*Mysore J. Agric. Sci., 59 (3) : 389-398 (2025)*

# Vegetation Clearance in Secondary Forests: Impact on Natural Regeneration

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*Received* : February 2025
*Accepted* : March 2025

**ABSTRACT**

Regeneration is the process by which new seedlings (recruitment) becomes established in the forest area. Disturbance to forest is known to influence the species composition, structure and natural regeneration. Present study assessed the impact of vegetation clearance (disturbance) on natural regeneration and compared with the uncleared area of the same forest. The analysis indicated that highest recruitment density was found in uncleared (undisturbed) area compared to cleared (disturbed) patch. The regenerating species area curve was saturated early for the cleared area than the uncleared patches, indicating in cleared forest small sampling will represent all the species, whereas in uncleared patches we need to sample more area to have all the species. The species richness observed was more in the uncleared area than cleared patches. Analysis indicated, in uncleared patches animal dispersed species are more, while cleared areas possess species that are dispersed mainly through wind. With respect to invasive and exotic species richness across the two categories of patches, no variation was observed. Considering the ecological factors, it is suggested to minimise vegetation clearance operations in secondary forests for better restoration and conservation of animal dispersed species with their dependant animals.

*Keywords* : Forest patches, Regeneration, Secondary forest, Vegetation clearing, Disturbance

FORESTS are particularly important to mankind as they provide essential harvestable produces such as wood, food, medicine, oils, gum, resins, tannins etc. and they are also useful as ornamental landscape; regulate climate, hydrology, mineral cycling, reduce soil erosion, creates habitat for wildlife, reduce air pollution, purify air and water etc. (Gordon, 1996; Ferguson, 1996; Chapin *et al.,* 1998 and Kaufaman *et al.,* 1999). In spite of their enormous usefulness, forests are being threatened in tropics by variety of abiotic and biotic factors (Kozlowski, 2002). Consequently, forests are decreasing at an alarming rate. It is estimated that forested area of the world decreased by 129 million hectares during the past quarter-century (Jonasova, *et al.,* 2010) and only 30.8 per cent of remainder is primary forest in the last three decades between 1990 to 2020 (FAO & UNEP, 2020). As an alternative, in the last few decades the secondary forests are gaining importance in biodiversity conservation, catchment protection, climate control, ecosystem services and sustainability (Abbas *et al.,* 2016).

Natural regeneration in the forests contributes to ecological processes, serve as ecological indicators of habitat quality and provide food and shelter for numerous wildlife species (Willie, 2014). Recruitment also confers better ecosystem services and sustenance under disturbances. Natural regeneration is a much more amenable process for modelling (Alder, 1995).

Recruitment is the global biodiversity crisis (Shameem *et al.,* 2010). Regeneration indicates species and population subsistence in the natural habitat. Depending on the habitat conditions, species diversity and composition of regenerating individuals varies (Tambat *et al.,* 2014). Forest canopy and its structure promote the recruitment growth of certain species while hinder it by competitions.

Secondary forests accumulate woody plant species rapidly, although the mechanisms are complex and no clear pattern has emerged (Matos *et al.,* 2020). Compared to mature forests, secondary forests show faster biomass accumulation, litter production and net primary productivity. More organic matter is produced and transferred to the soil in younger secondary forests than stored in above-ground vegetation. Nutrients accumulate quickly in secondary vegetation and are rapidly returned to the soil through litter fall and decomposition, allowing for efficient nutrient uptake by roots (Matos *et al.,* 2020). In secondary forests, species diversity can also recover substantially across various taxa (Barlow *et al.,* 2007), with positive co-benefits for carbon stocks and the diversity of birds, dung beetles and amphibians in the Tropical Andes (Basham *et al.,* 2016 and Gilroy *et al.,* 2014) and trees, birds and dung beetles in the Brazilian Amazon (Ferreira *et al.,* 2018 and Lennox *et al.,* 2018). Tree plantations in degraded areas can facilitate the regeneration of native species that may otherwise struggle to establish due to herbaceous competition or unfavorable microsites (Lugo, 1992). Numerous studies highlight the role of tree plantations in accelerating natural succession in tropical and subtropical regions (Keenan *et al.,* 1999; Parrotta, 1999; Otsamo, 2000 and Carnevale & Montagnini, 2002).

Regeneration could be affected by natural and anthropogenic disturbances including individual tree fall, catastrophic wind events, catastrophic fire and timber harvesting that increase light and expose soil (Elliott & Vose, 2011 and Belote *et al.,* 2012). Management practices such as ground vegetation clearance, salvage logging, etc and plantation types also known to influence the regeneration (Pradeep and Murthy, 2023). To achieving multiple social and environmental benefits at minimal cost natural regeneration is the best option (Chazdon and Guariguata, 2016). Studies on ecological processes and natural regeneration in secondary forests are limited particularly in Indian conditions.

The tree arboretum is one of the oldest secondary forests in the GKVK campus. The tree arboretum remained undisturbed and allowed for natural regeneration. Arboretum of GKVK is the best secondary forests for regeneration studies, as it mimics the natural forest conditions. Last year, an area of arboretum was subjected to ground vegetation clearance while most areas remained undisturbed.

A study was conducted to analyse regenerating species in cleared and uncleared area of tree arboretum (total 4 ha area) in GKVK campus. The aim was to understand underlying processes with regards to natural regeneration in secondary forests as influenced by ground vegetation clearance. The association between regeneration in cleared an uncleared with the plant traits such as habit, dispersal mode, invasiveness, nativity, etc. were analysed. The out-come of the study will be help while developing suitable management practices and strategies for secondary forest management.

## MATERIAL AND METHODS

### Study Area

Study was undertaken in tree arboretum (biodiversity heritage site - E7) of Gandhi Krishi Vigyana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore. The tree arboretum is a plantation of mixed species (different tree species planted in rows) established during the year 1986. It was allowed to grow naturally and is assumed to behave as natural forest patch. The altitude of GKVK campus is 924 mabove MSL and it receives rainfall ranging from 528 to 1374 mm annually (mean rainfall 915 mm). The study area is characterized by an average temperature of 23.32°C (Sumanth and Prasanna, 2022).

**Sampling Design and Vegetation Data Collection**

The entire tree arboretum was categorised as cleared and uncleared patches. Vegetation clearance in the forest patch was referred as disturbed and uncleared area was referred as undisturbed forest. Random quadrats of size 1 $m^2$ were laid to enumerate only regenerating species in both cleared and uncleared forest patches. Totally 60 random quadrats were laid *i.e.*, 30 numbers in cleared and 30 numbers in uncleared patch. In each quadrat all the regenerating individuals were identified to the species level and their numbers were recorded. Identification of the species was done with the help of local floras and comparing the voucher specimen with the collection in the herbarium UAS-B, Mahatma Gandhi Botanical Garden, UAS, GKVK, Bangalore.

**Data Analysis**

*Density:* Number of individuals per quadrat was recorded and expressed as density per quadrat (1 $m^2$).

*Regeneration composition and species diversity:* Regeneration data was compiled and summarized using Microsoft Excel. Shannon's diversity index (H′) and Simpson's diversity index (1-D) were determined using the following formula.

$$H' = \sum_{i=1}^{S} Pi \ln Pi$$

$$D = \sum_{i=1}^{S} ni(ni-1)/N(N-1)$$

where,

n = Number of individuals of the $i^{th}$ species
N = Total number of individuals, Pi = n/N of $i^{th}$ species
S = Total number of species

The Shannon's diversity index is a commonly used measure of diversity and all the species from a community are included in the sample (Yemata and Haregewoien, 2022).

*G Test:* To study the association between plant parameters and regeneration, a likelihood analysis *i.e.*, a non-parametric Chi-test (G-test; if number in a cell is < 5) was performed.

The structure of the community was analysed in terms of density, frequency and importance value index of all herbaceous plant species.

Frequency is the probability or the probability of finding a species in any given quadrat. The frequency value obtained reflects the pattern of distribution. Using relative frequency and relative density, importance value index was calculated. The formula used as follows;

$$\text{Frequency} = \frac{\text{Number of quadrats in which species present}}{\text{Total number of quadrats studied}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

$$\text{Relative Density (RD)} = \frac{\text{Number of individuals of the species}}{\text{Total number of individuals of all species}} \times 100$$

*Importance value index(IVI)* : It often reflects the extent of dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992). For calculating the IVI of herbaceous species, we use the formula,

IVI = Relative density + Relative frequency

Since, the study focusing on regenerative individuals basal area not been calculated and IVI constitutes only RD and RF.

## RESULTS AND DISCUSSION

*Density:* In the uncleared patches, the density was higher and is 16.30 ± 11.00 per quadrat compared to the cleared areas, where it was 13.13 ± 9.45 per quadrat (Fig. 1). It suggests forest clearance has negative effect on regeneration density, but t test was found non-significant.

*Species area curve:* As the sampled area increases the species number also increased (added new species) in both the forest patches. The species curve developed

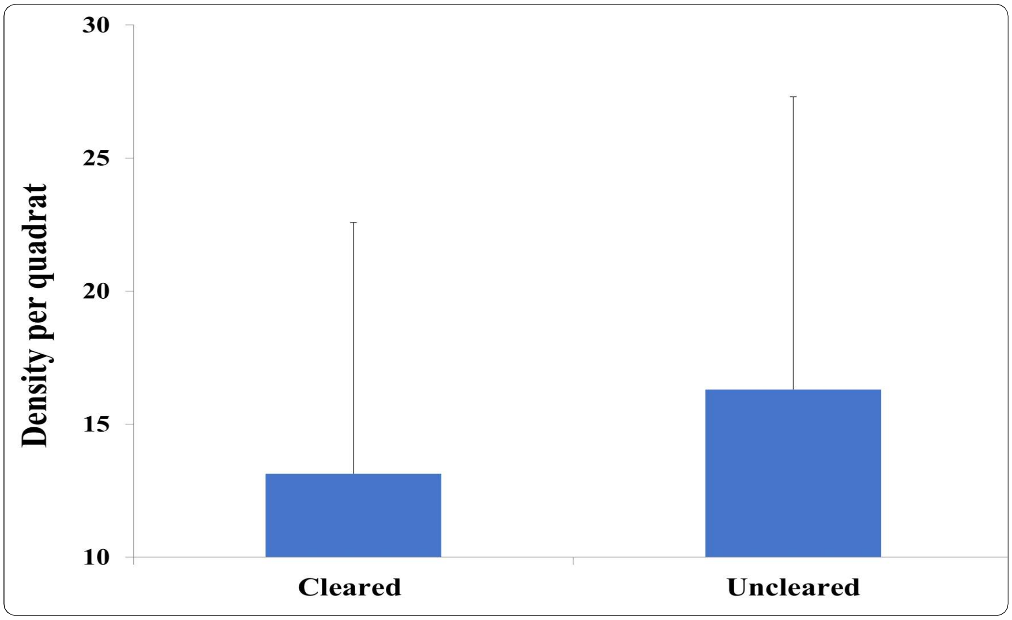


Fig. 1 : Density of individuals per quadrat in cleared and uncleared forest patches

was steeper for the cleared patch whereas, it was gradually increased in the uncleared patch. Further, in cleared forest the curve saturated after 21st quadrat whereas, it was saturated after 28th quadrat in the uncleared forest patch (Fig. 2). This indicates disturbance facilitates the dispersal of species across the area, while in uncleared area species are restricted to certain area. Thus, as the area increases species richness also increases but gradually in uncleared area.

*Species Richness and Unique Species* : Across the two forest patches totally 41 regenerative plant species

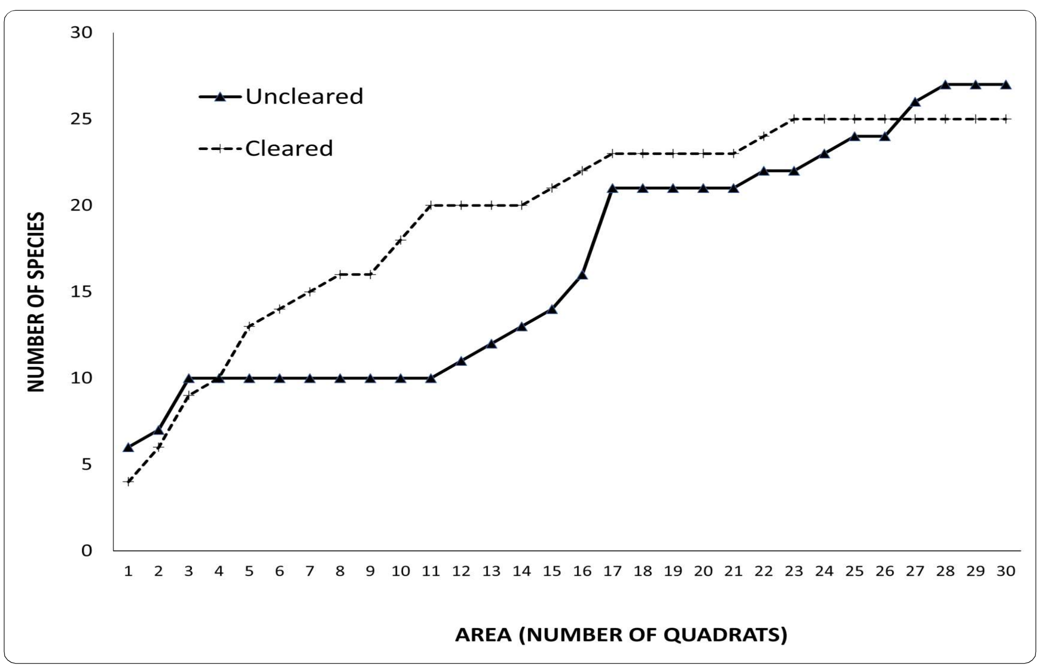


Fig. 2 : Species area curve for disturbed and undisturbed forest patches

**TABLE 1**

**List of plant species with their family, habit and nativity**

| Species name | Family | Habit | Nativity |
|---|---|---|---|
| *Ailanthus triphysa* | Simaroubaceae | Tree | Native |
| *Albizia lebbeck* | Fabaceae | Tree | Native |
| *Alternanthera ficoidea* | Amaranthaceae | Herb | Exotic |
| *Artocarpus hirsutus* | Moraceae | Tree | Native |
| *Blepharis maderaspatensis* | Acanthaceae | Herb | Native |
| *Bombax ceiba* | Malvaceae | Tree | Native |
| *Spermacoce hispida* | Rubiaceae | Herb | Native |
| *Breynia vitis-idaea* | Phyllanthaceae | Shrub | Native |
| *Canthium coromandelicum* | Rubiaceae | Shrub | Native |
| *Caryota urens* | Arecaeae | Tree | Native |
| *Senna spectabilis* | Fabaceae | Tree | Exotic |
| *Centrosema pubescens* | Fabaceae | Climber | Exotic |
| *Chukrasia tabularis* | Meliaceae | Tree | Native |
| *Dendrocalamus strictus* | Poaceae | Shrub | Native |
| *Chromolaena odorata* | Asteraceae | Shrub | Exotic |
| *Panicum repens* | Poaceae | Herb | Exotic |
| *Hopea parviflora* | Dipterocarpaceae | Tree | Native |
| *Ipomoea obscura* | Convolvulaceae | Climber | Native |
| *Ixora brachiata* | Rubiaceae | Tree | Native |
| *Lantana camara* | Verbenaceae | Shrub | Exotic |
| *Leucaena leucocephala* | Fabaceae | Tree | Exotic |
| *Mallotus philippensis* | Euphorbiaceae | Tree | Native |
| *Murrayak oenigii* | Rutaceae | Shrub | Native |
| *Oplismenus compositus* | Poaceae | Herb | Native |
| *Passiflora foetida* | Passifloraceae | Climber | Exotic |
| *Peltophorum pterocarpum* | Fabaceae | Tree | Exotic |
| *Persea macrantha* | Lauraceae | Tree | Native |
| *Pithecellobium dulce* | Fabaceae | Tree | Exotic |
| *Plumbago zeylanica* | Plumbaginaceae | Herb | Native |
| *Monoon longifolium* | Annonaceae | Tree | Native |
| *Pongamia pinnata* | Fabaceae | Tree | Native |
| *Santalum album* | Santalaceae | Tree | Native |
| *Secamone emetica* | Apocynaceae | Climber | Native |
| *Flueggea leucopyrus* | Phyllanthaceae | Shrub | Native |
| *Simarouba glauca* | Simaroubaceae | Tree | Exotic |
| *Solanum seaforthianum* | Solanaceae | Climber | Exotic |
| *Spathodea companulata* | Bignoniaceae | Tree | Exotic |
| *Tamarindus indica* | Fabaceae | Tree | Native |
| *Zanthoxylum asiaticum* | Rutaceae | Climber | Native |
| *Triumfetta rhomboidea* | Malvaceae | Herb | Exotic |
| *Ziziphus oenopolia* | Rhamnaceae | Shrub | Native |

were recorded (Table 1). Out of the 41 species recorded, 25 species (394 individuals) were from the cleared area and 27 species (489 individuals) were from the uncleared area. Among the species recorded, 11 species (27%) were common to both forest patches, 16 species (39%) were exclusive to uncleared forest patch and 14 species (34%) were exclusive to cleared forest patch (Fig. 3). This also indicates the forest clearance has negative effect on species richness.

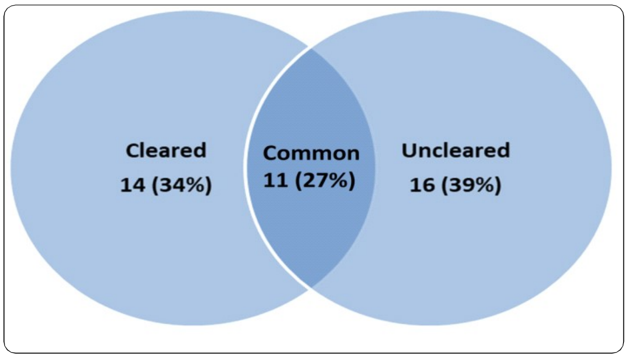


Fig. 3 : Number of species found common and unique (exclusive) to both the forest patches

*Species diversity* : As a measure of diversity, Shannon's and Simpson's indices were estimated as depicted in Table 2. In the cleared area Shannon's index was higher (2.161) compared to the uncleared area (1.856). The Simpson's index was also found higher in the cleared (0.850) area than uncleared area (0.749). This clearly indicates there is even distribution of species in disturbed areas compared to undisturbed because of the selective clearing.

TABLE 2

**Diversity indices in cleared and uncleared patches of tree arboretum**

| Indices | Cleared area | Uncleared area |
|---|---|---|
| Shannon's Index | 2.161 | 1.856 |
| Simpson'sIndex | 0.850 | 0.749 |

**Associations of Regenerating Individuals with that of different Plant Traits across the Two Categories of Forest Patches are Given below.**

*Habit* : The species richness with respect to plants habit is presented in Table 3. In the cleared forest area majority of the regenerating species were belongs trees species (64%) followed by Shrubs (24%), herbaceous species (8%) and climbers (4%). Whereas, in uncleared patches, the regenerating species distributed almost evenly among tree, shrubs, herbaceous and climbers with 33, 26, 22 and 19 per cent, respectively.

TABLE 3

**Species richness with respect to habit, dispersal mode, invasiveness and nativity**

| Particular | Cleared (N=25) | Uncleared (N=27) |
|---|---|---|
| Trees | 16 (64%) | 9 (33%) |
| Shrubs | 2 (24%) | 7 (26%) |
| Herbs | 6 (08%) | 6 (22%) |
| Climbers | 1 (04%) | 5 (19%) |
| **Chi test G value** | **7.0308** | **NS** |
| Animal dispersed | 14 (44%) | 14 (52%) |
| Wind and Passive dispersed | 11 (56%) | 13 (48%) |
| **Chi test G value** | **0.08988** | **NS** |
| Exotic species | 9 (36%) | 10 (37%) |
| Native species | 16 (64%) | 17 (63%) |
| **Chi test G value** | **0.00602** | **NS** |
| Invasive | 9 (36%) | 11 (41%) |
| Non-invasive species | 16 (64%) | 16 (59%) |
| **Chi test G value** | **0.32549** | **NS** |

*Dispersal Mode* : The species richness with respect to dispersal mode was assessed (Table 3). In the cleared forest patches majority of the species were wind (including passive mode) dispersed (56%) and animal dispersed species are relatively less (44%). Whereas, in the uncleared forest patches, animal dispersed species were relatively more (52%) than the wind dispersed species (48%). The results indicated clearance has reduced the animal dispersed species and facilitate wind dispersed species.

*Nativity* : The species richness with respect to native and exotic species was assessed (Table 3). In the cleared forest patches majority of the species were native (native to India, 64%) and rest are exotics (36%). Similar pattern was observed in the uncleared forest patch also (native 63% and exotic 37%).

*Invasiveness:* The species richness with respect to invasiveness was assessed (Table 3). In the uncleared forest patches invasive species represents only 36 per cent, whereas non-invasive species represents 64 per cent. A similar trend was observed in the cleared forest patches with invasive species 41 per cent and non-invasive species 59 per cent.

*Importance value index (IVI)* : According to the IVI values, in cleared patches the top five species were *Panicum repens, Leucaena leucocephala, Centrosema pubescens, Hopea parviflora* and *Persea macrantha*. Whereas, in uncleared patches, according to the IVI values the top five species obtained were *Panicum repens, Leucaena leucocephala, Senna spectabilis, Alternanthera ficoidea* and *Breyniavitis-idaea* (Table 4).

The higher numbers of species recorded in undistributed patches are attributed to intermediate levels of disturbance that increased species richness (Hubbel and Foster, 1986). Our study corroborates with Hubbel *et al.* (1999) who attributed the increased in species richness with intermediate disturbance. Ground vegetation cover increased in cleared sites than uncleared ones. Several plots in the uncleared sites had either sparse or very sparse ground vegetation cover. Most plots had 'dense' to 'very dense' ground vegetation cover in the cleared sites.

Although the analysis showed statistically non-significant results, yet we consider the trend is true, as analysis using the proportion of individuals data showed similar pattern. Non significance could be due to small sampling number/area or premature season (just one year after clearance). In these forest patches, we observed that disturbance influences plant species diversity and composition of regeneration assemblages. The study implies that disturbance encourages wind-dispersed species and suppresses animal-dispersed species. The species composition of regenerative species belong to woody plants is affected by disturbance.

The numbers of surviving adult trees and natural regeneration determine the succession and other ecological processes after a disturbance (Rammig *et al.,* 2006). Dispersal and establishment of pioneer species is promoted by the disturbances to soil surface, increased light intensity and wind movement. In our study, it clearly revealed that selective clearing leads to the reduction of density of species, but the species diversity is higher compared to uncleared patches.

Reduction of natural regeneration and lack of dead wood as substrate for tree seedlings is the most important consequences of tree felling (Foster and Orwig, 2006). Other effect includes disturbed soil surface, changing species composition, structure, nutrient cycle, etc. (Jonášová & Prach, 2008 and Bischoff *et al.,* 2008). Our analysis indicate that clearing will facilitate selective species/habit dominance such as tree species, but in contrast, uncleared patches represented by fairly equal proportion of individuals of all habit forms (trees, herbs, shrubs and climbers).

Various habitats can be regarded as spatially and temporally dynamic patches of vegetation being subjected to diverse human interference (Bhuju and

**TABLE 4**

**IVI values for top five species in the cleared and uncleared forest patches**

| Species | Cleared | Species | Uncleared |
|---|---|---|---|
| *Panicum repens* | 39.03 | *Panicum repens* | 59.41 |
| *Leucaena leucocephala* | 34.12 | *Leucaena leucocephala* | 51.22 |
| *Centrosema pubescens* | 24.81 | *Senna spectabilis* | 13.15 |
| *Hopea parviflora* | 23.11 | *Alternanthera ficoidea* | 10.87 |
| *Persea macrantha* | 17.69 | *Breynia vitis-idaea* | 07.85 |

Ohsawa, 2001). Stability and vulnerability of ecosystems depend on species diversity that is defined by the spatio-temporal alteration in species composition and their distribution (Gillet *et al.,* 1999). Herbaceous plant species diversity and composition are affected by topography and environmental variables along with trees species composition and structure (Akhtar and Bergmeier, 2015). Tree canopies also play role in the spatio-temporal build-up of herbaceous species diversity and production (Sanchez-Jardon *et al.,* 2010). In our study, the disturbed sites had clumped distribution pattern with dense to very dense ground vegetation cover compared to undisturbed sites.

At this juncture, several factors are contributing to natural regeneration in secondary forests (in our case arboretum). Vegetation clearance as interventions have long term effects on natural regeneration which are additionally modulated by seed dispersal modes. Wind-dispersed plant species will become dominant in disturbed forests over time, while animal-dispersed species will be lost when no additional conservation practices are adopted. Future research on local processes such as seed production, seed dispersal and seedling recruitment across different microhabitats in such forest patch, could provide additional insight. Foresters aiming at establishing forests with high biodiversity need to be aware of the dispersal ability and recruitment potential of plants in secondary forests.

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