similarity of tree species composition between two forest types is determined by Bray Curtis similarity percentage by using function "vegdist". For the comparison of dominant tree species, the importance value index (IVI, the sum of relative dominance, relative density, and relative frequency) is calculated for both the forest types. Similarly, relative abundance for the larger sapling/smaller woody stems (≥4cm DBH and ≤1m height) and relative frequency for predominant/entire ground covers are determined to compare their values between the two forest types. For the structural analysis, plants were categorized into larger sapling/smaller woody stems (≥4cm DBH and ≤1m height), small trees (5-9 cm DBH) and large trees (≥10cm DBH). The density was calculated for all three categories of plants while the basal area was calculated only for the large trees (≥10cm DBH) as they are well-established trees. ANOVA and post hoc Tukey test was performed using package multcomp (Hothorn *et al.*, 2008) to determine the statistical difference in the densities and the basal area between the regrowth and old-growth forests. All analysis was performed in R (R Core Team, 2019).

RESULT

Species composition of trees (≥5 cm DBH) in regrowth forest and old-growth forests

A total of 160 species of trees are recorded in 107 plots of regrowth and old-growth forests. About 53% (84) species are common to the two forest types, (17%) 28 and (30%) 49 species are unique to regrowth forests and old-growth forests and respectively (Table S1). Unshared species between regrowth and old-growth forests are mostly of low importance value index (Table S1). The species accumulation curve of old-growth forests is relatively stepper than those of regrowth forests, except AB7 (36–39 yrs.) (Fig. 2). This indicates the regrowth forests have relatively lower species richness than their adjacent old-growth forests except for AB7 (36–39 yrs.). AB2 and AB6 show the least curved, indicating lowest species richness.

The plots ordination by DCA shows that the plots of regrowth forest show affinity towards their adjacent old-growth forest as well as assembled similar to that of the old-growth forests according to their elevation gradient from higher to lower along the DCA Axis 1(Fig. 3).

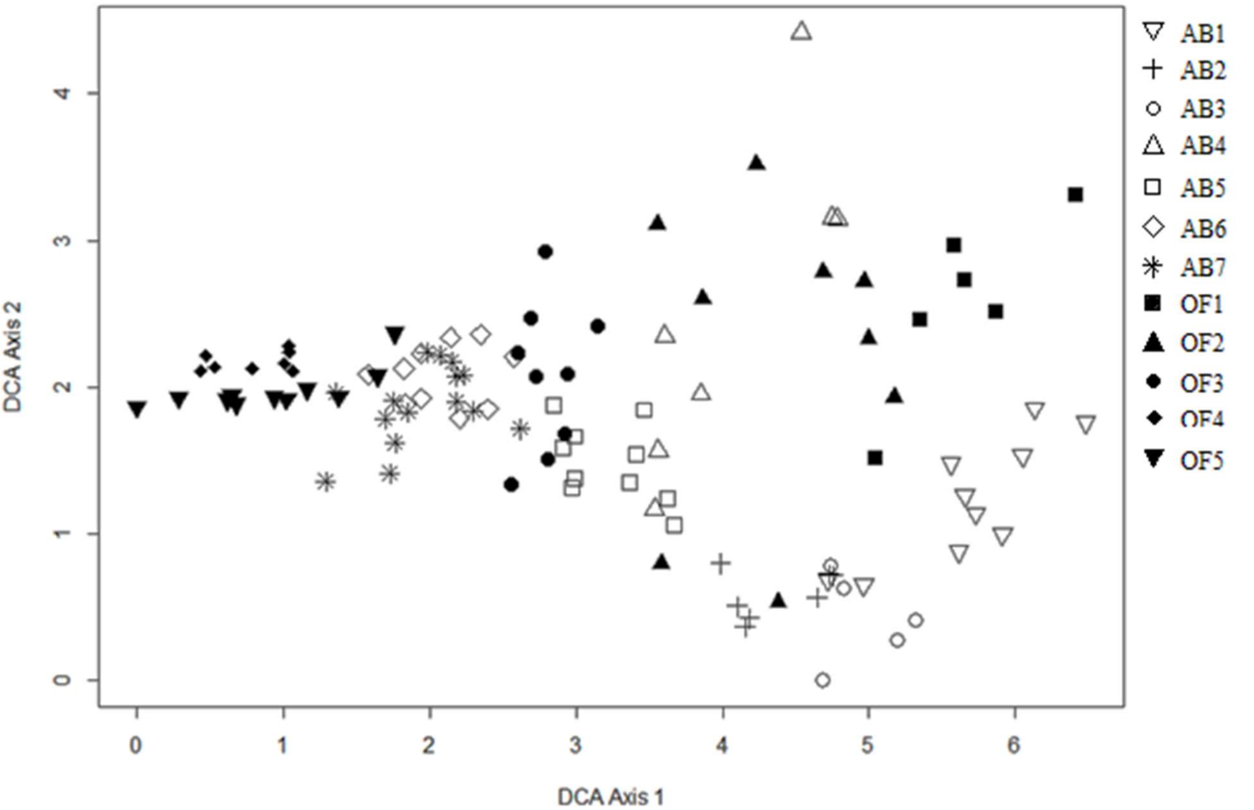

Fig. 3. Detrended correspondence analysis ordination for plots sampled in seven abandoned lands/regrowth forests (AB1–AB7) and five old-growth forests (OF1–OF5). The length of the axis was 6.48 SD long. First ordination 'eigenvalue' was 0.775, and second ordination 'eigenvalue' was 0.444

However, despite the elevation difference, plots in AB3 (abandoned dryland) and AB1 (abandoned dryland) assemble closer than their neighboring AB4 (abandoned slash burn) and AB2 (abandoned slash burn) respectively.

Species composition of AB1 (23–26yrs), AB2 (25–28yrs.) and AB3 (20–23 yrs.) are 10% similar to their adjacent old-growth forests (OF1, OF2) by Bray Curtis similarity percentage (Fig 4). AB4 (40–42 yrs.) and AB5 (30–33 yrs.) are 42% and 51% similar respectively to their adjacent old-growth forest (OF3). AB6 and AB7 showed 50% similar to their adjacent old-growth forests (OF4 and OF5). Few non-indigenous species, e.g., *Citrus maxima* **(**Burm**.)** Merr. (Rutaceae), *C reticulata* Blanco (Rutaceae), *Justicia adhatoda* L. (Acanthaceae) are recorded in younger regrowth forests (AB1 and AB2) (Table S1). AB3 (abandoned dryland) and AB1 (abandoned dryland) are 42% similar to each other, despite the elevation difference (Fig 4).

The two forest types have few dominant species in common, e.g., *Lithocarpus elegans* **(**Blume**)** Hatus**.** Ex Soepadmo (Fagaceae) in AB7 and OF3, and *I. orientalis* Hemsl**.** (Salicaceae) in AB1, OF1 and OF2 (Fig 5.). *Elaeocarpus lanceifoliu* Roxb. (Elaeocarpaceae) and *Magnolia hodgsonii* **(**Hook**.**f**.** & Thomson**)** H.Keng (Magnoliaceae) are dominant in old-growth forests (OF4 and OF1 respectively) but absent in regrowth forests. Dominance of *Beilschmeidia gammieana* King ex Hool**.**f (Lauraceae) occurs in old-growth forests (OF5 and OF4), but only low IVI of it occurs in regrowth forests. Conversely, the high dominance of *Betula alnoides* Buch**.-**Ham**.** ex D**.**Don is common among regrowth forests derived from abandoned slash burns (AB5, AB6, and AB7) at higher elevation but rarely occurred in old-growth forests (Fig. 5.). Likewise, dominance of *Lithocarpus fenestratus* **(**Roxb**.)** Rehder is common in abandoned slash burns (AB2 and AB4) at a lower elevation, particularly the AB2 shows the highest dominance. Considerable IVI of *Schima wallichii* Choisy spreads in many regrowth forests, but high dominance of it occurred in abandoned drylands (AB1 and AB2) (Fig 5). Higher IVI of *Castanopsis hystrix* Hook**.**f**.** & Thomson ex A**.** DC**.** spreads widely in abandoned slash burns (AB2, AB4, and AB5) (Fig. 5.). Although *Maesa indica* **(**Roxb.) A.DC. (Primulaceae) and *M. chisa* Buch**.-**Ham. ex D**.** Don are shrubby/small trees; they show considerable IVI in both forest types. The variation in the proportion of IVI of dominant species is higher in the age bracket of 20-28 years old regrowth forests (AB1, AB2, AB3) and dominated by one or two species unlike in older regrowth forests and old-growth forests (Fig. 5).

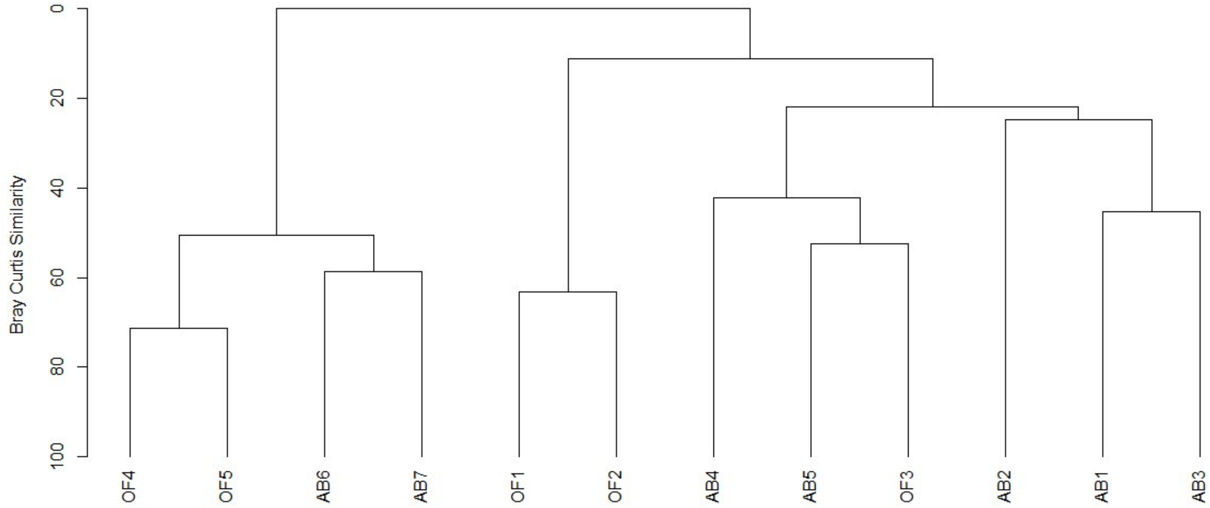

Fig. 4. Bray Curtis similarity percentage between abandoned farmlands/regrowth forests (AB1–AB7) and five old-growth forests (OF1–OF5).

Species composition of large saplings/shrubs (≥4cm DBH and ≤1m height) and predominant ground covers in regrowth forest and old-growth forests

63% (45) of the total species (72) are shared species in the two forest types while 15% (11) and 22% (16) are unique to regrowth forests and old-growth forests respectively (Table S2). Generally, the species richness of this category of plants in regrowth forests is relatively lower than the old-growth forests (Table S2), while species richness in the rest of regrowth forests is similar to old-growth forests. Among the top relative abundance of large saplings/shrubs, 49% are shared species in both forest types (Fig. 6). The majority of them are of large saplings of prominent trees, e.g., *B. gammieana*, *B. assamica* Meisn**.** (Lauraceae), *Ostodes paniculata* Blume (Euphorbiaceae), *S. wallichii*, *I. Orientalis*, *L. fenestratus*, *Eurya acuminata* DC. (Pentaphylaceae), *E. cerasifolia* **(**D.Don**)** Kobuski (Pentaphylaceae) while few are large saplings of smaller trees, e.g., *Camellia kissi* Wall. (Theaceae), *Maesa indica* (Primulaceae), *Mysirine semiserrata* Wall. (Primulaceae) and shrubs, i.e., *Flemingia macrophylla* (Wild.) Merr. (Leguminosae).

Frequency and species richness of predominant ground covers are distinctly higher in the old-growth forest than regrowth forests (Table S3). About 35% (7) of the total species is present in both forest types while 55% (11) and 10% (2) species are unique to the old-growth forest and regrowth forests, respectively. Ferns, *Piper* spp. (Piperaceae), *Molineria capitulata* (Lour.) Herb. (Hypoxidaceae) and *Ardisia* sp. (Primulaceae), and *Drepanostachyum* sp. (Poaceae) are common in several sites including both the forest types. Few species, e.g., *Ampelocalamus* sp. (Poaceae) and *Calanthe* sp. (Orchidaceae) occur at distinctly high frequency only in the old-growth forests (i.e., OF3 and OF4 respectively). No predominant ground cover is found in AB2 where *L. fenestratus* has highly dominated.

Density and basal area of woody plants in regrowth forest and old-growth forests

The density of trees (≥10 cm DBH) in AB2 exceeds its adjacent old-growth forest significantly while the density of the trees in other regrowth forests shows no significant difference to their adjacent old-growth forests (Fig. 7A). The density of small trees (5-9cm DBH) in AB5 is significantly higher than the old-growth forests and all other regrowth forests while the rest of the regrowth forests show no significant difference to their adjacent old-growth forests (Fig. 7B). The density of large saplings/shrubs (≥4cm DBH and ≤1m height) in regrowth forests show no significant difference to their adjacent old-growth forests except AB4 shows significantly lower than its adjacent old-growth forest (Fig. 7C). Basal area of large trees (≥10 cm DBH) in AB7 and AB5 is significantly higher than all other regrowth forests and many of the old-growth forests respectively (Fig. 7D). However, the basal area in AB6 is significantly lower than its adjacent old-growth forest. The remaining regrowth forests show no significant difference to its adjacent old-growth forests.

DISCUSSION

Species composition of old-growth forests and regrowth forests and their land-use history

The species richness among the regrowth forests differs greatly unlike among the old-growth forests. Generally, the species richness of trees is relatively lower in regrowth forests than old-growth forests. Nevertheless, one of the regrowth forests (AB7, 36–39 yrs.) has higher species richness than the old-growth forests, which reveals the high potential of recovery of tree species in abandoned farmland. The highest species richness around this stage of the regeneration of forest is reported in other similar studies of abandoned farmlands

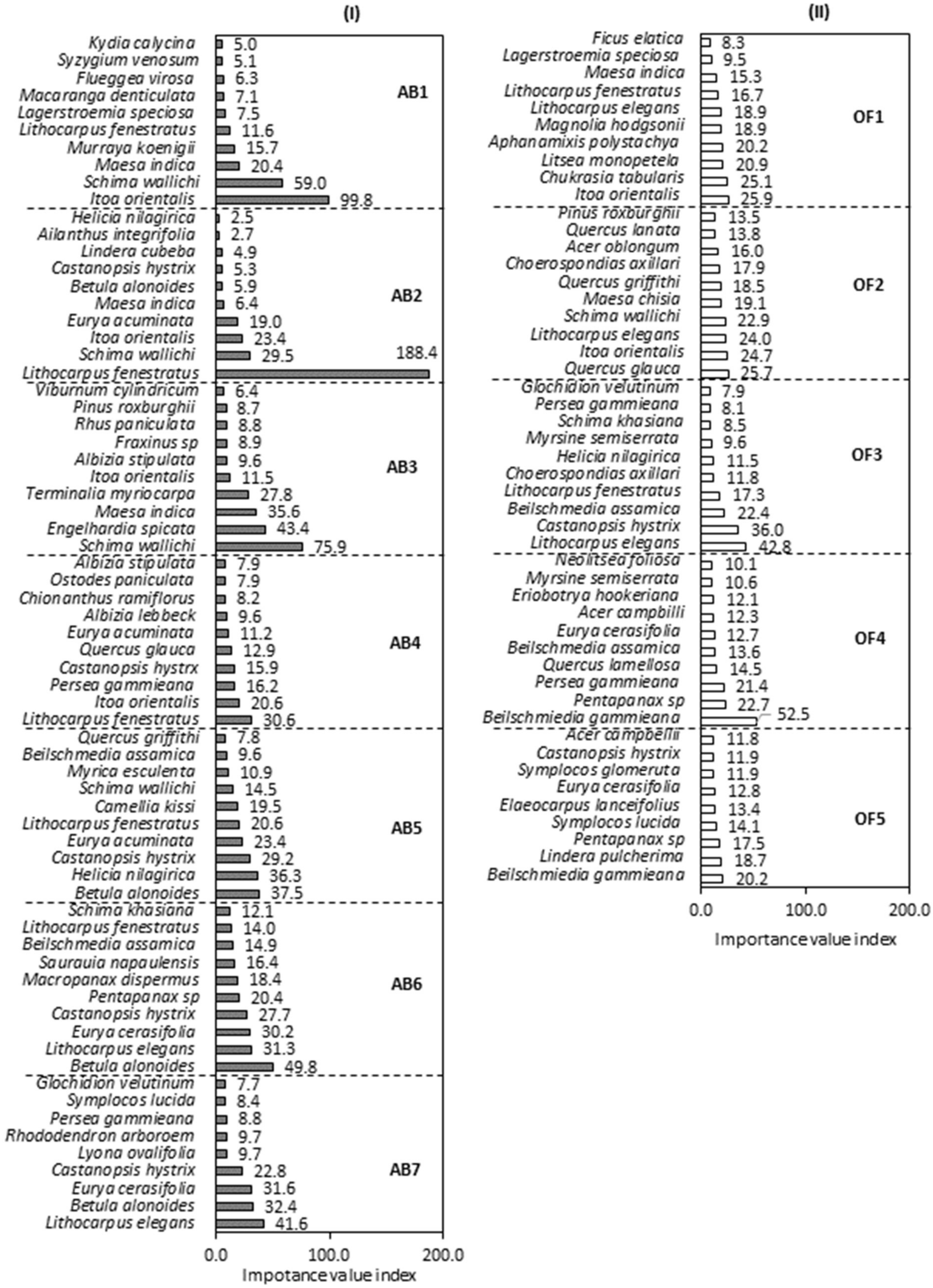

Fig. 5. Ten highest importance value index of trees in abandoned farmlands/regrowth forests (**I**) AB1–AB7 and five old-growth forests (**II**) OF1–OF5.

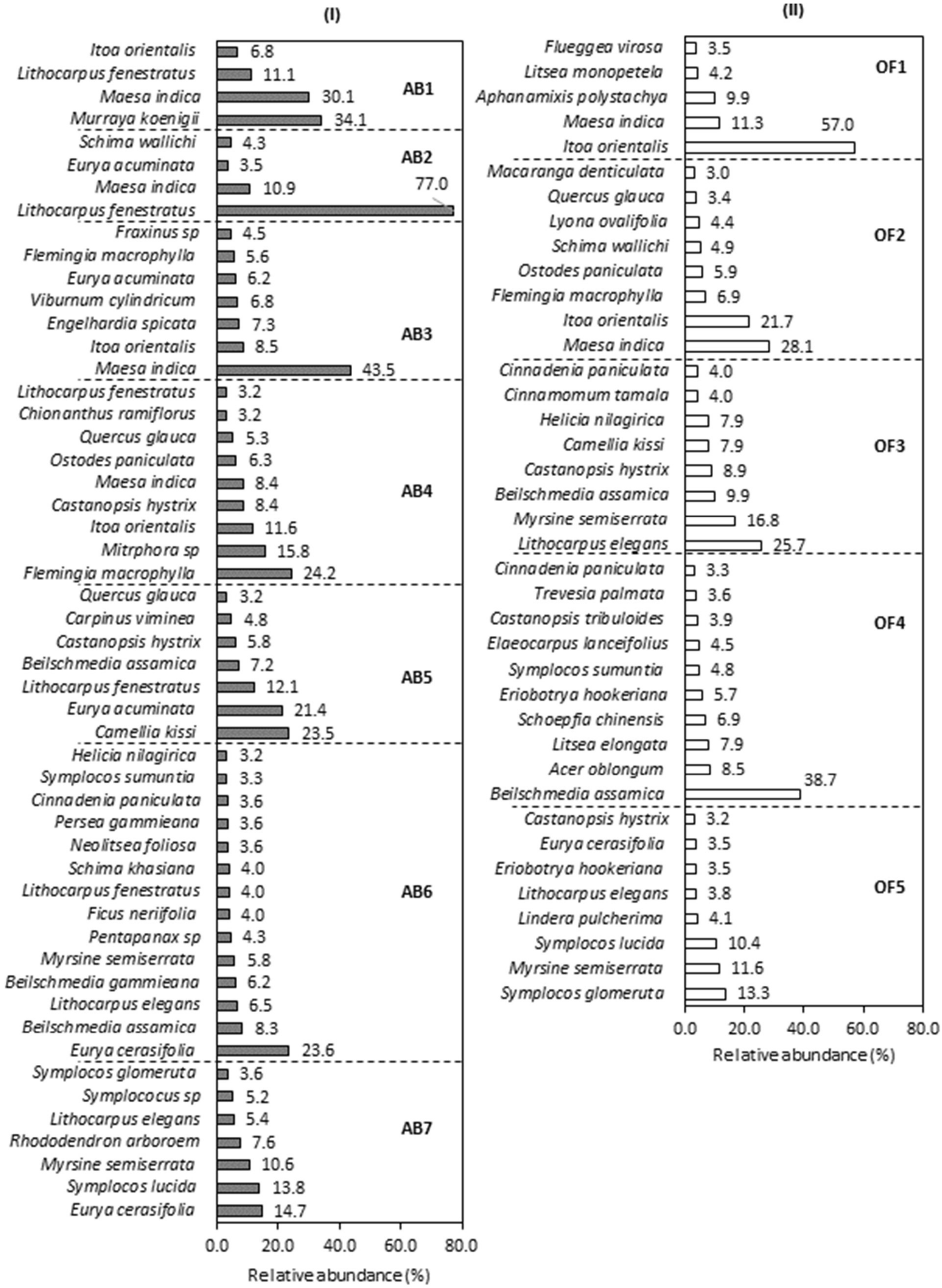

Fig. 6. Highest relative abundance (>3%) of large sapling/smaller woody stem the abandoned farmlands/regrowth forests (**I**) AB1–AB7 and five old-growth forests (**II**) OF1–OF5.

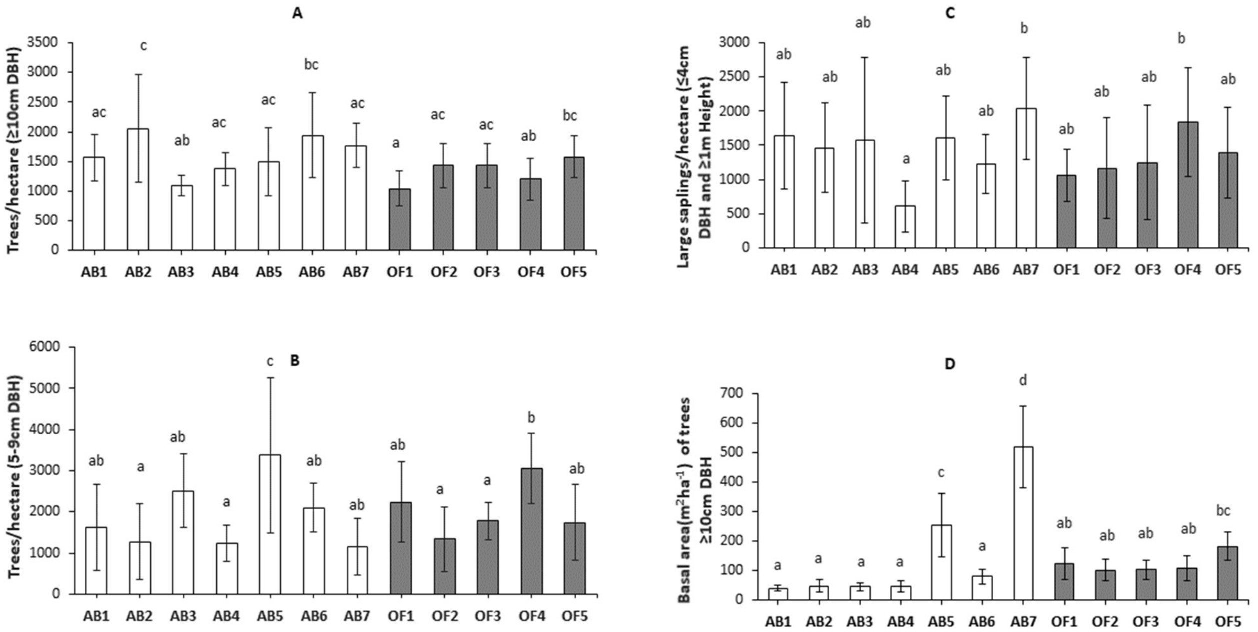

Fig. 7. Mean density of (**A**) of trees (≥10 cm DBH) per hectare (ANOVA, F(11,95)=7.802,P=0.001); (**B**) of trees (6-9cm DBH) per hectare (ANOVA, F(11,95)=13.29,P=0.001); (**C**) Density of saplings/shrubs (≤4cm DBH and ≥1m height) (ANOVA, F(11,95)=2.681,P=0.01); (**D**) Mean basal area (m2) of trees (≥10 cm DBH) per hectare (ANOVA, F(11,95=49.59, P=0.001). Seven abandoned farmlands/regrowth forests: AB1–AB7; and five old-growth forests: OF1–OF5. Different lower case letters indicate a significant difference (P<0.05; Tukey HSD)

(Ruiz *et al.*, 2005; Plieninger *et al.*, 2014) and abandoned pasture (Pascarella *et al.*, 2000), but the species richness of the regrowth forests rarely exceeds the old-growth forests. The species richness would probably decrease in the later stage as shown lower value in AB6 (55–60 yrs.), which is located at the same elevation range. In the tropical forests, species richness in regrowth forest remains lower than old-growth forests even at the age of 50 years (Teegalapalli and Datta 2016).

Regrowth forests maintain the variation of species composition of trees along the elevation gradient similar to old-growth forests which indicate the influence of elevation on the regenerations. The species composition of trees in regrowth forests also retain a certain similarity to adjacent old-growth forests and a considerable percentage of species is shared species in the various proportion of IVI in general. The result could be also speculated as to the influence of adjacent old-growth forests on the species composition of regenerations on abandoned farmlands as suggested in other studies (Endress *et al.*, 2001; Martin *et al.*, 2004; Rolim *et al.*, 2017). The species composition of regrowth forests of 30-60 years old is more similar to old-growth forests than regrowth forests of 20–28 years old. Moreover, older regrowth forests have lower variation in the proportion of IVI of dominant species than younger ones. These results might assert a gradual convergence of species composition towards the surrounding old-growth forests. The presence of few non-indigenous species in the few younger regrowth forests might correspond to the study of Pascarella *et al.* (2000) where non-indigenous species are diverse in the younger recoveries and gradually decline in the older recoveries.

Probably, *L. Elegan*, *C. Hystrix*, *I. orientalis* and *S. wallichii* recover faster than other prominent trees in the regrowth forests because they are dominant as old-growth forests. The species such as *S. wallichii*, *I. orientalis* and *L. fenestratus* might have been the pioneer species in abandoned farmlands at lower elevation since they are dominant and homogenous. Likewise, other studies support that the secondary forest of the post-agricultural succession is dominated by *S. wallichii* in montane forests (Fukushima *et al.*, 2008; Do *et al.*, 2010) and *I. orientalis* in sub-tropical forests (Yang *et al.*, 2018). Species such as *I. orientalis*, *B alnodies* and *S. wallichi* might be favored by their easy mode of dispersal by wind owing to their light seeds. Probably, the Acorn species are favored by hoarding animals in seed dispersal because the continuous forest of regrowth and old-growth forest in the region is suitable for them to live. The common dominance of species in the two forest types does not make the same structure of forests. Medium-sized trees i.e., *I. orientalis* comprise the major homogenous canopies in regrowth forest while they comprise only the understories or few the sub-canopies in old-growth forests. The dominance of *B. alnoides* and its emergent structure in regrowth forests at a higher elevation creates distinct patches different from the old-growth forest. The species is the pioneer and fast-growing species in the montane forests (Ohsawa, 1991) and has persisted as dominant species around 60 years of abandonment. A relative of this genus, e.g., *Betula pendula* is one of the pioneer species in woodland regeneration in broad-leaved forests and can persist in the forest up to around 70 years (Falinski, 1998). Besides *B. alnoides*, the high dominance of Fagaceae species is more in regrowth forest of slash burns history than the abandoned drylands. The correspondence of dominant trees and high similarity of species composition between the same land-use type might be the influence of land-use history. Likewise, the dominance of *L. fenestratus* singly in AB2 (abandoned slash burn) corresponds to the study of Fukushima *et al.* (2008) where the dominance of single species is observed in the history of intensive farming system in abandoned slash burn in montane forests. Intensive farming could have destroyed the seed bank and resulted in less species richness and dominance of one or two species. *I. orientalis*, *E. accuminata*, *E. cerasifolia, M indica* and *M. chisa* appear among top dominant species even though they are generally of shrubby/small trees to medium-size trees. Thus, they constitute dominant species among the sub-canopy and understory layers. These species are also observed in an early stage of succession as pioneer species in lower montane forests (Ohsawa, 1991) and tropical forest (Teegalapalli and Datta, 2016).

The regrowth forest and old-growth forest have a high percentage of shared species of large saplings/shrubs which make them similar species composition of understories. The appearance of *B. gammieana* and *B. assamica* at considerable abundance among the saplings in regrowth forests reveals the recovery of some old-growth species in a much later stage. Similar to this study, Toriola *et al.* (1998) observed that the occurrence of primary forest species in the young regeneration in the 19 years old secondary forest.

The frequency and species richness of predominant groundcovers in regrowth forests are lower than old-growth forests. The study of Barthlott *et al.* (2000) and Martin *et al.* (2004) reported that epiphytic orchids and ferns are also more diverse in an old-growth forest than the secondary forest, which is not included in this study. Recovery of old-growth groundcover species in abandoned farmlands is probably difficult. Nevertheless, relatively higher frequency and species richness of ground covers in older regrowth forests than younger ones show the gradual potential of recovery. Moreover, the regrowth forests have unique ground cover species that contribute to the diverse species composition of the forests.

Density and basal area of woody stems in old-growth and regrowth forests and their land-use history

The density of trees in regrowth forests is comparable to old-growth forests. The density of large trees (≥10cm DBH) of the regrowth forest has reached to the level of old-growth forests in more than 20 years of abandonment in the lower montane area. Similar to this study, the density of trees in abandoned shifting cultivation shows similar value to the old-growth forest at the age of around 25 years in Tropical (Gehring *et al.*, 2005) and Mountain broad-leaved forest (Do *et al.*, 2010). Nevertheless, the complexity of the structure of the forests between the two forest types is still different. Generally, the homogenous canopy trees contribute the average density in the regrowth forest; while the sub-canopies and understories mainly contribute to the average density in old-growth forests. One of the regrowth forests i.e., AB5 (30–33 years old) has a greater density of small trees (6–9cm DBH) than the old-growth forests. It is comparable to the intermediate state where density reached a peak and decreased in an older state in the studies of Pascarella *et al.* (2000) and Rivera *et al.* (2000). The density of sapling/shrubs is similar in both forest types, and the mixture of saplings and shrubs have contributed to the density. The mixture of saplings and shrubs occur in the early succession as well, the presence of shrub and its density do not impede the growth of sapling (Duncan and Chapman, 2003).

The overall average basal area of the tree (≥10cm DBH) of regrowth forests has approached to the old-growth forest at the age of forest greater than 20–23 years in the lower montane area. Unlike other similar studies, few regrowth forests i.e., AB5 (30–33yrs) and AB7 (37–39 years) have a distinctly higher basal area than old-growth forests which is a unique and fast recovery of wood. The basal area of trees (≥10cm DBH) in abandoned slash burn is considerably lower than old-growth forests when the density of trees reached to the level of old-growth forests in the sub-tropical lower montane forest (Martin *et al.*, 2004) and tropical forests (Teegalapalli and Datta, 2016). The dominance of *B. alnoides* has profoundly contributed to the basal area of these regrowth forests because being it as fast-growing pioneer and it has greater DBH and density than other trees. However, their basal area might decline in a later stage because the basal area was lower in older stage AB6 (55–60 years) where the dominance of *B. alnoides* is the same. Although the species such as *L. fenestratus* and *I. orientalis* grow in high density, they do not contribute much to the basal area due to their habit of the medium-sized tree.

CONCLUSION

A considerable percentage of primary woody species has recovered in the regrowth forests and exhibited higher similarity of species composition towards old-growth forests by the older regrowth forests than the younger regrowth forests. Species composition of regrowth forests retains the variation along the elevations similar to old-growth forests. Likewise, similar land-use history i.e., age and land-use type correspond to similar species composition among regrowth forests. Recovery of density and basal area of trees of regrowth forest in the area is fast and robust. Regrowth forest has many unique species and dominance of species that contribute to the diverse species composition and structural complexity. Recovery of species composition and structural heterogeneity to the state of old-growth forests would be difficult to speculate at least within 60 years of abandonment in the area. Nevertheless, regrowth forest is important because it is naturally recovered forest, the natural history of it is valuable as the primary forests, and it enhances the floral biodiversity.

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