A MANUAL FOR NATURAL FOREST REHABILITATION

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TABLE OF CONTENTS

ABBREVIATIONS

ANR	Assisted Natural Regeneration.
BA	Basal area (m^2/ha)
D	Diameter at breast height (cm)
DARD	Department of Agriculture and Rural Development
DDF	Dry Dipterocarp Forest
DF	Degraded Forest.
EBLF	Ever-green Broad-Leaved Forest
FAO	Food and Agriculture Organization of the United Nations
GIZ	German Corporation for International Cooperation GmbH
GPS	Global Positioning System.
H	Tree height (m)
ICRAF	The World Agroforestry Centre
ITTO	The International Tropical Timber Organization.
IUCN	International Union for Conservation of Nature and Natural Resources
MARD	Ministry of Agriculture and Rural Development
N	Density of tree
n	Number of samples
N/D	Diameter distribution
N_{re}	Density of regeneration trees
N_{sp}	Density of trees per species
PCA	Principal Component Analysis.
SF	Secondary Forest.
WWF	Worldwide Fund for Nature

LIST OF GUIDELINE BOXES

LIST OF TABLES

LIST OF FIGURES

PART 1: INTRODUCTION

1 WHAT IS FOREST REHABILITATION?

At present, the natural forest is also the production forest, and after years of overexploitation and inadequate control, it has become seriously degraded. However, it still maintains some basic environmental ecological protection functions such as soil erosion prevention, water regulation, carbon accumulation, and conservation of diversity of wild forest animal and plant genetic resources. Therefore, if we continue to take the last step of converting degraded natural forests to short-term crops and monoculture, it is expected to bring many environmental ecological consequences and loss of biodiversity as well as the livelihoods of forest-dependent communities. Consequently, rehabilitation of degraded natural forests is an urgent and pressing task to bring back natural forests to contribute to sustainable development, when the area of natural forest is shrinking and seriously poor quality.

Forest rehabilitation is widely recognized as a way to reverse the degradation of unsustainable and unmanaged forest use processes; it increases the contribution to sustainable forest conservation and the contribution of forest ecosystems to human livelihoods, land improvement, and forest environmental services (FAO, 2015). Forest rehabilitation actions range from activities such as habitat protection, assisted natural regeneration (ANR), and enrichment planting to policy improvement, providing financial incentives, and continuous monitoring and learning. Forest rehabilitation presents opportunities for environmental and socio-economic benefits (FAO, 2015) for the following reasons:

- It helps to increase the natural capital on which rural livelihoods depend;
- It helps to increase landscape resilience, rehabilitation of forest ecosystems, and social systems in global change; and if well planned and managed, it is possible to meet the interests and needs of many stakeholders.

Forest rehabilitation is to directly impact on one or more components of the forest ecosystem such as restoring woody flora, non-timber plants, forest animals, fungi, and forest microorganisms, from which it impacts indirectly on rehabilitation of land, hydrology, and forest ecology. In which, restoration of woody flora is the most important, because this is a decisive component of forest ecology, affecting the relationships of components in the forest ecosystem and the food chains of forest creatures. Therefore, rehabilitation of forest ecosystems is mainly aimed at restoring woody plants and possibly some more species of non-timber plants to meet and balance economic, social and environmental purposes.

2 PURPOSES OF NATURAL FOREST REHABILITATION

Natural forest rehabilitation can be approached in four different directions (Figure 1), including:

- Direction 1: The forest ecosystem and human livelihoods are restored at a high level. Achieving forest rehabilitation in this direction requires resources and a long time.
- Direction 2: The forest ecosystem and human livelihoods are restored at an average level. Achieving forest restoration in this direction requires moderate resources and time, and harmony between economic goals and the environment. The restoration of forest plant component will select trees with both ecological and economic value, with a not too long harvest time.
- Direction 3: The forest ecosystem is achieved at a high level while the human livelihood is at a low level. This approach only applies mainly to conservation and strict protection forests; for production forests, it will be less sustainable by removing human livelihoods from the forest. The restoration of forest plant component will select trees with ecological value, primary biodiversity conservation and slow growth.
- Direction 4: The forest ecosystem is achieved at a low level while the human livelihood is at a high level. This approach is mainly to convert natural forests to monoculture of fast-growing trees and industrial crops with economic value. This approach will bring immediate income, but in the long run it will be very unsustainable because of the loss of the ecological and environmental functions of the natural forest.

Accordingly, in sustainable development, natural forest rehabilitation in the second direction is most appropriate, which means the forest is restored to its ecological functions and in harmony with the community's livelihood goals as in the Sunderlin’s analysis (2005) for sustainable development. The approach to rehabilitation towards the second direction helps to harmonize rehabilitation of forest ecological functions with creating livelihoods and cultural preservation for the community of ethnic minorities with their life attached to the forest.

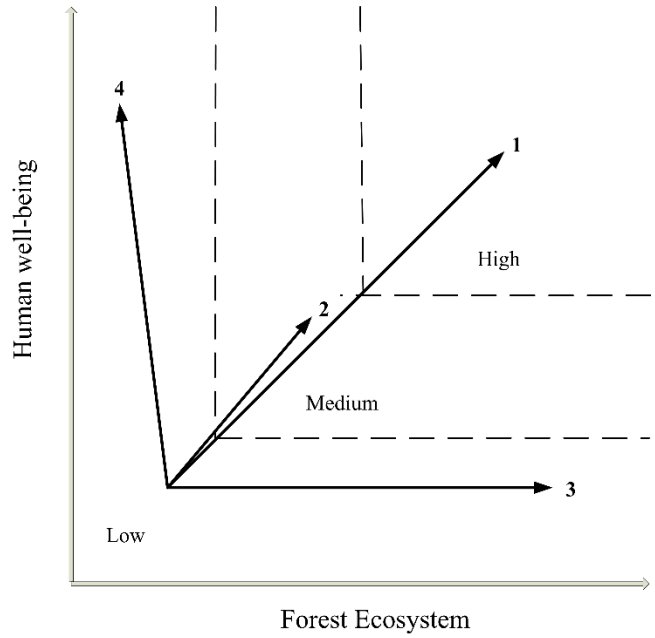


Figure 1. Levels and relationships between rehabilitation of forest ecosystem and human well-being (Adapted from Lamb and Gilmour, 2003)

Hence, natural forests rehabilitation today and in the future requires a new approach:

- *Multi-purpose and multi-product forest rehabilitation:* Forest rehabilitation is *not only aimed at the purpose of logging as tradition*, but also aimed towards *multi-purpose and multi-product*. Woody trees help to restore forest ecology, but not only for timber, sometimes without timber, but also for other product purposes such as fruit, resin, leaf, bark for many needs of food, pharmaceutical products, flavorings, raw materials for manufacturing industries, ...
- *Restoration of forest ecology associated with forest environment services:* The forest rehabilitation is not only for producing and creating forest products, but also for making an important contribution to the protection of ecological environment, such as watershed protection and regulation, soil erosion protection, soil improvement, carbon sequestration for climate change mitigation, biodiversity conservation, …. and from there *earning income from forest environmental services that is not dependent on income from forest products.* In this direction, it is possible to restore fast-growing native plants that function as upstream protection, carbon rapid accumulation, and food, leaves, fruits provision for animals to restore the wildlife and biodiversity.

3 PURPOSES OF DEVELOPING A MANUAL FOR NATURAL FOREST REHABILITATION

Currently, to restore natural forests, it is mainly required to apply Circular No. 29/2018/TT-BNNPTNT (MARD, 2018a) "Regulations on silvicultural measures". Also, this circular requires the Department of Agriculture and Rural Development (DARD) of provinces to provide detailed guidelines for households, communities, and forest owners to implement this circular.

Issues when applying Circular No. 29/2018/TT-BNNPTNT (MARD, 2018a) to households and communities:

- Regarding the object does not specify the specific forest type, while in Dak Lak province, dipterocarp forest has different characteristics compared to the popular evergreen broad-leaved forest.
- The community has not been able to access forest characteristics to determine what different silvicultural measures of forest rehabilitation are applied to the objects, such as determining the density of timber trees (N, trees/ ha), density of potential regenerated trees (N_{re}, trees/ ha.), canopy cover (1/10), forest cover (%), slope (degree), area of gaps in the forest, spatial distribution of the trees is uniformly dispersed or not.
- The community has not been able to access and apply silvicultural techniques under guidelines of the circular.
- People have not been able to select tree species for forest rehabilitation that suit the ecology and economy.
- The resources have not been pointed out for people to perform forest rehabilitation.

For households and communities to apply this circular, the following issues need to be clarified and guided in more detail:

- Guidelines on planning of forest landscape restoration at village-level should be provided.
- It is necessary to have guidelines on forest rehabilitation to each specific forest type and status.
- Making comparison tables of criteria is needed to select suitable silvicultural measures.
- There should be guidelines for villagers to determine the technical standards outlined in the guiding circular for selecting silvicultural measures, such as:

  + How to determine the density of timber trees, regenerated trees, planting density per hectare.

  + How to determine forest canopy cover.

  + How to determine the area of the forest, the area of the gaps.

  + Whether the tree is uniformly dispersed.

+ How to use the tool to determine the slope.

+ How to set up the planting row based on the contour lines where the slope is > 25 degrees, using the compass to determine the east-west direction of the row on a flat land.

- List of native timber trees species, multi-purpose trees, and non-timber species by each forest type, ecological requirements, and planting technique of the species
- Detailed guidelines are needed to illustrate forest rehabilitation techniques.

Therefore, the initiative to develop a "Guidelines on natural forest rehabilitation techniques" is necessary and urgent to give communities and forest owners a basis to restore currently degraded natural forests.

4 PURPOSES, OBJECTS AND HOW TO USE THE MANUAL

4.1 The purposes of the manual

- Helping target groups of households, communities, and other forest owners to implement silviculture measures to rehabilitate degraded natural forest areas.
- Promoting capacity development for forestry staff to guide and support local people and forest owners to restore forests.
- Contributing to the rehabilitation of natural forest ecosystems and livelihoods for people who are managing and using degraded forests. Restricting continued clear-cutting of forests with forest products being depleted to change forest use purposes for economic purposes.

4.2 Objects and limitations of technical guidelines for natural forest rehabilitation

The objects and limitations of these guidelines are applied as follows:

i) Regarding the users:

- Communities, households are allocated land and forest for management, protection, and long-term benefits, from that directly applying in their natural forest rehabilitation.
- Forestry technicians, forestry extension at all levels, local staff use the guidelines to train and guide people to apply.
- With the aim to apply to local communities, households, so the guidelines are presented simply and easy to understand; however, these technical guidelines are fully applicable to all other forest owners.
- The guidelines can also be used as a reference for managers, researchers, lecturers, and students about natural forest rehabilitation research and practice.

ii) Regarding the forest objects and the forest component that need to be restored:

- Applying to two main groups of forest objects, which are degraded primary forest after selective exploitation and regenerated secondary forest after over exploitation or fallow after shifting cultivation (Figure 2) of two main forest types in the Central Highlands of Viet Nam, which is dry dipterocarp forest (DDF) and evergreen broad-leaved forest (EBLF). These groups of forest objects, if there is no measure to restore the forest, they will be at risk of becoming degraded forest land (Figure 2).
- Applying mainly to production forests and can be extended to protection forests where appropriate.
- Rehabilitation of forest ecosystem component should primarily and directly target woody flora and/or possibly non-timber plants and harmonizing rehabilitation of forest environment ecological functions with economic development from forests.

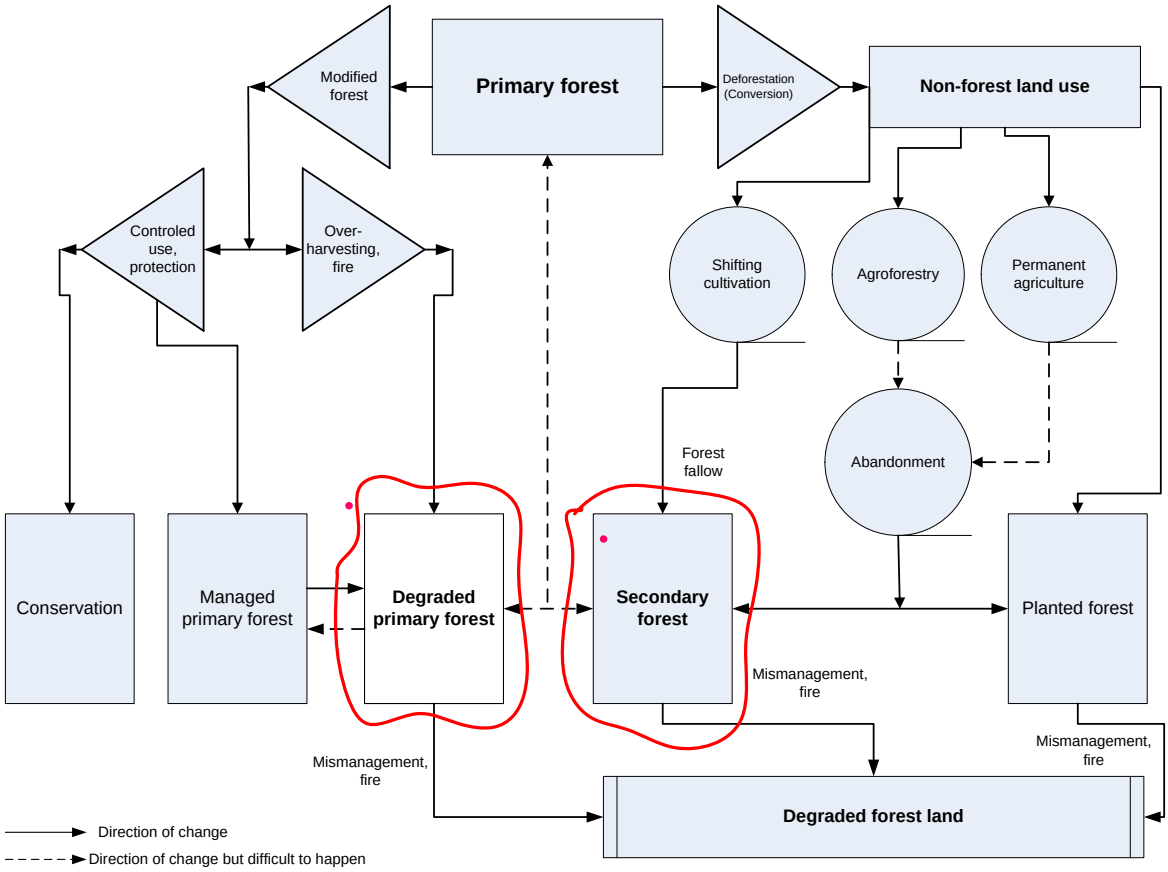


Figure 2. Direction of tropical forests in developing countries like Viet Nam (Adapted from ITTO, 2002).

Note: In the red circled area is the objects that need forest rehabilitation in this manual

4.3 How to use the manual

Different parts of the manual should be used for each specific user as follows:

- For those applying natural forest rehabilitation techniques such as communities, households, and other forest owners, refer to Part 1 for the concept and purpose of forest rehabilitation and to use detailed guidelines in Part 3 to practice in the selection and application of natural forest restoration techniques on the natural forest objects that they manage and use.
- As for scientists, technicians and managers can refer to all three Parts 1, 2 and 3 of the guidelines for full information, scientific basis, practice, and natural forest rehabilitation techniques.

PART 2: SCIENCE AND PRACTICAL BASIS OF THE MANUAL

1 APPROACHES FOR DEVELOPING TECHNICAL GUIDELINES OF NATURAL FOREST REHABILITATION

These guidelines on natural forest restoration techniques are developed to be applicable to households and communities, so the general standard is to ensure silvicultural technical principles but at the same time accessible to local people. The following main approaches are therefore used to develop guidelines.

These technical guidelines for forest rehabilitation are based on the principles and guidelines of the Law on Forestry, technical norms, and silviculture regulations of the forestry sector.

At the same time, these guidelines also apply research results and achievements in the field of silvicultural rehabilitation in Viet Nam and especially the scientific advances in forest rehabilitation in the world.

Surveying on forest status, representative forest types to illustrate the forest objects to be restored and as a basis for building the way to determine objects and to choose appropriate silvicultural measures and techniques. Combining with collecting ideas, knowledge, and experience of local people about forest rehabilitation such as forest objects, tree species, traditional techniques to selectively include in the manual.

On the basis of determining the scientific basis and survey practice, to develop guidelines on natural forest rehabilitation in accordance with the forest type, the current forest status of degraded forests that need to be restored and the capacity for organizing and performing of the communities and forest owners.

2 METHODS AND RESULTS OF SURVEYS FOR DETERMINING FOREST OBJECTS, SILVICULTURAL MEASURES OF NATURAL FOREST REHABILITATION

2.1 The objects of the survey

The survey was conducted in two forest types, which are DDF and EBLF, each forest type surveyed in two different localities/sites, so there are four locations representing the ecological sub-regions with two main forest types distributed in Dak Lak province was surveyed. For EBLF surveyed in Krong Bong district (Tul Village, Yang Mao commune) and Lak district (Dung Village, Dak Phoi commune); For DDF surveyed in Ea HLeo district including Eawy commune and Ea Sol commune (Tali Village) (Table 1).

For each forest type surveyed at each site, data were collected on degraded forest objects after exploitation at different levels and after shifting cultivation. At the same time survey on the forest areas allocated to two subjects, namely households and communities (Table 1).

Table 1. Forest type, forest owner and ethnic group were surveyed to develop guidelines for natural forest rehabilitation.

Forest type	Forest owner	Ethnic group	Commune	District
EBLF	Households of Dung Village	M Nong	Dak Phoi	Lak
	Community of Tul Village	M Nong	Yang Mao	Krong Bong
DDF	Community of Ta Li Village	Ja Rai	Ea Sol	Ea H'Leo
	Households	Kinh	Ea Wy	Ea H'Leo

Note: EBLF: Ever-green Broadleaved Forest; DDF: Dry Dipterocarp Forest

2.2 Sampling plots to describe and test the object determination methods and natural forest rehabilitation techniques.

Using strip or square sample plots to collect data; for degraded forests at various levels, use typical strip sample plots of 500 m^2 (10 × 50 m) (Figure 3); for regenerated young forests after shifting cultivation and regenerated young forests after over exploitation with a high density of young trees, use typical strip sample plots of 300 m^2 (10 × 30 m); for pure bamboo forests, use typical sample plots of 100 m^2 (10 ×10 m). Data were collected on 5 plots in EBLF with various degrees of degradation; 2 plots in EBLF after shifting cultivation; 2 plots in pure bamboo forest; 2 plots in DDF with various degrees of degradation; and 6 plots in the regenerated DDF after over exploitation. As a result, there were 17 sample plots to collect data based on the forest objects that need to be restored of the two surveyed forest types. On each sample plot, measurement methods are tested to determine objects and silvicultural measures of forest rehabilitation.

In the sample plot, determine species, measure diameter at breast height (1.3 m above the ground) (D, cm) of the tree with D ≥ 5 cm, measure tree height (H, m), measure the distance to the nearest tree, evaluate the quality of the tree at three levels of good, medium and poor. Determining forest type, forest status (degradation level, after shifting cultivation), canopy cover (1/10), measure the area of canopy gaps > 1000 m^2 by GPS or diameter of canopy gaps, evaluate tree and regeneration dispersion (uniform, random and clumped), measure slope, altitude, determine soil type and soil thickness, collect local climatic information. The potential regeneration measure is the regenerated tree with D < 5 cm and H ≥ 1 m in 02 sub-plots 25 m^2 (5 × 5 m) (Figure 3). For bamboo

forest, measure the diameter and average height of culm and count the density of bamboo plants in the sample plot.

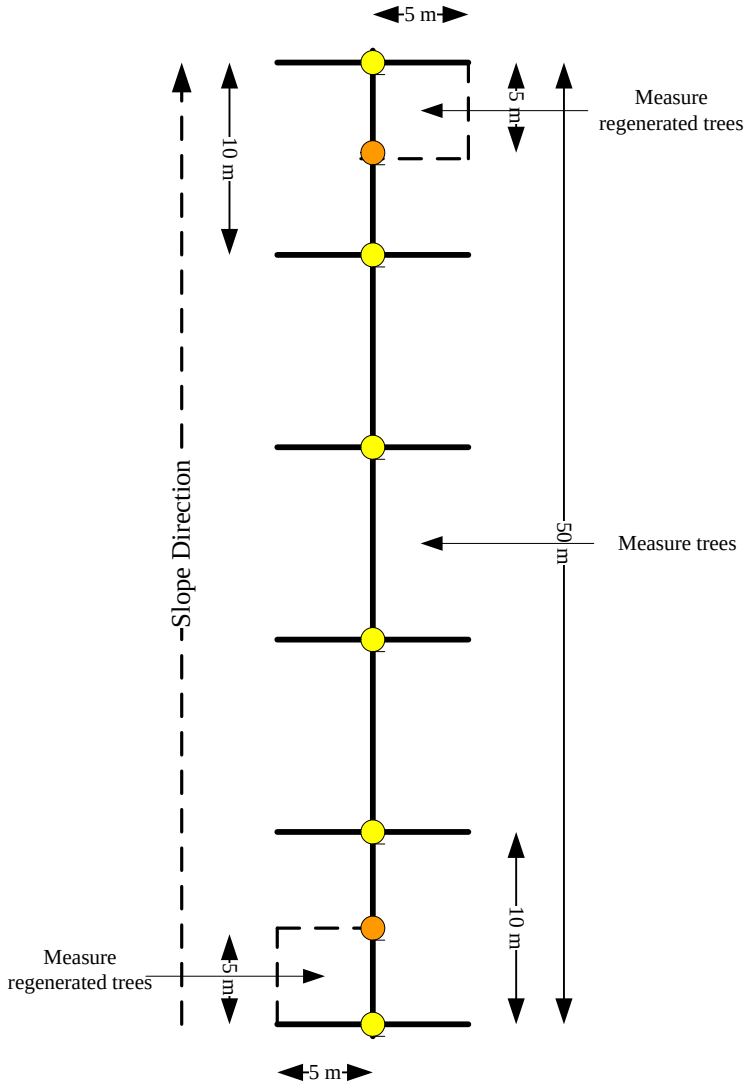


Figure 3. The strip sample plot of 10 × 50 m.

Note: Measure trees with D ≥ 5 cm in 5 sub-plots 10 × 10 m. Two sub-plots 5 × 5 m at two corners to measure the potential regenerated trees with D <5 cm and H ≥ 1 m

Information from the sample plots was used to identify the objects of forest to be rehabilitated and the techniques of reforestation.

In addition, it inherits sample plots in stable primary forests by forest type, with sample plot area of 1 ha, each forest type with at least 3 plots to model the ideal diameter distribution (N/D) based on the Meyer function (1952) to determine the optimal density of woody tree layers and predict the required potential regeneration density (Huy, 2017).

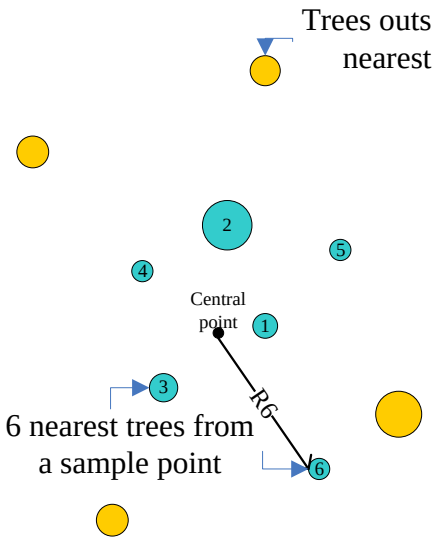
2.3 Verification to select the methods to determine the density of woody trees and regeneration.

The density of woody trees and regenerated trees is an important indicator in determining and distinguishing objects and different forest rehabilitation methods.

Normally, to determine the density, sample plots are often used; however, for the local community, sampling plots is difficult, requires precise and labor; therefore,

testing the K- tree sampling method (Kleinn and Vilcko 2006) with K = 6 for simpler density determination and reliability testing to propose application.

For woody trees with D ≥ 5 cm, in each sample plot of 10 × 50 m, select 3 representative sampling points to set up K- 6 tree sampling (K = 6). Measuring the radius from the central point to the center of the 6th tree trunk and calculate the density per hectare of the woody tree (N, trees/ ha). For potential regenerated trees with D < 5 cm and H ≥ 1 m, in the sample sub-plots 5 × 5 m, select 3 representative sampling points to set up K- 6 regenerated tree sampling (K = 6) (Figure 4). Measure the radius from the central point to the 6th regenerated tree and calculate the density of regenerated trees (Nre, trees/ ha) (Figure 4).



Note: Determine the 6 nearest trees from a sample central point, measure the distance R6 from the central point to the center of the farthest 6th tree trunk.

Figure 4. K- tree sampling (K=6) (Kleinn and Vilcko 2006)

Tree density (N) or regenerated tree density (Nre) per hectare are calculated from the K - 6 tree sampling as the following formula:

$$N, Nre = \frac{5.5 \times 10\,000}{3.14 \times R6^2} \quad (1)$$

In which, N or Nre is the number of tree or regenerated trees per hectare; 5.5 is the number of trees within the radius of the R_6 circle corresponding to K- 6 tree sampling.

Using t test to compare N and Nre from two methods of K- tree sampling (K = 6 nearest trees) and sample plots; the results are presented in Table 2, Figure 5 and Figure 6.

Table 2. The results of comparing N, Nre estimated by K- 6 trees sampling and sample plot

Statistical indicator	Tree (D ≥ 5 cm)		Regenerated tree (D < 5 cm, H ≥ 1 m)	
	K - 6 tree sampling	Plot 500 m^2	K = 6 regenerated tree sampling	Sub- Plot 25 m^2
Count	15	15	15	15
Average	1005.3	1127.1	2283.1	2706.6
Coeff. of variation, V%	54.9%	60.6%	97.7%	71.0%
Minimum	161.8	280.0	128.3	0.0
Maximum)	2233.0	2760.0	9744.1	6800.0
F-test to compare standard deviations	Null hypothesis: sigma1 = sigma2 Alt. hypothesis: sigma1 NE sigma2 F = 0.653 P-value = 0.435 Do not reject the null hypothesis for alpha = 0.05.		Null hypothesis: sigma1 = sigma2 Alt. hypothesis: sigma1 NE sigma2 F = 1.344 P-value = 0.586 Do not reject the null hypothesis for alpha = 0.05.	
t test to compare means	Null hypothesis: mean1 = mean2 Alt. hypothesis: mean1 NE mean2 t = -0.536 P-value = 0.596 Do not reject the null hypothesis for alpha = 0.05.		Null hypothesis: mean1 = mean2 Alt. hypothesis: mean1 NE mean2 t = -0.556 P-value = 0.582 Do not reject the null hypothesis for alpha = 0.05.	

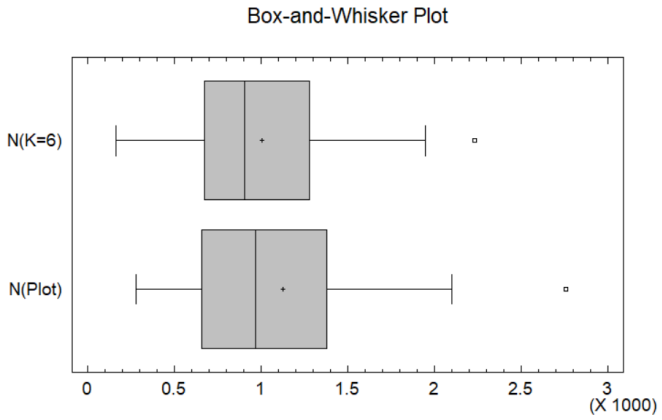


Figure 5. Box- and Whisker plot of tree density determined by the method K-6 tree sampling is N(K = 6) and according to sample plot is N(Plot).

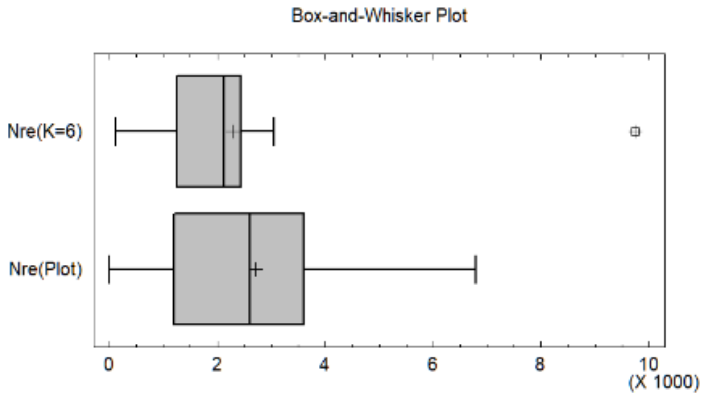


Figure 6. Box- and Whisker plot of regenerated density determined by the method K-6 tree sampling is Nre(K = 6) and according to the sample plot is Nre(Plot).

As a result of t tests showed that when using the K- 6 tree sampling to determine the density of trees and regenerated trees, there were no differences compared to density estimated by the traditional method of sample plots; Meanwhile, the K-6 tree sampling is quite simple, easy to perform and greatly reduces time and labor on the field.

Thus, to simplify and reduce costs for the local community, both layers of tree and regenerated tree can use the method K- 6 tree sampling to estimate the density for the forest objects that need to be restored.

2.4 Modelling the ideal diameter distribution and calculating the optimal tree and regeneration density to apply silvicultural measures to restore natural forests

The ideal diameter distribution (N/D) model based on the Meyer function (1952) is a model for sustainable uneven-aged mixed tropical forest management, which is widely recognized in the forestry academic science (Bao Huy, 2017).

The ideal N/D model is the basis for calculating the optimal tree density by diameter classes and potential optimal regeneration density (Nre); these are important criteria in determining objects and measures, silvicultural techniques for forest rehabilitation as well as adjusting forest density in enrichment planting and promoting natural regeneration.

On the basis of typical sample plots collected in stable primary forest under two different forest types, develop the ideal N/D models and determine the optimal N trees/ ha by the diameter classes (Table 3). From the ideal N/D models, backward prediction of optimal potential Nre for each forest type based on Meyer function (Figure 7, Figure 8).

Ideal diameter distribution models for two types of forest are below:

EBLF:

$$N = 519.32 \times e^{-0.071 \times D} \quad (2)$$

$$R^2 = 0.973$$

DDF:

$$N = 542.04 \times e^{-0.091 \times D} \quad (3)$$

$$R^2 = 0.948$$

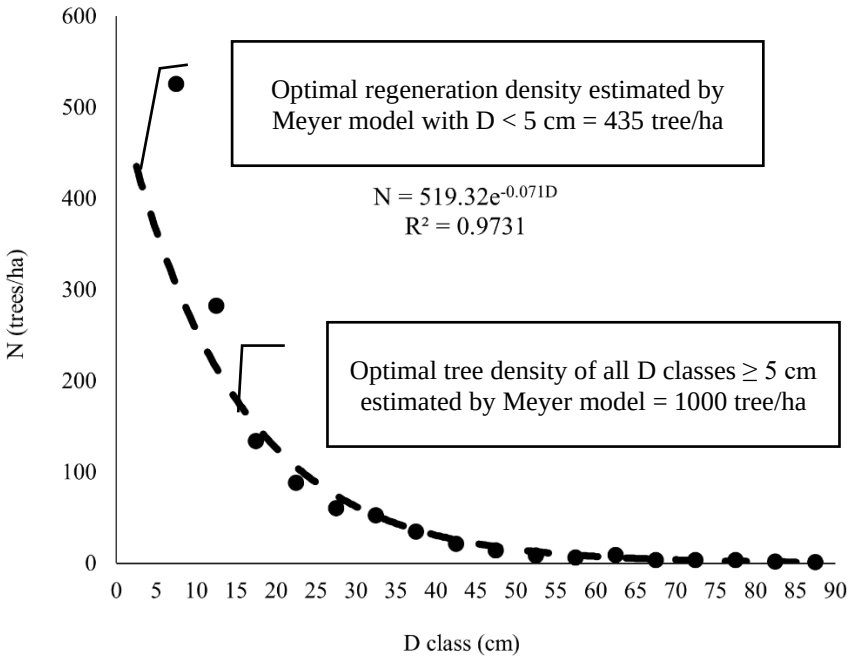


Figure 7. The ideal N/D model according to Meyer function for EBLF
Note: Dot: Observed value from stable forest; dashed line is value estimated by Meyer model

Table 3. Optimal density of EBLF and DDF follows the ideal N/D models based on Meyer function.

Class D (cm)	Mid- class D (cm)	EBLF		DDF	
		Observed density of stable primary forests (tree/ha)	Estimated optimal density (N tree/ha)	Observed density of stable primary forests (tree/ha)	Estimated optimal density (N tree/ha)
5-10	7.5	526	305	250	274
10-15	12.5	283	214	120	174
15-20	17.5	134	150	97	110
20-25	22.5	88	105	67	70
25-30	27.5	61	74	63	44
30-35	32.5	52	52	35	28
35-40	37.5	35	36	21	18
40-45	42.5	21	25	19	11

Class D (cm)	Mid- class D (cm)	EBLF		DDF	
		Observed density of stable primary forests (tree/ha)	Estimated optimal density (N tree/ha)	Observed density of stable primary forests (tree/ha)	Estimated optimal density (N tree/ha)
45-50	47.5	14	18	8	7
50-55	52.5	8	12	4	5
55-60	57.5	6	9	1	3
60-65	62.5	9	6	3	2
65-70	67.5	4	4	1	1
70-75	72.5	4	3		
75-80	77.5	4	2		
80-85	82.5	2	1		
85-90	87.5	1	1		
Total (tree/ha)		1250	1018	689	747

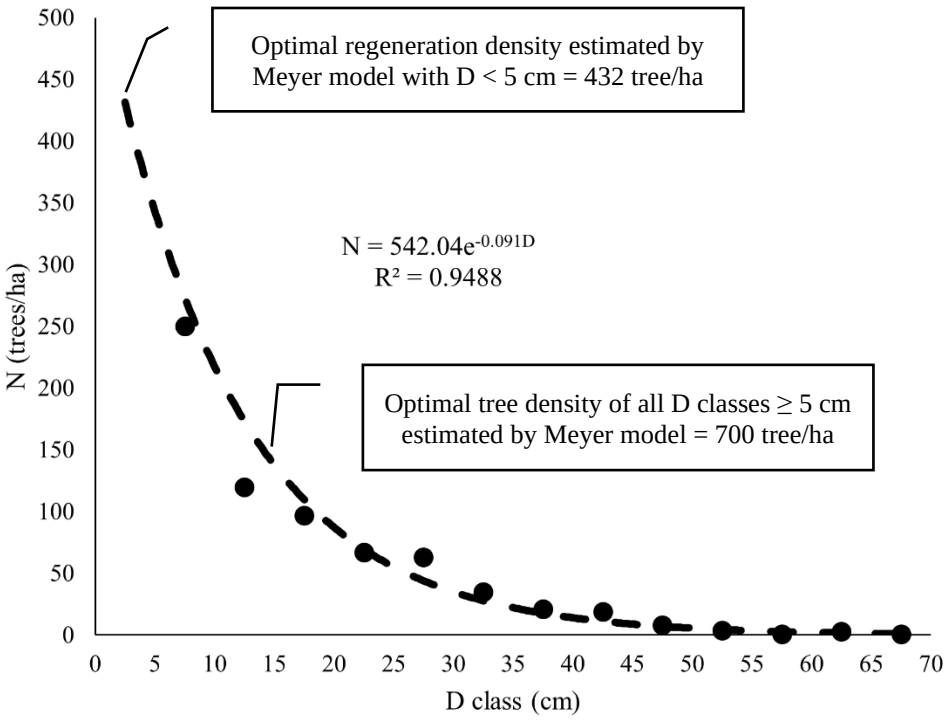


Figure 8. The ideal N/D model according to Meyer function for DDF
Note: Dot: Observed value from stable forest; dashed line is value estimated by Meyer model

The results of developing the ideal N/D models based on Meyer function show that the optimal density with D ≥ 5 cm for EBLF is 1018 trees/ ha, and DDF is 747 trees/

ha; for simplicity in the application, respectively rounding up to 1000 trees/ ha and 700 trees/ ha.

From the Meyer models, finding out the optimal number of regenerated trees with D <5 cm and H ≥ 1 m so that the forest can ensure that the regenerated tree generation is sufficient, with EBLF is 435 trees/ ha and DDF is 432 trees/ ha; in practice, for simplicity it is possible to take a higher value than round the number, which is 500 trees/ ha for both forest types.

2.5 The density of trees and regenerated trees and the observed diameter distribution in each forest type, status in need of forest rehabilitation

From the dataset of the sample plots, the important indicators for determining objects that need forest rehabilitation are listed, including density of trees, regenerated trees (Table 4), and the observed N/D compared with the ideal N/D model fit by Meyer function (1952) (Table 5 and Table 6).

Table 4. Density of trees and regenerated trees of forest objects needing rehabilitation

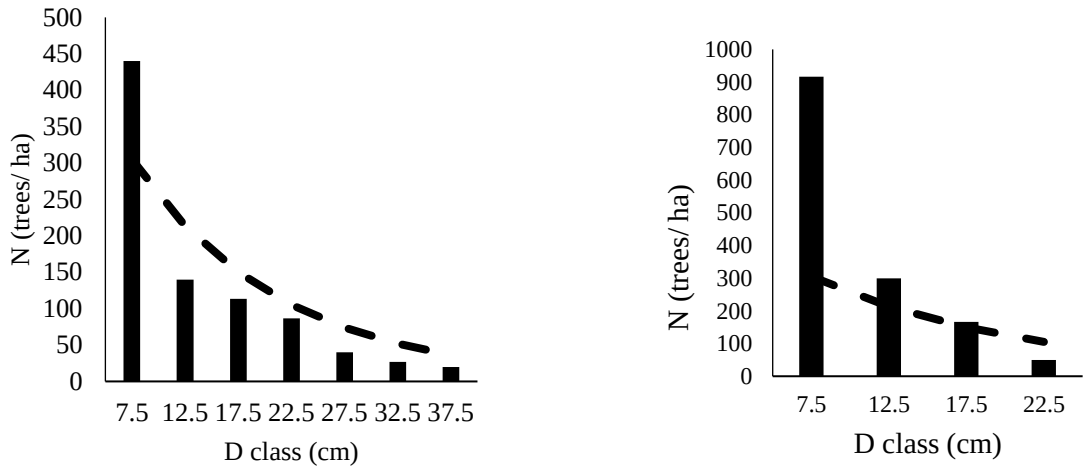
Forest objects in need of rehabilitation	Density of trees with D ≥ 5 cm			Density of regenerated trees with D < 5 cm and H ≥ 1 m		
	Average	Min.	Max.	Average	Min.	Max.
Degraded EBLF at various levels	867	560	1180	3600	400	6800
Regenerated EBLF after shifting cultivation	1433	867	2000	1900	1200	2600
Degraded DDF at various levels	1380	660	2100	2300	1400	3200
Regenerated DDF after over exploitation	873	280	1380	3466	2200	5800

Table 5. Observed N/D of EBLF objects in need of rehabilitation compared to ideal N/D model

Class D (cm)	Mid- class D (cm)	N of degraded forest (tree/ha)	N of regenerated forest after shifting cultivation (tree/ha)	N from ideal model (tree/ha)
5-10	7.5	440	917	305
10-15	12.5	140	300	214

Class D (cm)	Mid- class D (cm)	N of degraded forest (tree/ha)	N of regenerated forest after shifting cultivation (tree/ha)	N from ideal model (tree/ha)
15-20	17.5	113	167	150
20-25	22.5	87	50	105
25-30	27.5	40		74
30-35	32.5	27		52
35-40	37.5	20		36
40-45	42.5			25
45-50	47.5			18
50-55	52.5			12
55-60	57.5			9
60-65	62.5			6
65-70	67.5			4
70-75	72.5			3
75-80	77.5			2
80-85	82.5			1
85-90	87.5			1
Total (tree/ha)		867	1433	1018

Table 5 and Figure 9 show the observed N/D of the forest objects of EBLF that need to be restored and compared with the ideal N/D model fit by Meyer function. From the comparison graphs show that with degraded forests, most of the diameter classes are deficient, so it is necessary to enrich planting to restore the woody tree layers. It is possible to thin trees at the smallest diameter class because the density is high (class 5-10 cm); for forests after shifting cultivation for over 10 years, most of them are young trees with D < 25 cm, in which the density is quite high at the first diameter class 5-10 cm, it is necessary to thin.



(a) (b)

Figure 9. Observed and ideal N/D for EBLF

Note: (a): Degraded forest; (b): Regenerated forest after shifting cultivation (Column: Observed number of trees; Dashed line: Ideal model for sustainable forest according to Meyer function)

Table 6. Observed N/D of DDF objects in need of rehabilitation compared with ideal forest

Class D (cm)	Mid- class D (cm)	N of degraded forest (tree/ha)	N of regenerated forest after over exploitation (tree/ha)	N from ideal model (tree/ha)
5-10	7.5	725	673	274
10-15	12.5	175	165	174
15-20	17.5	163	27	110
20-25	22.5	125	27	70
25-30	27.5	13	8	44
30-35	32.5			28
35-40	37.5			18
40-45	42.5			11
45-50	47.5			7
50-55	52.5			5
55-60	57.5			3
60-65	62.5			2
65-70	67.5			1
Total (tree/ha)		1200	900	747

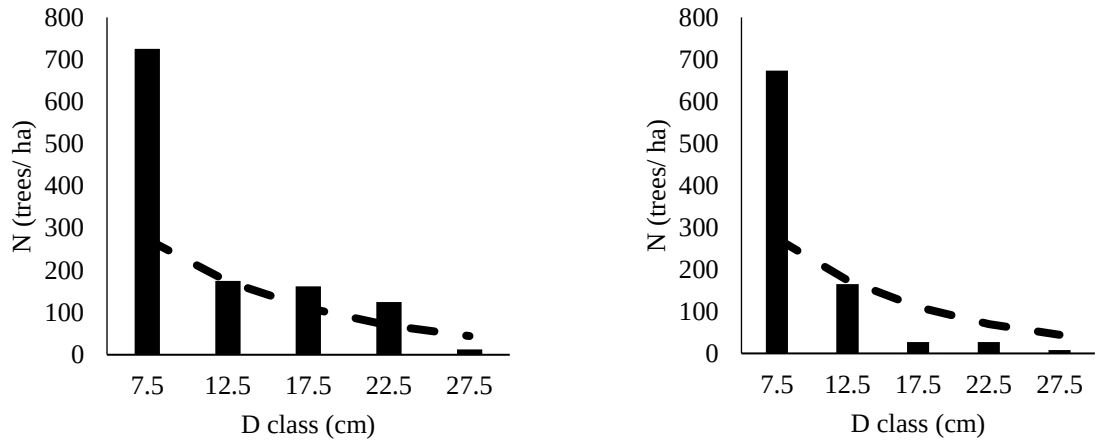


Figure 10. Observed and ideal N/D for DDF.

Note: (a): Degraded forest; (b): Regenerated forest after over exploitation (Column: Observed number of trees; Dashed line: Ideal model for sustainable forest according to Meyer function)

Table 6 and Figure 10 show the observed N/D of the forest objects of DDF that need to be rehabilitated and compared with the ideal N/D model fit by Meyer function. Result of the comparison of observed N/D graphs with the ideal N/D models shows that for degraded forests, the D classes reach 30 cm, it is necessary to maintain and thin trees at the smallest diameter class because the density is high (class 5- 10 cm); with regeneration forest after over exploitation, mostly young trees with D < 25 cm and shortage of larger tree layer, it needs to assist regeneration with additional planting, besides where the density is quite high such as at the first diameter class 5-10 cm that need thinning.

2.6 Evaluating the dispersion pattern of spatial distribution and determine the optimal distance.

Determine the dispersion pattern of forest trees on the forest ground support for selection of measures of additional planting, enrichment planting and thinning. Dispersion of spatial distribution is divided into three types: random, clumped or uniform.

Using U- statistical test to evaluate which dispersion pattern of forest objects to be restored were based on the distance from a randomly selected tree to the nearest tree (Clark and Evans, 1954; Huy, 2017).

$$U = \frac{(\bar{x}\sqrt{\lambda} - 0{,}5)\sqrt{n}}{0.26136} \quad (4)$$

where: $\bar{x}$: Average distance from a randomly selected tree to the nearest tree; λ: Number of trees per m^2 of forest land.

If: |U|≤ 1.96: Forest trees are randomly dispersed on the forest ground

U > 1.96: Forest trees are uniformly dispersed on the forest ground

U < -1.96: Forest trees are dispersed in clump on the forest ground

As a result, the dispersion pattern of spatial distribution of all forest objects that needs to be rehabilitated showed that there are clumped to very clumped dispersion (Table 7). Thus, in applying silviculture, the important measures in forest rehabilitation are thinning trees in areas with dense trees and additional planting, enrichment planting where thin trees or canopy gaps.

Table 7. Dispersion patterns of spatial distribution in the forest objects that need rehabilitation.

Forest object	n	Total area of sample plots (m^2)	$\overline{x}$ (m)	λ (trees/m^2)	U	Dispersion pattern
Degraded EBLF	130	1500	1.44	0.086667	-3.30	Clumped
EBLF after shifting cultivation	86	600	0.94	0.143333	-5.07	Very clumped
Degraded DDF	96	800	0.94	0.120000	-6.50	Very clumped
Regenerated DDF after over exploitation	234	2600	1.24	0.090000	-7.56	Very clumped

Note: For trees with D ≥ 5 cm

From the formula U, if U ≥ 2, we can determine the average distance $\bar{x}$ so that the forest trees have a random to uniform dispersion for thinning and density adjustment (Huy, 2017).

$$\bar{x} \geq \frac{\frac{2 \times 0.26136}{\sqrt{n}} + 0.5}{\sqrt{\lambda}} \quad (5)$$

where, n is the optimal density per ha from the ideal N/D model and λ = n/10000.

From formula (5), calculate the minimum average distance for the forest trees to achieve a random to uniform dispersion (Table 8); Use this indicator to thin trees where

overgrown and clumped to open appropriate space for remained forest trees, support and promote growth and productivity of forest trees and forest stands in forest rehabilitation measures. This distance is also considered to be the minimum from a planted tree to a natural forest tree when additional planting, enrichment planting in forest canopy gaps.

Table 8. Optimal average distance for trees to have a random – uniform dispersion according to the forest objects needing rehabilitation

Objects of forest rehabilitation	Optimal n according to ideal N/D model (trees/ha)	λ (trees/m^2)	U	$\bar{x}$ (m) minimum for trees to have a random - uniform dispersion
Degraded EBLF	935	0.093500	2.00	1.7
EBLF after shifting cultivation	774	0.077400	2.00	1.9
Degraded DDF	672	0.067200	2.00	2.0
Regenerated DDF after over exploitation	672	0.067200	2.00	2.0

Note: For trees with D ≥ 5 cm

2.7 Determining ecological relationships among tree species by forest type

Determination of ecological relationships among tree species by forest types is an important content in terms of forest ecology in natural forest rehabilitation. Understanding these relationships is the basis in adjusting species component when applying thinning, additional planting, and enrichment planting techniques. At present, this scientific content receives little interest for application in silvicultural techniques while it plays an important role in ensuring sustainable growth of the plant layer, on the basis of ensuring that tree species support each other, without ecological competition, to promote the formation of stable and sustainable forest plant layer.

Using Principal Component Analysis - PCA (Abdi and Williams, 2010; Janzekovic and Novak, 2012; Huy et al., 2020) to analyze the ecological relationships among tree species based on the observed indicator of species density (N_{sp}, trees/ sub-plots) in sub- plots of 100 m^2 for trees with D ≥ 5 cm and in sub-plots of 25 m^2 for regenerated trees with D < 5 cm and H ≥ 1 m by forest type; in order to divide species into three groups: Supportive, random and competitive.

2.7.1 PCA for ecological relationships among species in EBLF

2.7.1.1 *Ecological relationships among species in the woody tree layer of EBLF*

Using a dataset from 30 sub-plots of 100 m^2 to apply PCA method to consider the ecological relationships among tree species by species density factor.

A total of 76 species with D ≥ 5 cm of tree layer (Annex 3) were identified in the degraded EBLF at various levels, and over 10 years after shifting cultivation, and then ecological relationships among species were analyzed by PCA method.

PCA results showed that from 76 studied tree species, 11 closely related species were selected, with weight > 0.2; the other 65 species were weakly related (weight < 0.2), considered random. The results shown by the first principal component equation (PC1) represent the relationships among 11 tree species by the sign relationship (+/-) and the weight relationship:

$$\begin{aligned} PC1 = {} & 0.340122 \times Binh\ linh\ 3\ la + 0.195825 \times Cap\ moc + 0.340122 \times Cheo\ bong \\ & + 0.340122 \times Den + 0.207201 \times Khao\ thom + 0.237583 \times Ko\ nia + \\ & 0.259429 \times Lau\ tau + 0.346455 \times Man\ rung + 0.340122 \times Muong\ sumatra + \\ & 0.310685 \times Thanh\ nganh\ nam + 0.340122 \times Voi\ thuoc \end{aligned} \quad (6)$$

where species names in equation (6) are in Vietnamese that can be translated into Latin names by using Annex 3.

Consequently, in EBLF during both degradation and fallow after shifting cultivation stages; 11 species of the tree layer have positive relationships (supportive) (Figure 11); there are no competing species. Thus, the species in this forest type have stable species relationships, no need of adjusting the species component in terms of ecology; if necessary, only adjust the species economically. Also, note that these 11 tree species have supportive relationships, but these are not dominant or target species.

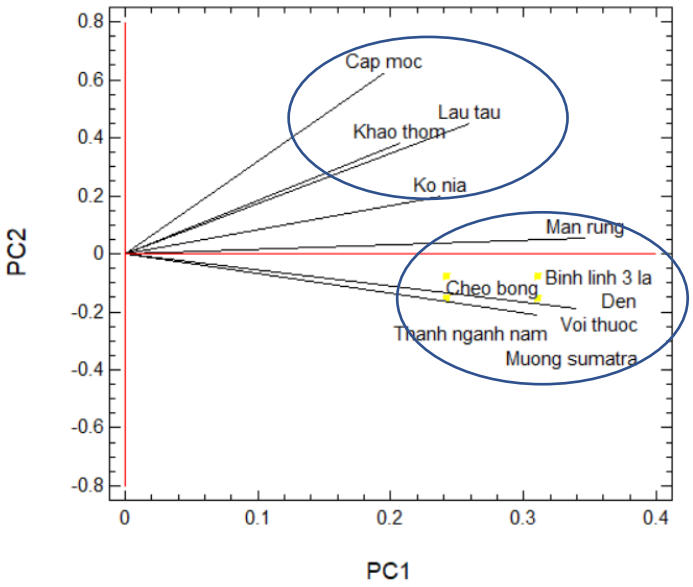


Figure 11. Ecological relationship among species of tree layer according to (-/+) and weight relationship by PCA for degraded EBLF at various levels and after shifting cultivation

Note: In the circle are groups of species with closely supportive relationships; the two species groups differ by < 45^0, have supportive relationship but weak. Species names in Vietnamese that can be translated into Latin names by using Annex 3

2.7.1.2 *Ecological relationship among species of the regenerated tree layer in EBLF*

42 species (Annex 3) of regenerated trees with D < 5 cm and H > 0.5 m; were identified in the degraded EBLF at various levels, and fallow over 10 years after shifting cultivation. Using a dataset from 12 sub-plots of 25 m^2 to apply PCA technique to determine the relationship among regenerated tree species by density factor.

PCA results showed that from 42 species, 7 closely related species were selected, with weight > 0.2; the other 35 species were weakly related (weight < 0.2), considered random. PCA results showed that like the tree layer, regenerated tree layer in EBLF has 7 species with positive relationship (supportive) (Table 12); there are no competing species. Thus, the species in this forest type have species ecological stability in the regeneration layer, no need to adjust the species component of the regenerated tree layer in terms of ecology; if necessary, only adjust the species economically.

The first principal component equation (PC1) shows the sign relationship (+/-) and the weight relationship (weight) for the 7 regenerated tree species:

$$PC1 = 0.42653 \times Bot\ ech + 0.237488 \times Buoi\ bung + 0.42653 \times Cu\ den\ thorelii + 0.386985 \times Don\ do + 0.42653 \times Gang\ gai + 0.356524 \times Hoac\ quang + 0.34778 \times Khao \quad (7)$$

where species names in equation (6) are in Vietnamese that can be translated into Latin names by using Annex 3.

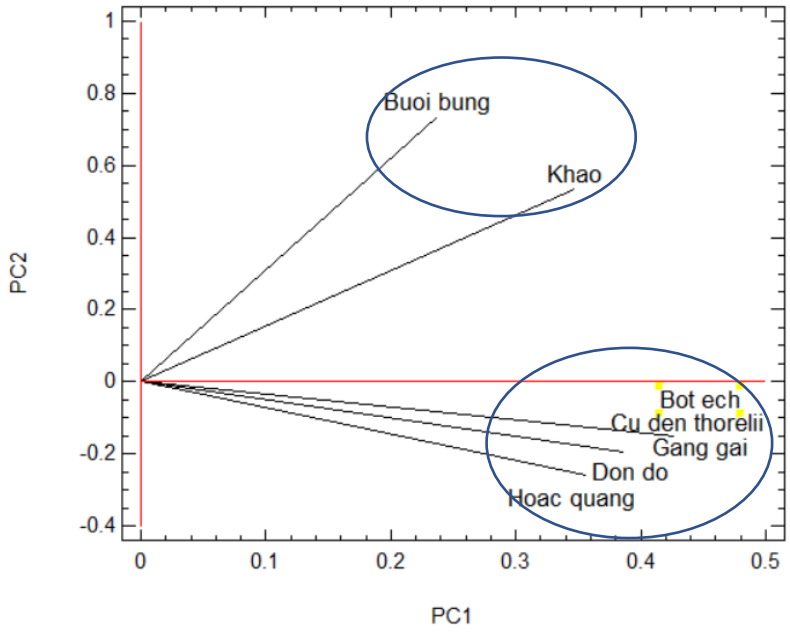


Figure 12. Ecological relationship among species of regenerated trees according to (-/+) and weight relationship by PCA for degraded EBLF at various levels and after shifting cultivation

Note: In the circle are groups of species with closely supportive relationships; the two species groups differ by < 45^0, have supportive relationship but weak. Species names in Vietnamese that can be translated into Latin names by using Annex 3

Thus, in the tropical EBLF, the regenerated tree layer and the large tree layer have no ecological competition; however, the species component is related to each other in the large tree layer and the regeneration tree layer is different. This can be explained that the regeneration process in EBLF takes place in a mosaic pattern, regenerated trees do not appear under the mother trees, but elsewhere with favorable ecological conditions for them, mainly area with canopy opening.

2.7.2 PCA on the ecological relationships among species in the DDF

2.7.2.1 *Ecological relationship among species in the tree layer of DDF*

From dataset from 8 sub-plots of 100 m^2. there were 38 tree species (Annex 3) in the tree layer surveyed in the degraded DDF at various levels. Applying PCA technique to consider the relationships among species by density factor. As a result, 12 closely related species were selected, with weight > 0.1; and there were 26 other tree species with weak relationships (weight < 0.1), considered random.

PCA results showed that in the DDF during the degradation stage, the species have three groups of supportive (+) and competitive (-) and random relationships (Figure 13). The first principal component equation (PC1) in terms of (+/-) relationship and weight relationship:

PC1 = 0.110778×Ca chit + 0.148802×Ca giam - 0.264672×Cam lien + 0.131959×Chieu lieu den - 0.46709×Chieu lieu xanh - 0.387802×Danh danh + 0.203606×Dau dong - 0.519934×De anh - 0.335915×Gang trang - 0.26941×Nhau - 0.0674426×Cam xe - 0.0883329×Giang huong (8)

where species names in equation (6) are in Vietnamese that can be translated into Latin names by using Annex 3.

The tree species groups in DDF follow the relationships in Figure 13:

- Group 1 (supportive relationship): *Terminalia chebula* + *Mitragyne* sp. + *Dipterocarpus tuberculatus* + *Shorea obtusa*
- Group 2 (supportive relationship): *Morinda citrifolia* + *Terminalia calamansanay* + *Catunaregam tomentosa* + *Castanopsis piriformis* + *Gardenia obtusifolia*
- Group 3 (supportive relationship): *Pentacme siamensis* + *Xylia xylocarpa* + *Pterocarpus macrocarpus*
- Species groups with competitive relationship: Group 1 and 3.
- Species groups with unknown and random relationship: Group 1 and Group 2 or Group 2 and Group 3

From this result, it is shown that depending on the stage of degradation and rehabilitation of the DDF, species groups with supportive relationships such as group 1 or group 2 or group 3 should be maintained, forming stable dominant flora in the DDF. If two competing species groups 1 and 3 appear at the same time, it is necessary to adjust the species component in either of these groups, this time it can reduce the less valuable and useful species.

Particularly, other species of Dipterocarpaceae family are not included in the above related species groups because they only have random relationships with these species, they can grow together with the above species groups without ecological competition.

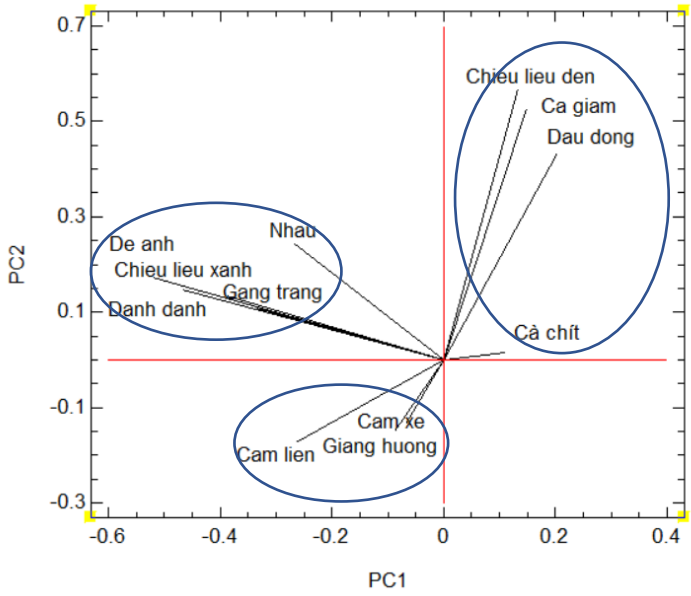


Figure 13. Ecological relationship among species of woody trees according to (-/+) and weight relationship by PCA analysis for degraded DDF at various levels

Note: Together in the circle are groups of species with supportive relationships. Two opposite groups of species (180^0) have a competitive relationship, and two positve or negative weight groups of species ($< 90^0$) has an unknown/random relationship. Species names in Vietnamese that can be translated into Latin names by using Annex 3

2.7.2.2 *Ecological relationships among species in the layer of regenerated trees in DDF*

From the data of 12 sub-plots of 25 m^2, 50 regenerated tree species were identified (Annex 3) in degraded DDF at various levels. Applying PCA technique to consider the relationships among these species by density factor.

As the PCA results of 50 species, 18 closely related species were selected, with weight > 0.1; the other 32 species had weak relationships (weight < 0.2), considered random. The first principal component equation (PC1) represents the sign relationship (+/-) and the weight relationship:

$$PC1 = 0.289776 \times Bang\ lang\ tim + 0.289776 \times Bot\ ech - 0.0683815 \times Ca\ chit - 0.0650998 \times Cam\ lien + 0.25459 \times Cam\ xe - 0.0392933 \times Chieu\ lieu\ den - 0.0316032 \times Dau\ dong + 0.223748 \times Den\ do + 0.289776 \times Gang\ trang + 0.289776 \times Go\ mat + 0.289776 \times Hoac\ quang + 0.289776 \times Ko\ nia + 0.203893 \times Nhoc + 0.258163 \times Sung\ nam\ bo + 0.289776 \times Tao\ rung + 0.289776 \times Thau\ tau + 0.275834 \times Thung\ muc\ long + 0.132652 \times Trams\ la\ do \quad (9)$$

where species names in equation (6) are in Vietnamese that can be translated into Latin names by using Annex 3.

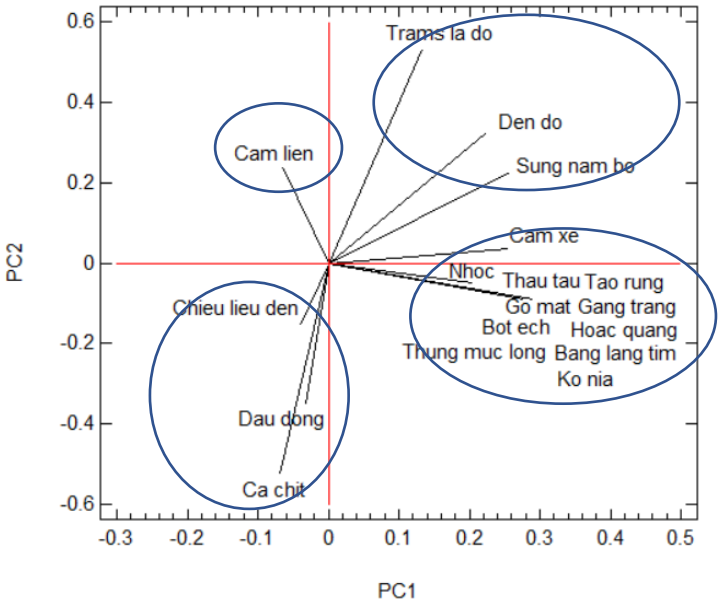


Figure 14. Ecological relationship among species of regenerated tree in weight and by two main component groups (PC1 and PC2) by PCA analysis for degraded DDF at various levels

Note: Together in the circle are species with supportive relationships. Two opposite groups of species (180^0) have a competitive relationship, and two positve or negative weight groups of species ($< 90^0$) has an unknown/random relationship. Species names in Vietnamese that can be translated into Latin names by using Annex 3

Figure 14 shows regeneration tree species in degraded DDF have two groups of supportive and competitive relationships as follows:

- Group 1 (supportive relationship): *Terminalia chebula* + *Dipterocarpus tuberculatus* + *Shorea obtusa*
- Group 2 (supportive relationship): *Canarium subulatum, Xylopia vielana, Semecarpus cochinchinensis, Xylia xylocarpa*
- Group 3 (supportive relationship): *Polyalthia nemoralis, Aporosa octandra var. malesiana, Ziziphus oenoplia, Sindora siamensis var. maritima, Catunaregam tomentosa, Glochidion zeylanicum var. tomentosum, Wendlandia paniculata, Wrightia pubescens, Lagerstroemia tomentosa, Irvingia malayana*
- Species groups with competitive relationship: Group 1 and 2; or Group 3 with *Pentacme siamensis*
- Species groups with unknown and random relationship: Group 1 and 3 or Group 2 and 3

The numbers of regenerated tree species in DDF that have the relationship are higher than the numbers of species in large tree layer. However, the relationships between the main species in the two layers of large trees and regeneration are quite

similar; therefore, the adjustment of species component to support ecology and sustainable development in large tree layer and regeneration can be done almost the same, create stability and component succession of the regenerated tree layer for the large tree layer.

Notes when adjusting the component of regenerated trees in DDF:

- Maintaining groups of species of Dipterocarpaceae family with supportive relationships.
- It is possible to reduce less valuable non-Dipterocarpaceae species that compete with valuable species of Dipterocarpaceae family.
- *Pentacme siamensis* (Miq.) Kurz is an important species of Dipterocarpaceae family that has a weak relationship with the rest of the species of Dipterocarpaceae family because it often dominates alone when regenerating. It has good relationships with *Xylia xylocarpa* (Roxb.) Taub. and *Canarium subulatum* Guillaumin, so it is necessary to maintain this group of species.
- Other regenerated species of Dipterocarpaceae family that do not appear in the above species groups are due to their random relationships and can grow together with the above species without ecological competition.

2.8 Synthesizing descriptions of the forest objects that need to be rehabilitated

Based on the results of observation and evaluation, to synthesize the characteristics for each forest object that need to be restored in Table 9. This is the basis for determining different forest objects to select and apply appropriate silvicultural measures of forest rehabilitation.

Table 9. Describing forest objects in need of rehabilitation

Objects of forest rehabilitation	Observed density		Optimal density		Observed N/D	Dispersion of trees on forest ground		Species ecological relationship	
	N with D ≥ 5 cm (trees/ ha)	Nre with D < 5 cm, H > 1 m (trees/ ha)	N with D ≥ 5 cm (trees/ ha)	Nre with D < 5 cm, H > 1 m (trees/ ha)		Dispersion type	Optimal distance from a random tree to the nearest tree (m)	Tree layer with D ≥ 5 cm	Regenerated tree layer with D < 5 m and H > 1 m
Degraded EBLF at various levels	560 - 1180	400 - 6800	1000	500	Trees reach D = 40 cm but most diameter classes are deficient, the density of the smallest diameter class is too high (class 5-10 cm)	Clumped, with canopy gaps	1.7	There are 11 species with supportive relationship, no species ecological competition	There are 7 species with supportive relationship, no species ecological competition
Regenerated forest after shifting cultivation (over 10 years)	867 - 2000	1200 - 2600	1000	500	Mainly young trees with D < 25 cm, the density is quite high at the first diameter class (5-10 cm)	Very clumped, with many canopy gaps	1.9		
Degraded DDF at various levels	660 - 2100	1400 - 3200	700	500	Trees reach maximum D = 30 cm, tree density at the smallest diameter class is too high (class 5-10 cm)	Very clumped, with many canopy gaps	2.0	There are 12 species with ecological relationships divided into 3 groups of support and competition	There are 18 species with ecological relationships divided into 3 groups of support and competition
Regenerated DDF after over exploitation	280 - 1380	2200 - 5800	700	500	Mainly young trees with D < 25 cm, the density is quite high at the first diameter class (5-10 cm)	Very clumped, with many canopy gaps	2.0		

From the information in Table 9, reflecting the characteristics of the forest objects that need to be restored, thereby pointing out the orientation of silvicultural measures that can be applied appropriately:

i) All degraded EBLF at various levels have densities lower than ideal densities with N < 1000 trees/ ha and some places with lack of potential regeneration (Nre < 500 trees/ ha); compared with the ideal N/D model, there are lacks trees in diameter classes, trees can reach D = 40 cm, the density is too high for the smallest diameter class (class D = 5-10 cm). Therefore, the silvicultural measure in this object is to enrich planting where the forest has clumped dispersion, creating small and large canopy gaps, also thinning the trees at a small diameter class along with adjusting the species according to the purposes.

ii) For regenerated EBLF after shifting cultivation, the number of potential regenerated trees is very high, the minimum potential regeneration density Nre = 1200 trees/ ha > 500 trees/ ha optimal; in which the density of large trees is mainly in the small diameter classes (< 25 cm) and high density at D = 5-10 cm; large trees are clumped dispersed in clusters. The silvicultural measure is to assist natural regeneration, in which it is necessary to thin the density of regenerated tree layer and small trees as well as adjust the species component according to the purposes. However, in places where regeneration disperses in clumps or in some places with lack of regeneration, additional planting is required.

iii) For degraded DDF at various levels, the minimum density is approximately equal to the ideal density with N = 700 trees/ ha, and the potential regeneration is very enough, minimum Nre = 1,400 trees/ ha > 500 trees/ ha optimal. Trees can reach D = 30 cm, according to the ideal N/D model, the density is too high for the smallest diameter class (class D = 5-10 cm). However, trees and regenerated trees have very clumped dispersion, so there are many canopy gaps in the forest. Therefore, it is necessary to apply the enrichment planting measure for this object to supplement the purpose timber trees in the canopy gaps to increase the productivity and quality of the forest and to thin the small diameter class trees, in which the species component is adjusted by the supportive groups, reduce species ecological competition because of PCA results.

iv) For regenerated DDF after over exploitation, the quantity of potential regenerated trees is very high, the minimum potential regeneration density Nre = 2220 trees/ ha > 500 trees/ ha optimal; in which the density of large trees is mainly in the small diameter classes (< 25 cm), some places where N is very low (280 trees/ ha) but high at class D = 5 - 10 cm; large trees are clumped dispersed in clusters, many clusters have gaps in canopy. The silvicultural measure is to assist natural regeneration of high densities places, in which it is necessary to thin the density of trees at the smallest class D and regenerated trees; and at the same time adjusting species component towards purposes, supporting and reducing ecological competition. In places where regeneration

disperses in clumps or some places with lack of regeneration trees, additional planting is required.

v) As for the bamboo forests (including *Gigantochloa* sp., *Bambusa procera* A.Chev. & A.Camus), the *Gigantochloa* sp. forest has an average density of 28,600 trees/ ha, the average diameter of 2.8 cm and the average height of 6.1 m; meanwhile, *Bambusa procera* forest has an average density of 730 trees/ ha, average diameter of 4.2 cm and average height of 7.5 m. The bamboo forests can grow either pure or together with timber trees, they provide a large amount of bamboo shoots and bamboo culms for the community's life and production, so it is necessary to maintain this forest type; only where the bamboo forest is degraded, or has a large area, it is possible to apply enrichment planting in cutting rows to supplement multi-purpose timber trees, while keeping bamboos in the remaining rows to serve the community life and production.

2.9 Collecting local people's opinions and experiences on forest rehabilitation

In four localities, doing research with ethnic communities managing different types of forests, conducting interviews and discussions in each locality with 3-5 people experienced in forest use and management. The aim is to understand community needs, knowledge and experiences in forest rehabilitation to include in the manual. Use open-ended questions in Box 1 to gather information. The results are incorporated into the technical measures of forest rehabilitation.

Box 1. Open-ended question for people on the topic of forest rehabilitation
1) The situation, level and scale of forest degradation of communities and households 2) Causes of forest degradation 3) Impacts of local forest degradation on the life and environment in the community 4) Community needs in rehabilitation of degraded forests and fallow shifting cultivation 5) What is the way to restore forests according to community experiences? 6) Species of timber trees, multi-purpose trees and non-timber plants that the community wants to plant and can grow for local forest rehabilitation. The techniques related to seed, seedling, planting, care, timing, and the way to harvest these plants. 7) Needed resources for forest rehabilitation that the community cannot afford 8) Other issues related to forest degradation and rehabilitation

2.10 Cataloging and describing plant species used for additional and enrichment planting.

Among the two silvicultural measures of forest rehabilitation, "Assisted natural regeneration with additional planting" and "Enrichment planting", it is necessary to indicate the appropriate plant species. This study cataloged plant species used in forest rehabilitation, including woody trees towards multi-purpose trees and non-timber plants,

for two forest types, degraded EBLF and DDF at various levels or regeneration after shifting cultivation in different ecological sub-regions of Dak Lak province.

Species are selected for rehabilitation based on the criteria in Box 2

Box 2. Criteria to select plant species for forest rehabilitation
- Native plants - Prioritize multi-purpose trees - Capable of supplying timber - Fast growth in height and diameter growth > 1.5 cm year^{-1} - Flowering regularly - Straight trunk shape - Small canopy - No/ less pestilent insect - Wide ecological amplitude
Source: ITTO (2002); Appanah (1998), Longman and Wilso (1995) and Circular No. 30/2018/TT-BNNPTNT (MARD, 2018b)

Among the criteria for selecting plant species to restore the natural forest, native trees are the first priority and compulsory. Since native trees have grown themselves in the ecological conditions of the forest objects that need to be restored in the past, there is no need for research to test the adaptation, only selecting based on the needs and purposes of forest rehabilitation (FAO, 2015).

Tree species selected for forest rehabilitation should be multi-purpose trees (Figure 15), providing a variety of products with economic value, easy to grow, rapid growth in height to surpass the shrub layer and compete for light, regular flowering, no/ less pestilent insect, ...

Based on criteria for selecting plant species for forest rehabilitation, cataloging, and describing selected trees on the basis of:

i) Surveying native trees in the field
ii) Knowledge and experiences gathered from local people
iii) The plant catalogue of the Ministry of Agriculture and Rural Development according to Circular No. 30/2018 / TT-BNNPTNT (MARD, 2018b) "Regulations on the Catalogue of major forest plant species; seed and source recognition; management of seed materials for major forestry plants" dated 11/16/2018.
iv) The results of research published in Viet Nam have been recognized as Ho (1999, 2006), Website of Viet Nam Academy of Forest Sciences (VAFS), WWF and GIZ, Huy (2014, 2019), and other authors.

v) The prestigious international research results in tropical forest rehabilitation include those of Appanah (1998), FAO (1989, 2015, 2020), Huy et al. (2018), ICRAF, International Tropical Timber Organization (ITTO, 2002), IUCN and WRI (2014), “Useful tropical plants” Website, "The Plan List" Website, GIZ and WWF.

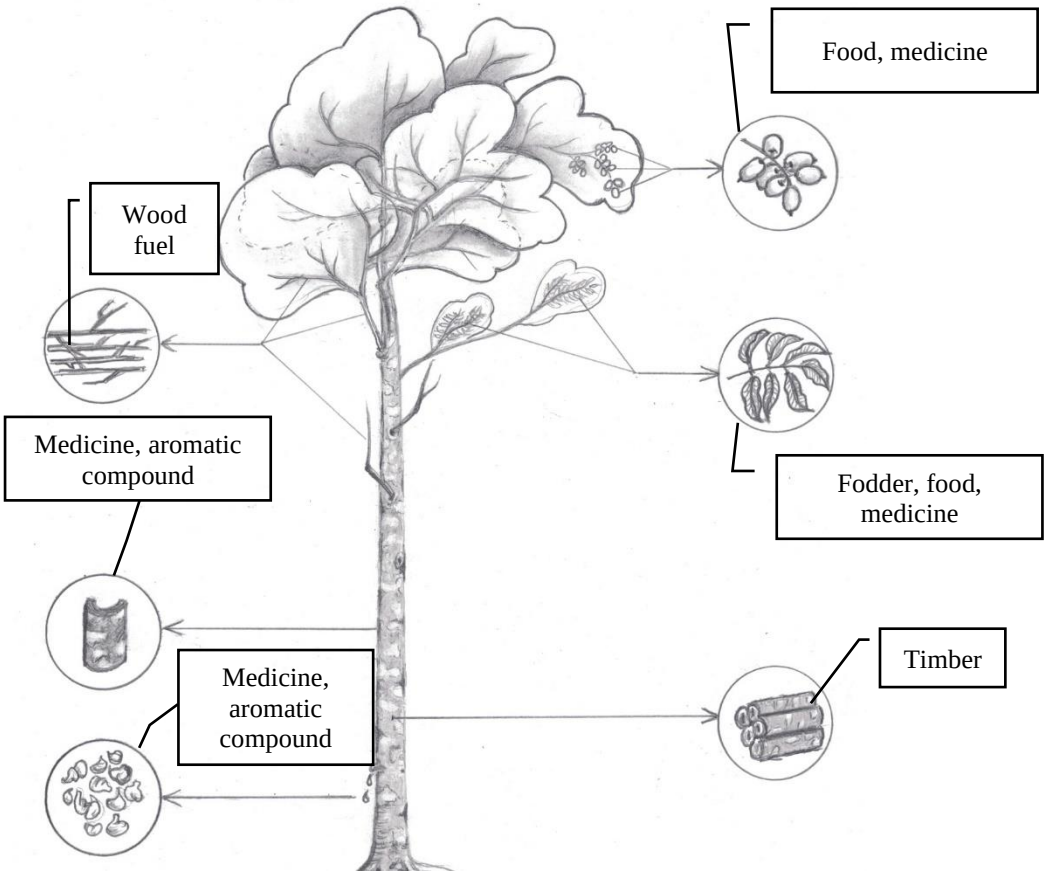


Figure 15. Illustration of multi-purpose indigenous trees: Food, medicine, aromatic compound, fodder, wood fuel, timber, etc.

As a result, 85 native plant species were selected to include in the catalogue of plant species used for forest rehabilitation (Annex 1), including:

- Regarding forest types: 83 species for EBLF; 23 species for DDF.
- Regarding the forest objects to be rehabilitated: 59 species for degraded forest and 84 species for regenerated forest after shifting cultivation, over exploitation.
- Regarding life form: 80 species of woody trees, 2 species of liana (rattan) and 3 species of bamboo
- Regarding purposes and uses: 72 multi-purpose species, 8 species for timber only and 5 species for Non-Timber Forest Products (NTFPs) only (rattan, bamboo)

Each selected plant species included in the catalogue is described in detail with the following contents: Pictures of stems, bark, leaves, flower, and fruits; Plant morphology description; Original distribution; Forest type; Ecological requirements, Biological characteristics; Product provided by species; Applied forest objects; Technology: Seed, seedling; and Information Sources.

PART 3: FOREST REHABILITATION TREATMENTS

1 SILVICULTURAL MEASURES AND INDICATORS

Based on the forest objects that need to be rehabilitated of two main forest types, namely DDF and EBLF, including degraded forests at various levels after over exploitation and clear-cutting forests for shifting cultivation then fallow; pursuant to Circular No. 29/2018/TT-BNNPTNT (MARD, 2018a) "Regulations on silvicultural measures", based on the results of description for forest objects in need of rehabilitation and referencing the results of forest rehabilitation researches in Viet Nam and in the world; the three silvicultural measures developed in this manual for natural forest rehabilitation are: i) Assisted Natural Regeneration (ARN); ii) Assisted Natural Regeneration with Additional Planting; and iii) Enrichment Planting.

1.1 Silvicultural measures of natural forest rehabilitation

i) Assisted Natural Regeneration - ANR

ANR is a silvicultural measure to enhance the restoration of degraded forests by maximizing the regeneration capacity, ecological succession, protecting and nurturing mother trees and regenerated trees inherent in the area. ANR is to speed up, instead of waiting for natural processes, support the seeding, germination, and assist the growth of natural regeneration by eliminating or reducing barriers to natural forest regeneration such as the elimination of competition from valueless weeds, lianas, shrubs and impacts such as fire, grazing; help improve the value and quality of young forests, regenerated trees that meet the purpose of forest management. With the ANR, forests develop faster than let them grow naturally (Circular No. 29/2018/TT-BNNPTNT (MARD, 2018a); FAO, 2020). In addition, ANR is a simple, low-cost forest rehabilitation method that can effectively convert damaged forest areas with degraded vegetation into more productive forests (Shono et al., 2007). Figure 16 illustrates the ANR measure.

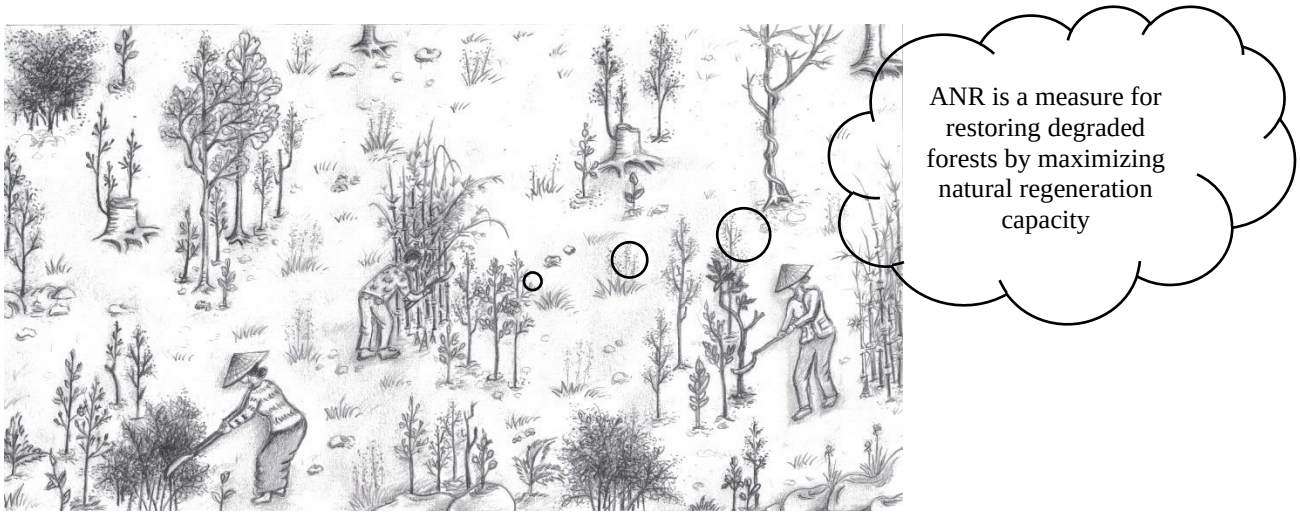


Figure 16. Assisted Natural Regeneration - ANR

ii) Assisted natural regeneration with additional planting

This is an extended measure of the ANR, including additional planting some species of purpose plants in areas with lack of regenerated trees to promote forest formation within a defined time limit and to increase the value and ecological function of the natural forest environment (Circular No. 29/2018/TT-BNNPTNT (MARD, 2018a); FAO, 2020). Figure 17 illustrates the ANR with additional planting.

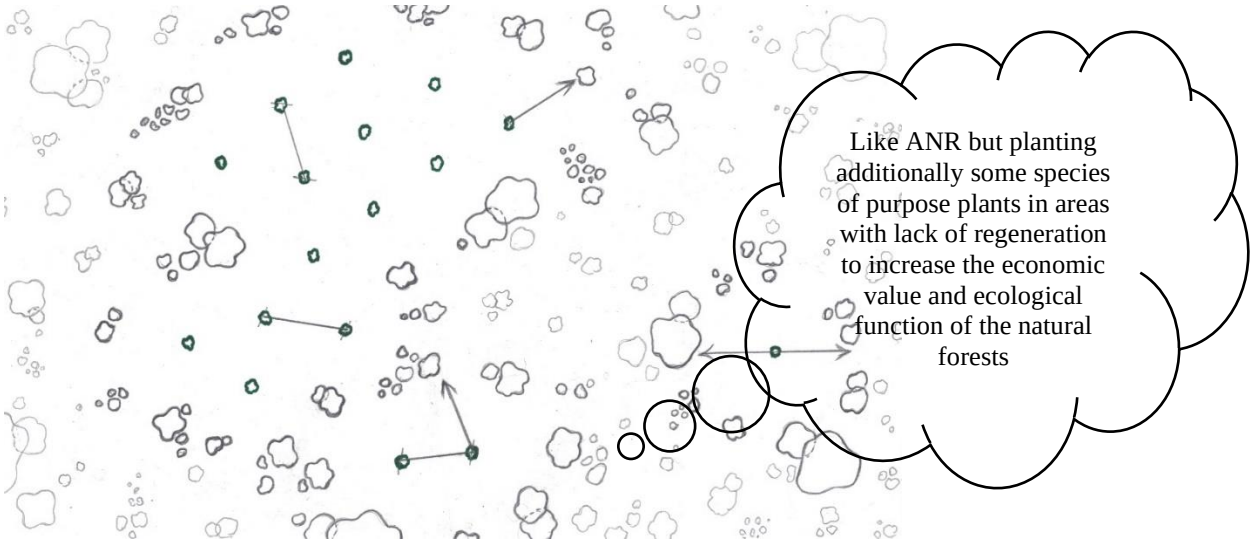


Figure 17. Assisted natural regeneration with additional planting by canopy gaps

iii) Enrichment planting

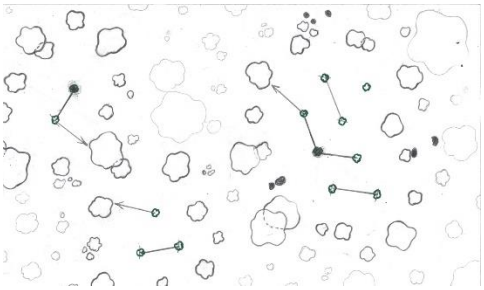
Enrichment planting is used to assist rehabilitation of degraded forests through planting more of purpose trees in canopy gaps or on cutting rows. Enriching planting while keeping natural purpose trees in forests and additionally planting for forests that

have degradation, poor value, degradation in ecological function, and lack of regeneration capacity; the used plants are fast- growing valuable and meet the goal of forest management. Enrichment planting is aimed at improving the productivity and quality of degraded forests and meeting the demand for forest products as well as promoting the ecological and environmental functions of natural forests (Circular No. 29/2018 / TT-BNNPTNT (MARD, 2018a); ITTO, 2002). Figure 18 illustrates techniques for enrichment planting.

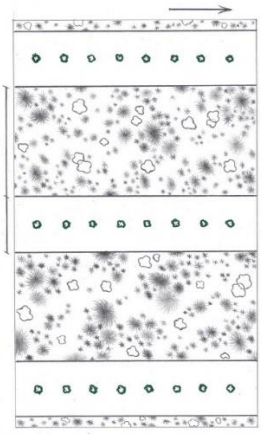
As for the measure of enrichment planting, it is necessary to be careful. The success of enrichment planting is various, and its effectiveness is sometimes questioned in the tropics. Some of the reasons cited in Southeast Asia and tropical America for forest enrichment fail are mainly due to the ecologically inadequate selection of species and difficult management, such as lack of proper canopy opening before planting and following the growth stage of the plant, lack of compliance with proper planting and care practices, lack of monitoring to protect plants from pests and diseases, seedlings must be replanted, therefore, a regular supply of seedlings is needed and it is labor demanding (ITTO, 2002).

Experiences from Viet Nam and international research have shown that the method of enrichment planting in cutting rows is more favorable when applied to fallow regenerated forests after shifting cultivation or after over exploitation than to degraded forests (ITTO, 2002). This finding relates to the light factor; the light is often sufficiently provided for enrichment plants in regenerated forests with low tree canopy, while in degraded forests it is difficult to adjust forest canopy to provide adequate light for enrichment plants in cutting rows at different growth stages.

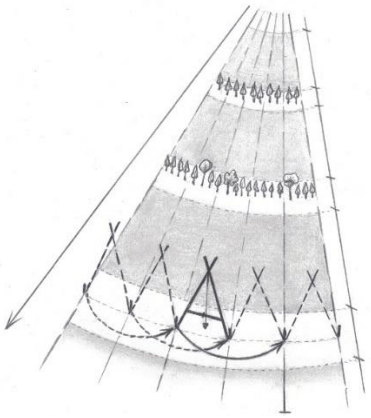
DDF is a thin and dry forest type with dominant species of Dipterocarpaceae family. Degraded DDFs often have a very thin density of large trees and have a lot of canopy gaps, so enrichment planting for improving productivity and quality is an important silvicultural measure (Appanah, 1998). *Enrichment planting of DDF should be planted in canopy gaps of degraded forests, without cutting the forest rows to plant trees, there is no destructive impact to the forest.* In addition, it is can be done simply and inexpensively because there is no need to cut the rows to plant, open the canopy over time; the plants that planted in canopy gaps are not in short of light. However, extreme ecological conditions of the DDF such as drought, lack of water and annual forest fire in the dry season; waterlogging in the rainy season; the soil and soil layer change, often thin, the soil is gravelly and low content of organic matter, etc. All these elements make it difficult to select economic valuable and ecologically suitable plants for enrichment planting (MEA, 2005; Huy, 2014, 2019; Huy et al., 2018)



(a)



(b)



(c)

Enrichment planting is additional planting for degraded forests in canopy gaps or in cutting rows with lack of regeneration capacity to enhance the ecological value and function of the natural forest environment.

Figure 18. Enrichment planting in canopy gaps (a); in rows on flat land (b); and in rows by contour line on sloping land (c)

In the long term, DDFs located in the arid region tends to degrade due to low rainfall, frequent droughts and hot weather, and human activities such as using fire, grazing cattle, cutting wood and non-timber plants, deforestation for pure industrial crops, lead to gradual forest degradation. At the same time, the species of Dipterocarpaceae family in DDF growing on arid land is a symbol of ecological function and they provide important environmental services; however, in more arid lands, the demand of communities for forest products is much higher than the sustainable supply of DDF ecosystems. As a result, in many places these resources are rapidly depleted

(FAO, 1989, 2015). Many people living in arid lands are trapped in a vicious cycle of poverty, due to irrational activities that degrade the forest environment. Furthermore, climate change is expected to exacerbate desertification and reduce land productivity in the DDF. Therefore, conservation, rehabilitation, and enrichment planting of DDF play an important role in sustainable development (Dobie, 2003).

1.2 The technical criteria to define the silvicultural measures of forest rehabilitation by different forest types

Forest objects to be rehabilitated in this manual include (Figure 19):

- The degraded EBLF at various levels
- The regenerated EBLF after shifting cultivation
- The degraded DDF at various levels
- The regenerated DDF after over exploitation
- The pure and primary bamboo forest or after shifting cultivation

Degraded after exploitation

Regeneration after shifting cultivation

EBLF

Degraded after exploitation

Regeneration after over exploitation

DDF

Pure and primary *Gigantochloa* sp. forest (*Gigantochloa nigrociliata* (Buse) Kurz.)

Regenerated *Bambusa procera* forest after shifting cultivation (*Bambusa* sp.)

Pure bamboo forest

Figure 19. Images of forest objects in need of rehabilitation in EBLF, DDF and bamboo forests

Table 10 shows the different silviculture measures of rehabilitation that applicable to different forest objects and forest types

Table 10. Silvicultural measures selected for application according to each forest object and forest type

Forest type, object	Assisted natural regeneration	Assisted natural regeneration with additional planting	Enrichment planting
Degraded EBLF after exploitation			In canopy gaps Thin trees and adjust species component towards purposes at small diameter class
Regenerated EBLF after shifting cultivation	Thin shoots, thin small timber trees, tend regenerated trees Adjust the component of regenerated species and trees at small diameter class towards purposes	Thin shoots, thin small timber trees, tend regenerated trees Adjust the component of regenerated species and trees at small diameter class towards purposes Additional planting in places with lack of regeneration purposes	

Forest type, object	Assisted natural regeneration	Assisted natural regeneration with additional planting	Enrichment planting
Degraded DDF after exploitation			In canopy gaps Thin trees at small diameter class along with adjusting species component towards supporting and reducing ecological competition
Regenerated DDF after over exploitation	Thin shoots, thin small timber trees, tend regenerated trees Adjust the component of regenerated species and trees at small diameter class towards supporting and reducing ecological competition	Thin shoots, thin small timber trees, tend regenerated trees Adjust the component of regenerated species and trees at small diameter class towards supporting and reducing ecological competition Additional planting in places with lack of regeneration purposes	
Pure bamboo forest (primary or fallow shifting cultivation)			Plant in cutting rows with native multi-purpose timber trees

Table 11 shows the use of indicators describing the characteristics of the forests to be restored such as regenerated tree density (Nre), large tree density (N), observed N/D, dispersion patterns in tree and regeneration layers, the area of canopy gaps of three forest types, which is EBLF, DDF and bamboo forest to choose one of four suitable silvicultural measures of rehabilitation such as ANR, ANR with additional planting and enrichment planting.

Table 11. Forest indicators and characteristics to determine silvicultural measures for forest rehabilitation according to forest types

Forest type	Forest indicators and characteristics	ANR	ANR with additional planting	Enrichment planting in canopy gaps, cutting rows
EBLF	Density of purpose regenerated trees (Nre) with D < 5 cm and H > 1 m	Sufficient density of potential regeneration: Nre > 500 trees/ ha	Lack of potential regeneration: Nre = 300 - 500 trees/ ha (optimal 500 trees/ ha)	Lack of potential regeneration: Nre = 400 – 500 trees/ ha (optimal 500 trees/ ha)
	Density of large trees (N) with D ≥ 5 cm and observed N/D	Large trees are mainly in small diameter classes (D < 25 cm)	Large trees are mainly in small diameter classes (D < 25 cm)	Lack of large tree density: N = 560 - 1000 trees/ ha (optimal 1000 trees/ ha), dispersed in classes D = 5 cm - 40 cm, most diameter classes have few trees, but the density of the smallest diameter class is too high (class 5-10 cm)
	Dispersion patterns of large trees and regenerated trees	Regeneration is quite uniform	Regenerated and large trees are dispersed in clumps to very clumps	Regenerated and large trees are dispersed in clumps to very clumps
	Area of canopy gaps in forest	Canopy gaps without/ with lack of regeneration < 1000 m^2	There are some canopy gaps 100 m^2 - 1000 m^2 or/ and large canopy gaps 1000 m^2 - 3000 m^2 without/ with lack of regeneration	There are some canopy gaps 100 m^2 - 1000 m^2 or/ and large canopy gaps 1000 m^2 - 3000 m^2
DDF	Density of purpose regenerated trees (Nre) with D < 5 cm and H > 1 m	Sufficient density of potential regeneration: Nre > 500 trees/ ha	Lack of potential regeneration: Nre = 300 - 500 trees/ ha (optimal 500 trees/ ha)	Sufficient density of potential regeneration: Nre > 500 trees/ ha (optimal)
	Density of large trees (N) with D ≥ 5 cm and observed N/D	Large trees are mainly in small diameter classes (D < 25 cm)	Large trees are mainly in small diameter classes (D < 25 cm)	Lack of large tree density: N = 600 - 700 trees/ ha (optimal 700 trees/ ha), dispersed in classes D = 5 cm - 30 cm, but most diameter classes have few trees; the

Forest type	Forest indicators and characteristics	ANR	ANR with additional planting	Enrichment planting in canopy gaps, cutting rows
				density of the smallest diameter class is too high (class 5-10 cm)
	Dispersion patterns of large trees and regenerated trees	Regeneration is quite uniform	Regenerated and large trees are dispersed in clumps to very clumps	Regenerated and large trees are dispersed in clumps to very clumps
	Area of canopy gaps in forest	Canopy gaps < 1000 m^2	There are some canopy gaps 100 m^2 - 1000 m^2 or/ and large canopy gaps 1000 m^2 - 3000 m^2 without/ with lack of regeneration	There are some canopy gaps 100 m^2 - 1000 m^2 or/ and large canopy gaps 1000 m^2 - 3000 m^2
Pure bamboo	Area of canopy gaps in forest			Canopy gaps < 1000 m^2

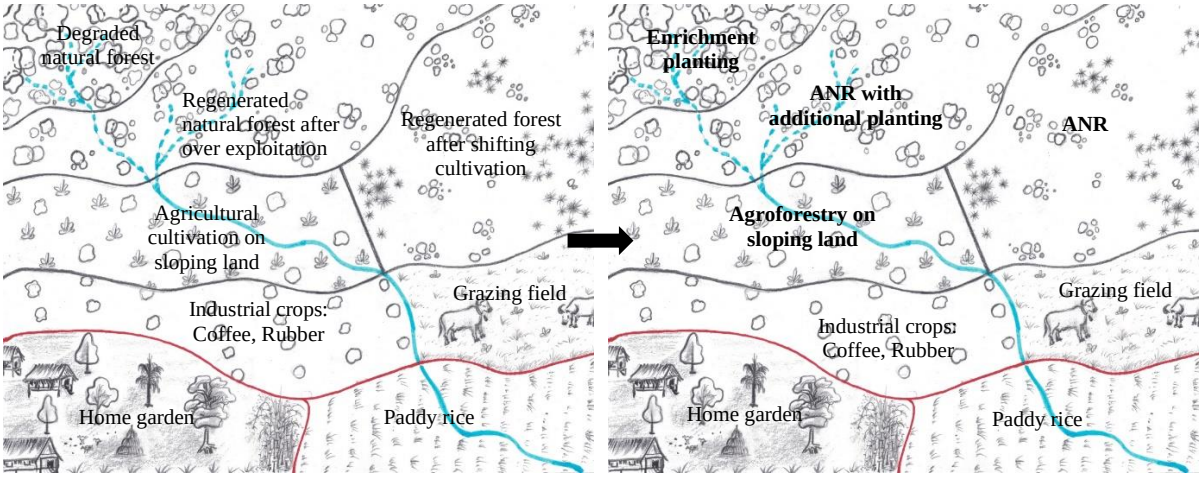
2 ESTABLISHMENT, MONITORING AND EVALUATION OF LANDSCAPE- BASED FOREST REHABILITATION PLAN

2.1 Landscape- based forest rehabilitation

Forest rehabilitation based on landscape is the task of restoring degraded natural forests in the landscape of using land or other resources of an area or locality; thereby ensuring forest rehabilitation has reciprocal and mutually supportive relationships with other resource using activities such as land and water in that landscape. From there, it is possible to develop forests and other resource using activities to be stable and long-term. A simple example, in a landscape using forestland resource of a village, what is the scale of natural forest rehabilitation to remain harmonious and secure land for agricultural crops on fallow land and grazing land? Or where in the basin that the forest needs to be rehabilitated to ensure that clean water is maintained for communities.

Forest rehabilitation based on landscape is to ensure that forest restoration meets the goal of sustainable development in a planned space-time. Basic questions in forest landscape restoration are: where, how to act, when, how much and why? Ideally, efforts should aim at establishing a forest ecological landscape, towards harmonizing the rehabilitation of forest environmental service functions with livelihood improvement and integration with preservation of indigenous cultural traditions of the community (Aronson et al., 2007).

Forest rehabilitation activities based on landscape are influenced by many factors, drivers such as ecological, and socio-economic goals; and economic expectations often require trade-offs with environmental goals (Clewell et al., 2000). Therefore, it is necessary to have an appropriate, harmony measure and approach in planning forest rehabilitation based on the local landscape. Figure 20 illustrates a schematic drawing of forest rehabilitation on the basis of village landscape.



Village landscape sketch before forest rehabilitation planning

Village landscape sketch after forest rehabilitation planning

Figure 20. Village landscape- based forest rehabilitation

2.2 Participatory village landscape- based forest rehabilitation planning

i) Objectives and expected results.

Villagers agree on a plan and resources to implement natural forest rehabilitation based on village landscape.

ii) Contents, methods, and steps to approach

Including the following contents and methods:

- Draw a participatory sketch of forest rehabilitation based on village landscape (Box 3)
- Participatory planning for forest rehabilitation based on village landscape (Box 4)

Box 3 Draw a participatory sketch of forest rehabilitation based on village landscape
1. Objectives and expected results: Recreate a general picture of the landscape of local land, forest use and draw an expected sketch to restore the forest in the village landscape.
2. Participants: - Village leader, deputy - Village elder - People who have experience in managing forest resources and land - Representatives for women and youth About 7-10 people

3. Materials and tools required:

- A map of forest status and forest land of the village
- Clear cellophane to cover the map for drawing
- Color pen: Red, black, blue
- Alcohol, cotton for erasing strokes
- Paper tape
- Camera

4. Performing method:

- Facilitators clarify the purposes of drawing a sketch of forest rehabilitation based on village landscape for all participants.
- Introduce the sketch of map of forest resources and land use in the village.
- Encourage participants to draw a sketch of the current status of forest resources and land on clear cellophane covered on the map:
    - Start drawing roads, rivers, mountains, houses (easily recognizable places on the map)
    - Interview and write local names of rivers, streams, mountains, and hills.
    - Assist with drawing different areas of forest resources and land use: Primary natural, degraded, and after shifting cultivation forests, farming, grazing fields, industrial trees, residential area, home gardens, …. (Illustrated as the left of Figure 20)
    - Take pictures of the drawn sketch of current status of the village's forest resources and land
- Encourage participants to draw a sketch of applying different forest rehabilitation measures on the drawn sketch of forest resource and land:
    - Facilitators provide an overview of silvicultural measures of forest rehabilitation such as ANR, ANR with additional planting and enrichment planting for different forest types (Use Table 10 for introduction, explanation)
    - Encourage participants to discuss where to apply silvicultural measures suitable for the community (Illustrated as the right of Figure 20)
    - Take pictures of the sketch of forest rehabilitation based on village landscape.
- Present and discuss the agreement about the sketch of forest rehabilitation based on village landscape at a village meeting (representing more than 2/3 of the households in the village)
    - One representative for the villager presents two sketches: Current status of forest resources, cultivated land and forest rehabilitation based on landscape in the village meeting.
    - Discuss, clarify, and adjust the sketch of forest rehabilitation based on village landscape.
    - Take pictures of the sketch of forest rehabilitation based on village landscape agreed in the community.

Box 4 Participatory planning for forest rehabilitation based on village landscape

1. Objectives and expected results:

Community agrees on a planning framework and resources to implement natural forest rehabilitation on the basis of village forest landscape.

2. Participants:

- Village leader, deputy
- Village elder
- People who have experience in managing forest resources and land
- Representatives for women and youth

About 7-10 people

3. Materials and tools required:

- A map of forest status and forest land within the village
- A drawn sketch of current status of forest and land
- A drawn sketch of forest rehabilitation based on landscape
- A_0 paper
- Color pen: Red, black, blue
- Paper tape
- Camera

4. Performing method:

- Facilitators clarify the targets and expected results of forest rehabilitation planning based on village landscape for all participants.
- Introduce the sketch of forest resources, land use and the agreed sketch of forest rehabilitation in the village.
- Encourage participants to plan based on the template in Table 12 by following these steps:
    - Start by recording the forest rehabilitation activities in the village from the results of drawing the sketch of forest rehabilitation based on the landscape (Figure 20) into the planning frame in the column "Forest rehabilitation activities".
    - Encourage exchange and discussion to agree on the contents in planning framework for each forest rehabilitation activity.
- Present and discuss the agreement about the plan of forest rehabilitation at a village meeting (representing more than 2/3 of the households in the village)
    - One representative for the villager presents the planned framework in the meeting.
    - Discuss, clarify and adjust the plan of forest rehabilitation.
    - Take pictures of the planning framework of forest rehabilitation based on village landscape agreed in the community.

Table 12. Planning framework for village landscape- based natural forest rehabilitation.

Id	Natural forest rehabilitation activities	Forest object	Indicators	Time	Place	Responsibility	Participants, and/or the way to implement	Resources
1	ANR							
2	ANR with additional planting							
3	Enrichment planting							

Note:

- Forest objects: EBLF or DDF: Degraded, or regenerated after shifting cultivation, over exploitation, primary and secondary bamboo forests.
- Indicators include: After how many years, how many areas of the forest to be restored, the number of surviving additional trees, the average size of the regenerated trees and of the trees to be reached, the density of trees, potential regeneration trees are achieved compared with the optimal density for each forest type (Table 9)
- Implementation time: It is the expected time to complete forest rehabilitation by each silvicultural measure, in a period of 5-10 years.
- Location: Specify the name of the forest blocks by the local landmarks such as river, mountain, waterfall, ...
- Participants or how to do it: Specify who does it and/or how it's done
- Resources: Indicate the amount of capital needed and from where; where labor comes from; seed sources, create nurseries, technical instructors….

2.3 Monitoring and evaluating the implementation of the village landscape-based forest rehabilitation plan.

A village landscape- based forest rehabilitation plan should be viewed as a plan of local forest land use and forest development; therefore, it is necessary to organize annual seasonal monitoring for each silvicultural measure and evaluate at the end of the forest rehabilitation period, when the degraded and after shifting cultivation forests applying silvicultural measures reach the ideal forest models.

2.3.1 Forest rehabilitation monitoring

Monitoring involves a system that collects and analyzes data over time to determine how the applied silvicultural measures make change and what problems need improvement during implementation. Monitoring is the observing and recording of the situation and progress of forest rehabilitation according to each measure on a regular basis by the annual season and ending at the end of the forest rehabilitation period. Therefore, monitoring helps to detect problems and helps to improve implementation process. It also helps in recording, synthesizing and learning from forest rehabilitation

techniques and practices and more importantly uncovering the causes if there are technical and organizational failures.

Monitoring should be carried out in a participatory process, as it provides reliable feedback on operations, results, and management. A participatory monitoring method also promotes learning from each other to better understand forest rehabilitation efforts and impacts. By measuring progress over time, monitoring the provision of evidence base, on which to improve techniques and community organizations for forest rehabilitation (FAO, 2015).

Box 5 introduces participatory monitoring method when applying forest rehabilitation techniques in communities.

Box 5. Monitoring method applied natural forest rehabilitation techniques based on village landscape

1. Supervisors, participants

- The leader or deputy head of the community forest management unit, or the team/group leader of the community forest rehabilitation as the monitoring team leader
- Participants: Households, groups of households performing forest rehabilitation
- Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists

2. Materials and tools

- Forest status map
- A sketch of forest rehabilitation based on village landscape
- Forest rehabilitation plan based on village landscape
- Detailed designs describing forest rehabilitation measures
- GPS to locate forest locations
- Tools, equipment for measuring D, H of forest trees, regenerated trees, planted trees.
- The 30- meter-long measurement tape for measuring the distance of forest trees and forest canopy
- Record sheets according to monitoring criteria for each forest object applying each silvicultural measure of forest restoration (Table 13)

3. Performing method

- Time: At the end of the growing season of forest trees (at the end of the rainy season)
- Location: Each forest block will be rehabilitated by each silvicultural measure
- Recording: use Table 13 to collect, record forest rehabilitation information
- Discuss in the monitoring group on two aspects, strengths and weaknesses of silvicultural measures of forest rehabilitation and used resources
- The monitoring team leader announces the results of the monitoring at the annual village meeting

Table 13. Record sheet of forest rehabilitation monitoring.

Supervisors:
Participants:
The implementers:
Place:
Monitoring time:
The time when forest rehabilitation measures start:
Forest object:
Applied silvicultural measure:

Monitoring and observing indicators	*Data, information collected*
Area of rehabilitated forest (ha)	
The density of large trees (N, trees/ ha) according to the K- 6 trees sampling	
The density of regenerated trees (Nre, trees/ ha) according to the K- 6 trees sampling	
Density of additional planting, initial enrichment planting and at monitoring time (counting in forest blocks), survival rate	
Average growth D of trees (K- 6 trees sampling)	
Average growth H of potential natural regenerated trees (K- 6 tree sampling)	
Growth of H plants (K- 6 tree sampling for planted trees)	
Forest canopy (1/10) (according to line intersect sampling)	
Dispersion of regenerated trees and large trees on the ground (clumped, random, uniform)	
Productivity of products harvested from rehabilitated forests and their value	
Strengths/ weaknesses in applied technical measures and resources	

Note:

- How to practice method K- 6 tree sampling refer to Figure 21 and Figure 29 and method K- 6 tree sampling is repeated 3 times in each forest block undergoing rehabilitation, placed in average representative positions.
- Calculate the average value of D, H of trees, regenerated trees according to the K- 6 tree sampling method: Measure D and H of 6 trees and averaged, then averaged from the sample points.
- The canopy cover by line intersect sampling refer to Figure 26
- The method of determining dispersion of forest trees and regenerated trees on forest ground refer to Figure 22
- Productivity of products harvested from restored forests and their value: Record the productivity of forest products harvested by season, by year, especially from additional planting, enrichment planting, and calculate into money.

2.3.2 Evaluation of forest rehabilitation plan

The evaluation aims to draw conclusions about the success or failure of the forest rehabilitation plan and lessons learned. The evaluation was carried out at the end of the

5- 10 years forest rehabilitation plan. The evaluation mainly compares the results achieved with the plan's expectations for the whole forest rehabilitation activities on a village landscape basis.

Evaluation includes a synthesis of the monitoring results to the final stage and final evaluation. The evaluation will provide a completion of silvicultural measures of forest rehabilitation and implementation, while also pointing out techniques that are not suitable and cannot be applied. Similar to monitoring, the evaluation should be conducted with the participation of all stakeholders and implementers in order to have a common understanding and consensus on the achievements of the plan and measures of forest rehabilitation (FAO, 2015).

Use the indicators that need to be achieved for each forest rehabilitation measure in each stage and at the end of the plan and compare with the results achieved, and conduct the evaluation with participation of villagers and stakeholders to draw conclusions about success or failure and lessons learned.

Box 6 introduces a participatory evaluation method for forest rehabilitation plan at village level.

Box 6. Method of participatory evaluating for village landscape- based natural forest rehabilitation plan

1. Evaluators, participants

- The leader or deputy head of the community forest management unit, or the team/group leader of the community forest rehabilitation as the monitoring team leader
- Participants: Households, groups of households performing forest rehabilitation
- Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists, district and provincial rangers, provincial agriculture and forestry extensionists, consultants

2. Materials and tools

- Forest status map
- A sketch of forest rehabilitation based on village landscape
- Forest rehabilitation plan based on village landscape
- Detailed designs describing forest rehabilitation measures
- Record sheets of monitoring results for each forest object applying each silvicultural measure of forest rehabilitation (Table 13)

3. Performing method

- Time: At the end of forest rehabilitation plan (5-10 years)
- Location: Some forest blocks rehabilitated under silvicultural measures and community house.
- Recording: Use Table 14 to collect, record field evaluation

- Discuss in the evaluation group by SWOT method (strengths, weaknesses, opportunities and threats) in the community hall (
- Table 15)
- The evaluation team leader announces the results of the evaluation during the village meeting

Table 14. Framework for evaluating village landscape- based natural forest rehabilitation plan

Evaluators:
Participants:
The implementers:
Place:
Evaluation time:
The time when forest rehabilitation starts:

Id	Natural forest rehabilitation activities	Forest objects	Indicators	Achieved results	Compare the archived results with the indicators (+/-)	Productivity of the product to be harvested and its value	Conclusion on techniques, resources, organization
1	ANR						
2	ANR with addition planting						
3	Enrichment planting						

Note:
- Forest objects: EBLF or DDF: Degraded, or regenerated after shifting cultivation, over exploitation, and bamboo forest.
- Indicators include: Taken from the plan sheet (Table 12)
- Achieved results: Field survey, using the results of annual and seasonal monitoring data in the last stage
- Comparing archived results with indicators (+/-): Quantitative indicators calculate results + or -, qualitative indicators explain the difference between results and indicators
- Productivity of harvested products and value from the restored forest: Synthesize the results of periodic monitoring until the end of the rehabilitation
- Conclusion on techniques, resources, organization: Discuss in the field to record evaluation conclusions

Table 15. SWOT analytical framework on results of natural forest rehabilitation

Evaluators:
Participants:
Implementers:
Place:
Evaluation time:
The time when forest rehabilitation starts:

S (Strengths)	W (Weaknesses)
O (Opportunities)	T (Threats)

Note:

- S and W are strengths and weaknesses in the implementation of forest rehabilitation in communities
- O and T are external opportunities and threats brought in the community forest rehabilitation process including policy, resource support, consultation, training, cooperation….

3 ASSISTED NATURAL REGENERATION (ANR)

3.1 Forest objects applying assisted natural regeneration

Forest objects applying ANR are regenerated forests after over exploitation, or regenerated forests on fallow land after shifting cultivation with sufficient potential natural regenerated trees and tree species meeting the purposes, dispersed uniformly on the forest ground. However, these regenerated trees may be blocked by other plants of less value, such as shrubs, bamboos ...; or the seeds of the mother plant have difficulty in contact with the soil for propagation.

Objects include EBLF and DDF and indicators for determination presented in Box 7.

Box 7. Forest objects applying assisted natural regeneration (ARN)
Forest type and forest status: - Regenerated EBLF after fallow shifting cultivation - Regenerated DDF after over exploitation
Technical indicators of the object: - N/D distribution mainly in the small diameter classes (D < 25 cm) - Sufficient density of purposed potential regenerated trees (Nre) (regenerated trees with D < 5 cm and H > 1 m) reaches over 500 trees/ ha - Dispersion of regeneration trees on forest ground is quite uniformly. - Canopy gaps without/ with lack of regeneration < 1000 m^2

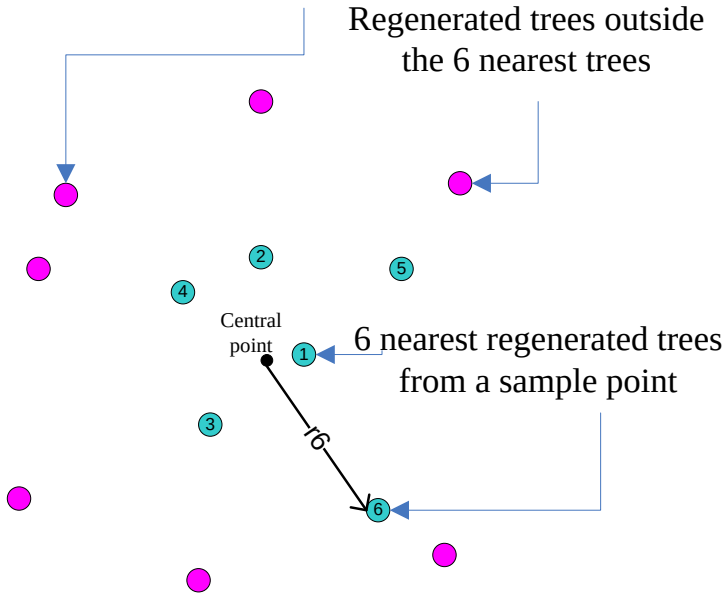
3.2 How to determine forest objects applying assisted natural regeneration measure

i) N/D distribution

Observing the forest blocks and forest objects applying ANR with only scattered trees of poor value and mainly distributed at the diameter classes < 25 cm.

ii) Determining the density of potential regeneration

The forest object applying ANR when there is sufficient density of potential regeneration (purposed trees with D < 5 cm and H > 1 m): Nre > 500 trees/ ha. To determine the density of potential regeneration, method K = 6 regenerated trees is used. In each forest block, select 3 representative points to set up K- 6 tree sampling (Figure 21).



Note: At each representative sampling point, select the nearest 6 potential regenerated trees (D < 5 cm and H > 1 m) according to this diagram.

Measure the distance from the central point to the 6th tree is r_6 (m)

From each K- 6 tree sampling, calculate the regeneration density per hectare (N_i) using the following formula:

$$Ni = \frac{60000}{3.14 \times {r_6}^2}$$

The final density of potential regeneration per hectare (Nre/ ha) is averaged from three sampling points:

$$Nre/ha = (N_1 + N_2 + N_3)/3$$

Data collected on point each K- 6 tree sampling for potential regenerated trees (D < 5 cm and H > 1 m): r_6 = (m)

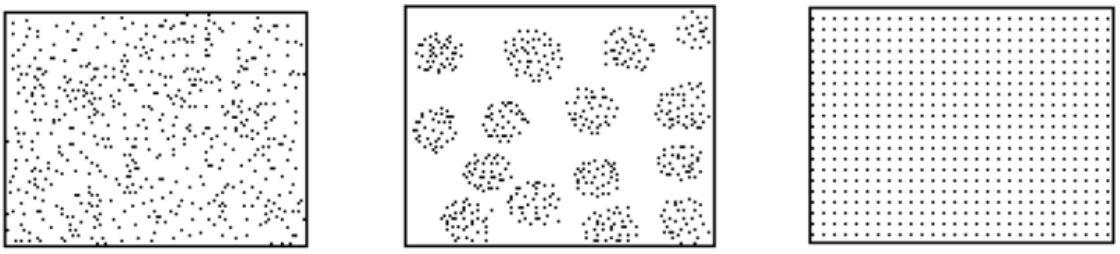
Indicators	Regenerated Tree 1	Regenerated Tree 2	Regenerated Tree 3	Regenerated Tree 4	Regenerated Tree 5	Regenerated Tree 6
Species name						
H of regenerated trees (m)						

Figure 21. K- 6 tree sampling to estimate the potential regeneration density per hectare (Kleinn and Vilcko 2006)

iii) Determining the dispersion pattern of spatial distribution

The ANR was conducted when potential regeneration is sufficient and dispersed quite uniformly on the forest ground.

The way to evaluate the dispersion is by observing representative points in the forest block and deciding what type of regeneration trees are dispersed in Figure 22



Random dispersion | Clumped dispersion | Uniform dispersion

Figure 22. Three dispersion patterns of spatial distribution (Jayaraman, 1999)

iv) Determining canopy gaps without/ with lack of regeneration in the forest

ANR is applied to the forest with/ without canopy gaps < 1000 m^2 in which without/ with lack of natural regeneration. Use GPS to measure the area of canopy gaps in the forest block following the guidelines in Box 8.

Box 8. Use GPS to measure the area of canopy gaps in the forest block (GPS 60CSx user guide)

- Enter Menu twice to enter Tracks and press Enter.
- Use the Clear button to clear old Track memory.
- Press Menu and select Area Calculation, press Enter twice to start the track.
- Use active GPS to go around the canopy gap area that needs to be drawn.
- When finished, press Enter twice to Stop Track; and read the area of the canopy gaps, then Save the drawing result, name the drawn area and select OK to finish.

Note that when using Track, only turn on the device in the drawn area and turn off the device when finished to move to another area, then continue to turn on the device to draw another area. If you turn on the device continuously even without drawing, the area borders will be stuck together, which is difficult to distinguish on GPS.

3.3 Assisted natural regeneration technique

ANR is carried out using the following main techniques and illustrated in Figure 23:

i) Thinning regenerated trees and shoots and adjusting species component of potential regenerated trees. Guidelines in Box 9.

ii) Assisting and tending potential regenerated trees: Clearing weeds, lianas, bamboos, and shrubs with poor value; forest fire prevention. Guidelines in Box 10.

iii) Thinning small trees with D = 5 - 10 cm by optimal distance, cutting bad-shaped trees and adjusting species component. Guidelines in Box 11.

The time to conduct ANR is 5 - 10 years, until the regeneration tree layer is assisted to join the large tree layer, and ensuring the optimal number of trees, species component and uniform dispersion.

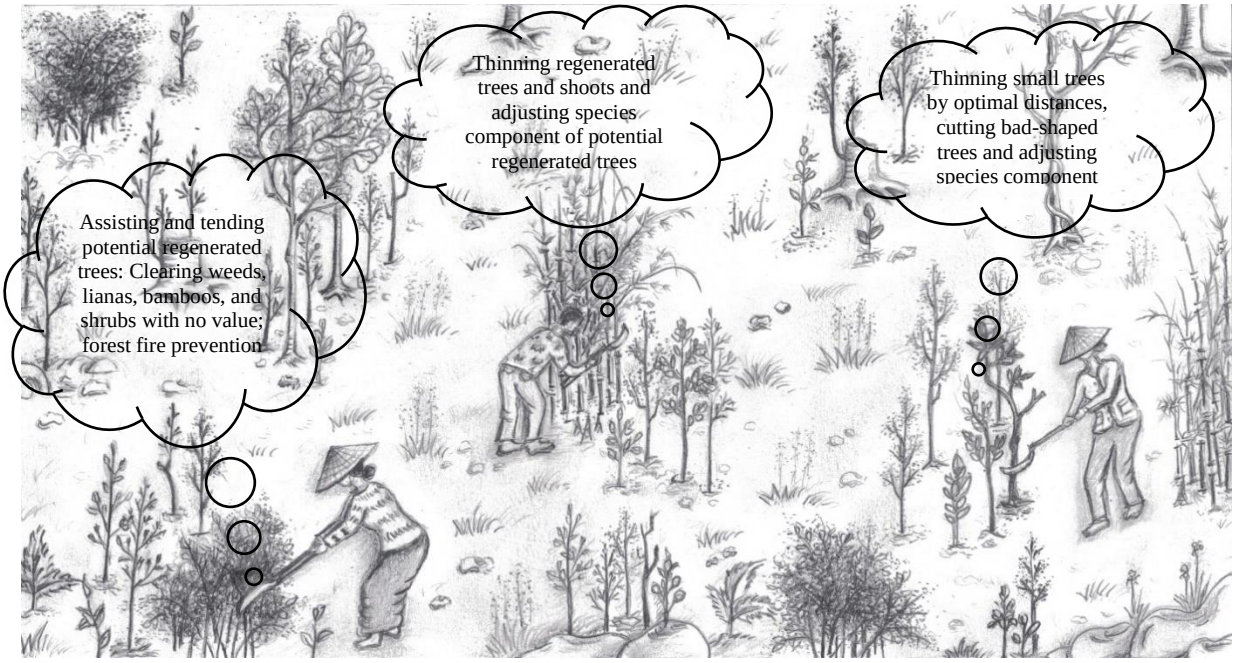


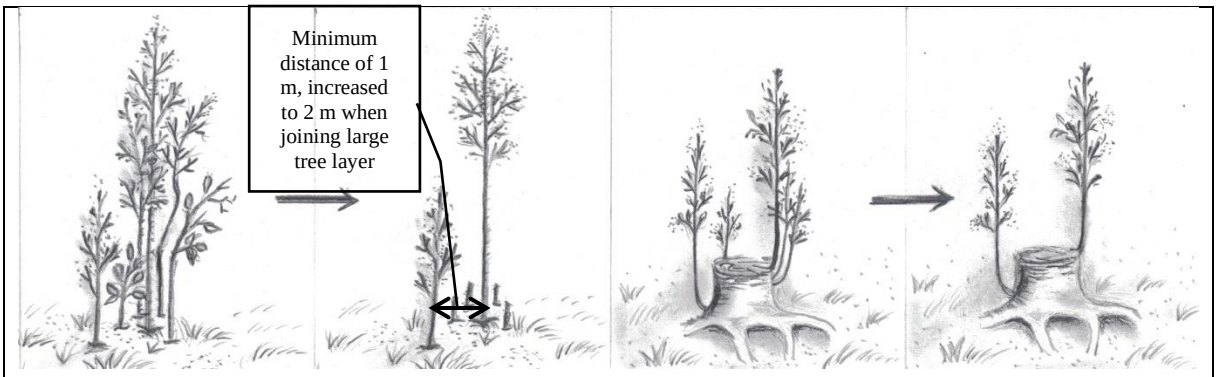
Figure 23. Techniques for assisted natural regeneration

Box 9. Guidelines for thinning regenerated trees and shoots and adjusting species component of potential regenerated trees

1. Guidelines for thinning regenerated trees and shoots for potential regenerated trees

The number of regenerated trees is sometimes very large and often blocking each other, density thinning is very necessary, which helps to increase light, and the nutrient space for the remaining potential regenerated trees to grow faster. The distance between two regenerated trees is about 1 m, when trees reach D ≥ 5 cm and start joining the large tree layer, thin and expand the distance to 2 m (Figure 24)

Many tree species capable of regenerating shoots, after a growing season, on one base may have many shoots, select one or two of the strongest shoots to retain and thin other shoots. (Figure 24)



Thinning regenerated trees with a minimum distance between two trees of 1 m, when the trees join the tree layer, expand the distance to 2 m

Thinning the regenerated shoots and retain one or two of the strongest shoots on one stump

Figure 24. Thinning natural regenerated trees

2. Guidelines for adjusting the species component of potential regenerated trees by forest type

Ecological relationships among tree species are complex, but understanding and adjusting tree species component right in the regeneration stage so that they support each other and avoid competing species coexisting for a long time. This will help forest trees to develop faster without mutual inhibitions and to shape stable and sustainable species populations in the future. Species ecological relationship should be considered by forest type and development stage.

- For EBLF: Regenerated tree species do not have a clear ecological competition, so when thinning regenerated trees, there is no need to pay attention to adjusting species component, but only on density.

- For DDF: In the regeneration stage, there are groups of tree species with supportive relationship that will later form forest population with dominant plant groups in the DDF; there are also ecologically competitive species groups; includes following species groups:
  - Group 1 (supportive relationship): *Terminalia chebula* + *Dipterocarpus tuberculatus* + *Shorea obtusa*
  - Group 2 (supportive relationship): *Canarium subulatum*, *Xylopia vielana*, *Semecarpus cochinchinensis*, *Xylia xylocarpa*
  - Group 3 (supportive relationship): *Polyalthia nemoralis*, *Aporosa octandra var. malesiana*, *Ziziphus oenoplia*, *Sindora siamensis var. maritima*, *Catunaregam tomentosa*, *Glochidion zeylanicum var. tomentosum*, *Wendlandia paniculata*, *Wrightia pubescens*, *Lagerstroemia tomentosa*, *Irvingia malayana*
  - Species groups with competitive relationship: Group 1 vs. Group 2; and Group 3 vs. *Pentacme siamensis* species

- Species groups with unknown or random relationship: Group 1 and Group 3 or Group 2 and Group 3.

Therefore, when thinning the regenerated trees of DDF, it is necessary to maintain species with supportive relationship by each group on the same forest area and adjust so that species in competing groups do not grow together in forest stand.

Note that the species in the above groups are not all species or the purpose species of DDF regeneration; they are just groups of species with different reciprocal relationships. Other regenerated tree species of Dipterocarpaceae family or other valuable species that do not appear in the above species groups are due to a random relationship with them, so it is possible to maintain species of Dipterocarpaceae family and other valuable species with the above species groups without affecting ecological competition.
In addition, for DDF, the main dominant is that the species of Dipterocarpaceae family form different forest populations with dominant 2-3 species and together with other supportive species. Therefore, based on the stand, it is necessary to simulate nature to maintain the regeneration species by the dominant species of Dipterocarpaceae family species and valuable species with other purposes that support dominant species according to the supportive species groups mentioned above.

It is also noted that when adjusting the component of regenerated trees, it is necessary to retain rare tree species listed in the IUCN Red Book (2020) and in groups IA and IIA of Decree 60/2019/ND-CP (Annex 2)

Box 10. Guidelines for assisting and tending potential regenerated trees

1. Clearing weeds, lianas, bamboos, and shrubs with poor value that block potential regenerated trees:

- Forest areas with a lot of weeds, shrubs, and bamboos of no purposes that cover the forest ground prevent seeds from contacting with the soil to germinate. Especially the winged seeds are often caught on bamboo branches and shrubs. In addition, when the seeds land, the factors of moisture and temperature determine the germination rate. Therefore, clearing the block and obscuration of the vegetations will provide light and temperature for the seed to germinate and the seedling to grow.
- For potential regenerated trees, clearing and removing weeds, shrubs, and bamboo trees of poor competitive value will support the faster growth and development of regenerated trees.

2. Forest fire prevention:

Large fire in the DDF affects the potential regenerated trees, cause the regenerated trees to die and regenerate shoots many times, leading to poor quality trees. Fire prevention is done by collecting burning materials such as fallen leaves, branches, fruits and other at the beginning of the dry season and conducting controlled burn.

However, it is also noted that forest fire is an ecological factor that helps the seeds of Dipterocarpaceae family species to germinate and assist the growth of young trees, destroying pests and diseases, it is possible to maintain annual forest fires in the DDF. In addition, only prevent big fire when there is a great danger of fire, burn down the entire layer of large trees and regenerated trees.

3. Annual time of assisted natural generation, period:

Assisting germination, seedlings: Conducted during the seeding season of the purpose trees. This is highly local-dependent, and the fruiting biology of each purpose tree species. Observing the fruiting season of the tree species that need to assist the regeneration to proceed activities of ARN.

Assisting growth of potential regenerated trees: During the first 3 years, conduct twice a year during the growing season of regenerated trees, which is in the early and mid-rainy season; the following years once in the first half of the rainy season.

ANR conducting time: This measure ends when the potential regenerated tree layer joins the large tree layer. About 5 - 10 years depending on species component and forest type

Box 11. Guidelines for thinning and adjusting the species component of small trees with D = 5 - 10 cm

In regenerated forests after shifting cultivation, after over exploitation and degradation, there is a layer of small trees D = 5 - 10 cm with very high density. Therefore, thinning this tree layer will contribute to open the canopy for natural regeneration by providing light, increasing the temperature for germination, and growing young trees; at the same time, it is also able to adjust the species component and density of small tree layers, thereby forming productive forests, meeting the purpose and species populations support each other stably.

1. Thinning small trees within range of D = 5 - 10 cm:

- Cutting down poor quality trees
- Thinning to reach the optimal distance between the two nearest trees, so that the trees have a random to uniform dispersion on the forest ground. The optimal distance between two nearest trees is 1.7 m - 2.0 m, depending on the density of each forest object, 1.7 m for EBLF and 2 m for DDF (Figure 25)

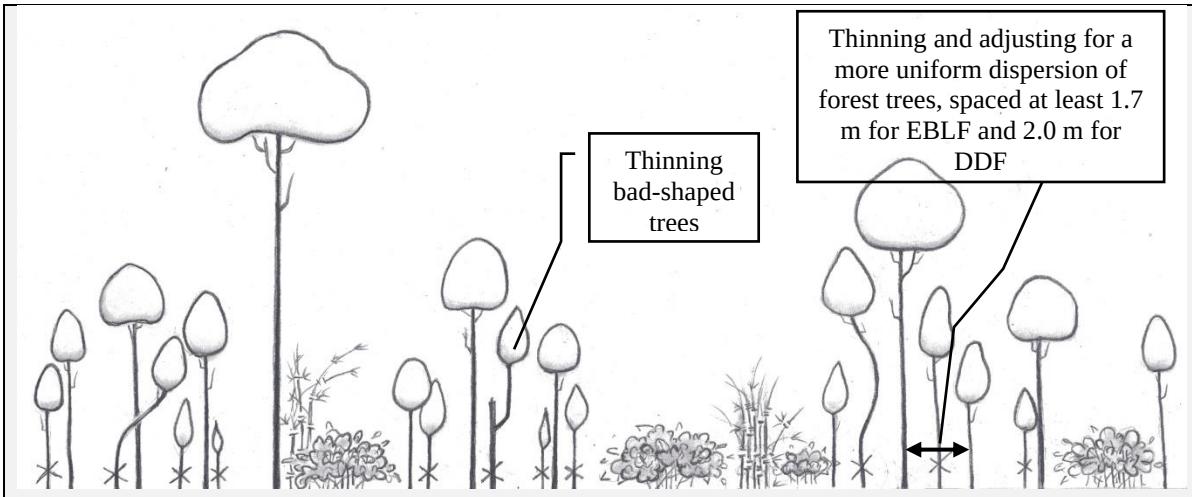


Figure 25. Thinning and adjusting optimal spacing for small trees

2. Thinning along with adjusting the species component of small tree layers:

Combining with thinning of the small tree layer to adjust the species component to direct the forest to an ecological stable population in the future. During the stage of young forest trees with high density, the species here form complex ecological relationships such as competition, ecological support. Discovering such relationships to eliminate competition when thinning and maintaining species groups with ecologically supportive relationships will help them grow faster, soon forming ecologically stable species populations.

The species ecological relationships of large tree layer in two forest types were discovered as follows:

- For EBLF: Tree species in the large tree layer do not have a clear ecological competition, so when thinning small timber trees, it is only necessary to cut down trees of poor quality and bad-shaped and poor growth through density adjustment without the need to adjust component of tree species.

- For DDF: In the timber tree layer, forming groups of tree species with supportive relationship, or random relationship or ecological competition relationship. The groups of mutual support will later form dominant floras with distinct dominant tree species in the DDF. When thinning if species are in supportive or random groups, only bad-shaped trees need to be removed; meanwhile, if the species belong to ecological competition groups (groups 1 and 3 below), it is necessary to adjust the species component of the forest to one of these two groups. Do not to alternate both groups in one forest stand. At this time, it is possible to reduce less valuable and less useful species.

The DDF species groups of large tree layer are related as follows:

- Group 1 (supportive relationship): *Terminalia chebula* + *Mitragyne* sp. + *Dipterocarpus tuberculatus* + *Shorea obtusa*
- Group 2 (supportive relationship): *Morinda citrifolia* + *Terminalia calamansanay* + *Catunaregam tomentosa* + *Castanopsis piriformis* + *Gardenia obtusifolia*

- Group 3 (supportive relationship): *Pentacme siamensis* + *Xylia xylocarpa* + *Pterocarpus macrocarpus*
- Species groups with competitive relationship: Group 1 vs. Group 3.
- Species groups with unknown relationship: Group 1 vs. Group 2 or Group 2 vs. Group 3

Note that the species in the above groups are not all species or purpose species of the DDF; they are just groups of species with different reciprocal relationships discovered. Species of Dipterocarpaceae family and other species that are not included in the above species groups are due to their random relationship with these species, and they can grow together with the above species without ecological competition.

In adjusting the species component of DDF, it is necessary to follow the ecological rule forming different plant populations with 2-3 dominant species of Dipterocarpaceae family and together with other supportive species. Therefore, based on reality, it is necessary to simulate nature in order to maintain the dominant species group of Dipterocarpaceae family and valuable species that support dominant species according to the supportive species groups mentioned above.

Also note that when adjusting the component tree species, it is necessary to keep the rare species listed in the IUCN Red Book (2020) and in groups IA and IIA of Decree 60/2019/ND-CP (Annex 2).

3.4 Monitoring and evaluating assisted natural regeneration

3.4.1 Monitoring silvicultural measures of assisted natural regeneration (ARN)

Monitoring the silvicultural measures of ANR is to collect and analyze data over time to determine how this silvicultural measure makes a difference in ANR or find out problems that need improvement during implementation. It is also more important to discover the cause if there is a failure in the technical measures and organizational implementation. Although it is mainly technical monitoring, it should be carried out in a participatory process, as it promotes mutual learning of a forest rehabilitation technique (FAO, 2015)

Box 12 introduces a participatory monitoring method when applying ANR techniques

Box 12. Monitoring method for assisted natural regeneration

1. Supervisors, participants

- The team/ group leader of the community forest rehabilitation as the monitoring group leader
- Participants: Households, groups of households implementing this silvicultural measure

- Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists
2. Materials and tools - A sketch of forest rehabilitation based on village landscape - Detailed designs describing ANR measures - GPS to locate forest locations - Measurement tapes for measuring D, H forest trees, regenerated trees - The 30-meter-long measurement tape for measuring the distance of forest trees and canopy - Record sheets according to monitoring criteria for silvicultural ANR measure in Table 16
3. Performing method - Time: At the end of the annual growth season of forest trees - Location: Each forest block applying silvicultural measures - Record: Use Table 16 to collect and record information about silvicultural measures - Discuss in the monitoring group on two aspects, strengths and weaknesses of silvicultural measures of ANR and resources - The leader of the monitoring group announces the results of the monitoring at the annual village meeting

Table 16. Record sheet of the ANR silvicultural measures monitoring

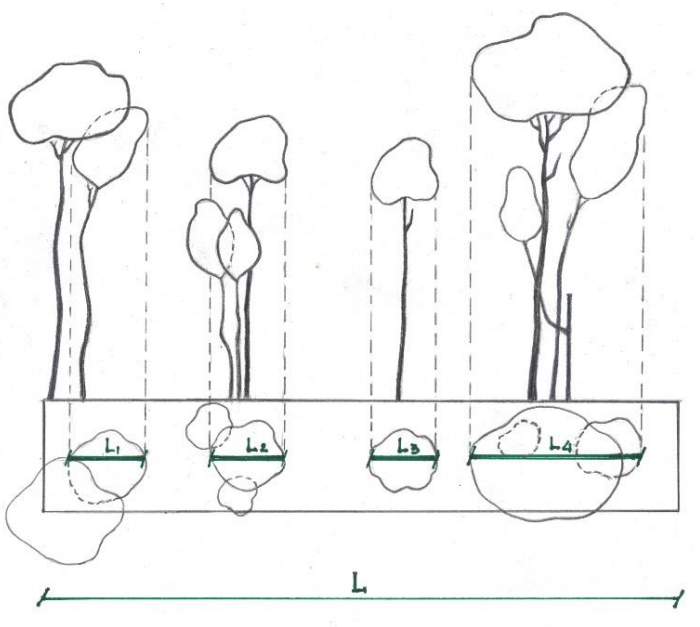
Supervisors:
Participants:
The implementers:
Applied silvicultural measures:
Place:
Monitoring time:
The time when application of ANR measure start:
Forest object:

Monitoring and observing indicators	*Data, information collected*
Area of the ANR forest (ha)	
The density of large trees (N, trees/ ha) according to the K- 6 tree sampling method	
The density of potential regenerated trees (Nre, trees/ ha) according to the K- 6 tree sampling method	
Averaged growth D of large trees (K- 6 tree sampling method)	
Averaged growth H of potential natural regenerated trees (K- 6 tree sampling method)	

Monitoring and observing indicators	*Data, information collected*
Dispersion of regenerated and large trees on forest ground (clumped, random, uniform)	
Forest canopy (1/10) (according to line intersect sampling)	
Productivity of harvested products and their value	
Strengths/ weaknesses in ANR measures and resources	

Note:

- How to implement method K- 6 tree sampling refer to Figure 21 and Figure 29; and method K- 6 tree sampling is repeated 3 times in each forest block undergoing rehabilitation, placed in average representative positions.
- Calculate the averaged value of D, H trees, regenerated trees according to the K- 6 tree sampling method: Measure D and H of 6 trees and averaged, then averaged from the sampling points.
- The method of determining dispersion of forest trees and regenerated trees on forest ground refer to Figure 22
- The canopy cover by line intersect sampling refers to Figure 26
- Productivity of products harvested and their value: Record the productivity of forest products harvested by season, by year from ANR forests and calculate into money.



Note: L around 20 – 30 m

Canopy = $(L_1 + L_2 + L_3 + L_4 + \ldots L_n) / L$

Figure 26. Line intersect sampling for calculating forest canopy (Korhonen et al., 2006).

3.4.2 Evaluating the silvicultural measures of assisted natural regeneration (ARN)

The evaluation aims to draw conclusions about the success or failure of the ANR silvicultural measures to rehabilitate local forests and draw lessons learned. Evaluation

is done at the end of this silvicultural measure, usually 5 - 10 years. The evaluation mainly compares the results achieved by the ANR with the forest status before measurement applied and with the stable and ideal forest models.

The evaluation also includes a synthesis of the monitoring results to the final stage and final evaluation. The evaluation will provide a completion of the ANR silvicultural measures of forest rehabilitation. Similar to monitoring, the evaluation should be conducted with the participation of all stakeholders and implementers in order to have a common understanding and consensus on the silvicultural measures of forest rehabilitation (FAO, 2015).

Box 13 introduces a participatory evaluation method for the ANR silvicultural measures.

Box 13. Evaluation method for assisted natural regeneration
1. Evaluators, participants - Team/ group leader conducting ANR as the evaluation team leader - Participants: Households, groups of households performing silvicultural measures - Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists, district and provincial rangers, provincial agriculture and forestry extensionists, consultants
2. Materials and tools - A sketch of forest rehabilitation based on village landscape - Detailed designs describing ANR measures - Record sheets of monitoring results for the ANR (Table 16)
3. Performing method - Time: At the final stage of the ANR (5-10 years) - Location: Some forest blocks rehabilitated under silvicultural measures and community house. - Recording: Use Table 17 to collect and record evaluation information. - The evaluation team leader announces the results of the evaluation during the village meeting

Table 17. Framework for evaluating the ANR

Evaluators:
Participants:
The implementers:
Place:
Evaluating time:
The time when application of ANR measures start:

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
1	Potential regeneration density (D < 5 cm and H > 1 m) (trees/ ha)			500		
2	Density of large trees with D ≥ 5 cm (trees/ ha)			1000 (EBLF) 700 (DDF)		
3	Distance and dispersion of trees with D ≥ 5 cm on forest ground (clumped, random, uniform)			> 2 m and random to uniform		
4	Dispersion of potential regenerated trees on forest ground (clumped, random, uniform)			Random to uniform		
5	Species component of potential regeneration trees			Supportive species groups according to the forest type		
6	Species component of large trees			Supportive species groups according to		

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
				the forest type		
7	Conclusion on the appropriateness of techniques, resources, organizations					

Note:

- Data at initiation: Collected at the first monitoring stage.
- Results at the end: Field survey, using results of annual monitoring data and of the final stage.
- Comparing the results with the optimal indicators and with initiation (+/-): For quantitative indicators, calculate results + or -, and for qualitative indicators, explain the difference between the results and the optimal indicators and with the initiation.
- Productivity of harvested products and value: Synthesized from the results of periodic monitoring to the end of the ANR stage.
- Conclusion on techniques, resources, organization: Discussing in the field and in the meeting to record evaluation conclusions.

4 ASSISTED NATURAL REGENERATION WITH ADDITIONAL PLANTING

4.1 Forest objects applying assisted natural regeneration with additional planting.

This object includes regenerated EBLF on fallow land after shifting cultivation or regenerated DDF after over exploitation. It is similar to the ANR forest object, but the difference is the lack of potential regeneration or the regeneration density is too high at some places, while other places lack regeneration (clumped dispersion); young timber trees also have clumped dispersion and form canopy gaps. This object needs to apply additional planting of some purpose plant species in areas with lack of regenerated trees, canopy gaps to promote faster forest formation and increase the value and ecological function of natural forest environment.

Objects include EBLF and DDF with indicators presented in Box 14.

Box 14. Forest objects applying assisted natural regeneration with additional planting
Forest type and forest status: - Regenerated EBLF on fallow land after shifting cultivation with lack of purpose and potential regeneration. - Regenerated DDF after over exploitation with lack of purpose and potential regeneration.
Technical indicators of the object: - N/D distribution mainly in the small diameter classes (D < 25 cm) - Lack of potential regenerated trees (trees with D < 5 cm and H > 1 m) meets the purpose (optimal 500 trees/ ha). The current density is Nre = 300 - 500 trees/ ha - Regeneration and young trees are dispersed in clumps to very clumps. - The forest has canopy gaps from 100 m^2 - 1000 m^2 or/ and the canopy gaps from 1000 m^2 - 3000 m^2 without or with lack of purpose and potential regeneration.

4.2 How to determine forest objects applying assisted natural regeneration measures with additional planting

i) N/D distribution

Observing generally in the forest blocks of forest objects applying ANR with additional planting; this forest object has only scattered trees of poor value and quality at the diameter classes < 25 cm.

ii) Determining the density of potential regeneration

The forest object applying ANR with additional planting when there is sufficient density of potential regeneration to meet the purpose (trees with D < 5 cm and H > 1 m), the current density is Nre = 300 - 500 trees/ ha. To determine Nre, K- 6 regenerated tree sampling is used. In each forest block, select 3 representative sampling points to set up K- 6 tree sampling and calculate the regeneration tree density as Figure 21.

iii) Determine the dispersion pattern of regeneration and young trees

ANR with additional planting is carried out when potential regeneration has clumped dispersion with many places lack regeneration and small trees also have clumped dispersion, creating canopy gaps.

The way to evaluate the dispersion of regeneration and forest trees on the forest ground is to observe at representative sampling points in the forest blocks and decide whether regenerated trees are dispersed in clumps or random or uniform as shown in Figure 22.

iv) Determining canopy gaps with lack of regeneration in the forest

The ANR with additional planting is applied when the forest has canopy gaps of 100 m^2 - 1000 m^2 or/ and the large canopy gaps of 1000 m^2 - 3000 m^2 without or with lack of potential regeneration. Using GPS to measure the area of canopy gaps in the forest block following the guidelines in Box 8.

4.3 Techniques for assisted natural regeneration with additional planting.

ANR with additional planting is conducted according to key techniques as that of the ANR, adding only additional planting techniques for purpose plants in areas with lack of regeneration and with canopy gaps, including:

i) Thinning regenerated trees and shoots and adjusting species component of potential regenerated trees. Guidelines in Box 9.

ii) Assisting and tending potential regenerated trees: Clearing weeds, lianas, bamboos, and shrubs with poor value; forest fire prevention. Guidelines in Box 10.

iii) Thinning small trees with D = 5 - 10 cm by optimal distance, cutting bad-shaped trees along with adjusting species component. Guidelines in Box 11.

iv) Planting additional purpose plants in areas with lack of potential regeneration trees and with canopy gaps. Including technical guidelines:

- Guidelines for selecting additional plant species for two forest types in Box 15, Table 18 and Table 19.
- Guidelines for determining canopy gaps, areas with lack of regeneration and distance, additional planting density (Box 16)
- Guidelines for planting techniques and tending additional plants (Box 17)

The time to conduct ANR with additional planting is 5 - 10 years, until the natural regeneration tree layer and the additional trees join the large tree layer, ensuring the optimal number of large trees, supportive species component and uniform dispersion.

Box 15. Guidelines for selecting additional plant species to plant into forest canopy gaps with lack of potential regeneration trees

In forests of regeneration, after shifting cultivation, or after over exploitation, there are often many regenerated trees because there is full light as the forest canopy is broken, large trees no longer exist; however, due to the lack of mother trees for seeds, the light is not uniformly dispersed, so regeneration of purpose and potential trees is often dispersed in clumps, some areas with very high density and some areas with low density or without regeneration. Therefore, additional planting of native multi-purpose plants in areas with lack of regeneration and canopy gaps is essential to rehabilitate forests with higher productivity and quality, to meet socio- economic and environmental goals.

The additional plant species must be *native trees, and multi-purpose trees should be selected* (Figure 15), possibly non-timber species such as bamboo, rattan. Besides meeting economic purposes, the selected species should also meet the purpose of rehabilitating the forest environment ecology and developing sustainable forests. Number of additional planting species *should be 2-3 species*, maximum 5 species.

Selection of additional plant species should be done with the participation of the local people. The technical staff should provide complete information about the tree species that can be additionally planted to the local forest and discuss with the villagers and let them make decision. For a participatory approach to plant selection, read "Handbook for Participatory Technology Development" (Huy et al., 2003).

On the basis of recognized research results in Viet Nam, and internationally reputable publications, two lists of species have been gathered, which can be additionally planted in regenerated forests for two forest types: DDF and EBLF (Table 18, Table 19).

In Table 18, 23 species are all indigenous, with 1 species of bamboo and 22 species of woody trees are multi-purpose trees, providing a variety of products and adapting to the ecological situation of the DDF.
The list of additional plant species for the DDF does not include some common species of Dipterocarpaceae family, as these species themselves have a strong ability to regenerate from the seed and the shoot in regenerated forests after over exploitation. Therefore, it is only necessary to thin and adjust the regeneration density of Dipterocarpaceae family species without additional planting.
In addition, the DDF also has several species with high value and rare species such as *Pterocarpus macrocarpus* Kurz, *Dalbergia cochinchinensis* Pierre, *Dalbergia* sp., *Xylia*

xylocarpa (Roxb.) Taub., *Afzelia xylocarpa* (Kurz) Craib, and *Sindora siamensis var. maritima* (Pierre) K.Larsen & S.S.Larsen; these are species that do not meet an indicator for additional planting because they grow too slowly. Therefore, with these rare species, if regeneration occurs, it is necessary to take care to support development without additional planting.

In Table 19, 82 species are indigenous trees; with 77 species of woody trees, 3 species of bamboo and 2 species of rattan; 70 species of woody trees are multi-purpose trees, providing a variety of products, 7 species for timber only and 5 species for NTFPs (bamboo, rattan); these are species adapted to the ecological situation of regenerated EBLF after shifting cultivation.

In the two categories of additional plant species mentioned above, it should be noted:

- Planting selection is not just about providing timber, selected plants should be multi-purpose trees. For example, the canopy of regenerated forest after over exploitation and after shifting cultivation is open canopy *with lots of the light*, so it is *very suitable for fruit trees* such as *Spondias pinnata* (L. f.) Kurz, *Tamarindus indica L.*, and *Canarium subulatum* Guillaumin in DDF; *Theobroma cacao* L., *Nephelium lappaceum* L., *Magnolia mediocris* (Dandy) Figlar, *Tamarindus indica* L., *Artocarpus heterophyllus* Lam., *Psidium guajava* L., *Durio zibethinus* L., *Ficus auriculata* Lour., … in EBLF. In addition, these species will also provide timber when mature, and they will have low impact from pests like pure planting in home gardens, because they are mixed with a diverse forest ecosystem of natural trees.
- Where providing forest environmental services, such as carbon accumulation, it is advisable to choose species that grow fast, with a wide range of ecology, adapted to harsh terrain, poor soil; for example in DDF, you can choose species such as: *Litsea glutinosa* (Lour.) C.B.Rob., *Spondias pinnata* (L. f.) Kurz, *Neolamarckia cadamba* (Roxb.) Bosser, *Ceiba pentandra* (L.) Gaertn., *Bombax ceiba* L., *Alstonia scholaris* (L.) R. Br., *Cratoxylum formosum* (Jacq.) Benth. & Hook.f. ex Dyer, *Tectona grandis* L.f., *Azadirachta indica* A.Juss., …. and in EBLF: *Dipterocarpus alatus* Roxb. ex G.Don, *Castanopsis piriformis* Hickel & A Camus, *Magnolia mediocris* (Dandy) Figlar, *Neolamarckia cadamba* (Roxb.) Bosser, *Bombax anceps* Pierre, *Canarium album* (Lour.) DC., *Melia azedarach* L., …. or bamboo species if it is necessary to protect watersheds, along rivers and streams.

Table 18. List of tree species used for additional planting to assist natural regeneration in regenerated DDF after over exploitation

Purpose:
T: Timber
M Multiple purpose
NTFPs: Non-Timber Forest Products

Forest type:
H&SHT Humid and semi-humid tropics
SADT Semi-arid (dry) tropics, dipterocarp

Objects of forest rehabilitation:
DF: Degraded forest
SF Secondary forest

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
1	Bầu nâu/ Trái mắm	*Aegle marmelos* (L.) Corrêa	M	Fruit, leaves, essential oil, resin, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
2	Bồ ngót rừng	*Melientha suavis* Pierre	M	Timber, leaves, flower, seed	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
3	Bời lời nhớt	*Litsea glutinosa* (Lour.) C.B.Rob.	M	Timber, bark	Woody	H&SHT, SADT	SF	Useful tropical plants
4	Cóc chuột	*Lannea coromandelica* (Houtt.) Merr.	M	Timber, leaves, bark	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Hop (2002)
5	Cóc rừng	*Spondias pinnata* (L. f.) Kurz	M	Timber, fruit, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
6	Dẻ anh	*Castanopsis piriformis* Hickel & A Camus	M	Fruit, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Thang (2016)
7	Gáo trắng	*Neolamarckia cadamba* (Roxb.) Bosser	M	Timber, fruit, bark, leaves	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Useful tropical plants, WFO
8	Gòn đỏ, gạo đỏ, Pơ lang	*Bombax ceiba* L.	M	Timber, fruit, leaves flower, root, resin, bark	Woody	H&SHT, SADT	SF	Useful tropical plants, Jain and Verma (2012), WFO

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
9	Gòn gai	*Bombax anceps* Pierre	M	Timber, bark, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
10	Kơ nia, cầy	*Irvingia malayana* Oliv. ex A.W.Benn.	M	Timber, fruit, seed	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
11	Lõi thọ	*Gmelina arborea* Roxb.	M	Timber, flower, fruit, root, resin	Woody	H&SHT, SADT	SF	Useful tropical plants
12	Me	*Tamarindus indica* L.	M	Timber, fruit	Woody	H&SHT, SADT	SF	VAFS, Useful tropical plants,
13	Quao khộp	*Heterophragma sulfureum* Kurz	M	Timber, root	Woody	SADT	DF, SF	Htun (2016)
14	Sóng rắn/ Bồ kết tây	*Albizia lebbeck* (L.) Benth.	M	Timber, bark, flower, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
15	Sữa, Mò cua	*Alstonia scholaris* (L.) R. Br.	M	Timber, resin, bark, flower	Woody	H&SHT, SADT	DF, SF	VAFS, Useful tropical plants,
16	Tếch	*Tectona grandis* L.f.	M	Timber, leaves, root, bark, flower, seed	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Huy et al. (2018), VAFS
17	Thành ngạnh đỏ ngọn	*Cratoxylum formosum* (Jacq.) Benth. & Hook.f. ex Dyer	M	Timber, leaves, bark, resin	Woody	H&SHT, SADT	SF	ITTO (2002), Useful tropical plants
18	Trám lá đỏ	*Canarium subulatum* Guillaumin	M	Timber, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
19	Trâm mốc, Vối rừng, Trâm vối	*Syzygium cumini* (L.) Skeels	M	Timber, fruit, leaves, bark	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
20	Tre gai	*Bambusa blumeana* Schult.f.	NTFP	Bamboo culm, Bamboo shoot	Bamboo	H&SHT, SADT	SF	VAFS, Useful tropical plants,
21	Trôm hôi	*Sterculia foetida* L.	M	Resin, timber	Woody	H&SHT, SADT	DF, SF	TT 30/2018, Useful tropical plants
22	Vỏ dụt	*Hymenodictyon orixense* (Roxb.) Mabb.	M	Timber, bark	Woody	H&SHT, SADT	SF	Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
23	Xoan chịu hạn	*Azadirachta indica* A.Juss.	M	Timber, fruit, leaves, flower, seed, bark	Woody	SADT	SF	ITTO (2002), Useful tropical plants

Table 19. List of tree species used for additional planting to assist natural regeneration in regenerated EBLF after shifting cultivation

Purpose:
T: Timber
M Multiple purpose
NTFPs: Non-Timber Forest Products

Forest type:
H&SHT Humid and semi-humid tropics
SADT Semi-arid (dry) tropics, dipterocarp

Objects of forest rehabilitation:
DF: Degraded forest
SF Secondary forest

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
1	Bầu nâu/ Trái mắm	*Aegle marmelos* (L.) Corrêa	M	Fruit, leaves, essential oil, resin, Timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
2	Bồ đề nam	*Styrax benzoides* W. G. Craib	M	Timber, resin	Woody	H&SHT	DF, SF	Useful tropical plants, GBIF
3	Bồ ngót rừng	*Melientha suavis* Pierre	M	Timber, leaves, flower, seed	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
4	Bời lời chanh	*Litsea cubeba* (Lour.) Pers.	M	Timber, bark, fruit, leaves	Woody	H&SHT	SF	Useful tropical plants
5	Bời lời đỏ, Kháo hoa nhỏ	*Machilus odoratissimus* Nees	M	Timber, bark	Woody	H&SHT	SF	VAFS, Useful tropical plants, WFO
6	Bời lời nhớt	*Litsea glutinosa* (Lour.) C.B.Rob.	M	Timber, bark	Woody	H&SHT, SADT	SF	Useful tropical plants
7	Bời lời vàng	*Litsea pierrei* Lecomte	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF, Tuan and Tiep (2017), VAFS
8	Bứa tai chua/ Bứa cọng	*Garcinia cowa* Roxb. ex Choisy	M	Timber, fruit, leaves, resin	Woody	H&SHT	DF, SF	Useful tropical plants, Rhaman et al.

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
								(2016) Thanh (2019)
9	Bưởi bung	*Acronychia pedunculata* (L.) Miq.	M	Timber, essential oil, leaves, bark	Woody	H&SHT	DF, SF	Useful tropical plants
10	Bụp cò ke (gỗ đổi màu)	*Hibiscus grewiifolius* Hassk.	T	Timber	Woody	H&SHT	DF, SF	Useful tropical plants, GBIF
11	Ca cao	*Theobroma cacao* L.	M	Fruit, timber, bark	Woody	H&SHT	SF	VAFS, Useful tropical plants,
12	Cáng lò	*Betula alnoides* Buch.-Ham. ex D.Don	M	Timber, bark	Woody	H&SHT	SF	VAFS, Useful tropical plants, Nghia and Thu (2009), Toai and Duong (2012), Đinh (2008)
13	Chò xót, Vối thuốc	*Schima crenata* Korth.	M	Timber, flower, bark	Woody	H&SHT	DF, SF	GIZ, Ho (1999)
14	Chôm chôm	*Nephelium lappaceum* L.	M	Fruit, seed, Timber	Woody	H&SHT	SF	ITTO (2002)
15	Cóc chuột	*Lannea coromandelica* (Houtt.) Merr.	M	Timber, leaves, bark	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Hop (2002)
16	Cóc rừng	*Spondias pinnata* (L. f.) Kurz	M	Timber, fruit, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
17	Cồng tía	*Calophyllum calaba var. bracteatum* (Wight) P.F.Stevens	M	Timber, resin	Woody	H&SHT	DF, SF	GIZ, WWF
18	Dâu da	*Baccaurea ramiflora* Lour.	M	Fruit, Timber	Woody	H&SHT	DF, SF	Useful tropical plants, Qiang et al. (2014)
19	Dầu rái	*Dipterocarpus alatus* Roxb. ex G.Don	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, VAFS
20	Dẻ anh	*Castanopsis piriformis* Hickel & A Camus	M	Fruit, Timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Thang (2016)
21	Dẻ đỏ, Dẻ đá đỏ	*Lithocarpus ducampii* (Hickel & A.Camus) A.Camus	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF, VAFS
22	Gáo trắng	*Neolamarckia cadamba* (Roxb.) Bosser	M	Timber, fruit, bark, leaves	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Useful tropical plants, WFO

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
23	Giổi ăn hạt, Giổi balansa	*Magnolia balansae* A.DC.	M	Timber, fruit	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants, Nam (2017)
24	Giổi xanh	*Magnolia mediocris* (Dandy) Figlar	M	Timber, seed	Woody	H&SHT	DF, SF	Useful tropical plants, VAFS, Sam et al. (2004)
25	Giổi xanh quả to	*Magnolia citrata* Noot. & Chalermglin	M	Timber, seed, leaves	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants, Nam (2017)
26	Gòn	*Ceiba pentandra* (L.) Gaertn.	M	Fruit, leaves, bark, resin, Timber	Woody	H&SHT	SF	ITTO (2002)
27	Gòn đỏ, gạo đỏ, Pơ lang	*Bombax ceiba* L.	M	Timber, fruit, leaves flower, root, resin, bark	Woody	H&SHT, SADT	SF	Useful tropical plants, Jain and Verma (2012), WFO
28	Gòn gai	*Bombax anceps* Pierre	M	Timber, bark, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
29	Hoàng linh, Lim vàng	*Peltophorum dasyrrhachis* (Miq.) Kurz	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF
30	Hồng ăn quả	*Diospyros kaki* L.f.	M	Fruit, Timber	Woody	H&SHT	SF	VAFS, Useful tropical plants,
31	Kháo, Dung nam bộ	*Symplocos cochinchinensis* (Lour.) S. Moore	M	Timber, seed, bark	Woody	H&SHT	DF, SF	GIZ, WWF, Liu et al (2017)
32	Kơ nia, cầy	*Irvingia malayana* Oliv. ex A.W.Benn.	M	Timber, fruit, seed	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
33	Lát hoa, nhựa	*Chukrasia tabularis* A.Juss.	M	Timber, resin, juice extracted from bark, leaves, root	Woody	H&SHT	SF	VAFS, Useful tropical plants,
34	Lõi thọ	*Gmelina arborea* Roxb.	M	Timber, flower, fruit, root, resin	Woody	H&SHT, SADT	SF	Useful tropical plants
35	Lòng mức lông	*Wrightia pubescens* R.Br.	M	Timber, bark	Woody	H&SHT	SF	Useful tropical plants, VAFS
36	Mắc khén/ Hoàng mộc	*Zanthoxylum rhetsa* DC.	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
37	Măng cụt	*Garcinia mangostana* L.	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants; Rahna et al., (2016)
38	Mây nếp	*Calamus tetradactylus* Hance	NTFP	Sợi mây, rattan shoot	Dây leo	H&SHT	DF, SF	ITTO (2002), WFO
39	Me	*Tamarindus indica* L.	M	Timber, fruit	Woody	H&SHT, SADT	SF	VAFS, Useful tropical plants,
40	Mít	*Artocarpus heterophyllus* Lam.	M	Timber, fruit	Woody	H&SHT	SF	ITTO (2002), VAFS
41	Mít nài, mít rừng	*Artocarpus rigidus subsp. asperulus* (Gagnep.) F.M.Jarrett	M	Timber, leaves, resin	Woody	H&SHT	DF, SF	GIZ, WWF
42	Mò cua lá hẹp	*Alstonia angustifolia* Wall. ex A.DC.	M	Timber, bark, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
43	Mỡ Phú Thọ	*Magnolia chevalieri* (Dandy) V.S.Kumar	T	Timber	Woody	H&SHT	DF, SF	VAFS
44	Mỡ, Vàng tâm	*Magnolia conifera* (Dandy) V.S.Kumar	T	Timber	Woody	H&SHT	DF, SF	VAFS
45	Muồng đen	*Senna siamea* (Lam.) H.S.Irwin & Barneby	M	Timber, flower, fruit, leaves	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants,
46	Muồng hoa đào	*Cassia javanica* L.	M	Timber, bark, seed	Woody	H&SHT	SF	VAFS, Useful tropical plants,
47	Ngát vàng	*Gironniera subaequalis* Planch.	M	Timber, bark	Woody	H&SHT	DF, SF	Useful tropical plants
48	Ngọc lan trắng	*Michelia alba* DC.	M	Timber, essential oil	Woody	H&SHT	DF, SF	VAFS
49	Núc nác	*Oroxylum indicum* (L.) Kurz	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants, ICRAF
50	Ổi	*Psidium guajava* L.	M	Timber, fruit, leaves, bark	Woody	H&SHT	SF	VAFS, Useful tropical plants,
51	Quế	*Cinnamomum cassia* (L.) J.Presl	M	Timber, bark	Woody	H&SHT	DF, SF	TT 30/2018, VAFS, Useful tropical plants
52	Sang máu, máu chó lá to	*Horsfieldia amygdalina* (Wall.) Warb.	M	Timber, seed	Woody	H&SHT	DF, SF	GIZ, WWF
53	Sao đen	*Hopea odorata* Roxb.	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, VAFS, Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
54	Sầu riêng	*Durio zibethinus* L.	M	Fruit, seed, Timber, root	Woody	H&SHT	DF, SF	ITTO (2002)
55	Sòi tía	*Triadica cochinchinensis* Lour.	M	Timber, root, seed	Woody	H&SHT	DF, SF	Useful tropical plants
56	Sơn muối	*Rhus chinensis* Mill.	M	Timber, fruit, resin, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
57	Sơn tra, Táo mèo	*Docynia indica* (Wall.) Decne.	M	Timber, fruit	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants
58	Song bột	*Calamus poilanei* Conrard	NTFP	Rattan, rattan shoot	Dây leo	H&SHT	DF, SF	Useful tropical plants, Sombun (2002), Dung (2013)
59	Sóng rắn/ Bồ kết tây	*Albizia lebbeck* (L.) Benth.	M	Timber, bark, flower, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
60	Sữa, Mò cua	*Alstonia scholaris* (L.) R. Br.	M	Timber, resin, bark, flower	Woody	H&SHT, SADT	DF, SF	VAFS, Useful tropical plants,
61	Tếch	*Tectona grandis* L.f.	M	Timber, leaves, root, bark, flower, seed	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Huy et al. (2018), VAFS
62	Thành ngạnh đỏ ngọn	*Cratoxylum formosum* (Jacq.) Benth. & Hook.f. ex Dyer	M	Timber, leaves, bark, resin	Woody	H&SHT, SADT	SF	ITTO (2002), Useful tropical plants
63	Thông 2 lá, Thông nhựa	*Pinus latteri* Mason Pinus merkusii Jungh. & de Vriese	M	Timber, resin, bark	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants
64	Thông 3 lá	*Pinus kesiya* Royle ex Gordon	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants,
65	Trám hồng	*Canarium bengalense* Roxb.	M	Timber, resin	Woody	H&SHT	DF, SF	GIZ, WWF
66	Trám lá đỏ	*Canarium subulatum* Guillaumin	M	Timber, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
67	Trâm mốc, Vối rừng, Trâm vối	*Syzygium cumini* (L.) Skeels	M	Timber, fruit, leaves, bark	Woody	H&SHT, SADT	DF, SF	GIZ, WWF

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
68	Trám trắng	*Canarium album* (Lour.) DC.	M	Fruit, resin, Timber	Woody	H&SHT	SF	ITTO (2002), Useful tropical plants, TT 30/2018, GIZ-WWF
69	Tre bát độ	*Dendrocalamus latiflorus* Munro.	NTFP	Bamboo culm, Bamboo shoot	Bamboo	H&SHT	SF	VAFS, Useful tropical plants
70	Tre gai	*Bambusa blumeana* Schult.f.	NTFP	Bamboo culm, Bamboo shoot	Bamboo	H&SHT, SADT	SF	VAFS, Useful tropical plants,
71	Tre vàng sọc	*Bambusa vulgaris* Schrad.	NTFP	Bamboo culm, Bamboo shoot	Bamboo	H&SHT	SF	VAFS, Useful tropical plants,
72	Trôm hôi	*Sterculia foetida* L.	M	Resin, Timber	Woody	H&SHT, SADT	DF, SF	TT 30/2018, Useful tropical plants
73	Ươi	*Scaphium macropodum* (Miq.) Beumée ex K.Heyne	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants; Thanh et al., (2018)
74	Vả	*Ficus auriculata* Lour.	M	Fruit, Timber	Woody	H&SHT	SF	ITTO (2002), VAFS, Useful tropical plants
75	Vải rừng/ Trường chua	*Nephelium hypoleucum* Kurz	M	Fruit, Timber	Woody	H&SHT	DF, SF	Useful tropical plants, WFO
76	Vạng trứng	*Endospermum chinense* Benth.	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF
77	Vỏ dụt	*Hymenodictyon orixense* (Roxb.) Mabb.	M	Timber, bark	Woody	H&SHT, SADT	SF	Useful tropical plants
78	Vông đồng	*Hura crepitans* L.	M	Timber, leaves, bark, fruit, seed, seed oil and resin	Woody	H&SHT	SF	VAFS, Useful tropical plants,
79	Vông nem	*Erythrina variegata* L.	M	Timber, bark, leaves, seed, root, flower	Woody	H&SHT	SF	VAFS, Useful tropical plants,
80	Xoan đào	*Prunus arborea var. montana* (Hook.f.) Kalkman	M	Timber, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
81	Xoan mộc	*Toona sureni* (Blume) Merr.	M	Timber, bark, leaves	Woody	H&SHT	DF, SF	ITTO (2002)

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
82	Xoan ta	*Melia azedarach* L.	M	Timber, resin, bark, leaves, flower, fruit, bark	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants.

Box 16. Guidelines for determining canopy gaps without or with lack of purpose and potential regeneration; determining distance, additional planting density

1. *Determining canopy gaps without or with lack of potential regeneration for additional planting:*
   - Small canopy gaps with 6 meters in diameter: they can be planted with a minimum of one tree, additional trees will be at least 3 meters away from regenerated trees or woody trees.
   - Large canopy gaps: they can be planted with some trees in the canopy gaps from 1000 m^2 to 3000 m^2, usually the canopy gaps of this object are not very large, within 1000 m^2. Using GPS to determine the area of the canopy gaps following the guidelines in Box 8
2. *Distance and density of additional plants:*
   - Plant distance:
     - When planting a tree in the canopy gap, this tree should be at least 3 meters away from regenerated trees or natural woody trees.
     - When planting many trees in the canopy gap, the planted trees should be 3 meters apart and at least 3 meters away from regenerated trees or natural woody trees.
   - Additional planting density: Depending on the current density of the purpose and potential regenerated trees to determine the additional planting density, maximum of about 500 trees/ ha.

Figure 27 illustrates canopy gaps and distance of additional planting.

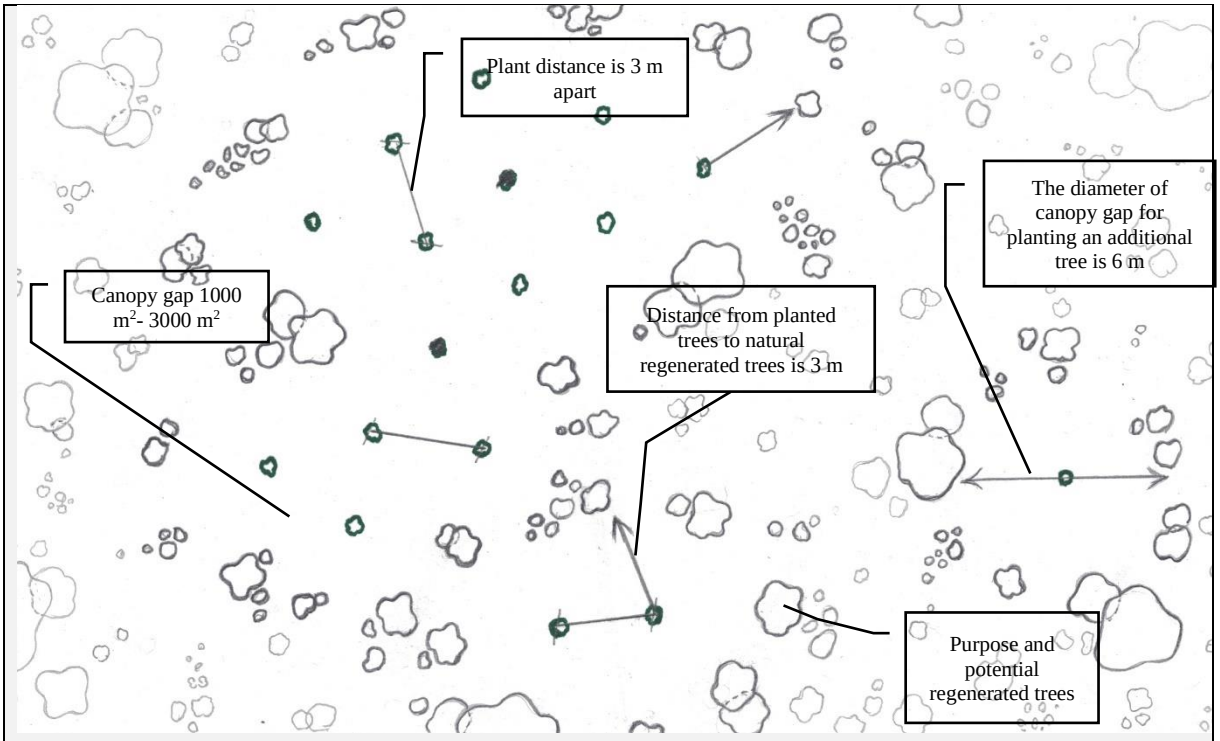


Figure 27. Assisted natural regeneration with additional planting by canopy gaps

3. Digging out the purpose and potential regenerated trees in areas with high density to plant in areas with lack of regeneration:

This technique makes use of the purpose and natural regenerated trees in the forest with too high density that need thinning, digging out and planting in canopy gaps and areas with lack of regeneration density, including:

- Digging out the purpose and potential regenerated trees with D < 5 cm and H > 0.5 - 1.0 m in areas with too high density, the distance between regenerated trees < 1 m. After digging out, the distance between the remaining regenerated trees is 1- 2 m
- Digging out trees must include their root balls, not to loosen roots from the soil, wrapping them with leaves and plastic bag.
- Planting the dug-out trees into the canopy gaps with lack of regeneration, the planted trees are 3 meters apart and at least 3 meters away from regenerated trees or natural woody trees.

Notes on techniques for digging out regenerated trees in high density areas to plant in low density areas:

- Applied mainly to EBLF, where there is thick soil layer, and tree can be dug out together with their root balls; where the soil is gravelly with rocks, and especially in many places in the DDF that trees cannot be dug out together with their root balls, this technique should not be applied, as it is difficult for seedlings to survive when their roots are loosened from soil.
- Limit the application of this technique to DDF because besides the difficulty of digging the trees together with their root balls due to the gravelly soil, the seedlings dug out for planting could not grow roots to the surrounding soil after one rainy

season. And in the next harsh dry season like drought and fire, the roots of the seedlings dug out for planting are usually not able to survive during this harsh period and the plants will have difficulty recovering in the next rainy season.

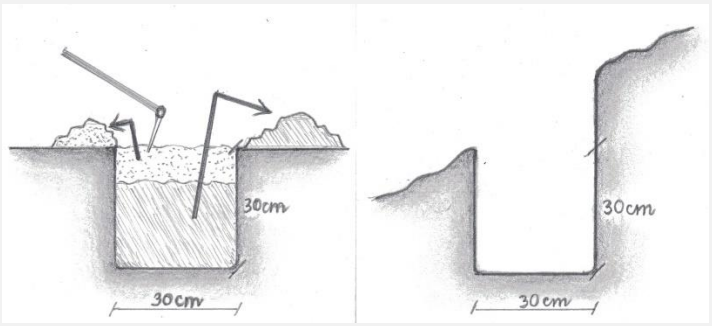
Box 17. Guidelines for planting, taking care trees of additional plants, enrichment planting

1. Seedling standards

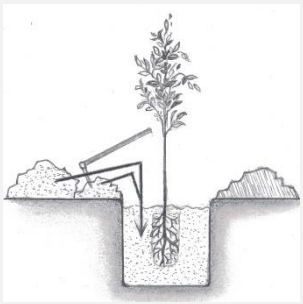
Planted with seedlings from seeds or graft or stump (depending on species), seedlings are 0.5 m – 1 m high. Usually, the height must reach from 0.8 m - 1 m or more to limit competition of weeds, bamboo, and natural shrubs.

2. Planting techniques:

- Planting trees at the beginning of the rainy season
- Planting techniques include digging holes, planting trees, covering stumps, and fencing. Illustrated in Figure 28

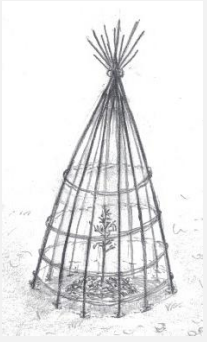


Digging holes: The hole has dimensions from 30 cm × 30 cm × 30 cm to 50 cm × 50 cm × 50 cm, depending on the tight and gravelly level of the forest soil and the root ball's size of the seedlings to be planted (left: on flat land, and right: on sloping land). When digging hole, 10 - 20 cm of topsoil should be kept separate (left) and keep the next lower soil layer aside (right).



Filling holes, planting trees: Put the topsoil from the left to the bottom of the hole, place the root collar of the plants on the ground level, take the topsoil next to the hole to fill, compact the hole.

Using litter to cover around the stump with a diameter of 0.6 m



Fence around planted trees by available branches and bamboo to prevent animals

Figure 28. Forest tree planting techniques

3. Taking care of additional plants

Taking care of additional plants, including:

- Planting to replace the dead plants in the 2^{nd} – 3^{rd} year.
- Weeding, clearing lianas, shrubs, cultivating around the stump of additional plants, using litter to cover around the stump with a diameter of 0.6 m or more.
- Pruning branches and thinning shoots: For trees that have a lot of shoots or branches, thinning is required and leaves only one shoot per stump, pruning horizontally branches under the tree canopy (for example, Teak)
- Protection and forest fire prevention in DDF: Clearing weeds, bamboo and gathering burning materials at the beginning of the dry season for controlled burn.

The time to take care and protect planted trees is from 5 to 10 years; in the first 3 years, taking care at least twice a year in the beginning and middle of the rainy season. In the following years, talking care once a year and in the first half of the rainy season.

4.4 Monitoring and evaluating measures of assisted natural regeneration with additional planting

4.4.1 Monitoring silvicultural measures of assisted natural regeneration with additional planting

Monitoring silvicultural measures of ANR with additional planting is intended to collect and analyze data over time to determine how this silvicultural measure makes a difference and especially monitoring the growth of additional plants; at the same time finding out problems that need improvement or identifying causes if there is a failure in the technical measures and implementation. Monitoring should be carried out in a participatory process, as it promotes mutual learning about a forest rehabilitation technique, especially new plants. (FAO, 2015)

Box 18 introduces a participatory monitoring method when applying techniques for ANR with additional planting.

Box 18. Monitoring method when applying techniques for assisted natural regeneration with additional planting

1. Supervisors, participants

- The team/ group leader of the community forest rehabilitation as the monitoring group leader
- Participants: Households, groups of households implementing this silvicultural measure
- Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists

2. Materials and tools

- A sketch of forest rehabilitation based on village landscape

- Detailed designs describing measures of ANR with additional planting
- GPS to locate forest locations
- Measurement tapes for measuring D, H forest trees, regenerated trees.
- The 30-meter-long measurement tape for measuring the distance of forest trees and canopy.
- Record sheets according to monitoring indicators for silvicultural measure of ANR with additional planting in (Table 20)

3. Performing method

- Time: At the end of the annual growing season of the forest tree
- Location: Each forest block applying silvicultural measures
- Recording: Use Table 20 to collect, record silvicultural measure information
- Discuss in the monitoring group on two aspects, strengths and weaknesses of silvicultural measures of ANR with additional planting and implementation resources
- The monitoring team leader announces the results of the monitoring at the annual village meeting

Table 20. Record sheet for monitoring silvicultural measures of ANR with additional planting

Supervisors:
Participants:
The implementers:
Applied silvicultural measures:
Place:
Monitoring time:
The time when application of measure of ANR with additional planting start:
Forest object:

Monitoring and observing indicators	*Data, information collected*
Area of ANR with additional planting forest (ha)	
The density of large trees (N, trees/ ha) according to the K- 6 tree sampling method	
The density of potential regenerated trees (Nre, trees/ ha) according to the K- 6 tree sampling method	
Density of additional planting, survival rate (K- 6 tree sampling method)	
Averaged growth D of large trees (K- 6 tree sampling method)	
Averaged growth H of potential natural regenerated trees (K- 6 tree sampling method)	
Averaged growth H of additional trees (K- 6 tree sampling method)	

Monitoring and observing indicators	*Data, information collected*
Dispersion of regenerated and large trees on forest ground (clumped, random, uniform)	
Forest canopy (1/10) (according to line intersect sampling)	
Productivity of harvested products and their value	
Strengths/ weaknesses in the ANR measures and resources	

Note:

- How to practice K- 6 tree sampling refer to Figure 21 and Figure 29 and K- 6 tree sampling is repeated 3 times in each forest block conducting technical measures, placed in average representative positions.
- Calculate the averaged value of D, H large trees, regenerated, additional plants according to the K- 6 tree sampling method: Measure D and H of 6 trees and averaged, then averaged from the sample points.
- Survival rate based on K- 6 tree sampling method: Including dead trees and count the number of dead trees in each point.
- The canopy cover by line intersect sampling refer to Figure 26
- The method of determining dispersion patterns of forest trees and regenerated trees on forest ground refer to Figure 22
- Productivity of products harvested and their value: Record the productivity of forest products harvested by season, by year from forests applying ANR with additional planting, and calculate into money.

4.4.2 Evaluating silvicultural measures of assisted natural regeneration with additional planting

Evaluation aimed at drawing conclusions about measures of ANR with additional planting. In which attention is paid to the adaptation and meeting the purpose of additional plant species to rehabilitate local forests and draw lessons from experience. Evaluation is done at the end of this silvicultural measure, usually 5-10 years. The evaluation mainly compares the results achieved by the ANR with additional planting with the forests before and with the stable and ideal forest models.

The evaluation also includes a synthesis of the monitoring results to the final stage and final evaluation. The evaluation will provide a completion of the silvicultural measures of ANR with additional planting to rehabilitate forest and implementation. Paying attention to the selection of additional plant species that are adaptable and meet local goals and implementation. Similar to monitoring, the evaluation should be conducted with the participation of all stakeholders and implementers in order to have a common understanding and consensus on the silvicultural measures of forest rehabilitation (FAO, 2015).

Box 19 introduces a participatory evaluation method for silvicultural measures of the ANR with additional planting.

Box 19. Method of evaluating measures of assisted natural regeneration with additional planting

1. Evaluators, participants

- Team/ group leader conducting ANR as the evaluation team leader
- Participants: Households, groups of households performing silvicultural measures
- Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists, district and provincial rangers, provincial agriculture and forestry extensionists, consultants

2. Materials and tools

- A sketch of forest rehabilitation based on village landscape
- Detailed designs describing measures of ANR with additional planting
- Record sheet of monitoring results for ANR with additional planting (Table 21)

3. Performing method

- Time: At the end of ANR with additional planting (5-10 years)
- Location: Some forest blocks conducting silvicultural measures and community house.
- Recording: Use Table 21 to collect and record evaluation information
- The evaluation team leader announces the results of the evaluation during the village meeting

Table 21. Framework for evaluating silvicultural measures of ANR with additional planting

Evaluators:
Participants:
The implementers:
Place:
Evaluating time:
The time when application of measure of ANR with additional planting start:

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
1	Additional planting density has D ≥ 5 cm (K- 6 tree sampling method) (trees/ ha)			300 (EBLF) 270 (DDF)		

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
2	Potential natural regeneration density (D < 5 cm and H > 1 (K- 6 tree sampling method) (trees/ ha)			500		
3	Density of large trees including additional trees with D ≥ 5 cm (K- 6 tree sampling method) (trees/ ha)			1000 (EBLF) 700 (DDF)		
4	Distance and dispersion of trees and additional trees with D ≥ 5 cm on forest ground (clumped, random, uniform)			> 2 m and random to uniform dispersion		
5	Dispersion of potential regenerated trees and additional trees on forest ground (clumped, random, uniform)			Random to uniform		
6	Species component of potential			Supportive species groups		

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
	regeneration trees and additional trees			according to the forest type		
7	Species component of large trees including additional trees			Supportive species groups according to the forest type		
8	Conclusion on the appropriateness of techniques, resources, organizations					

Note:

- Data at initiation: Collected at the first monitoring stage
- Results at the end: Field survey, using results of annual monitoring data and of the final stage
- Comparing the results with the optimal indicators and with initiation (+/-): For quantitative indicators, calculate results + or -, and for qualitative indicators, explain the difference between the results and the optimal indicators and with the initiation.
- Productivity of harvested products and value: Synthesized from the results of periodic monitoring to the end of the stage for ANR with additional planting.
- Conclusion on techniques, resources, organization: Discussing in the field and in the meeting to record evaluation conclusions.

5 ENRICHMENT PLANTING

5.1 Forest objects of enrichment planting

Forest objects of enrichment planting are degraded forests but with the ability to rehabilitate; however, the current forest density of large trees or/ and potential regeneration is not sufficient compared with the ideal model, the clumped dispersion creates many canopy gaps in the forests; therefore, it is necessary to take measures to thin, adjust the component of small tree species, and at the same time plant more purpose trees in canopy gaps, or in cutting rows.

Objects include EBLF, DDF and bamboo forests, according to the indicator introduced in Box 20.

Box 20. Forest objects that apply enrichment planting

Forest type and forest status:

- Degraded EBLF after selective exploitation
- Degraded DDF after selective exploitation
- Pure bamboo forest, or mixed bamboo-woody forest

Technical indicators of the objects:

- N/D distribution is found in classes D = 5 cm - 30 cm (or up to 40 cm) cm, but most of the diameter classes' density is low, the density is high at the smallest diameter class 5- 10 cm.
- Potential regeneration: EBLF often lack purpose and potential regenerated trees (trees with D < 5 cm and H > 1 m) with N = 400 - 500 trees/ ha (optimal 500 trees/ ha). DDF are often have sufficient purpose and potential regeneration (reaching over the optimal 500 trees/ ha) because the regeneration capacity of this forest type is strong, but the dispersion is not uniform, very clumped.
- Deficiency of density (N) of large trees layer compared to ideal forest: EBLF: N = 500 – 1000 trees/ ha (optimal 1000 trees/ ha), DDF: N = 600 – 700 trees/ ha (optimal 700 trees/ ha).
- Regenerated trees and large trees are both dispersed in clumps to very clumps
- The forest has a few canopy gaps of 100 m^2 - 1000 m^2 or/ and the large canopy gaps of 1000 m^2 - 3000 m^2 without or with lack of purpose and potential regeneration.
- Bamboo forests have a canopy coverage rate of over 70%, with or without woody trees, capable of cutting the rows to plant trees (for *Bambusa blumeana* species grow into dense clumps and difficult to create cutting rows, they are not included in this object) and the forest type has a need to rehabilitate mixed woody- bamboo forests.

5.2 How to determine the forest objects applying enrichment planting method

i) N/D distribution

Observing in the forest blocks and forest objects that can be applying enrichment planting are restoring, there are large trees with diameter class reaches 40 cm (for EBLF) and 30 cm (for DDF), number of small trees is higher than of the big trees, trees are mainly at the smallest diameter class 5 - 10 cm.

ii) Determining the density of potential regeneration

Forest objects of EBLF are applied for enrichment planting due to lack of purposed potential regeneration density (trees with D < 5 cm and H > 1 m), current density Nre < 500 trees/ ha. For DDF, due to its strong ability to regenerate species of Dipterocarpaceae family from seeds and shoots, Nre is usually sufficient (> 500 trees/ ha), however, it is often dispersed in very clumps, many areas lack regeneration requiring additional planting. To determine the potential regeneration density, method K- 6 regenerated tree sampling is used. In each forest block, select 3 representative sampling points and calculate the averaged regeneration density as instructed in Figure 21.

iii) Determining the density of large trees and comparing to the optimal density by forest type

For the objects of enrichment planting, the forests are in the rehabilitation first stage, but in many areas the density (N) is not sufficient, the EBLF has: N < 1000 trees/ ha, and for DDF: N < 700 trees/ ha. To determine the density of trees, the method K- 6 tree sampling is used. In each forest block, select 3 representative sampling points and calculate the averaged density as instructed in Figure 29.

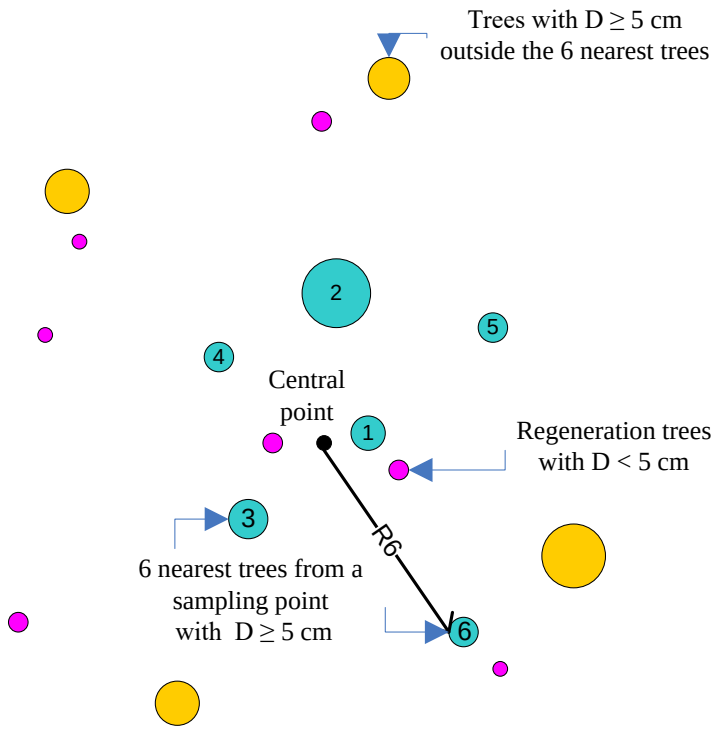
iv) Determining the dispersion pattern of regenerated and large trees on forest ground

The measure of enrichment planting is applied when potential regenerated trees are large trees have clumped dispersion, creating canopy gaps, and in many areas lack regeneration.

The way to evaluate the dispersion of regeneration and large trees on the forest ground is to observe representative points in the forest block and decide whether regenerated trees and large trees have clumped, or random or uniform dispersion as shown in Figure 22

v) Determining canopy gaps in the forest without or with lack of potential regeneration

Enrichment planting is applied when the forest has a few small canopy gaps from 100 m^2 - 1000 m^2 or/ and the large canopy gaps of 1000 m^2 - 3000 m^2 without or with lack of potential regeneration. Using GPS to measure the area of canopy gaps in the forest block following the guidelines in Box 8.



Note: At each representative sampling point, select the nearest 6 large trees (D ≥ 5 cm) according to this diagram. Measure the distance from the central point to the 6th tree is R_6 (m)
From each sampling point, calculate tree density per hectare (Ni) using the following formula:

$$N = \frac{5.5 * 10000}{3.14 \times {R_6}^2}$$

The tree density per hectare (N/ ha) is averaged as following formula:

$$N/ha = (N_1 + N_2 + N_3)/3$$

Data collected at K- 6 tree sampling: R_6 = (m)

Indicators	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Tree 6
Species						
D of trees (cm) (D ≥ 5 cm)						

Figure 29. Method K- 6 tree sampling to estimate large tree density (Kleinn and Vilcko 2006)

vi) Canopy coverage rate of bamboo forests

Enrichment planting where bamboo canopy cover over 70%, where there is a need to rehabilitate mixed timber - bamboo forests. Visual observation is often used to determine the coverage rate of bamboo forests.

5.3 Techniques for enrichment planting

Enrichment planting is carried out using the following main techniques:

i) Thinning small trees with D = 5 - 10 cm according to optimal distance, cutting bad-shaped trees along with adjusting the species component in enrichment planting forests by canopy gaps or on remaining rows in enrichment planting in cutting rows. Guidelines in Box 11.

ii) Enrichment planting; includes technical guidelines:

- Guidelines on techniques for enrichment planting by canopy gaps for degraded forests after selective exploitation (Box 21)
- Guidelines on techniques for enrichment planting in cutting rows for pure bamboo forests or mixed bamboo-woody forests (Box 22)
- Guidelines for selecting enrichment plant species for two forest types are in Box 23, Table 22 and Table 23.
- Guidelines on techniques for planting trees and tending trees for enrichment planting (Box 17)

The implementation of enrichment planting is done within 5-10 years, until the enrichment plant layer joins the large tree layer, ensuring sufficient number of large trees, supportive species component and random - uniform dispersion.

Enrichment planting is a challenging silvicultural measure for successful outcome in Viet Nam and in tropical regions of the world (ITTO, 2002, Huy et al., 2018). For that reason, when applying this silviculture measure, we need to be cautious. Because enrichment planting requires strict adherence to techniques such as selecting species suitable for forest ecology, replacing the dead planted trees and tending trees regularly, especially to provide sufficient light for planted trees at each stage of their growth.

Box 21. Guidelines for enrichment planting of degraded natural forests by canopy gaps

1. The reasons for choosing enrichment planting by canopy gaps:

The light factor is of primary importance for the survival and development of enrichment plants; when enriching planting in cutting rows in degraded forests, it is very difficult to adjust the light according to the growth stages of the planted species, there have been many failures of enrichment planting in cutting rows in degraded forests in Viet Nam and in the world (ITTO, 2002). Whereas degraded forest after over exploitation often has a lot of canopy gaps with enough width, or/ and the large canopy gaps to plant trees for enrichment planting. In this way, there is no impact of deforestation to cut the rows for tree planting and can provide plants with sufficient light from a canopy gap with appropriate width.

Therefore, enrichment planting in cutting rows for tree planting should not be applied to degraded forests after over selective logging.

Enrichment planting by canopy gaps is suitable for DDF, because the original DDF's density was thin, and after over selective logging, the density became even lower. A forest with many canopy gaps can be planted with one to several trees in one canopy gap. The successful study of enriching the DDF with teak has also been carried out in this way and is very effective, taking advantage of the forest ground with low density and enriching planting without cutting the rows, so it does not affect the forests. (Huy et al. 2018).

Therefore, it is recommended to enrich degraded forests after over selective logging by the method of canopy gaps.

2. Determining canopy gaps without or with lack of potential regeneration for enrichment planting:

- Canopy gaps: Canopy gaps that can be planted with a minimum of one tree mút have minimum gap diameter of 6 m for DDF and 10 m for EBLF. Since the DDF has lower tree height, so the gaps can receive more light, so the gaps' diameter can be smaller than EBLF that has taller trees, obscuring more light, and the gaps' diameter must be larger.
- Canopy gaps: It is possible to plant a number of trees in the canopy gaps from 1000 m^2 to 3000 m^2, usually canopy gaps of this forest object is not very large, within 1000 m^2. Using GPS to determine the area of the canopy gaps following the guidelines in Box 8

3. Distance and density of enrichment plants:

- Distances among natural and planted trees:
    - When planting a tree in the small canopy gap, this tree should be at least 3 meters away from natural large trees for DDF and 5 meters for EBLF.
    - When planting many trees in the large canopy gap, the planted trees should be 3 – 5 meters apart depending on the species and at least 3 meters away from natural trees for DDF and 5 meters for EBLF.
    - The planted tree is 3 - 5 meters away from the purposed natural regenerated.
- Enrichment planting density: Depending on the current density of the purposed potential regenerated trees to determine the enrichment planting density, about 500 trees/ ha.

Figure 30 illustrates enrichment planting by canopy gaps

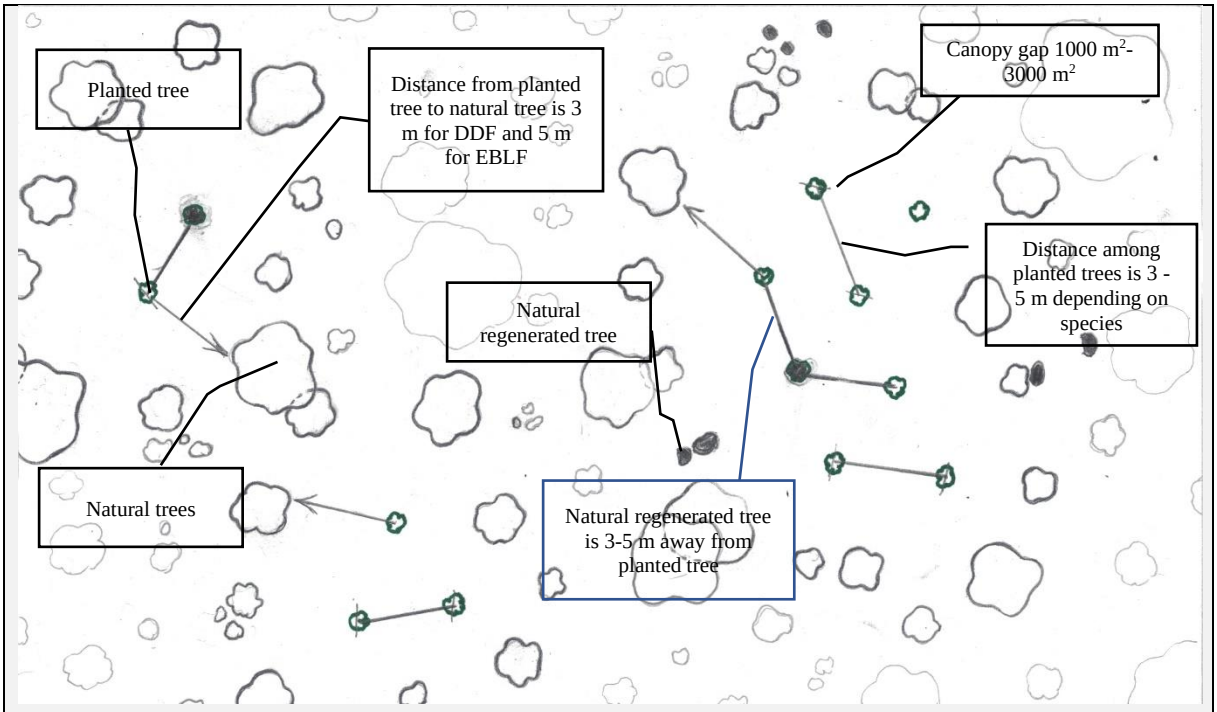


Figure 30. Enrichment planting by canopy gaps in degraded natural forest

Box 22. Guidelines for enrichment planting in cutting rows for bamboo forests or mixed bamboo-woody forests

1. The reason for choosing to enrich the bamboo forest or mixed bamboo-woody forest in cutting rows

The enrichment planting in cutting rows should only apply to forest object of pure bamboo with more than 70% of the canopy coverage, and/or mixed with few timber trees. For this subject, it is difficult to find canopy gaps to plant trees; in addition, the cutting of bamboo in rows to plant trees will not damage the perennial large tree layer (just cut bamboo with a much shorter lifespan, 5-6 years maximum), easy to regulate light in the cutting rows for planted timber trees because the bamboo forest is not tall (about 10 m in height) and the canopy is not wide. In addition, for forest blocks with *Bambusa blumeana* species grow into dense clumps, difficult to cut the rows and to dig out bamboo roots to plant trees in the rows, they are not the object of enrichment planting.

Therefore, the enrichment planting in cutting rows should be applied to pure bamboo forests.

It should also be noted that bamboo forests are also providing a large amount of bamboo shoots, bamboo culms for the life and production of the local community; therefore, it is necessary to maintain these forest types; only where the bamboo forest is degraded, or a large area is invaded by bamboos on fallow forest land, it is possible to apply enrichment planting in cutting rows to supplement multi-purpose trees, at the same time keep bamboos in the remaining rows to serve community life and watershed protection.

There are two types of enrichment planting in rows:

- In cutting rows following east-west direction when the bamboo forest is on flat or sloping land < 25^0
- Designing cutting rows following contour lines when the bamboo forest is on a slope > 25^0

2. Enrichment planting in cutting rows following the east-west direction on flat or sloping land < 25^0

On flat land, cutting rows for enrichment planting is carried out in the east-west direction so that the planted trees in the rows can receive the most sunlight. Cutting the rows, treating the remaining rows, and planting trees on the cutting rows as instructed in Figure 31.

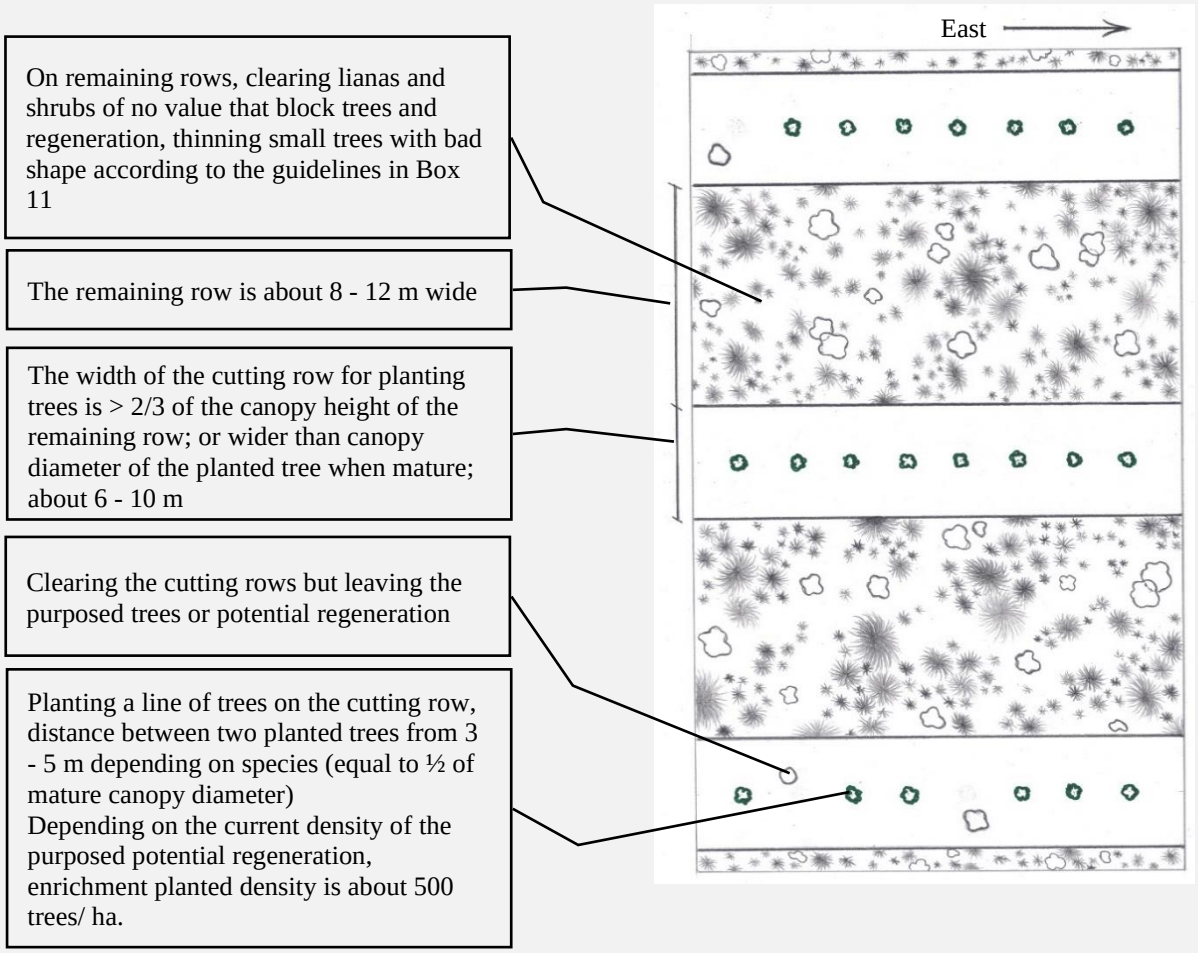


Figure 31. Enrichment planting in cutting rows following the east-west direction on sloping land < 25^0

3. Enrichment planting by the cutting rows on sloping land > 25^0

On sloping land > 25^0, enrichment planting in cutting rows should be carried out along contour lines to avoid soil erosion.

3.1. Measuring the slope

The slope measurement can be done using simple, self-designed tools with plumb line. Here is a guide to using Clinometer device (Suunto) to measure forest ground slope.

Using the device to aim at the top of a pole that is as high as the eye of the observer, creating a line of sight parallel to the ground, reading the graduations to the left for a slope (reading from small numbers to the horizontal line, in where the graduations is separated by 1 degree). (Figure 32)

If the ground slopes > 25^0, it is necessary to cut the rows for enrichment planting following contour lines.

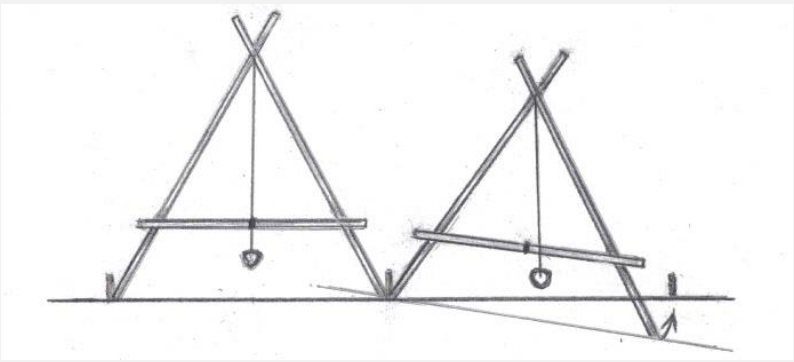
Using Suunto

Suunto Clinometer

Figure 32. Using Suunto Clinometer to measure forest ground slope

3.2. Using A- tool to design cutting rows for enrichment planting following contour lines

Guidelines for making and using A- tool to design cutting rows for enrichment planting following contour lines on sloping land > 25^0 (Figure 33)



(Longman and Wilso, 1995)

Note:
A- tool can be made of materials available in the forest such as bamboo, branches, and small woods.

Right: The plumb line is not at the center of the crossbar, the two feet of the A-tool are not on the contour line;

Left: The plumb line is exactly at the center of the

crossbar, the two feet of the A- tool are on the contour line

Figure 33. Making A- tool and use it to design cutting rows by contour line

3.3. Performing enrichment planting techniques in cutting rows following contour lines on sloping land

On sloping land > 25^0, designing the cutting rows for enrichment planting following contour lines by using the A- tool, then conducting cutting the rows, processing the remaining rows, planting trees on the cutting rows according to the guidelines in Figure 34.

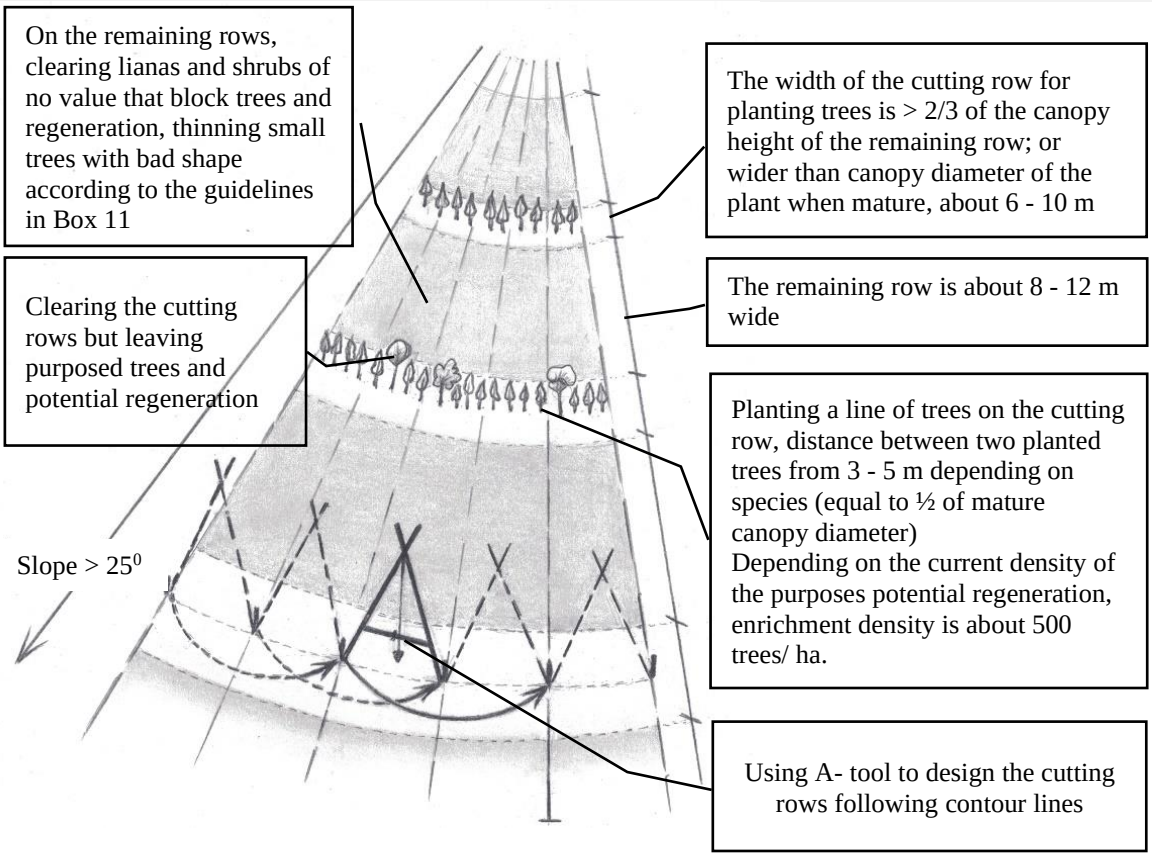


Figure 34. Technique of enrichment planting in cutting rows by contour lines when forest on sloping land > 25^0

Box 23. Guidelines for selecting plant species for enrichment of degraded natural forests of DDF and EBLF

Selection of tree species for enrichment planting is a difficult silviculture technique, *requiring trees to be suitable with forest ecology and forest rehabilitation purposes*; in addition, they must be indigenous, and multi-purpose trees (Figure 15). Besides the economic purposes, the selection of trees for enrichment planting must also be in harmony with the purpose of restoring the forest environment ecology and developing sustainable forests, and *it is advisable to conduct enrichment planting with 2 - 3 species, maximum 5 species to form sustainable forest of diverse species.*

The selection of tree species for enrichment planting should also be conducted with the participation of local people. The technical staff should provide complete information about the species that can be planted for enrichment in the local degraded forest types and discuss with the villagers and let them decide on their options. For a participatory approach to plant selection, read "Handbook on Participatory Technology Development" (Huy et al., 2003).

On the basis of recognized research results in Viet Nam, and internationally reputable publications, two lists of species have been gathered, which can be chosen for enriching degraded forests for two forest types as EBLF and DDF are as follows:

Table 22. : In which 15 species are all indigenous, woody, and multi-purpose trees, providing a variety of products and adapting to the ecological situation of the DDF.
The list of enrichment plant species for the DDF does not include some common species of Dipterocarpaceae family, as these species themselves have a strong ability to regenerate from seeds and shoots in degraded DDF after over selective exploitation. Therefore, it is only necessary to thin and adjust the regeneration density of Dipterocarpaceae family species without enrichment planting.
In the woody flora of the DDF, with specific ecological characteristics, there are some species of trees that grow very slowly but have high environmental economic value such as *Pterocarpus macrocarpus* Kurz, *Dalbergia cochinchinensis* Pierre, *Dalbergia* sp., *Xylia xylocarpa* (Roxb.) Taub., *Afzelia xylocarpa* (Kurz) Craib, *Sindora siamensis var. maritima* (Pierre) K.Larsen & S.S.Larsen; these are species that do not meet an indicator for enrichment planting because they grow too slowly. Therefore, with these rare species, if regeneration occurs, it is necessary to keep and take care to support development without additional planting.

Table 23. : In which 58 species are indigenous trees; with 56 species of woody trees, 2 species of rattan; 48 species of woody trees are multi-purpose trees, providing a variety of products, 8 species for timber only and 2 species for NTFPs (bamboo, rattan); these are species adapted to the ecological situation of degraded EBLF.

In the two categories of enrichment plant species mentioned above, it should be noted:

- Selection of planted tree is not just about providing timber, selected plants should be multi-purpose trees. For example, such as the DDF has species providing NTFPs such as *Spondias pinnata* (L. f.) Kurz, *Canarium subulatum* Guillaumin, *Sterculia foetida* L., …; and EBLF has species such as *Baccaurea ramiflora* Lour., *Magnolia mediocris* (Dandy) Figlar, *Garcinia mangostana* L., *Cinnamomum cassia* (L.) J.Presl, *Durio zibethinus* L., *Scaphium macropodum* (Miq.) Beumée ex K.Heyne, … In addition, these species will also provide timber when mature, and will reduce or not suffer from pests like pure planting in home gardens, because they are mixed with a diverse forest ecosystem of natural trees.
- Where forest environmental services of carbon sequestration to mitigate climate change, it is advisable to choose species that are fast growing, with a wide range of ecology, adapted to harsh terrain, poor soil. For DDF, you can choose species such as: *Spondias pinnata* (L. f.) Kurz, *Bombax anceps* Pierre, *Alstonia scholaris* (L.) R. Br., *Tectona grandis* L.f., *Sterculia foetida* L., … and in EBLF: *Litsea pierrei* Lecomte, *Spondias pinnata* (L. f.) Kurz, *Baccaurea ramiflora* Lour., *Dipterocarpus alatus* Roxb. ex G.Don, *Neolamarckia cadamba* (Roxb.) Bosser, *Bombax anceps* Pierre, *Alstonia scholaris* (L.) R. Br., *Melia azedarach* L.

Box 24 introduces the use of teak to enrich degraded DDF

Table 22. List of plant species used to enrich degraded DDF

Purpose:
T: Timber
M Multiple purpose
NTFP: Non-Timber Forest Products

Forest type:
H&SHT Humid and semi-humid tropics
SADT Semi-arid (dry) tropics, dipterocarp

Objects of forest rehabilitation:
DF: Degraded forest
SF Secondary forest

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
1	Bầu nâu/ Trái mắm	*Aegle marmelos* (L.) Corrêa	M	Fruit, leaves, essential oil, resin, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
2	Bồ ngót rừng	*Melientha suavis* Pierre	M	Timber, leaves, flower, seed	Woody	H&SHT, SADT	DF, SF	Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
3	Cóc chuột	*Lannea coromandelica* (Houtt.) Merr.	M	Timber, leaves, bark	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Hop (2002)
4	Cóc rừng	*Spondias pinnata* (L. f.) Kurz	M	Timber, fruit, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
5	Dẻ anh	*Castanopsis piriformis* Hickel & A Camus	M	Fruit, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Thang (2016)
6	Gáo trắng	*Neolamarckia cadamba* (Roxb.) Bosser	M	Timber, fruit, bark, leaves	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Useful tropical plants, WFO
7	Gòn gai	*Bombax anceps* Pierre	M	Timber, bark, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
8	Kơ nia, cầy	*Irvingia malayana* Oliv. ex A.W.Benn.	M	Timber, fruit, seed	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
9	Quao khộp	*Heterophragma sulfureum* Kurz	M	Timber, root	Woody	SADT	DF, SF	Htun (2016)
10	Sóng rắn/ Bồ kết tây	*Albizia lebbeck* (L.) Benth.	M	Timber, bark, flower, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
11	Sữa, Mò cua	*Alstonia scholaris* (L.) R. Br.	M	Timber, resin, bark, flower	Woody	H&SHT, SADT	DF, SF	VAFS, Useful tropical plants,
12	Tếch	*Tectona grandis* L.f.	M	Timber, leaves, root, bark, flower, seed	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Huy et al. (2018), VAFS
13	Trám lá đỏ	*Canarium subulatum* Guillaumin	M	Timber, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
14	Trâm mốc, Vối rừng, Trâm vối	*Syzygium cumini* (L.) Skeels	M	Timber, fruit, leaves, bark	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
15	Trôm hôi	*Sterculia foetida* L.	M	Resin, timber	Woody	H&SHT, SADT	DF, SF	TT 30/2018, Useful tropical plants

Box 24. Introduction of teak for additional planting in regenerated DDF after over logging and for enrichment planting in degraded DDF

1. Tree description, uses:

Teak is a large woody tree that reaches a height of more than 30 m, and the diameter reaches 60- 80 cm. With growing demand teak for timber along with processing technology development, teak can be traded in small logs 20-25 cm in diameter over a period of 15 years. Teak also is a multi-purpose tree: Using timber, leaves, roots, bark, flowers, seeds

- Timber has high economic value in domestic and international markets. The wood has a core of golden brown, durable, and beautiful grain.
- Leaves used for dyeing foods, fabrics; as a diuretic, slimming agent, stimulant, detoxifier and diarrhea agent, cure tuberculosis, respiratory infections such as laryngitis, bronchitis, lung.
- Root oil extract for eczema, ringworm, and inflammatory diseases.
- The bark is used as an astringent and for treating bronchitis.
- Flower is used as a diuretic, treating diabetes mellitus, bronchitis and urinary disorders.
- The seeds are used as diuretics. Oil extracted from the seeds makes hair growth medicine.

2. Ecological requirements and techniques for planting teak in regenerated DDF after over logging and degradation:

Teak is used to rehabilitate the DDF ecosystem, increase economic value due to teak with high value and restore the ecological functions of the DDF, increasing forest carbon accumulation thanks to its relatively rapid growth.

Ecological requirements for planting teak in DDF

Id	Ecological indicators	Required to be able to plant teak
1.	Average annual rainfall	500-5.000 mm/ year
2.	Lighting intensity. Temperature	High light intensity. Average annual temperature from 27- 36^{0}C
3.	Light requirement	From 70% to full light
4.	Number of dry months	3- 5 months
5.	Altitude above sea level	< 1.000 m
6.	Soil type	Many types of soil from limestone, shale, gneiss, shale, basalt ...
7.	Thick layer of soil	Depth 30- 50 cm for small timber (roots ≤ 30 cm) Depth up to 50 cm for large timber (roots ≤ 50 cm)
8.	Drainage	The soil must be well drained. No waterlogging
9.	Physical properties of the soil: gravel, mixed stone, sand	Suitable to soil mixed with gravel about 50%, clay, a bit heavy soil. Not suitable to soil mixed with sandy or clay of over 30%

10.	Soil pH_{H2O}	6.5- 7.5
11.	Calcium content	High
12.	Content of NPK of soil	Medium to high
13.	Forest fire	Withstands fire, shoot regeneration after fire
14.	Plant physiology: Deciduous, stopped growing in the dry season	Withstands dry season thanks to deciduous trees and stops growing for 3 to 5 months
15.	DDF species indicative for planting teak	*Dipterocarpus tuberculatus* Roxb., *Terminalia chebula* Retz., or *Xylia xylocarpa* (Roxb.) Taub., or *Pentacme siamensis* (Miq.) Kurz, a grass species (cỏ lào (*Chromolaena odorata* (L.) R.M.King & H.Rob.)) indicate a good site for teak. Teak is not suitable for areas with dầu trà beng (*Dipterocarpus obtusifolius* Teijsm. ex Miq.); sổ đất (*Dillenia hookeri* Pierre) và mộc hoa (*Holarrhena curtisii* King & Gamble) (these two species indicate waterlogging).

In Dak Lak province, Viet Nam about 25% area of the degraded DDF (about 25,000 ha) can be planted with teak, enriching the forest. Therefore, not all DDF can be planted with teak, and do not clear-cutting the DDF to plant pure teak. Teak planted in the DDF has a harvest time of 15 years for small timber (20-25 cm in diameter); and 30 years for large timber (over 40 cm in diameter).

Technique to enrich degraded DDF with teak in Figure 35 and illustrations in Figure 36:

- Teak is planted in canopy gaps of the DDF, the gaps with diameter > 6 m can be planted with at least one teak seedling.
- Larger canopy gaps can be planted with more trees. Teak planted in the DDF in canopy gaps with distances 3 m apart and 3 m away from the DDF trees
- The density of teak planting depends on the density of the remaining DDF timber trees, ranging from 200 to 500 trees/ ha depending on the area of canopy gaps.

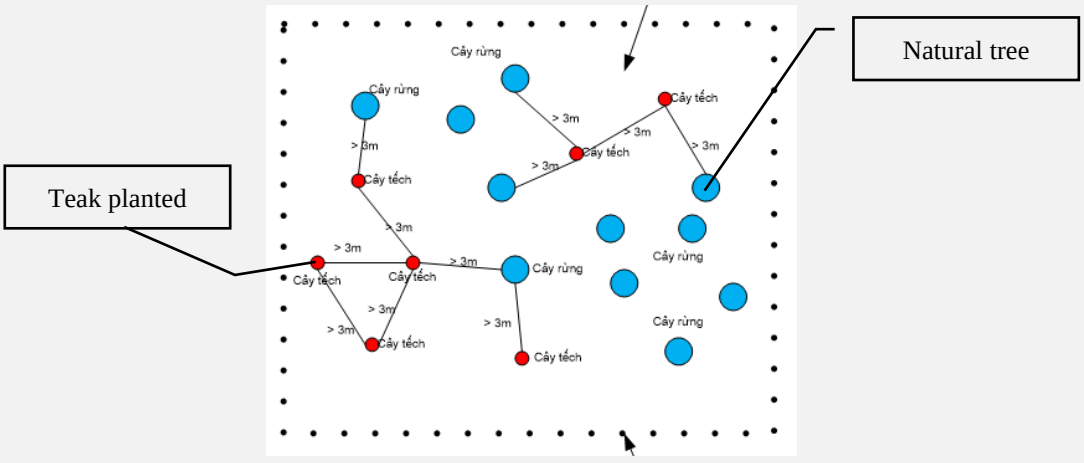


Figure 35. Sketch of planting teak in canopy gaps of degraded DDF

Figure 36. Image of teak in the enrichment of DDF

In place of good suitability level at the age of 6 years, planted teak reach 10- 12 cm in diameter (Huy et al., 2018)

Source:

- *Huy, B., 2014. Determine the site, appropriate forest status and techniques to enrich dipterocarp forest with teak (Tectona grandis* L.f.). *Technical report. Department of Science and Technology of Dak Lak province (in Vietnamese).*
- *Huy, B., Tri, P.C., Triet, T. 2018. Assessment of enrichment planting of teak (Tectona grandis* L.f.) *in degraded dry deciduous dipterocarp forest in the Central Highlands, Viet Nam, Southern Forests: a Journal of Forest Science, 80:1, 75-84.*
- *ITTO (International Tropical Timber Organization), 2002. ITTO guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests. 86 pp.*
- *Useful tropical plants: http://tropical.theferns.info/*

Table 23. List of plant species used for enrichment of degraded EBLF

Purpose:
T: Timber
M Multiple purpose
NTFP: Non-Timber Forest Products

Forest type:
H&SHT Humid and semi-humid tropics
SADT Semi-arid (dry) tropics, dipterocarp

Objects of forest rehabilitation:
DF: Degraded forest
SF Secondary forest

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
1	Bầu nâu/ Trái mắm	*Aegle marmelos* (L.) Corrêa	M	Fruit, leaves, essential oil, resin, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
2	Bồ đề nam	*Styrax benzoides* W. G. Craib	M	Timber, resin	Woody	H&SHT	DF, SF	Useful tropical plants, GBIF
3	Bồ ngót rừng	*Melientha suavis* Pierre	M	Timber, leaves, flower, seed	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
4	Bời lời vàng	*Litsea pierrei* Lecomte	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF, Tuan and Tiep (2017), VAFS
5	Bứa tai chua/ Bứa cọng	*Garcinia cowa* Roxb. ex Choisy	M	Timber, fruit, leaves, resin	Woody	H&SHT	DF, SF	Useful tropical plants, Rhaman et al. (2016) Thanh and Trang (2019)
6	Bưởi bung	*Acronychia pedunculata* (L.) Miq.	M	Timber, essential oil, leaves, bark	Woody	H&SHT	DF, SF	Useful tropical plants
7	Bụp cò ke (gỗ đổi màu)	*Hibiscus grewiifolius* Hassk.	T	Timber	Woody	H&SHT	DF, SF	Useful tropical plants, GBIF
8	Chò xót, Vối thuốc	*Schima crenata* Korth.	M	Timber, flower, bark	Woody	H&SHT	DF, SF	GIZ, Ho (1999)
9	Cóc chuột	*Lannea coromandelica* (Houtt.) Merr.	M	Timber, leaves, bark	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Hop (2002)
10	Cóc rừng	*Spondias pinnata* (L. f.) Kurz	M	Timber, fruit, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
11	Cồng tía	*Calophyllum calaba var. bracteatum* (Wight) P.F.Stevens	M	Timber, resin	Woody	H&SHT	DF, SF	GIZ, WWF
12	Dâu da	*Baccaurea ramiflora* Lour.	M	Fruit, timber	Woody	H&SHT	DF, SF	Useful tropical plants, Qiang et al. (2014)
13	Dầu rái	*Dipterocarpus alatus* Roxb. ex G.Don	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, VAFS
14	Dẻ anh	*Castanopsis piriformis* Hickel & A Camus	M	Fruit, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Thang (2016)
15	Dẻ đỏ, Dẻ đá đỏ	*Lithocarpus ducampii* (Hickel & A.Camus) A.Camus	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF, VAFS
16	Gáo trắng	*Neolamarckia cadamba* (Roxb.) Bosser	M	Timber, fruit, bark, leaves	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Useful tropical plants, WFO

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
17	Giổi ăn hạt, Giổi balansa	*Magnolia balansae* A.DC.	M	Timber, fruit	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants, Nam (2017)
18	Giổi xanh	*Magnolia mediocris* (Dandy) Figlar	M	Timber, seed	Woody	H&SHT	DF, SF	Useful tropical plants, VAFS, Sam et al. (2004)
19	Giổi xanh quả to	*Magnolia citrata* Noot. & Chalermglin	M	Timber, seed, leaves	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants, Nam (2017)
20	Gòn gai	*Bombax anceps* Pierre	M	Timber, bark, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
21	Hoàng linh, Lim vàng	*Peltophorum dasyrrhachis* (Miq.) Kurz	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF
22	Kháo, Dung nam bộ	*Symplocos cochinchinensis* (Lour.) S. Moore	M	Timber, seed, bark	Woody	H&SHT	DF, SF	GIZ, WWF, Liu et al (2017)
23	Kơ nia, cầy	*Irvingia malayana* Oliv. ex A.W.Benn.	M	Timber, fruit, seed	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
24	Mắc khén/ Hoàng mộc	*Zanthoxylum rhetsa* DC.	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants
25	Măng cụt	*Garcinia mangostana* L.	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants; Rahna et al., (2016)
26	Mây nếp	*Calamus tetradactylus* Hance	NTFP	Rattan, rattan shoot	Liana	H&SHT	DF, SF	ITTO (2002), WFO
27	Mít nài, mít rừng	*Artocarpus rigidus subsp. asperulus* (Gagnep.) F.M.Jarrett	M	Timber, leaves, resin	Woody	H&SHT	DF, SF	GIZ, WWF
28	Mò cua lá hẹp	*Alstonia angustifolia* Wall. ex A.DC.	M	Timber, bark, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
29	Mỡ Phú Thọ	*Magnolia chevalieri* (Dandy) V.S.Kumar	T	Timber	Woody	H&SHT	DF, SF	VAFS
30	Mỡ, Vàng tâm	*Magnolia conifera* (Dandy) V.S.Kumar	T	Timber	Woody	H&SHT	DF, SF	VAFS
31	Muồng đen	*Senna siamea* (Lam.) H.S.Irwin & Barneby	M	Timber, flower, fruit, leaves	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants,
32	Ngát vàng	*Gironniera subaequalis* Planch.	M	Timber, bark	Woody	H&SHT	DF, SF	Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
33	Ngọc lan trắng	*Michelia alba* DC.	M	Timber, essential oil	Woody	H&SHT	DF, SF	VAFS
34	Núc nác	*Oroxylum indicum* (L.) Kurz	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants, ICRAF
35	Quế	*Cinnamomum cassia* (L.) J.Presl	M	Timber, bark	Woody	H&SHT	DF, SF	TT 30/2018, VAFS, Useful tropical plants
36	Sang máu, máu chó lá to	*Horsfieldia amygdalina* (Wall.) Warb.	M	Timber, seed	Woody	H&SHT	DF, SF	GIZ, WWF
37	Sao đen	*Hopea odorata* Roxb.	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, VAFS, Useful tropical plants
38	Sầu riêng	*Durio zibethinus* L.	M	Fruit, seed, timber, root	Woody	H&SHT	DF, SF	ITTO (2002)
39	Sồi bộp, Dẻ bội, Sồi áo tơi	*Quercus poilanei* Hickel & A.Camus	T	Timber	Woody	H&SHT	DF	GIZ, WWF, WFO, Lehmann (2003)
40	Sòi tía	*Triadica cochinchinensis* Lour.	M	Timber, root, seed	Woody	H&SHT	DF, SF	Useful tropical plants
41	Sơn muối	*Rhus chinensis* Mill.	M	Timber, fruit, resin, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
42	Sơn tra, Táo mèo	*Docynia indica* (Wall.) Decne.	M	Timber, fruit	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants
43	Song bột	*Calamus poilanei* Conrard	NTFP	Rattan, rattan shoot	Liana	H&SHT	DF, SF	Useful tropical plants, Sombun (2002), Dung (2013)
44	Sóng rắn/ Bồ kết tây	*Albizia lebbeck* (L.) Benth.	M	Timber, bark, flower, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
45	Sữa, Mò cua	*Alstonia scholaris* (L.) R. Br.	M	Timber, resin, bark, flower	Woody	H&SHT, SADT	DF, SF	VAFS, Useful tropical plants,
46	Tếch	*Tectona grandis* L.f.	M	Timber, leaves, root, bark, flower, seed	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Huy et al. (2018), VAFS
47	Thông 2 lá, Thông nhựa	*Pinus latteri* Mason Pinus merkusii Jungh. & de Vriese	M	Timber, resin, bark	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
48	Thông 3 lá	*Pinus kesiya* Royle ex Gordon	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants,
49	Trám hồng	*Canarium bengalense* Roxb.	M	Timber, resin	Woody	H&SHT	DF, SF	GIZ, WWF
50	Trám lá đỏ	*Canarium subulatum* Guillaumin	M	Timber, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
51	Trâm mốc, Vối rừng, Trâm vối	*Syzygium cumini* (L.) Skeels	M	Timber, fruit, leaves, bark	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
52	Trôm hôi	*Sterculia foetida* L.	M	Resin, timber	Woody	H&SHT, SADT	DF, SF	TT 30/2018, Useful tropical plants
53	Ươi	*Scaphium macropodum* (Miq.) Beumée ex K.Heyne	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants; Thanh et al., (2018)
54	Vải rừng/ Trường chua	*Nephelium hypoleucum* Kurz	M	Fruit, timber	Woody	H&SHT	DF, SF	Useful tropical plants, WFO
55	Vạng trứng	*Endospermum chinense* Benth.	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF
56	Xoan đào	*Prunus arborea var. montana* (Hook.f.) Kalkman	M	Timber, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
57	Xoan mộc	*Toona sureni* (Blume) Merr.	M	Timber, bark, leaves	Woody	H&SHT	DF, SF	ITTO (2002)
58	Xoan ta	*Melia azedarach* L.	M	Timber, resin, bark, leaves, flower, fruit, bark	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants,

5.4 Monitoring and evaluating the measures of enrichment planting

5.4.1 Monitoring the silvicultural measures of enrichment planting

Monitoring the silvicultural measures of enrichment planting is to focus on collecting data to examine the adaptability and growth of enrichment planting species over time. From there, determine how this silviculture measure makes changes in forest rehabilitation; at the same time, detecting problems that need improvement or finding the causes if there are failures in the technical measures and the implementation. Monitoring should be conducted in a participatory process, as it promotes mutual learning about a forest rehabilitation technique, especially new plants. (FAO, 2015)

Box 25 introduces a participatory monitoring method when applying enrichment planting techniques

Box 25. Monitoring method when applying enrichment planting techniques

1. Supervisors, participants

- The team/ group leader of the community forest rehabilitation group as the monitoring group leader
- Participants: Households, groups of households implementing this silvicultural measure
- Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists

2. Materials and tools

- A sketch of forest rehabilitation based on village landscape
- Detailed designs describing enrichment planting measures
- GPS to locate forest locations
- Measurement tapes for measuring D, H forest trees, regenerated trees.
- The 30-meter-long measurement tape for measuring the distance of forest trees and canopy
- Record sheets according to monitoring indicators for silvicultural measures of enrichment planting (Table 24)

3. Performing method

- Time: At the end of the annual growing season of the forest trees
- Location: Each forest block applying silvicultural measures
- Recording: Use Table 24 to collect, record silvicultural measure information
- Discuss in the monitoring group on two aspects, strengths, and weaknesses of silvicultural measures of enrichment planting and used resources
- The monitoring team leader announces the results of the monitoring at the annual village meeting

Table 24. Record sheet for monitoring silvicultural measures of enrichment planting

Supervisors:
Participants:
The implementers:
Applied silvicultural measures:
Place:
Monitoring time:
The time when application of measure of enrichment planting start:
Forest object:

Monitoring and observing indicators	*Data, information collected*
Area of enrichment planting forest (ha)	
The density of large trees (N, trees/ ha) according to the K- 6 tree sampling method	

The density of potential regenerated trees (Nre, trees/ ha) according to the K- 6 tree sampling method
Density of enrichment planting, survival rate (K- 6 tree sampling method)
Averaged growth D of large trees (K- 6 tree sampling method)
Averaged growth H of potential natural regenerated trees (K- 6 tree sampling method)
Averaged growth H of additional trees (K- 6 tree sampling method)
Dispersion of regenerated and large trees on forest ground (clumped, random, uniform)
Forest canopy (1/10) (according to line intersect sampling)
Productivity of harvested products and their value
Strengths/ weaknesses in the ANR measures and resources

Note:

- How to implement method K- 6 tree sampling refer to Figure 21 and Figure 29 and method K- 6 tree sampling is repeated 3 times in each forest block conducting technical measures, placed in average representative positions.
- Calculate the average value of D, H trees, regenerated, additional plants according to the K- 6 tree sampling method: Measure D and H of 6 trees and averaged, then averaged from the sampling points.
- Survival rate based on K- 6 tree sampling method: Including dead trees and count the number of dead trees in each point.
- The method of determining dispersion pattern of forest trees and regenerated trees on forest ground is refer to Figure 22
- The canopy cover by line intersect sampling refer to Figure 26
- Productivity of products harvested and their value: Record the productivity of forest products harvested by season, by year from forests applying enrichment planting, and calculate into money.

5.4.2 Evaluating the silvicultural measures of enrichment planting

The evaluation aims to draw conclusions about measures of enrichment planting, with consideration to the adaptation and meeting purpose of enrichment plants to restore local forests and to draw lessons learned. Evaluation is done at the end of this silvicultural measure, usually 5- 10 years. The evaluation mainly compares the results achieved by enrichment planting with the forest status before and with the ideal forest models along with indicators and objectives.

The evaluation also includes a synthesis of the monitoring results to the final stage and final evaluation. The evaluation will provide a completion of the silvicultural measures of enrichment planting for forest rehabilitation. Pay attention to the selection of enrichment plants to see whether they are adaptable and meet the set goals in locality or not and organize the implementation to apply. Similar to monitoring, the evaluation

should be conducted with the participation of all stakeholders and implementers in order to have a common understanding and consensus on the silvicultural measures of forest rehabilitation (FAO, 2015).

Box 26 shows a participatory evaluation method for implementing silvicultural measures of enrichment planting

Box 26. Evaluation method for measures of enrichment planting
1. Evaluators, participants - Team/ group leader conducting enrichment planting as the evaluation team leader - Participants: Households, groups of households performing silvicultural measures - Stakeholders: Local forest rangers, commune agriculture and forestry staff, district agriculture extensionists, district and provincial rangers, provincial agriculture, and forestry extensionists, consultants
2. Materials and tools - A sketch of forest rehabilitation based on village landscape - Detailed designs describing enrichment planting measures - Record sheets of monitoring results for the enrichment planting (Table 24)
3. Performing method - Time: At the end of enrichment planting period (5-10 years) - Location: Some forest blocks applying silvicultural measures and community house - Recording: Use Table 25 to collect, record information on evaluation - The evaluation team leader announces the results of the evaluation during the village meeting

Table 25. Framework for evaluating silvicultural measures of enrichment planting

Evaluators:
Participants:
The implementers:
Place:
Evaluating time:
The time when application of measure of enrichment planting start:

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
1	Enrichment planting density with D ≥ 5 cm (K- 6			300 (EBLF) 270 (DDF)		

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
	tree sampling method) (trees/ ha)					
2	Potential regeneration density (D < 5 cm and H > 1 m) (trees/ ha)			500		
3	Density of large trees including enrichment trees with D ≥ 5 cm (trees/ ha)			1000 (EBLF) 700 (DDF)		
4	Distance and dispersion of large trees and enrichment trees with D ≥ 5 cm on forest ground (clumped, random, uniform)			> 1.7 m for EBLF and 2.0 m for DDF and random to uniform dispersion		
5	Dispersion of potential regenerated trees and enrichment trees on forest ground (clumped, random, uniform)			Random to uniform		
6	Species component of potential regeneration trees and planted trees			Supportive species groups according to the forest type		

Id	Technical indicators	Data at the start	Results at the end	From ideal model	Compare the results with the optimal and initial indicators (+/-)	Productivity of harvested product and value
7	Species component of trees including planted trees			Supportive species groups according to the forest type		
8	Conclusion on the appropriateness of techniques, resources, organizations					

Note:

- Data at initiation: Collected at the first monitoring stage
- Results at the end: Field survey, using results of annual monitoring data and of the final stage
- Comparing the results with the optimal indicators and with initiation (+/-): For quantitative indicators, calculate results + or -, and for qualitative indicators, explain the difference between the results and the optimal indicators and with the initiation.
- Productivity of harvested products and value: Synthesized from the results of periodic monitoring to the end stage of enrichment planting.
- Conclusion on techniques, resources, organization: Discussing in the field and in the meeting to record evaluation conclusions

6 RESOURCES TO IMPLEMENT THE REHABILITATION OF DEGRADED NATURAL FORESTS

Rehabilitation of degraded natural forests caused by over exploitation, regeneration after shifting cultivation is a challenging task not only in terms of technique but also in terms of organization and resources to perform. Forest rehabilitation to provide forest products and generate income requires a long time, the fastest also from 5 to 10 years for additional plants, enrichment plants as multi-purpose trees; meanwhile, local communities managing forests often do not have the financial and other resources to implement.

Therefore, the following resources should be considered to support and promote communities to rehabilitate degraded natural forests.

6.1 Create native forest seedlings locally

Rehabilitation of degraded natural forests applying silvicultural measures of ANR with additional planting or/and enrichment planting requires indigenous species seedlings. Meanwhile, forest seedlings from the market often do not have native species of natural forest, only a few species are commonly produced for planting on the streets in urban such as *Hopea odorata* Roxb., *Dipterocarpus alatus* Roxb. ex G.Don; therefore, to be able to restore forests towards using native plants, it is necessary to have a strategy for developing forest nursery locally.

Organizing to create the seedlings of native forest trees in local communities, specifically:

- *Organization:* Forming a group specializing in producing indigenous seedlings in the community, depending on the scale of the restored forest to determine the scale of seedlings to be produced annually, thereby determining the required manpower. On average, it takes about 5 people to form a group of forest seedlings, with a group leader and secretary to take notes and expenses.
- *Collecting the seeds and propagating materials:* Seeds or propagating materials like cuttings should be collected from local forests or neighboring localities with the same ecological conditions and forest types. It is necessary to rely on local knowledge of the community to determine the timing of seed collection, seed materials and storage.
- *Nursery establishment*: Nurseries should be established in the local community, preferably close to rehabilitated forests and water sources to reduce the transport of the seedlings for planting and to have water for irrigation in nursery. The size of the nursery depends on the seedling demand. Community forest tree nurseries do not need to be built for long- term, only need temporary nursery for a few years, because the planting of trees for forest rehabilitation takes place only for a while. Using natural forest materials such as bamboo, cogon grass, rattan for building nursery.

- *Seed treatment and seedling creation:* Different species, the treatment of seeds and creating seedlings are different, diverse. Depending on knowledge up to now, some species are clear about collection and propagation, but some species have not had much experience, with these species requiring further testing in the community. In creating seedlings should use locally available muck, avoid using chemical fertilizers, do not use herbicides, chemical pesticides. Microbial and organic fertilizers, or lime can be used if the species requires a lot of lime.

6.2 Financial policies for rehabilitation of degraded natural forests in communities

Rehabilitation of degraded natural forests requires a fairly long-term financial source, at least for 5 years, preferably 10 years, for implementation. Here are the sources to consider:

- *From the source of payment for watershed forest environmental services*: For communities allocated forests located in basins with hydroelectric plants, revenue from this service is available. After paying back to individuals and households for forest protection, many communities retain an annual source of funds, the rate of which is kept as a fund depends on the community and forest area; funds are used for general affairs in the community, to build infrastructure. On this basis it is possible to further advise the community on the appropriate retention rate as a fund and how to use this fund to restore natural forests.
- *Expected revenue from environmental services of forest carbon sequestration*: Currently, the Government and many international organizations are supporting Viet Nam to pilot the payment for environmental services of forest carbon accumulation, soon if this service is widely deployed, it will create a meaningful source of revenue for natural forest management in communities; this is a potential source of revenue for the community to use partly for natural forest rehabilitation. Because according to the principle of paying for carbon sequestration services, the more quickly the forest recovers and grows, the more carbon it will accumulate, and the payment will be proportional. Therefore, reinvestment from revenue of environmental services of forest carbon accumulation is necessary and reasonable.
- *Proposing the state to compensate and support communities in protecting and enhancing ecological values of degraded natural forests*: In some places where community forests are not in basin with hydropower, so there is no revenue from watershed environmental services, at the same time revenue from environmental services of carbon accumulation needs to wait for some more time. While the community is protecting an area of degraded forest, not much giving income from forest products, but these forests still have many ecological meanings such as accumulating carbon to mitigate climate change, protecting watershed, land for the society; therefore, the state needs to have appropriate payment and

compensation policies in these areas. This can be considered as payment to the community for forest ecological services that the community is providing to the society through forest protection. If the communities have this source of payment and compensation, they can completely restore degraded natural forests effectively.

- *The state supports the capacity building training for communities on rehabilitation of degraded natural forests:* The system of agricultural and forestry extensionists and rangers at commune and district level needs to budget from the state sources annually to carry out training courses for communities on rehabilitation of degraded natural forests.

6.3 Training the community to apply the guidelines for degraded natural forest rehabilitation

This manual target local communities and households for the rehabilitation of their degraded natural forests. However, in the first time, there should be the introduction and guidance from technical staff with expertise in silviculture such as forest rangers, agricultural and forestry extensionist, forestry university lecturers to support community access and practice through a few times.

Methods to conduct training for communities need a participatory approach and practice, namely:

- Organizing training for trainers (ToT) before the trainers do the training for the community. This step is important to ensure that the technical contents will be clearly and accurately transferred to the community through the trainers.
- Trainers use these manuals as teaching materials and provide them to learners who are members of the community for reference and application.
- From the manual, selecting and printing the Posters from guidelines of Figures, Tables, Boxes to introduce and train the community
- When training, each silviculture measure should be practiced on forest blocks as a sample of about 0.3 - 0.5 ha and repeated 2-3 times and there is one non-applicable control block.

Besides organizing the initial training for communities to apply natural forest rehabilitation, the support staff should also have a plan to join with communities conducting forest rehabilitation to help them monitor, evaluate, learn, and share experiences, from there to draw lessons to support more effectively for other communities.

6.4 Organization of implementation

In order to organize the implementation of the "Manual for natural forest rehabilitation", departments and units at different levels need to implement:

- Provincial Forest Protection Department is the unit responsible for managing and guiding district forest protection units and commune forest rangers on how to implement. Provincial forest rangers train district and commune forest rangers (ToT). Monitoring and evaluation of natural forest rehabilitation activities.
- The Provincial Agriculture and Forestry Extension Center coordinates with the Provincial Forest Protection Department to carry out ToT trainings for district and commune extensionists; and organizing training directly to the community. Participating in monitoring and evaluating the natural forest rehabilitation activities with the Forest Protection Department.
- Forest Protection Units, Agriculture and Forestry Extension Station at districts are under the management and guidance of DARD, Forest Protection Department to plan implementation of training activities for the community and participate in direct support for the community and monitoring, evaluating the results of implementing natural forest rehabilitation.
- Universities and forestry-related Research Institutes participate in ToT training and provide trainers on rehabilitation of degraded natural forests. Participating in monitoring and evaluating natural forest rehabilitation activities.
- Communities, individuals, households, and other forest owners who are allocated to manage and use natural forests for a long time, apply these technical guidelines to restore degraded natural forests they are managing.

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ANNEXES

Annex 1: LIST OF SPECIES FOR PLANTING TO REHABILITATE NATURAL FOREST IN EBLF AND DDF IN THE CENTRAL HIGHLANDS OF VIET NAM

Purpose:
T: Timber
M Multiple purpose
NTFP: Non-Timber Forest Products

Forest type:
H&SHT Humid and semi-humid tropics
SADT Semi-arid (dry) tropics, dipterocarp

DF: Degraded forest
SF Secondary forest

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
1	Bầu nâu/ Trái mắm	*Aegle marmelos* (L.) Corrêa	M	Fruit, leaves, essential oil, resin, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
2	Bồ đề nam	*Styrax benzoides* W. G. Craib	M	Timber, resin	Woody	H&SHT	DF, SF	Useful tropical plants, GBIF
3	Bồ ngót rừng, Rau sắng	*Melientha suavis* Pierre	M	Timber, leaves, flower, seed	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
4	Bời lời chanh	*Litsea cubeba* (Lour.) Pers.	M	Timber, bark, fruit, leaves	Woody	H&SHT	SF	Useful tropical plants
5	Bời lời đỏ, Kháo hoa nhỏ	*Machilus odoratissimus* Nees	M	Timber, bark	Woody	H&SHT	SF	VAFS, Useful tropical plants, WFO
6	Bời lời nhớt	*Litsea glutinosa* (Lour.) C.B.Rob.	M	Timber, bark	Woody	H&SHT, SADT	SF	Useful tropical plants
7	Bời lời vàng	*Litsea pierrei* Lecomte	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF, Nguyễn Anh Tuấn (2017), VAFS

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
8	Bứa tai chua/ Bứa cọng	*Garcinia cowa* Roxb. ex Choisy	M	Timber, fruit, leaves, resin	Woody	H&SHT	DF, SF	Useful tropical plants, Rhaman et al. (2016) Thanh and Trang (2019)
9	Bưởi bung	*Acronychia pedunculata* (L.) Miq.	M	Timber, essential oil, leaves, bark	Woody	H&SHT	DF, SF	Useful tropical plants
10	Bụp cò ke (gỗ đổi màu)	*Hibiscus grewiifolius* Hassk.	T	Timber	Woody	H&SHT	DF, SF	Useful tropical plants, GBIF
11	Ca cao	*Theobroma cacao* L.	M	Fruit, timber, bark	Woody	H&SHT	SF	VAFS, Useful tropical plants,
12	Cáng lò	*Betula alnoides* Buch.-Ham. ex D.Don	M	Timber, bark	Woody	H&SHT	SF	VAFS, Useful tropical plants, Nghia and Thu (2009), Toai and Duong (2012), Dinh (2008)
13	Chò xót, Vối thuốc	*Schima crenata* Korth.	M	Timber, flower, bark	Woody	H&SHT	DF, SF	GIZ, WWF; Ho (1999)
14	Chôm chôm	*Nephelium lappaceum* L.	M	Fruit, seed, timber	Woody	H&SHT	SF	ITTO (2002)
15	Cóc chuột	*Lannea coromandelica* (Houtt.) Merr.	M	Timber, leaves, bark	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Hop (2002)
16	Cóc rừng	*Spondias pinnata* (L. f.) Kurz	M	Timber, fruit, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
17	Cồng tía	*Calophyllum calaba var. bracteatum* (Wight) P.F.Stevens	M	Timber, resin	Woody	H&SHT	DF, SF	GIZ, WWF
18	Dâu da	*Baccaurea ramiflora* Lour.	M	Fruit, timber	Woody	H&SHT	DF, SF	Useful tropical plants, Qiang et al. (2014)
19	Dầu rái	*Dipterocarpus alatus* Roxb. ex G.Don	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, VAFS
20	Dẻ anh	*Castanopsis piriformis* Hickel & A Camus	M	Fruit, timber	Woody	H&SHT, SADT	DF, SF	Useful tropical plants, Thang; et al., (2016, 2017)
21	Dẻ đỏ, Dẻ đá đỏ	*Lithocarpus ducampii* (Hickel & A.Camus) A.Camus	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF, VAFS

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
22	Gáo trắng	*Neolamarckia cadamba* (Roxb.) Bosser	M	Timber, fruit, bark, leaves	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Useful tropical plants, WFO
23	Giổi ăn hạt, Giổi balansa	*Magnolia balansae* A.DC.	M	Timber, fruit	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants, Nam (2017)
24	Giổi xanh	*Magnolia mediocris* (Dandy) Figlar	M	Timber, seed	Woody	H&SHT	DF, SF	Useful tropical plants, VAFS, Sam et al. (2004)
25	Giổi xanh quả to	*Magnolia citrata* Noot. & Chalermglin	M	Timber, seed, leaves	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants, Nam (2017)
26	Gòn	*Ceiba pentandra* (L.) Gaertn.	M	Fruit, leaves, bark, resin, timber	Woody	H&SHT	SF	ITTO (2002)
27	Gòn đỏ, gạo đỏ, Pơ lang	*Bombax ceiba* L.	M	Timber, fruit, leaves flower, root, resin, bark	Woody	H&SHT, SADT	SF	Useful tropical plants, Jain and Verma (2012), WFO
28	Gòn gai	*Bombax anceps* Pierre	M	Timber, bark, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
29	Hoàng linh, Lim vàng	*Peltophorum dasyrrhachis* (Miq.) Kurz	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF
30	Hồng ăn quả	*Diospyros kaki* L.f.	M	Fruit, Timber	Woody	H&SHT	SF	VAFS, Useful tropical plants,
31	Kháo, Dung nam bộ	*Symplocos cochinchinensis* (Lour.) S. Moore	M	Timber, seed, bark	Woody	H&SHT	DF, SF	GIZ, WWF, Liu et al (2017)
32	Kơ nia, cầy	*Irvingia malayana* Oliv. ex A.W.Benn.	M	Timber, fruit, seed	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
33	Lát hoa, nhựa	*Chukrasia tabularis* A.Juss.	M	Timber, resin, juice extracted from bark, leaves, root	Woody	H&SHT	SF	VAFS, Useful tropical plants,

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
34	Lõi thọ	*Gmelina arborea* Roxb.	M	Timber, flower, fruit, root, resin	Woody	H&SHT, SADT	SF	Useful tropical plants
35	Lòng mức lông	*Wrightia pubescens* R.Br.	M	Timber, bark	Woody	H&SHT	SF	Useful tropical plants, VAFS
36	Mắc khén/ Hoàng mộc	*Zanthoxylum rhetsa* DC.	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants
37	Măng cụt	*Garcinia mangostana* L.	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants; Rahna et al., (2016)
38	Mây nếp	*Calamus tetradactylus* Hance	NTFP	Rattan, rattan shoot	Liana	H&SHT	DF, SF	ITTO (2002), WFO
39	Me	*Tamarindus indica* L.	M	Timber, fruit	Woody	H&SHT, SADT	SF	VAFS, Useful tropical plants
40	Mít	*Artocarpus heterophyllus* Lam.	M	Timber, fruit	Woody	H&SHT	SF	ITTO (2002), VAFS
41	Mít nài, mít rừng	*Artocarpus rigidus subsp. asperulus* (Gagnep.) F.M.Jarrett	M	Timber, leaves, resin	Woody	H&SHT	DF, SF	GIZ, WWF
42	Mò cua lá hẹp	*Alstonia angustifolia* Wall. ex A.DC.	M	Timber, bark, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
43	Mỡ Phú Thọ	*Magnolia chevalieri* (Dandy) V.S.Kumar	T	Timber	Woody	H&SHT	DF, SF	VAFS
44	Mỡ, Vàng tâm	*Magnolia conifera* (Dandy) V.S.Kumar	T	Timber	Woody	H&SHT	DF, SF	VAFS
45	Muồng đen	*Senna siamea* (Lam.) H.S.Irwin & Barneby	M	Timber, flower, fruit, leaves	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants
46	Muồng hoa đào	*Cassia javanica* L.	M	Timber, bark, seed	Woody	H&SHT	SF	VAFS, Useful tropical plants
47	Ngát vàng	*Gironniera subaequalis* Planch.	M	Timber, bark	Woody	H&SHT	DF, SF	Useful tropical plants
48	Ngọc lan trắng	*Michelia alba* DC.	M	Timber, essential oil	Woody	H&SHT	DF, SF	VAFS
49	Núc nác	*Oroxylum indicum* (L.) Kurz	M	Timber, fruit	Woody	H&SHT	DF, SF	Useful tropical plants, ICRAF
50	Ổi	*Psidium guajava* L.	M	Timber, fruit,	Woody	H&SHT	SF	VAFS, Useful tropical plants,

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
				leaves, bark				
51	Quao khộp	*Heterophragma sulfureum* Kurz	M	Timber, root	Woody	SADT	DF, SF	Htun (2016)
52	Quế	*Cinnamomum cassia* (L.) J.Presl	M	Timber, bark	Woody	H&SHT	DF, SF	TT 30/2018, VAFS, Useful tropical plants
53	Sang máu, máu chó lá to	*Horsfieldia amygdalina* (Wall.) Warb.	M	Timber, seed	Woody	H&SHT	DF, SF	GIZ, WWF
54	Sao đen	*Hopea odorata* Roxb.	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, VAFS, Useful tropical plants
55	Sầu riêng	*Durio zibethinus* L.	M	Fruit, seed, timber, root	Woody	H&SHT	DF, SF	ITTO (2002)
56	Sồi bộp, Dẻ bội, Sồi áo tơi	*Quercus poilanei* Hickel & A.Camus	T	Timber	Woody	H&SHT	DF	GIZ, WWF, WFO, Lehmann (2003)
57	Sòi tía	*Triadica cochinchinensis* Lour.	M	Timber, root, seed	Woody	H&SHT	DF, SF	Useful tropical plants
58	Sơn muối	*Rhus chinensis* Mill.	M	Timber, fruit, resin, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
59	Sơn tra, Táo mèo	*Docynia indica* (Wall.) Decne.	M	Timber, fruit	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants
60	Song bột	*Calamus poilanei* Conrard	NTFP	Rattan, rattan shoot	Liana	H&SHT	DF, SF	Useful tropical plants, Sombun (2002), Dung (2013)
61	Sóng rắn/ Bồ kết tây	*Albizia lebbeck* (L.) Benth.	M	Timber, bark, flower, leaves	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
62	Sữa, Mò cua	*Alstonia scholaris* (L.) R. Br.	M	Timber, resin, bark, flower	Woody	H&SHT, SADT	DF, SF	VAFS, Useful tropical plants,

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
63	Tếch	*Tectona grandis* L.f.	M	Timber, leaves, root, bark, flower, seed	Woody	H&SHT, SADT	DF, SF	ITTO (2002), Huy et al. (2018), VAFS
64	Thành ngạnh đỏ ngọn	*Cratoxylum formosum* (Jacq.) Benth. & Hook.f. ex Dyer	M	Timber, leaves, bark, resin	Woody	H&SHT, SADT	SF	ITTO (2002), Useful tropical plants
65	Thông 2 lá, Thông nhựa	*Pinus latteri Mason* Pinus merkusii Jungh. & de Vriese	M	Timber, resin, bark	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants
66	Thông 3 lá	*Pinus kesiya* Royle ex Gordon	M	Timber, resin	Woody	H&SHT	DF, SF	TT 30/2018, Useful tropical plants
67	Trám hồng	*Canarium bengalense* Roxb.	M	Timber, resin	Woody	H&SHT	DF, SF	GIZ, WWF
68	Trám lá đỏ	*Canarium subulatum* Guillaumin	M	Timber, fruit	Woody	H&SHT, SADT	DF, SF	Useful tropical plants
69	Trâm mốc, Vối rừng, Trâm vối	*Syzygium cumini* (L.) Skeels	M	Timber, fruit, leaves, bark	Woody	H&SHT, SADT	DF, SF	GIZ, WWF
70	Trám trắng	*Canarium album* (Lour.) DC.	M	Fruit, resin, timber	Woody	H&SHT	SF	ITTO (2002), Useful tropical plants, TT 30/2018, GIZ-WWF
71	Tre bát độ	*Dendrocalamus latiflorus* Munro.	NTFP	Bambo culm, bamboo shoot	Bamboo	H&SHT	SF	VAFS, Useful tropical plants
72	Tre gai	*Bambusa blumeana* Schult.f.	NTFP	Bambo culm, bamboo shoot	Bamboo	H&SHT, SADT	SF	VAFS, Useful tropical plants
73	Tre vàng sọc	*Bambusa vulgaris* Schrad.	NTFP	Bamboo culm, bamboo shoot	Bamboo	H&SHT	SF	VAFS, Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
74	Trôm hôi	*Sterculia foetida* L.	M	Resin, timber	Woody	H&SHT, SADT	DF, SF	TT 30/2018, Useful tropical plants
75	Ươi	*Scaphium macropodum* (Miq.) Beumée ex K.Heyne	M	Timber, seed	Woody	H&SHT	DF, SF	Useful tropical plants; Thanh et al., (2018)
76	Vả	*Ficus auriculata* Lour.	M	Fruit, timber	Woody	H&SHT	SF	ITTO (2002), VAFS, Useful tropical plants
77	Vải rừng/ Trường chua	*Nephelium hypoleucum* Kurz	M	Fruit, timber	Woody	H&SHT	DF, SF	Useful tropical plants, WFO
78	Vạng trứng	*Endospermum chinense* Benth.	T	Timber	Woody	H&SHT	DF, SF	GIZ, WWF
79	Vỏ dụt	*Hymenodictyon orixense* (Roxb.) Mabb.	M	Timber, bark	Woody	H&SHT, SADT	SF	Useful tropical plants
80	Vông đồng	*Hura crepitans* L.	M	Timber, leaves, bark, fruit, seed, seed oil and resin	Woody	H&SHT	SF	VAFS, Useful tropical plants
81	Vông nem	*Erythrina variegata* L.	M	Timber, bark, leaves, seed, root, flower	Woody	H&SHT	SF	VAFS, Useful tropical plants
82	Xoan chịu hạn	*Azadirachta indica* A.Juss.	M	Timber, fruit, leaves, flower, seed, bark	Woody	SADT	SF	ITTO (2002), Useful tropical plants
83	Xoan đào	*Prunus arborea var. montana* (Hook.f.) Kalkman	M	Timber, leaves	Woody	H&SHT	DF, SF	Useful tropical plants
84	Xoan mộc	*Toona sureni* (Blume) Merr.	M	Timber, bark, leaves	Woody	H&SHT	DF, SF	ITTO (2002)
85	Xoan ta	*Melia azedarach* L.	M	Timber, resin, bark, leaves,	Woody	H&SHT	DF, SF	VAFS, Useful tropical plants

Id	Species in Vietnamese	Species in Latin	Purpose	Products	Living form	Forest type	Objects of forest rehabilitation	Sources
				flower, fruit				

Annex 2: LIST OF SPECIES IN IUCN RED LIST AND DECREE 06/2019/ND-CP IN EBLF AND DDF OF THE CENTRAL HIGHLANDS OF VIET NAM

Forest types: Ever-green Broad-Leaved Forest (EBLF); Dry Dipterocarp Forest (DDF)
IUCN: Red List: Critically Endangered: CR; Endangered: EN; Vulnerable: VU; Near Threatened: NT
Decree 06/2019: Consisting of two groups of species IA or IIA

Id	Species in Vietnamese	Species in Latin		Forest type	Living form	IUCN 2020	Decree 06/2019/ NĐ-CP
1	Bách xanh	*Calocedrus macrolepis*	Kurz	EBLF	Woody	NT	IIA
2	Cà te, Gõ đỏ.	*Afzelia xylocarpa*	(Kurz) Craib	EBLF and DDF	Woody		IIA
3	Các loài dây na rừng	*Kadsura spp.*		EBLF	Liana		IIA
4	Cẩm lai	*Dalbergia oliveri*	Prain	EBLF and DDF	Woody	EN	IIA
5	Chè đuôi	*Camellia petelotii*	(Merr.) Sealy	EBLF	Herbaceous	EN	
6	Chò đen	*Shorea stellata*	(Kurz) Dyer	EBLF	Woody	VU	
7	Đẳng sâm	*Codonopsis javanica*	(Blume) Hook.f. & Thomson	EBLF	Liana		IIA
8	Dầu cát, dầu mít	*Dipterocarpus costatus*	C.F.Gaertn.	EBLF	Woody	VU	
9	Dầu con quay	*Dipterocarpus turbinatus*	C.F.Gaertn	EBLF	Woody	VU	
10	Dầu con rái, dầu nước	*Dipterocarpus alatus*	Roxb. ex G.Don	EBLF	Woody	VU	
11	Dầu lông, Dầu trai	*Dipterocarpus intricatus*	Dyer	DDF	Woody	EN	
12	Đỉnh tùng	*Cephalotaxus mannii*	Hook.f.	EBLF	Woody	VU	IIA
13	Du sam	*Keteleeria evelyniana*	Mast.	EBLF	Woody	VU	
14	Du sam núi đất	*Keteleeria davidiana*	(C.E.Bertrand) Beissn.	EBLF	Woody		IA
15	Dương xỉ gỗ	*Cyathea grabla*	(Wall. ex Hook.) Copel.	EBLF	Herbaceous		IIA
16	Dương xỉ thân gỗ	*Cyathea latebrosa*	(Wall. ex Hook.) Copel.	EBLF	Herbaceous		IIA
17	Giáng hương quả to	*Pterocarpus macrocarpus*	Kurz	EBLF and DDF	Woody	EN	IIA
18	Giổi B'lao	*Magnolia blaoensis*	(Gagnep.) Dandy	EBLF	Woody	VU	
19	Gõ nước	*Sindora tonkinensis*	K.Larsen & S.S.Larsen	EBLF	Woody		IIA
20	Gụ mật, Gõ mật.	*Sindora siamensis*	Miq.	EBLF and DDF	Woody		IIA
21	Gừng collinsi	*Zingiber collinsii*	Mood & Theilade	EBLF and DDF	Herbaceous	VU	
22	Hoàng đằng	*Fibraurea recisa*	Pierre	EBLF	Liana		IIA
23	Hoàng đằng	*Fibraurea tinctoria*	Lour.	EBLF	Liana		IIA
24	Kiền kiền	*Hopea pierrei*	Hance	EBLF and DDF	Woody	VU	IA
25	Lan lọng evrardi	*Bulbophyllum evrardii*	Gagnep.	EBLF	Herbaceous	EN	IIA

Id	Species in Vietnamese	Species in Latin		Forest type	Living form	IUCN 2020	Decree 06/2019/ NĐ-CP
26	Mã hồ	*Mahonia nepalensis*	DC. ex Dippel	EBLF	Herbaceous		IIA
27	Mây poa lan	*Calamus poilanei*	Conrard	EBLF	Liana		IIA
28	Pơ mu	*Fokienia hodginsii*	(Dunn) A.Henry & H H.Thomas	EBLF	Woody		IIA
29	Ráng tiên toạ có cuống	*Cyathea podophylla*	(Hook.) Copel.	EBLF	Herbaceous		IIA
30	Sao đen	*Hopea odorata*	Roxb.	EBLF	Woody	VU	
31	Sao Hải nam	*Hopea hainanensis*	Merr. & Chun	EBLF and DDF	Woody	EN	
32	Sao xanh	*Hopea ferrea*	Laness.	EBLF and DDF	Woody	EN	
33	Sến mật, Cà đoong, Sến mủ	*Shorea roxburghii*	G.Don	EBLF and DDF	Woody	VU	
34	Tắc kè đá	*Drynaria bonii*	Christ	EBLF and DDF	Herbaceous		IIA
35	Tất cả các loài bình vôi thuộc chi Stephania	*Stephania spp.*		EBLF and DDF	Liana		IIA
36	Tất cả các loài lan hài thuộc chi Paphiopedilum	*Paphiopedilum spp.*		EBLF	Herbaceous		IA
37	Tất cả các loài trong họ lan Orchidaceae trừ loài đã quy định ở nhóm IA	*ORCHID IIA*		EBLF and DDF	Herbaceous		IIA
38	Thạch tùng răng cưa	*Huperzia serrata*	(Thunb.) Trevis.	EBLF	Herbaceous		IIA
39	Thích	*Acer calcaratum*	Gagnep.	EBLF	Woody	VU	
40	Thông 5 lá	*Pinus dalatensis*	Ferré	EBLF	Woody		IIA
41	Thông lá dẹt	*Pinus krempfii*	Lecomte	EBLF	Woody	VU	IIA
42	Thông nước	*Glyptostrobus pensilis*	(Staunton ex D.Don) K.Koch	EBLF	Woody	CR	IA
43	Trắc	*Dalbergia cochinchinensis*	Pierre	EBLF and DDF	Woody		IIA
44	Trắc dây, Rịp lá	*Dalbergia rimosa*	Roxb.	EBLF and DDF	Liana		IIA
45	Trầm	*Aquilaria crassna*	Pierre ex Lecomte	EBLF	Woody	CR	
46	Tuế chìm	*Cycas siamensis*	Miq.	EBLF and DDF	Herbaceous		IIA
47	Tuế lá chẻ	*Cycas micholitzii*	Dyer	EBLF and DDF	Herbaceous	VU	IIA
48	Tuế lược	*Cycas pectinata*	Buch.-Ham.	EBLF and DDF	Herbaceous	VU	IIA
49	Vàng đắng	*Coscinium fenestratum*	(Goetgh.) Colebr.	EBLF	Liana		IIA
50	Vên vên	*Anisoptera costata*	Korth.	EBLF and DDF	Woody	EN	
51	Xá xị	*Cinnamomum balansae*	Lecomte	EBLF	Woody		IIA
52	Xoài vàng	*Mangifera flava*	Evrard	EBLF	Woody	VU	

Annex 3: LATIN NAME OF SPECIES USING IN THE MANUAL

Id	Species in Vietnamese	Species in Latin	
1	Ba bét	*Mallotus paniculatus*	(Lam.) Müll.Arg.
2	Bản xe	*Albizia lucidior*	(Steud.) I.C.Nielsen
3	Bằng lăng	*Lagerstroemia sp.*	
4	Bằng lăng ổi	*Lagerstroemia calyculata*	Kurz
5	Bằng lăng tím	*Lagerstroemia tomentosa*	C. Presl
6	Bình linh	*Vitex pinnata*	L.
7	Bình linh 3 lá	*Vitex trifolia*	L.
8	Bình linh cánh	*Vitex pinnata*	L.
9	Bồ an	*Colona erecta*	(Pierre) Burret
10	Bồ đề nam	*Styrax benzoides*	W. G. Craib
11	Bời lời	*Litsea baviensis*	Lecomte
12	Bời lời 1 cánh hoa	*Litsea monopetala*	(Roxb.) Pers.
13	Bời lời lá hẹp	*Litsea baviensis*	Lecomte
14	Bời lời lá to	*Litsea grandis*	(Nees) Hook.f.
15	Bọt ếch	*Glochidion zeylanicum var. tomentosum*	(Dalzell) Trimen
16	Bứa	*Garcinia gummi-gutta*	(L.) Roxb.
17	Bùi tía	*Ilex annamensis*	Tardieu
18	Bưởi bung	*Maclurodendron oligophlebium*	(Merr.) T.G. Hartley
19	Cà chít	*Shorea obtusa*	Wall.
20	Cà giam	*Mitragyne sp.*	
21	Cà giam chuồn	*Mitragyna diversifolia*	(Wall. ex G.Don) Havil.
22	Cẩm lai	*Dalbergia sp.*	
23	Cẩm liên	*Pentacme siamensis*	(Miq.) Kurz
24	Căm xe	*Xylia xylocarpa*	(Roxb.) Taub.
25	Cáp mộc	*Craibiodendron henryi*	W.W.Sm.
26	Cây bồng	*Lophopetalum wallichii*	Kurz
27	Chân chim	*Schefflera heptaphylla*	(L.) Frodin
28	Chân chim lá to	*Schefflera macrophylla*	(Dunn) R.Vig.
29	Chè rừng	*Camellia fleuryi*	(A.Chev.) Sealy
30	Chẹo bông	*Engelhardtia spicata*	Lechen ex Blume
31	Chiêu liêu đen	*Terminalia chebula*	Retz.
32	Chiêu liêu nước	*Combretum pyrifolium*	Kurz
33	Chiêu liêu ổi	*Terminalia corticosa*	Pierre ex Laness.
34	Chiêu liêu xanh	*Terminalia calamansanay*	Rolfe
35	Chò	*Shorea farinosa*	C.E.C.Fisch.
36	Chò xót	*Schima superba*	Gardner & Champ.
37	Chòi mòi	*Antidesma ghaesembilla*	Gaertn.
38	Chùm ruột núi	*Phyllanthus emblica*	L.
39	Cò ke	*Microcos tomentosa*	Sm.
40	Cóc chuột	*Lannea coromandelica*	(Houtt.) Merr.
41	Cóc rừng	*Spondias pinnata*	(L. f.) Kurz
42	Côm	*Elaeocarpus kontumensis*	Gagnep.
43	Côm lá lớn	*Elaeocarpus balansae*	DC.
44	Cù đèn	*Croton delpyi*	Gagnep.
45	Cù đèn thorelii	*Croton thorelii*	Gagnep.

Id	Species in Vietnamese	Species in Latin	
46	Dành dành	*Gardenia obtusifolia*	Roxb. ex Hook.f.
47	Dấu dầu	*Melicope pteleifolia*	(Champ. ex Benth.) T.G. Hartley
48	Dầu đồng	*Dipterocarpus tuberculatus*	Roxb.
49	Dầu trà beng	*Dipterocarpus obtusifolius*	Teijsm. ex Miq.
50	Dẻ	*Lithocarpus sp.*	
51	Dẻ anh	*Castanopsis piriformis*	Hickel & A Camus
52	Dẻ cọng mảnh	*Lithocarpus stenopus*	(Hickel & A.Camus) A.Camus
53	Dẻ gai	*Castanopsis indica*	(Roxb. ex Lindl.) A.DC.
54	Dẻ lindley	*Lithocarpus lindleyanus*	(Wall. ex A.DC.) A.Camus
55	Dẻ trái nhỏ	*Lithocarpus microbalanus*	A.Camus
56	Dền	*Xylopia pierrei*	Hance.
57	Dền đỏ	*Xylopia vielana*	Pierre
58	Đơn đỏ	*Ixora coccinea*	L.
59	Găng gai	*Canthium horridum*	Blume
60	Găng trắng	*Catunaregam tomentosa*	(Blume ex DC.) Tirveng.
61	Găng tu hú	*Gmelina asiatica*	L.
62	Gạo hoa trắng	*Bombax anceps*	Pierre
63	Giáng hương	*Pterocarpus macrocarpus*	Kurz
64	Giổi	*Magnolia mediocris*	(Dandy) Figlar
65	Gõ mật	*Sindora siamensis var. maritima*	(Pierre) K.Larsen & S.S.Larsen
66	Gòn	*Ceiba pentandra*	(L.) Gaertn.
67	Hoắc quang	*Wendlandia paniculata*	(Roxb.) DC.
68	Huỳnh đường	*Dysoxylum loureirii*	(Pierre) Pierre ex Laness.
69	Ké núi	*Stereospermum neuranthum*	Kurz
70	Kha thụ nguyên	*Castanopsis pseudoserrata*	Hickel & A. Camus sec. Phamh
71	Kha thụ tật lê	*Castanopsis tribuloides*	(Sm.) A.DC
72	Kháo	*Machilus parviflora*	Meisn.
73	Kháo hoa nhỏ	*Machilus parviflora*	Meissn.
74	Kháo thơm	*Machilus odoratissimus*	Nees
75	Kháo thunberg	*Machilus thunbergii*	Siebold & Zucc.
76	Kơ nia	*Irvingia malayana*	Oliv. ex A.W.Benn.
77	Làu táu	*Vatica odorata*	(Griff.) Symington
78	Le	*Gigantochloa* sp.	
79	Lim vàng	*Peltophorum dasyrrhachis*	(Miq.) Kurz
80	Lồ ô	*Bambusa procera*	A.Chev. & A.Camus
81	Lôi	*Crypteronia paniculata*	Blume
82	Lòng máng	*Pterospermum diversifolium*	Blume
83	Lòng mức	*Wrightia sp.*	
84	Mà ca	*Buchanania cochinchinensis*	(Lour.) M.R.Almeida
85	Mã tiền	*Strychnos nux-vomica*	L.
86	Mán đĩa	*Archidendron clypearia*	(Jack) I.C.Nielsen
87	Mận rừng	*Syzygium jambos*	(L.) Alston
88	Mật nhân	*Eurycoma longifolia*	Jack

Id	Species in Vietnamese	Species in Latin	
89	Me rừng	*Phyllanthus emblica*	L.
90	Mít nài	*Artocarpus rigida*	Blume
91	Mỡ	*Manglietia sp.*	
92	Mưng	*Careya arborea*	Roxb.
93	Muồng	*Senna sp.*	
94	Muồng sumatra	*Ormosia sumatrana*	(Miq.) Prain
95	Ngái	*Ficus hispida*	L.f.
96	Ngái lông	*Ficus hirta*	Vahl
97	Ngát vàng	*Gironniera subaequalis*	Planch.
98	Nhãn rừng	*Lepisanthes rubiginosa*	(Roxb.) Leenh.
99	Nhàu	*Morinda citrifolia*	L.
100	Nhọc	*Polyalthia nemoralis*	Aug.DC.
101	Nhọc trâu	*Polyalthia cerasoides*	(Roxb.) Bedd.
102	Quắn hoa trung bộ	*Helicia cochinchinensis*	Lour.
103	Quế rừng	*Cinnamomum iners*	Reinw. ex Blume
104	Săng mả	*Carallia brachiata*	(Lour.) Merr.
105	Săng máu	*Horsfieldia amygdalina*	(Wall.) Warb.
106	Sến	*Madhuca alpina*	(A.Chev. ex Lecomte) A.Chev.
107	Sến mủ	*Shorea roxburghii*	G.Don
108	Sổ	*Dillenia indica*	L.
109	Sổ 5 nhị	*Dillenia pentagyna*	Roxb.
110	Sòi	*Balakata baccata*	(Roxb.) Esser
111	Sòi tía	*Triadica cochinchinensis*	Lour.
112	Sóng rắn	*Albizia lebbeck*	(L.) Benth.
113	Sóng rắn lá nhỏ	*Albizia lebbekoides*	(DC.) Benth.
114	Sữa lá hẹp	*Alstonia angustifolia*	Wall. ex A.DC.
115	Sung	*Ficus racemosa*	L.
116	Sung bộng	*Ficus septica*	Burm.f.
117	Sưng nam bộ	*Semecarpus cochinchinensis*	Engl.
118	Tân bời lời tích lan	*Neolitsea zeylanica*	(Nees & T. Nees) Merr.
119	Táo rừng	*Ziziphus oenoplia*	(L.) Mill.
120	Tếch	*Tectona grandis*	L.f.
121	Thành ngạnh	*Cratoxylum formosum*	(Jacq.) Benth. & Hook.f. ex Dyer
122	Thành ngạnh nam	*Cratoxylum polyanthum*	(Lour.) Blume
123	Thẩu mật	*Bridelia retusa*	(L.) A.Juss.
124	Thầu tấu	*Aporosa octandra var. malesiana*	Schot
125	Thị mâm	*Diospyros ehretioides*	Wall. ex G.Don
126	Thổ mật	*Bridelia ovata*	Decne.
127	Thừng mức lông	*Wrightia pubescens*	R.Br.
128	Trắc curtis	*Dalbergia curtisii*	Prain
129	Trai lý	*Fagraea fragrans*	Roxb.
130	Trâm	*Syzygium levinei*	(Merr.) Merr.
131	Trâm đỏ	*Syzygium zeylanicum*	(L.) DC.
132	Trám lá đỏ	*Canarium subulatum*	Guillaumin
133	Trâm lá nhỏ	*Syzygium antisepticum*	(Blume) Merr. & L.M.Perry
134	Trôm lá thon	*Sterculia lanceolata*	Cav.
135	Vải rừng	*Dimocarpus longan*	Lour.

Id	Species in Vietnamese	Species in Latin	
136	Vạng trứng	*Endospermum chinense*	Benth.
137	Vỏ dụt	*Hymenodictyon orixense*	(Roxb.) Mabb.
138	Vối thuốc	*Schima wallichii*	Choisy
139	Vông rừng	*Erythrina variegata*	L.
140	Vừng	*Careya arborea*	Roxb.
141	Xoan đào	*Prunus ceylanica*	(Wight.) Miq.
142	Xương cá	*Canthium dicoccum*	(Gaertn.) Merr.