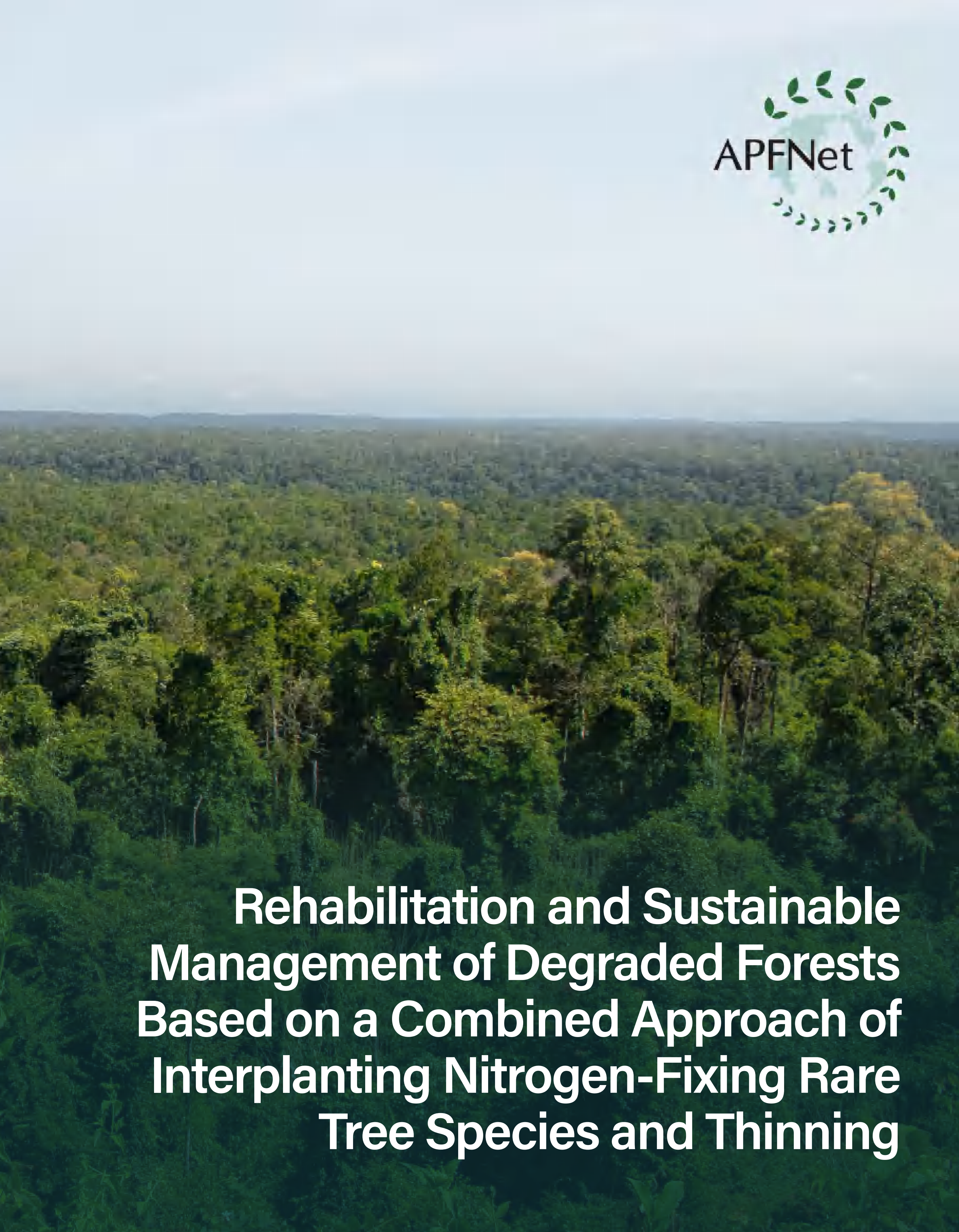

APFNet

Rehabilitation and Sustainable Management of Degraded Forests Based on a Combined Approach of Interplanting Nitrogen-Fixing Rare Tree Species and Thinning

ACKNOWLEDGEMENTS

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We would like to again express our gratitude to APFNet for funding the project "Rehabilitation and Sustainable Management of Degraded Forests based on a Combined Approach of Interplanting Nitrogen-Fixing Rare Species and Thinning". We would also like to thank the ECTF and IRD research teams for their valuable input to this project. We are, too, indebted to the residents of the Cambodian communities for their assistance and cooperation throughout the project. We appreciate the counsel that the Project Steering Committee provided, which helped us to smoothly and successfully complete the project and compile this report.

EXECUTIVE SUMMARY

Due to years of land use change and excessive logging, Cambodia is currently confronting issues, such as low forest quality and forest degradation. Between January 2019 and June 2022, the APFNet project “Rehabilitation and Sustainable Management of Degraded Forests Based on a Combined Approach of Interplanting Nitrogen-Fixing Rare Tree Species and Thinning” executed by ECTF and IRD, commenced in Bos Thom Village, Siem Reap Province, Cambodia, by designating a part of the local community forest (CF) as a demonstration forest. This forest was then restored while also providing technical training to both villagers and professionals in order to facilitate better restoration and sustainable forest management. This project also focused on the improvement of local livelihoods by establishing home gardens, installing solar panels, and setting up a revolving fund for marketing village products. This report provides a detailed account of the key processes, outputs, and experiences in improving forest ecosystem services and the socio-economic status of people living in degraded Cambodian forests through various activities. We hope that the publication of this report will enable the wider application of the here employed tropical degraded forest restoration techniques in Cambodia and other surrounding tropical areas, which will contribute to slowing tropical forest degradation and support the restoration of forests, as well as increase carbon sequestration and provide a richer biodiversity in the future.

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ACRONYMS AND ABBREVIATIONS

APFNet	Asia-pacific Network for Sustainable Forest Management and Rehabilitation
CF	Community forest
CNFM	Close-to-nature forest management
DBH	Diameter at breast height
ECTF	The Experimental Center of Tropical Forestry, Chinese Academy of Forestry
IRD	Institute of Forest and Wildlife Research and Development, Forestry Administration, Cambodia
NTFP	Non-Timber Forest Product
USD	United States Dollar

Chapter 1

INTRODUCTION

1.1 CURRENT STATUS OF THE DEGRADATION OF CAMBODIAN FORESTS

Cambodia is blessed with rich forest resources. However, due to deforestation, excessive logging, years of civil war, and dwindling timber supplies triggered by population growth and the development of forestry and industry at large, the forest cover in Cambodia has been shrinking. In the late 1960s, Cambodia was endowed with 13.17 million hectares of total forest, covering 73% of its total area. However, by 2014, it had dropped to 49%, although it showed signs of recovery, reaching 61% in 2022.

Recognizing the pressing need for resource protection, since 1994, the Cambodian government has issued multiple codes, regulations and a legislation for the protection of forest resources. For instance, in 2002, the Forestry Law was enacted to regulate the management, harvesting, use, development and protection of forests in the Kingdom of Cambodia. For a subset of production forests owned by the state but effectively managed by local communities, in 2006, the Community Forestry Development Guidelines were drafted to provide guidance on the development of community forestry in Cambodia. In 2008, the Protected Areas Law was enacted to protect 7 million hectares of Cambodian forests, including national parks, wildlife sanctuaries, wetlands, and other specific protected areas.

However, factors such as lagging economic development, insufficient supervisory capabilities, and a lack of disciplinary mechanisms have hampered the effectiveness of these laws. Consequently, Cambodian forests continue to be degraded, calling for a reform of the management of degraded forests. Hence, Cambodia is in need of an appropriate methodology for forest operations and management to not only maintain but even increase its forest cover, thereby safeguarding the economy's prosperity, genetic resources, and ecosystems. In 2010, Cambodian authorities approved the National Forest Program (2010-2029), which is a pivotal strategic document for sustainable forest management that covers six thematic programmes. Among these, Program 2 aims to facilitate forest restoration, conservation and forest ecosystem recovery in order to meet the needs of national economic development.

1.2 PROJECT LOCATION

The project is carried out in Bos Thom Village, Khna Po Commune, Sot Nikum District, Siem Reap Province, Cambodia (13°26°35°N, 104°11°40°E), which is 32 km away from the city of Siem Reap (Figure 1.1). The average annual temperature in the region is 28.2°, and the annual rainfall ranges from 1,500 to 2,000 mm. The rainy season extends from May to October, and accounts for 75% of the total annual rainfall. Conversely, the dry season spans from November to April, with a notably milder climate with less rainfall from December to the following February. The landscape primarily consists of a plain plateau with an elevation of 50-80 m and the soil type is reddish-yellow and gray loam of plain alluvial soil. The soil layer is deep and sandy, with poor retention of water and fertilizer.

FIGURE 1.1 The location of Bos Thom Village in Cambodia

FIGURE 1.2 The degraded community forest of Bos Thom Village

FIGURE 1.3 Seminar between the project crew and the villagers

FIGURE 1.4 A typical house in Bos Thom Village

Bos Thom Village is home to 300 people, dispersed through the area. Education level is low, with 51% being illiterate. Men enjoy a more privileged status in general. The village's economy is heavily dependent on agriculture and comparatively underdeveloped (Figure 1.3 and Figure 1.4). The residents, among which 81% are farmers, mostly grow rice and live off other crops like beans and cucumbers (Figure 1-5 and Figure 1-6). Any remaining crops left after household consumption are sold on the market to cover daily expenses. Each household cultivates less than 1 hectare with crops, and the average annual income per household is less than USD 300. Thus, the residents grapple with severe economic hardships. Therefore, it is essential to first improve their living standards to ensure the feasibility of forest restoration.

FIGURE 1.5 Green beans cultivated by villagers

FIGURE 1.6 Farmers get the vegetables seeds from our project

1.3 PROJECT OVERVIEW

Project name:	Rehabilitation and sustainable management of degraded forests based on a combined approach of interplanting nitrogen-fixing rare tree species and thinning [2018P4-CAF]
Executive Organization:	Experimental Center of Tropical Forestry Chinese Academy of Forestry, China
Administrative Organization:	Institute of Forest and Wildlife Research and Development Forestry Administration, Cambodia
Project Duration:	January 2019 to December 2021. Extended to June 2022
Total Budget:	USD 503,000
APFNet Funding:	USD 378,000
Counterpart Contribution:	USD 125,000
Target Economy:	Cambodia
Project Site:	Bos Thom Village, Khna Po Commune, Sot Nikum District, Siem Reap Province, Cambodia

PROJECT GOALS:

Reverse forest degradation via forest restoration and promote sustainable forest management in Cambodia through the establishment of demonstration forests and the training of technical personnel. Improve the livelihoods of local people through supporting livelihood activities outside traditional forestry.

PROJECT OBJECTIVES:

- Demonstrate techniques for the effective transformation of degraded forests, i.e., facilitating forest rehabilitation and sustainable forest management, improving forest growth and stand quality, and enhancing forest ecosystem services. Specifically, establish a demonstration forest spanning 50 hectares to showcase thinning and the interplanting of nitrogen-fixing rare tree species.
- Improve the livelihoods of impoverished local residents who depend on forests. Thus, establish home gardens for short-term, high-yield fruit trees or high-value cash crops on 10 hectares of land and install 16 sets of small-scale solar power equipment to provide a reliable power supply.
- Share best practices and knowledge on forest restoration and rehabilitation. Organize one technical training session for local villagers and one international conference on tropical forest restoration and rehabilitation for professionals to increase their exposure to and knowledge about forest restoration and sustainable forest management. Compile and publish a technical manual to share the project's best practices and experiences.

KEY ACTIVITIES:

To achieve the objectives of the project a number of key activities in the areas of restoration of tropical degraded forests, livelihood improvement, forest eco-economic benefits evaluation, technical training, international seminar, and technical manual compiling were conducted.

ESTABLISHING A 50 HA DEMONSTRATION FOREST

Three types of forest restoration models were developed specifically for varying degrees of forest degradation. 50 ha of the CF was set aside as a demonstration forest and thus first restored and then maintained. Each model covered different areas, with the severely degraded forest covering 5 hectares, the moderately degraded forest covering 20 ha, and the mildly degraded forest covering 25 ha. A total of 16,598 nitrogen-fixing seedlings of rare tree species were planted in the parts of the demonstration forests identified as severely and moderately degraded. 20 target tree species in mildly degraded forests were managed using close-to-nature forest management (CNFM) principles. Overall, these efforts have resulted in a significant improvement in the condition of these degraded forests.

IMPROVING LOCAL LIVELIHOODS

A total of 20 hectares of home gardens were established by planting fruit trees or short-term cash crops. A solar power system was installed for each of the 20 households that previously had no access to electricity. The project also provided a revolving fund of USD 7,840 for 37 impoverished villagers to improve their livelihoods. To date, the revolving fund has increased to USD 8,950 and can be used for various livelihood activities, including cattle raising and agricultural endeavors. Over the course of the project, a livelihood assessment questionnaire was conducted annually for 37 households, and the results showed a significant improvement in the annual income of local residents.

SHARING INFORMATION AND BEST PRACTICES ON THE RESTORATION OF DEGRADED FORESTS IN CAMBODIA

The *International Symposium on China-Cambodia Restoration and Sustainable Management of Tropical Degraded Forests* was held, where the current status and causes of tropical forest degradation were discussed, and solutions for future tropical forest restoration were proposed. In addition, the Chinese project team conducted two technical training sessions in Cambodia for local forest management personnel and villagers to enhance their skill sets. They also compiled and distributed 300 copies of a technical manual titled *Techniques for Tropical Forest Restoration and Sustainable Management* and created a 12-minute video, as well as a web page, to share best practices and experiences in restoring degraded tropical forests. In short, this project has significantly contributed to the protection and restoration of degraded forests in Cambodia, setting itself as a successful forestry case for the implementation of the *Belt and Road* initiative[1] in terms of having strengthened Chinese-Cambodian cooperation in the forestry realm.

[1] In 2013, the Chinese President Xi Jinping proposed the "Belt and Road" initiative to strengthen connectivity between China and the rest of the world, especially the Eurasian continent, the Middle East, Europe and Africa.

Chapter 2

EXPLORING AND IMPLEMENTING RESTORATION MODELS FOR DEGRADED FORESTS, IMPROVING FOREST ECOSYSTEM SERVICES

The establishment of the 50-hectare demonstration forest for the restoration of degraded forests is divided into three steps:

1. Forest inventory and tree species selection
2. Setting up the demonstration forest for the three levels of degradation
3. Evaluating ecological and economic benefits from the forest

For the restoration models, the approach of Close-to-Nature Forest Management (CNFM) was adopted. The approach advocates improving productivity, stand quality, and stand stability simultaneously, thus enhancing economic and ecological services through only minimal and absolutely necessary human interventions.

CLOSE-TO-NATURE FOREST MANAGEMENT

DEFINITION:

CNFM is a concept originating from Germany and proposed in the EU Forest Strategy for 2030. It aims to improve the conservation values and climate resilience of multifunctionally managed forests. This is a planning and management approach that takes advantage of the natural development of a forest from natural regeneration to a stable climax community to plan and design various management activities based on that forest growth cycle so as to optimize forest structure and function. It also suggests a constant utilization of various natural ecological processes related to the forest to continuously optimize forest management, gradually transforming the forests that have been disturbed by human intervention into a more natural state.

PRINCIPLES:

1. Choosing native tree species as target trees
2. Stability of stand structure (multi-age, multi-strata)
3. Naturalness of operational measures (e.g. no clearcuts)

2.1 FOREST INVENTORY AND TREE SPECIES SELECTION

i. FOREST INVENTORY

The forest inventory targets degraded secondary forests, primarily consisting of mixed evergreen and deciduous forests. Due to excessive logging of large trees, grazing, and forest clearing for rice fields, some forests have only a few remaining large trees while there are also dense forests with many young trees that require thinning and pruning. Based on the stand structure and degree of human disturbance, the forest is divided into the following three types:

SEVERELY DEGRADED FORESTS

Severely degraded forests are the closest to the residential area and so are usually most heavily affected by human disturbance. They are characterized by a lack of trees and significant gaps in the canopy due to logging, with a canopy density[2] of less than 20%. The remaining main vegetation is composed of a clumping, low-growing shrub and herbaceous layer, which partially has its origin in resprouting from previously cut rootstock. The height of the resprouted trees is less than 5 meters, and species diversity is relatively limited. The herbaceous layer has a high coverage (Figure 2.1).

FIGURE 2.1 Severely degraded forests

[2] *Canopy density refers to the ratio of the total ground projection area of the tree crown under direct sunlight to the total land area of the forest.*

MODERATELY DEGRADED FORESTS

Moderately degraded forests are relatively close to the residential area and are considerably affected by human disturbance. There are no tall trees in the stand and they are usually sparse forests formed after forest destruction. The forest communities that belong to this category are composed of a few short trees, resprouted or naturally regenerated, and shrubs. Yet their species richness is relatively high. The coverage of the herbaceous layer is significantly lower than that of the heavily degraded forest due to a higher canopy density (between 20% and 60%) (Figure 2.2).

FIGURE 2.2 Moderately degraded forests

MILDLY DEGRADED FORESTS

Mildly degraded forests are comparatively far away from the residential area and thus are only lightly disturbed. There are a high number of plant species, and the forest structure is similar to that of the original forest, with many vines growing between and connecting the trees. Only a few large trees with high timber value are cut down in the forest community; that being said the share of large-diameter trees is lower than that of the original forest. Their canopy cover is relatively high, surpassing 60% (Figure 2.3).

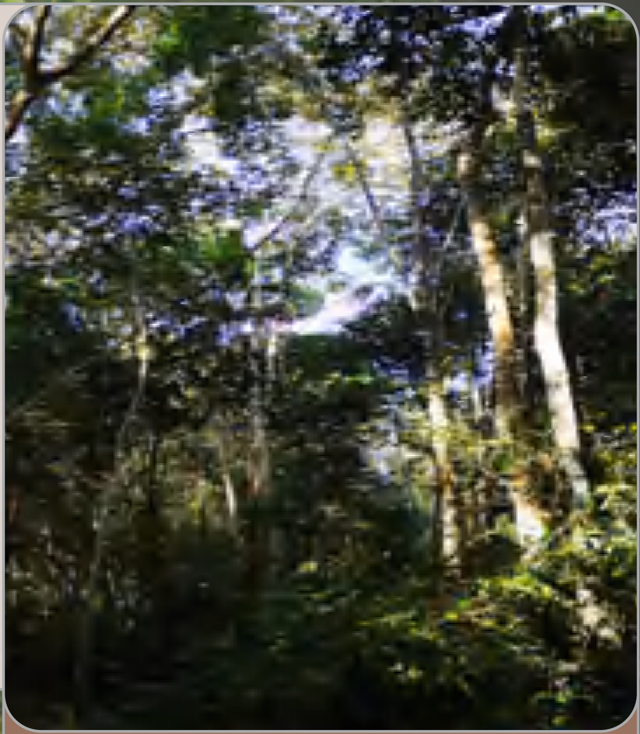


FIGURE 2.3 Mildly degraded forests

In December 2018, three locations were randomly selected to set up sample plots for each category of degraded forest (with a radius of 13.8 meters and an area of 600 m^2); 9 sample plots in total (Figure 2.4). Soil fertility, stand growth, stock volume, plant diversity, and other factors were surveyed in each plot.

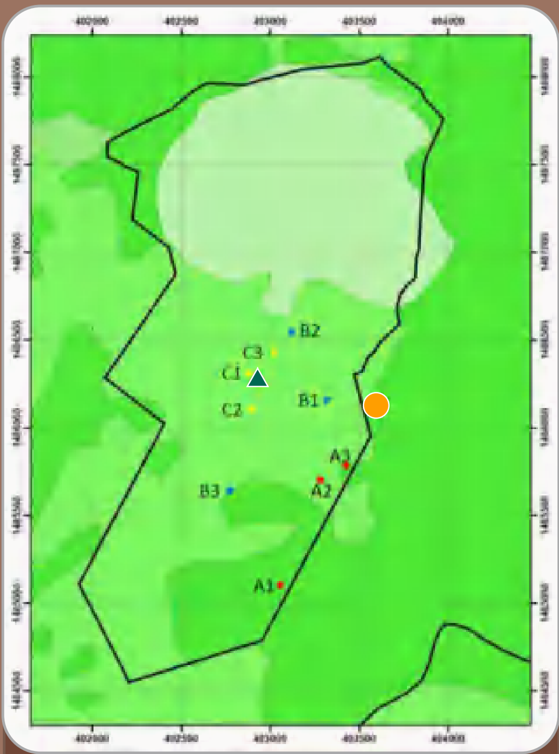


FIGURE 2.4 Nine permanent sample plots

A Severely Degraded Forest
B Moderate Degraded Forest
C Slightly Degraded Forest
▲ Pavilion
● Parking
Community Forest Boundary

The average diameter at breast height (DBH), average tree height, average stand volume, and the species richness index of the mildly degraded forest were significantly higher than those of the other two types. All three categories of degraded forests were primarily constituted of trees with a small DBH (Table 2.1). The soil of the degraded forests is all sandy loam, strongly acidic (pH 4.7-5.0), with low soil moisture (7.1-8.3%) and soil organic matter. Total nitrogen and phosphorus contents measure at 2.3-3.0%, 0.12-0.16%, and 0.03-0.04%, respectively.

TABLE 2.1 Stand characteristics of three degraded levels in a demonstration forest

Indicator	Severely degraded	Moderately	Mildly degraded
Number of trees /ha	139c	656b	1328a
Average DBH (cm)	10.69±6.55b	8.8 ±4.74b	12.28±7.41a
Average height (m)	8.38±3.62b	8.11±3.37b	13.85±4.90a
Average stock volume (m^3/ha)	5.77c	18.64b	115.73a
Species richness index at tree layer	11c	26b	34a
Species richness index at shrub layer	12c	22b	31a

Note: The values in the table are expressed as mean ± standard deviation. Different letters in the same row indicate significant differences (P<0.05) among different types of degraded forests, whereas the lack of different letters indicates no significant difference.

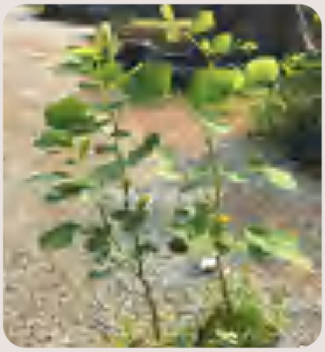
ii. TREE SPECIES SELECTION

In December 2018, based on the existing species directory in Cambodia and field surveys (Figure 2.5 and Figure 2.6), the project team selected four native tree species that are highly adaptable, of high economic value, and capable of nitrogen fixation (Table 2.2). Among these, *Dalbergia cochinchinensis* and *Pterocarpus macrocarpus* are priority species. *Afzelia xylocarpa* and *Cassia siamea* are alternatives.

FIGURE 2.5 Tree species selection seminar held in December 2018

FIGURE 2.6 Project crew's field survey in December 2018

TABLE 2.2 Biological characteristics and major uses of the four selected tree species

Name and image of seedling	Biological characteristics and main applications
Dalbergia cochinchinensis 	*D. cochinchinensis*, a member of the Dalbergia genus in the Fabaceae family, is a deciduous tree known for its nitrogen-fixing capability, drought-tolerance, and ability to grow in poor soil conditions. *D. cochinchinensis* seedlings are shade-tolerant when young but become more light-loving as they mature. The wood of *D. cochinchinensis* is notable for its hardness, glossy appearance and high strength. It exhibits good resistance to corrosion and insects, and usually has a straight grain and a fine and even structure. It is easy to process and has a smooth chamfer. It is primary used as a material for high-end furniture and musical instruments, among other applications.
Pterocarpus macrocarpus 	*P. macrocarpus* is member of the Pterocarpus genus in the Fabaceae family. This deciduous tree is also nitrogen-fixing and is highly adaptable. It prefers warm, humid tropical climates and is tolerant of low temperatures. The heartwood of *P. macrocarpus* is a preferred material for high-end rosewood furniture, crafts, musical instruments, carvings, and decorative items. Its bark and roots have medicinal values, traditionally used to treat bladder diseases and diarrhea.
Afzelia xylocarpa 	*A. xylocarpa* is a member of the Afzelia genus in the Fabaceae family. This evergreen tree is nitrogen-fixing and prefers light and moist environments. It is drought-tolerant, and can grow in relatively poor soil conditions. The seeds of *A. xylocarpa* can be used for carving or for medicinal purposes to treat toothaches and eye diseases. Its flowers are heat-toxin-relieving and thus may be able to reduce inflammation. Its wood can be used as a corrosion-resistant building material, as well as for fine craftsmanship and shipbuilding.
Cassia siamea 	*C. siamea* is a nitrogen-fixing evergreen tree in the Cassia genus of the Fabaceae family. It has a fast growth rate and strong resprouting ability, is heat- and drought-tolerant, and can grow in poor soil conditions. The wood is hard, dense, water-resistant, and insect-resistant, making it an excellent material for high-quality furniture. The wood from mature trees is black and has beautiful patterns, rendering it suitable for decorating musical instruments. The bark and fruit pods contain tannin, which can be extracted to make oak gum.

2.2 ESTABLISHING A DEMONSTRATION FOREST

This project has set up a 50-hectare demonstration forest for the restoration of tropical degraded forests, including 5 hectares of severely degraded forest, 20 hectares of moderately degraded forest, and 25 hectares of mildly degraded forest.

i. RESTORATION DEMONSTRATION OF SEVERELY DEGRADED FORESTS

RESTORATION OBJECTIVES

The four selected nitrogen-fixing tree species are used for afforestation to quickly establish a forest with a good vertical structure with layers of trees, shrubs, and grasses on the bare land. This will restore forest ecosystem services while also increasing the economic value of the forest, ultimately achieving sustainability on every level.

TECHNIQUES

An intercropping technique, consisting of alternating planting and reservation belts (Figure 2.7), is adopted. All vegetation within the planting belt (4 meters) is cleared and afforested with nitrogen-fixing trees, while all vegetation within the reserved belt (3 meters) is retained (Figure 2.8).

During the rainy season, tree planting is carried out using one-year-old robust container seedlings with a density of 1,430 plants per hectare, with a spacing of 2 meters by 2 meters between each plant, and in a hole sized 50x50x30 cm (length x width x depth). Only 1 tree species was used per planting belt. A total of 16,598 seedlings were planted, including 9,650 *Dalbergia cochinchinensis* seedlings, 4,000 *Pterocarpus macarocarpus* seedlings, 1,598 *Afzelia xylocarpa* seedlings, and 1,350 *Cassia siamea* seedlings. Three years after afforestation, the grass within a 1-meter radius around each seedling is eradicated ~3 times annually. The weeds are used to cover the soil above the roots of the seedlings to maintain soil moisture (Figure 2.9). The vines are cut and the trees are pruned every 5-8 years. Three years after the planting, the survival rate of the seedlings reached 90% or more.

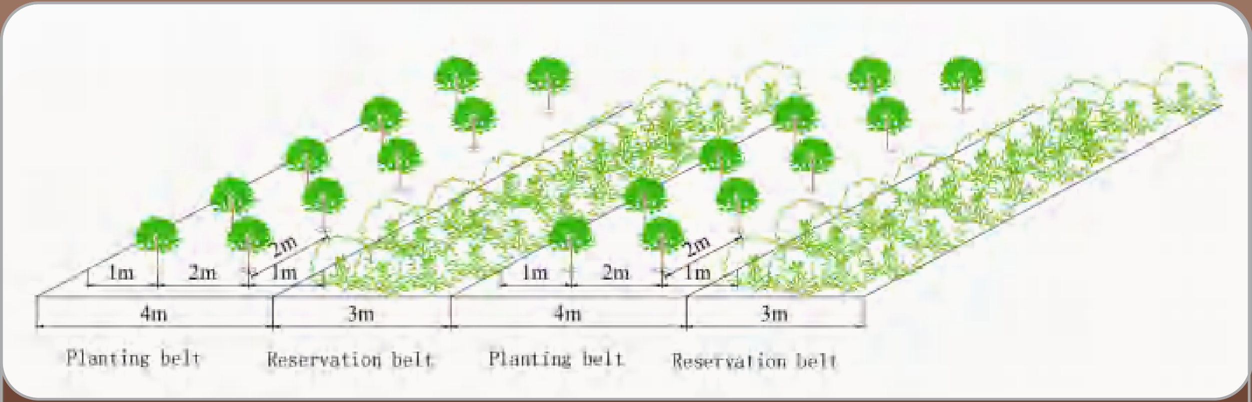


FIGURE 2.7 Scheme of the intercropping pattern between planting and reservation belts

FIGURE 2.8 Clearing of vegetation in the planting zone

FIGURE 2.9 Tree planting in the planting zone

ii. RESTORATION DEMONSTRATION OF MODERATELY DEGRADED FORESTS

RESTORATION OBJECTIVES

The four selected nitrogen-fixing tree species are used for afforestation to quickly establish a forest with a good vertical structure with layers of trees, shrubs, and grasses on the bare land. This will restore forest ecosystem services while also increasing the economic value of the forest, ultimately achieving sustainability on every level.

TECHNIQUES

The group interplanting model in forest gaps in moderately degraded forests is adopted (Figure 2.10). Specifically, this means that gaps are created in areas where trees are short, have small canopy cover, and are sparse. The vegetation within the gap is cleared (Figure 2.11).

There are 90 to 120 gaps per hectare with each measuring 6 meters in diameter and they are in average 10 meters apart from one another. Four planting holes are dug at the corners of a 2x2 m square in the center of the gap, each measuring 50x50x30 cm (length x width x depth). These holes are used to plant the four selected nitrogen-fixing tree species and only one tree species was planted in each gap (Figure 2.12). During the first three years after planting, the weeds in forest gaps will be cleared 2-3 times a year to ensure the protection of the planted valuable tree species is ensured. The survival rate reached 90% or above, in terms of maintenance vines are cut and trees are pruned every 5-8 years.

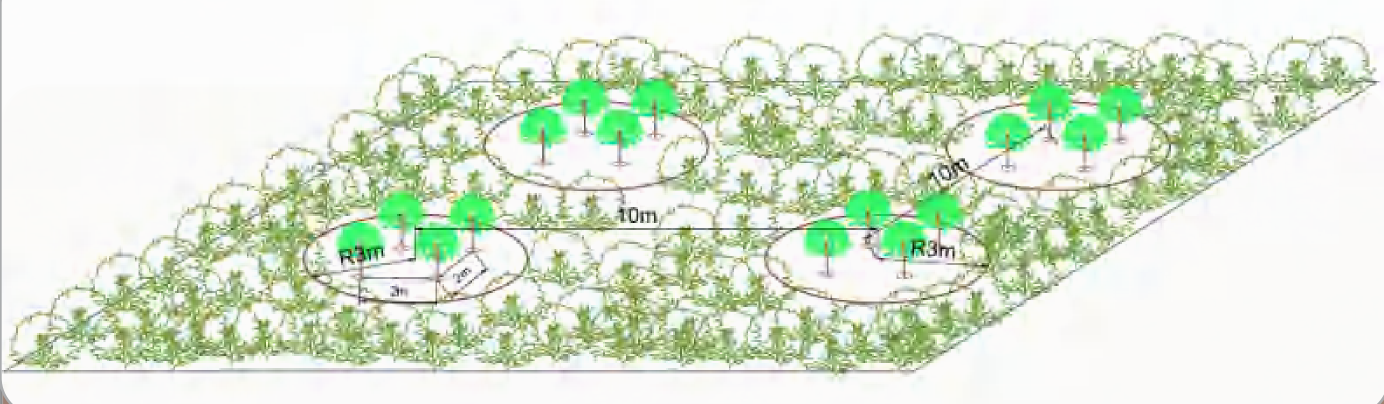


FIGURE 2.10 Scheme of gap planting in moderately degraded forests

FIGURE 2.11 Clearing of vegetation for a gap

FIGURE 2.12 Tree planting in a gap

iii. RESTORATION DEMONSTRATION OF MILDLY DEGRADED FORESTS

RESTORATION OBJECTIVES

Understanding the principles of natural succession and adhering to the theory of CNFM, we make use of the forest's natural regeneration power to the fullest possible extent to conserve community-building species and target tree species. In turn, we are able to influence the succession trajectory by reducing the share of non-target tree species. This will speed up succession, promote ecological restoration of degraded forest ecosystems and increase their economic value.

TECHNIQUES

The target tree cultivation technique is used, which includes four main steps: target tree selection, competitor tree identification and removal, target tree pruning, and selective logging and regeneration.

Target Tree Selection: Select 90 to 120 target trees per hectare, then mark them with red paint around the trunk at DBH height (1.3 m) (Figure 2.13).

FIGURE 2.13 Selecting and marking the target tree

The criteria for target tree selection are as follows:

- Dominant community-building species in the forest community and tall trees in the upper forest layer.
- Straight and well-formed, with a good trunk shape.
- No damage to the trunk and no large knots.
- Good timber and processing properties, with high economic value.
- Good natural regeneration capability.

As per the target tree selection criteria, the project team selected 20 economic tree species with a total of 2,534 target trees, all of which were of high value and good growth potential (Table 2.3).

TABLE 2.3 Target tree species and quantity in mildly degraded forests

Latin name of tree species	Local common name	Number of the species
Anisoptera costata Kort	Phdeak	163
Artocarpus sampor Gagnep	Som Por	2
Artocarpus rigidus Blume	Khnol Prey	64
Carallia brachiata Merr	Tro Meng	118
Dehaasia cuneata Blume	Khtet	4
Dialium cochinchinensis Pierre	Krolanj	188
Diospyros pilosanthera	Tro Yeng	312
Dipterocarpus alatus Roxb	Che Teal	4
Dipterocarpus intricatus Dyer	Trach	79
Eugenia Spp	Pring	451
Hopea odorata Roxb	Koki	1
Irvingia malayana	Chombok	269
Lagerstroemia calyculata Kurz	Sro Lov	43
Mangifera indica L.	Svay Prey	5
Parinarium annamensis Hance	Thlok	199
Peltophorum dasyrrhachis	Tro Sek	349
Pterocarpus macrocarpus Kurz	Thuong	22
Shorea cochinchinensis Pierre	Popel	44
Sindora cochinchinensis H.Baill	Kor Kos	85
Vatica odorata Griff	Chromas	132
Sum		2534

Competitor tree identification and removal: Trees whose crowns are adjacent to or partially overlap with the crowns of target trees affect the growth of target trees. These adjacent trees should be identified as competitor trees (Figure 2.14). To avoid any negative influence on the growth of target trees, the competitor trees and vines around them should be removed (Figure 2.15).

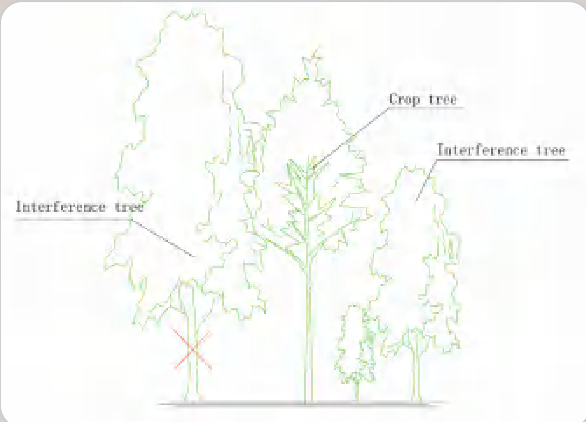


FIGURE 2.14 Diagram for determining the target tree and competitor tree

FIGURE 2.15 After removing competitor tree

Target tree pruning: After the removal of competitor trees, the target tree should be pruned in the same year. This involves the one-time removal of live and dead branches on the trunk of the target tree below 9 meters.

Selective logging and regeneration: Given the insufficient time passed since the project's initiation, selective logging and regeneration of target trees have not been conducted, yet. However, the plan is, when the target trees reach a DBH of 60 cm or more, for the trees to be selectively harvested. After selective logging, the canopy density will be maintained at around 50%. In general, the forest should now be able to recover mostly via natural regeneration, with thinning and enrichment planting as additional measures to promote regeneration wherever natural regeneration is sparse. The tended forests will gradually develop into a multi-species, uneven-aged, stratified forests.

2.3 EVALUATING FOREST ECOLOGICAL AND ECONOMIC BENEFITS

The growth of forest stands, its stand structure, plant diversity, carbon storage, and changes in soil physical and chemical properties are compared in nine permanent sample plots before and after project implementation to evaluate the project's impact on the forest's ability to provide ecological and economic benefits.

i. IMPROVING SOIL PHYSICAL AND CHEMICAL PROPERTIES AND ENHANCING FOREST ECOSYSTEM SERVICES

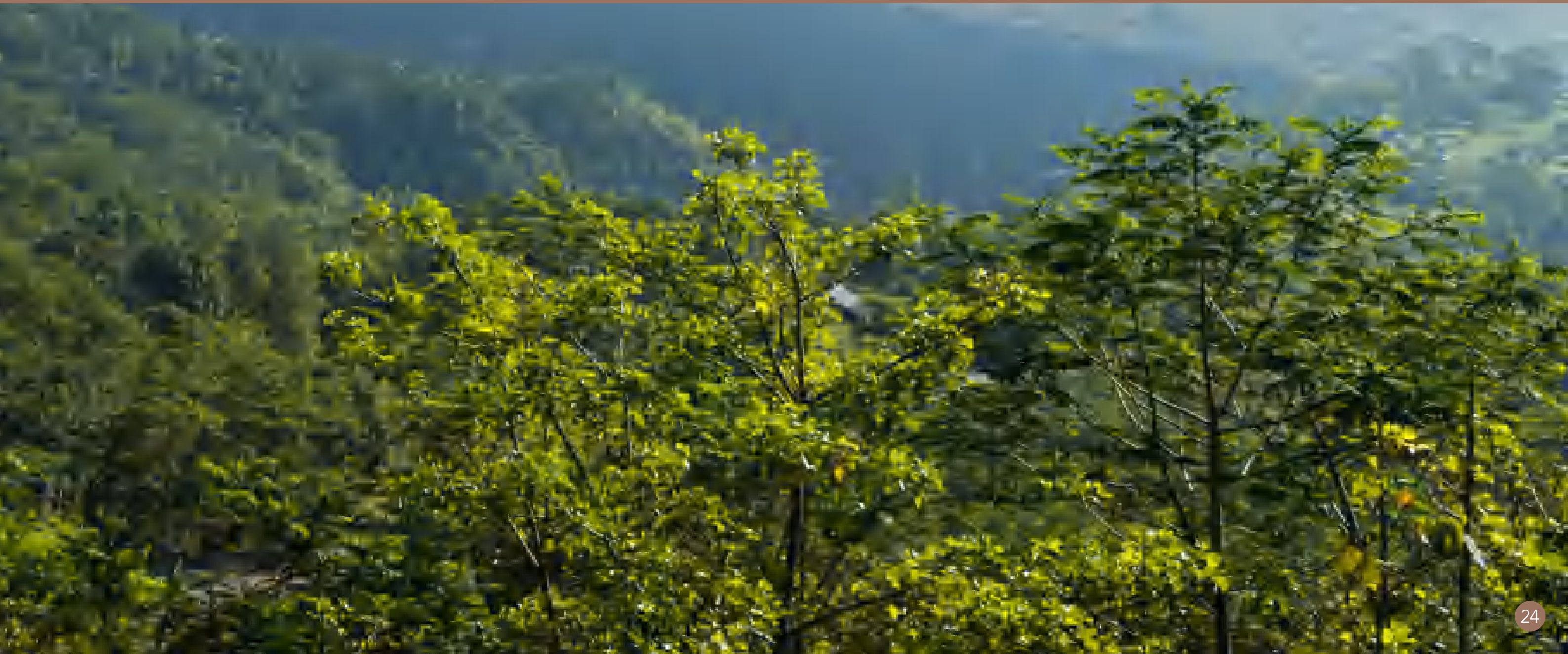
Three soil profiles, 200 grams per profile, were dug in every permanent sample plot at the depth of 0-20, 20-40, and 40-60 cm. Compared to project start, the total phosphorus content in the 0-20 cm soil layer of heavily degraded forest types increased by 26.8% after the intervention. The total nitrogen content in the 20-40 cm soil layer of moderately degraded forests increased by 40% after the intervention. For mildly degraded forests, the soil organic matter, total carbon, and available phosphorus content in the 0-20 cm soil layer increased by 20.1%, 20.1%, and 4.5%, respectively (Table 2.4). However, the organic matter and total carbon content in the 0-20 cm soil layer of severely degraded forests showed a slight decrease, which is due to soil nutrient leaching[3] caused by the necessary land preparation for reforestation during the early stage of the project. Later, as nitrogen-fixing tree species are continuously planted, nitrogen fixation capacity will gradually increase, and the soil nutrient conditions are expected to improve significantly. Overall, the soil organic matter and total nitrogen content of each forest degradation type are relatively higher, reaching a medium to high level. However, the total phosphorus content is deficient.

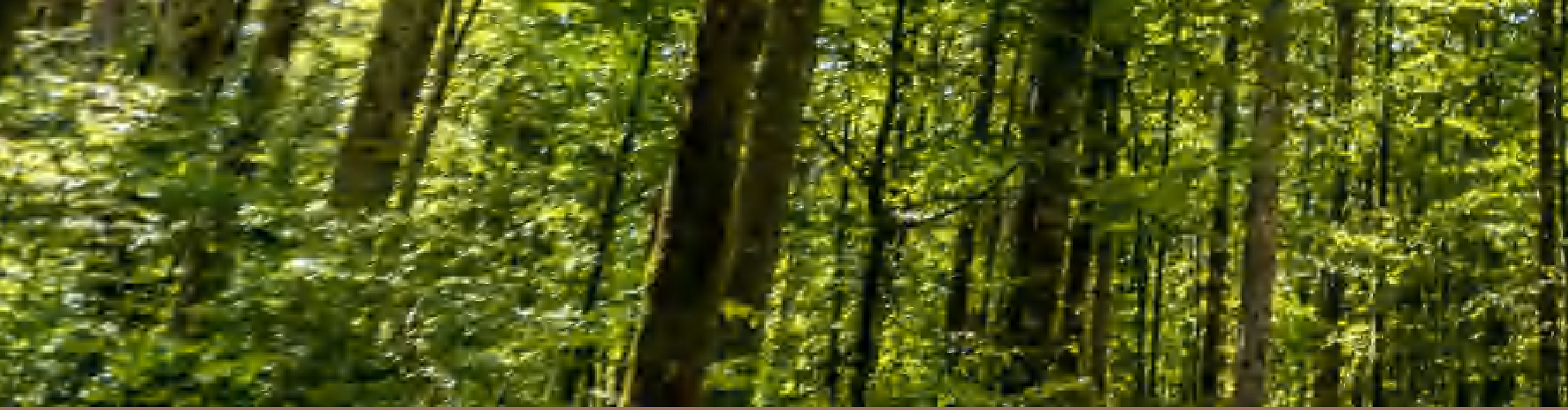
[3] Soil nutrient leaching refers to the process in which rainfall or irrigation water enters the soil, moves downward through soil due to gravity, and carries dissolved and undissolved small soil particles to deeper soil layers. This process can lead to soil nutrient loss, and a deterioration of soil physical and chemical properties especially in the upper soil horizons, and thus to a decrease in soil fertility.

TABLE 2.4 Soil chemical properties of severely, moderately and mildly degraded forests

Forest type	Soil layer (cm)	Year	Organic matter (%)	Total Carbon (%)	Total Nitrogen (%)	Total phosphorus (%)	Available phosphorus (ppm)
Severely degraded forest	0- 20	2018	2.59±0.22a	1.50±0.13a	0.17± 0.02	0.041±0.005b	36.3± 3.1
		2022	2.21±0.02b	1.28±0.01b	0.16± 0.01	0.052±0.002a	31.0± 1.2
	20- 40	2018	1.92± 0.25	1.12± 0.15	0.13± 0.02	0.031± 0.002	26.2± 1.9
		2022	2.30± 0.04	1.33± 0.03	0.13± 0.01	0.036± 0.004	26.3± 0.8
	40- 60	2018	1.83± 0.25	1.06± 0.15	0.11± 0.01	0.025± 0.00	25.3± 1.6
		2022	2.15± 0.05	1.25± 0.03	0.11± 0.01	0.029± 0.00	25.7± 0.7
Moderately degraded forests	0- 20	2018	2.90± 0.30	1.68± 0.17	0.15± 0.01	0.034± 0.005	29.7± 1.8
		2022	3.39± 0.56	1.97± 0.32	0.14± 0.01	0.044± 0.008	28.7± 0.9
	20- 40	2018	2.47± 0.06	1.44± 0.04	0.10±0.01b	0.029± 0.004	26.3± 0.7
		2022	2.65± 0.18	1.54± 0.11	0.14±0.00a	0.036± 0.005	25.0± 1.6
	40- 60	2018	2.26± 0.11	1.31± 0.06	0.10± 0.02	0.026± 0.002	26.7± 1.8
		2022	2.18± 0.07	1.27± 0.04	0.12± 0.02	0.034± 0.005	27.0± 1.7
Mildly degraded forests	0- 20	2018	2.83±0.12b	1.64±0.07b	0.17± 0.01	0.030± 0.004	28.7±0.8b
		2022	3.40±0.18a	1.97±0.10a	0.15± 0.01	0.047± 0.011	30.0±0.0a
	20- 40	2018	2.66± 0.09	1.54± 0.05	0.15± 0.01	0.030± 0.007	28.3± 0.4
		2022	2.69± 0.43	1.56± 0.25	0.13± 0.01	0.037± 0.003	28.7± 1.5
	40- 60	2018	2.28± 0.30	1.32± 0.18	0.13± 0.02	0.026± 0.002	26.7± 0.7
		2022	2.47± 0.24	1.43± 0.14	0.11± 0.01	0.029± 0.003	27.0± 0.8

Note: The values in the table are expressed as mean ± standard deviation. Different letters in the same column indicate significant differences (P<0.05) between different years in the same soil layer and forest type, and vice versa.



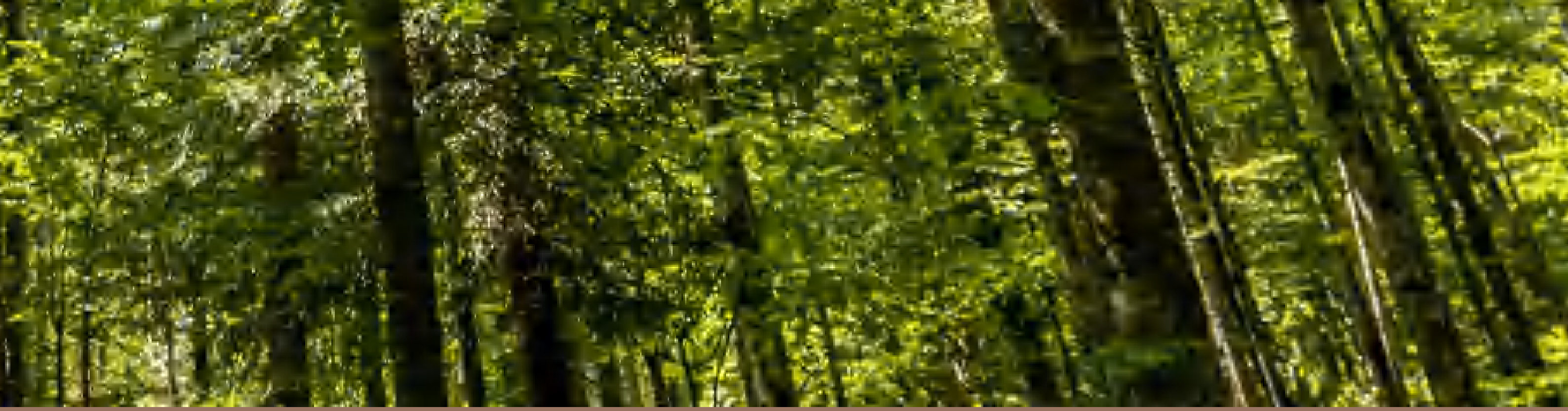


ii. REPLANTING NITROGEN-FIXING VALUABLE TREE SPECIES CAN IMPROVE AND ENHANCE THE FOREST STAND STRUCTURE AND ITS ECONOMIC VALUE

In the early stages of the project, three permanent sample plots were established in severely and moderately degraded forests where 100 trees or 25 clusters (4 trees per cluster) were surveyed in the center of each sample plot; a total of 300 seedlings were surveyed for each degraded forest category. The survival rate of the surveyed seedlings was above 90%, which not only improved the stand structure but also boosted its overall economic value. Yet, due to seasonal drought and the poor water and nutrient retention capacity of sandy soil, the annual tree height growth rate is less than 0.5 meters (Table 2.5). In order to fully leverage the potential of having planted nitrogen-fixing rare tree species in the restoration, it is recommended to adopt measures, such as apply water-retaining agents and well-rotted farmyard manure to counter the problem of drought and nutrient stress on tree growth. It is also important to continue the tending of newly planted trees via a periodical pruning of vines and weeds.

TABLE 2.5 Survival rate and height growth of nitrogen-fixing tree species in severely and moderately degraded forests

Forest type	Tree species	Age of seedlings (years old)	Number of mature trees	Tree species Proportion (%)	Total survival rate (%)	Tree height (m)	Annual growth of tree height (m)
Severely degraded forest	*Dalbergia cochinchinensis*	3	185	67.3	92	1.09	0.36
	Pterocarpus macrocarpus	3	73	26.5		0.69	0.23
	Afzelia xylocarpa	3	11	4.0		1.02	0.34
	Cassia siamea	3	6	2.2		1.32	0.44
Moderately degraded forests	*Dalbergia cochinchinensis*	2	125	46.5	90	0.87	0.44
	Pterocarpus macrocarpus	2	87	32.3		0.73	0.37
	Afzelia xylocarpa	2	51	19.0		0.78	0.39
	Cassia siamea	2	6	2.2		0.25	0.13



iii. FOREST STRUCTURE OPTIMIZED, STAND QUALITY SIGNIFICANTLY IMPROVED

Three years after the implementation of the project, the tree density in moderately degraded forests has increased by 122.7%. This is because the seedlings in these forest stand grew faster, resulting in a significant increase in the number of trees reaching the diameter level eligible for measurement (≥5 cm). The forest stand density has increased by 16.7%. The average DBH, tree height, and stock volume have increased by 5.0%, 2.9%, and 57.3%, respectively. The species richness index at the tree layer and shrub layer has increased by 15.4% and 9.1%, respectively. This indicates that the forest stand structure of this category is progressing toward a positive and benign succession. In terms of the mildly degraded forests, given the removal of some low-quality and low-value impinging trees and vines, the growth of retained trees has been facilitated. The average DBH, tree height, and stock volume have increased by 7.8%, 5.0%, and 22.3%, respectively. The species richness index at the tree layer has also increased by 2.9%, thereby improving the quality of the forest stand (Table 2.6).

TABLE 2.6 Growth, stock volume, and plant diversity of moderately and mildly degraded forests

Forest category	Moderately degraded forests		Mildly degraded forests	
Year of survey	2018	2022	2018	2022
Density (trees/ ha)	656	1461	1356	1372
Canopy closure	0.6	0.7	0.9	0.9
Average DBH (cm)	8.8± 0.4	9.3± 0.4	12.7± 1.0	13.7± 1.3
Average height (m)	7.9± 1.5	8.2± 1.5	14.8± 1.5	15.5± 1.6
Average stock volume (m^3/ha)	18.8± 8.2	29.6± 8.6	129.0± 13.6	157.7± 19.5
Species richness index at tree layer	26	30	34	36
Species richness index at shrub layer	22	24	31	31

Note: The values in the table are presented as mean ± standard deviation. Due to the low density and small canopy cover of the tree layer (measured at ≥5cm DBH) in the severely degraded forest type, as well as the low species diversity and little inter-annual variation, the forest structure of this category was not surveyed.

iv. GROWING CARBON STORAGE IN FOREST STANDS

Since the implementation of the project, the carbon storage of the soil layer and on ecosystem-level in moderately degraded forests has increased by 22.4% and 23.8%, respectively, while tree layer of the slightly degraded forest has increased by 20.1% (Table 2.7). This indicates that the overall forest carbon storage has increased, and the growth rate of the moderately degraded forest is higher than that of the slightly degraded forest type. However, the current forest ecosystem-level carbon storage is still low. For example, the carbon storage in the tree layer in moderately and mildly degraded forests is only 9.28 tons/ha and 51.25 tons/ha, respectively, which is below the level of locally high-yielding forest stands. This is mainly caused by the long-term degradation of the tree layer that leads to fewer large-diameter trees in these types of stands. Hence, it is necessary to continue forest tending, that is the timely removal of vines and competitor trees that affect the growth of target trees, creating favorable conditions for the growth of dominant trees, and thus increasing the number of large-diameter trees in the stand in the long term to further improve the forest's sequestered carbon and its economic value.

TABLE 2.7 Carbon storage in moderately and mildly degraded forests

Forest category	Moderately degraded forests		Mildly degraded forests	
Year of survey	2018	2022	2018	2022
Tree layer	6.11 ± 2.65 (5.70)	9.28 ± 2.81 (6.99)	42.66± 0.33b (23.94)	51.25± 1.11a (29.69)
Shrub layer	1.14 ± 0.11 (1.06)	1.24 ± 0.12 (0.93)	1.28 ± 0.03 (0.72)	1.37 ± 0.01 (0.79)
Herbaceous layer	0.61 ± 0.07 (0.56)	0.65 ± 0.07 (0.49)	0.34 ± 0.08 (0.19)	0.27 ± 0.07 (0.16)
Soil layer	99.36± 7.14b (92.67)	121.59± 6.07a (91.59)	133.92 ± 12.96 (75.15)	119.70 ± 4.37 (69.36)
Ecosystem	107.22± 9.97b (100.00)	132.76± 9.07a (100.00)	178.20 ± 13.40 (100.00)	172.59 ± 5.56 (100.00)

Note: The values in the table are presented as mean ± standard deviation. The parenthesized values are the percentage of ecosystem carbon storage. Different letters in the same row indicate a significant difference ($P<0.05$) between different years in the same forest layer, while the absence of different letters indicates no significant difference. The period of time necessary for the recovery of carbon storage in severely degraded forest types is longer than the project period, so the carbon storage of this category has not been investigated. During the restoration of degraded forests, some competing trees or vines need to be cut down, producing a large amount of abnormal litter. Therefore, only the carbon storage of the tree layer, shrub layer, herb layer, and soil layer is estimated.

Chapter 3

LIVELIHOOD ACTIVITIES BEYOND FORESTRY TO IMPROVE LOCAL LIVELIHOODS

3.1 BUILDING HOME GARDENS, BEAUTIFYING THE LIVING ENVIRONMENT

In 2019 and 2020, the IRD team selected 51 impoverished households (with an annual average income of USD 1,438) in Bos Thom Village and provided them with free high-value fruit tree seedlings (such as lemons, oranges, and mangoes) and short-term crop seeds (such as long beans, eggplants, etc.) (Figure 3.1), supporting the creation of a total of 19.94 ha of home gardens. Selling vegetables for three years brings each household an average income of USD 337 per year. Compared to the assets (USD 925) of the respondents in 2019, the assets in 2020 and 2021 increased by USD 513 and USD 432, respectively. The free fruit tree seedlings received by the farmers have not yet yielded any economic benefits due to the number of years it initially takes them to bear fruit, but they are expected to do so in the future. The economic benefits generated from the home gardens go entirely to the households, which makes them popular in Cambodia. This activity not only increases the local residents' income but also beautifies and greens the living environment, thereby reducing their excessive reliance on forests, both indirectly protecting existing forests and promoting the restoration of degraded forests.

FIGURE 3.1 Providing free vegetable seeds and fruit tree seedlings to local villagers

Based on the size of the land owned by each household and their preferences, the farmers could adopt one of the following two management models:

i. FRUIT AND VEGETABLE INTERCROPPING MODEL

Fruit trees: Row spacing of 6x10 meters between each plant, with a density of 166 trees/ha.
Vegetables: Planted in the open spaces around the fruit trees, the density is determined according to the villagers' preferences (Figure 3.2 and Figure 3.3).

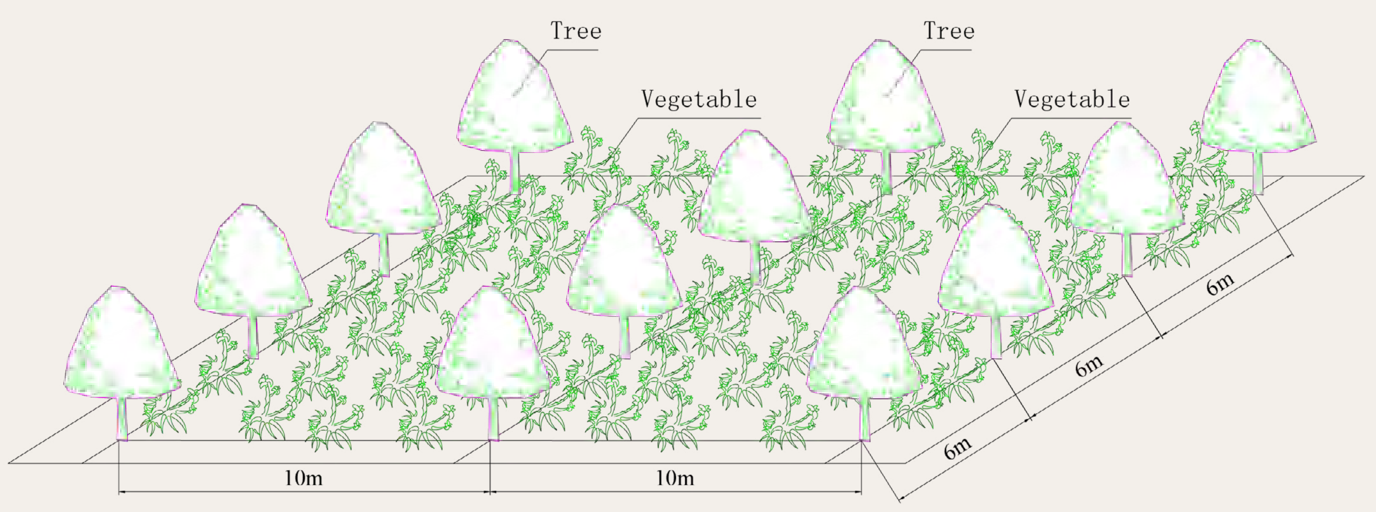


FIGURE 3.2 Scheme of intercropping management for fruits and vegetables

FIGURE 3.3 Intercropping management for fruits and vegetables

ii. MONOCULTURE FRUIT ORCHARD

Fruit trees: Row spacing of 4x5 meters between each plant, with a density of 500 trees/ha (Figure 3.4 and Figure 3.5).

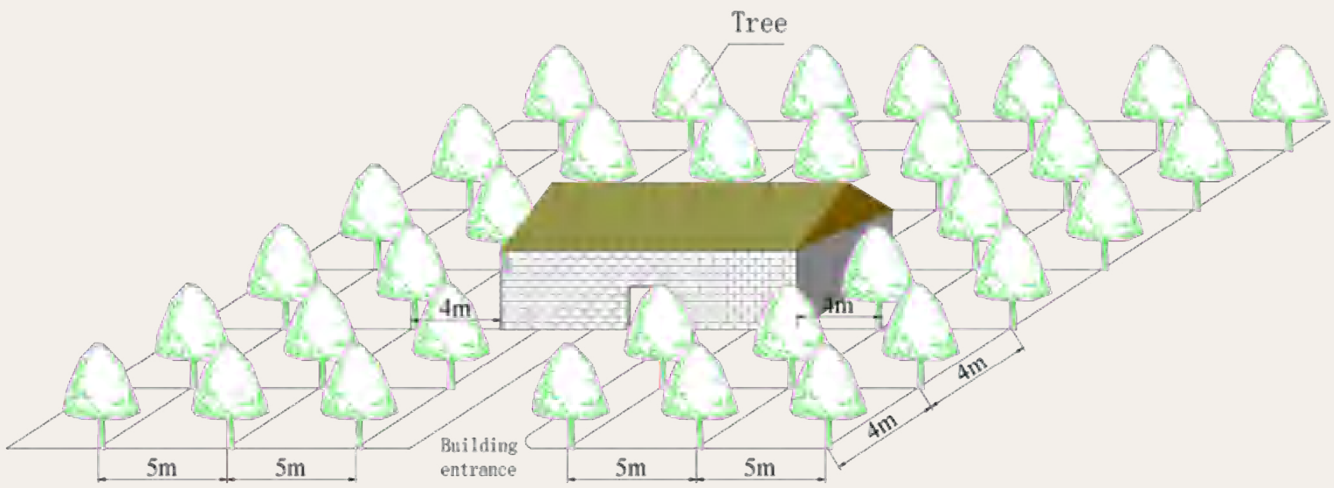


FIGURE 3.4 Scheme of the monoculture fruit orchard

FIGURE 3.5 Monoculture management for fruit trees

3.2 DEVELOPING ALTERNATIVE ENERGY SOURCES FOR THE COMMUNITY AND CONSERVING FOREST RESOURCES

Although the electricity grid has been connected to Bos Thom Village, many households still lack access to it because many cannot afford to pay the electricity bills. After consulting the village chief and community leaders, the project team selected 20 of the poorest households to provide each of them with a set of small solar power equipment, which generates electricity through solar panels and provides for the daily needs of the household (Figure 3.6). 8 sets of solar power systems were installed in 2019 and 2020, respectively. As still a considerable number of households had no access to electricity, the team provided an additional 4 sets of solar power equipment, totaling 20 sets, helping each household to save USD 57 in electricity every year. It was a significant help for poor household because many households didn't even reach the village's moderate annual average income of USD 1,438. It should be noted, though, that during the rainy season solar energy may not be sufficient for power generation, so some households use regular batteries for power, but they have to pay for the charging fees.

FIGURE 3.6 Providing solar power equipment to farmers

The criteria for the selection of households to install solar equipment were the following:

(1) The household actively participates in community activities, such as patrolling to prevent illegal logging or poaching of wildlife.

(2) The household owns land large enough to establish a home garden.

(3) The household does not have access to electricity, yet.

3.3 SETTING UP A REVOLVING FUND TO IMPLEMENT AGRICULTURAL ACTIVITIES

Local residents in Cambodia still have a low living standard and often lack funds to start a livelihood that could improve their current situation. Therefore, the project team launched a revolving fund and provided a total loan of USD 7,840 to 39 households in 4 groups. Each household can borrow between USD 100 to USD 250, with a loan period of 12 months and an annual interest rate of 1.8%. This helps them start a livelihood in areas such as agriculture, animal husbandry, and supply stores for agricultural products (Figure 3.7). Once they have repaid all their loans to the fund management committee, the household can apply for another one.

FIGURE 3.7 Revolving fund for livelihood improvement activities

The loan is managed by a fund committee consisting of 5 members, including 3 women (Figure 3.8). The committee develops regulations and loan contracts and is managed jointly by the committee and project coordinators to ensure the proper use of the fund. The fund management committee has developed the following plan for the obtained interest from each loan:

a) 65% of the interest is re-invested into loans or used for forestry development.
b) 25% of the interest is given to the committee.
c) 5% of the interest is used for administrative expenses.
d) 5% of the interest is used for community donations.

FIGURE 3.8 Establishment of the revolving fund and its management committee

The project team follows up on the use of the revolving fund (Figure 3.9). As of March 2023, the revolving fund has expanded from the initial USD 7,840 to USD 10,331. This fund is used to support the improvement of residents' livelihoods. The remaining funds will continue to be used for livelihood improvement activities for local villagers after project completion, such as agricultural and animal husbandry production.

FIGURE 3.9 The project team learns about the usage of the revolving fund

3.4 ASSESSING LIVELIHOOD IMPROVEMENTS

The project aims to improve the livelihoods of rural residents by increasing their sources of income from fruit trees, and vegetables, providing solar facilities, and encouraging locals to participate in reforestation efforts. Thus between 2019 to 2021, the IRD team conducted annual livelihood assessments, interviewing and surveying 37 households that directly benefited from the project (Figure 3.10) to evaluate general demographics, socio-economic conditions, and how project funds were utilized.

FIGURE 3.10 Survey with households on their livelihoods

i. DEMOGRAPHICS

81% of the respondents were male (household representatives), with most of them being less than 45 years old (Figure 3.11). 81% of them were farmers (Figure 3.12), and 51% of the respondents were illiterate (Table 3.1). Each household has 2 to 8 members, with 4-people households being the most common.

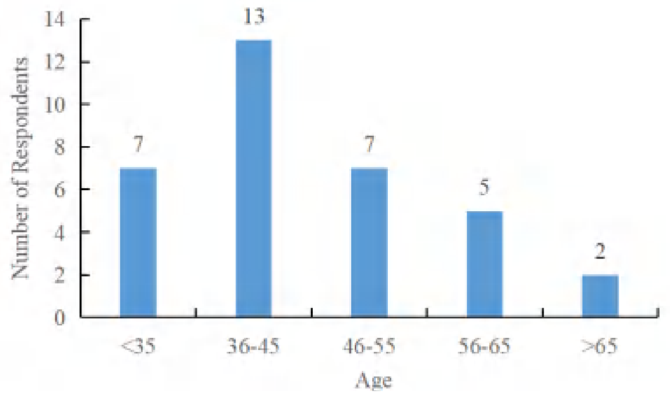


FIGURE 3.11 Age of respondents

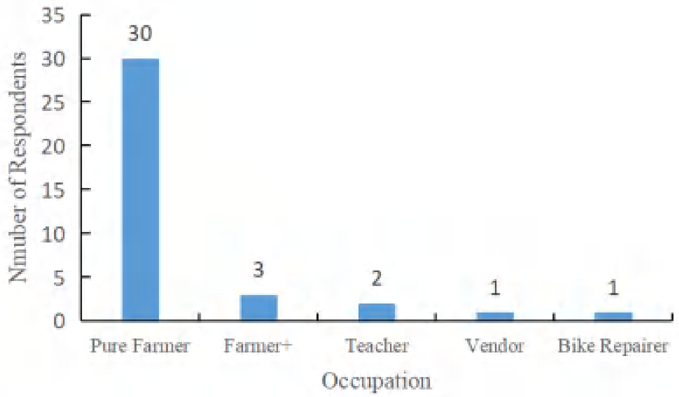


FIGURE 3.12 Occupation of respondents

TABLE 3.1 Education level of respondents

Education	Frequency	Percentage %
None	19	51.35
Primary	12	32.43
Secondary	5	13.51
High school	1	2.70

ii. SOCIO-ECONOMIC CONDITIONS

The survey aimed to understand the social and economic status by investigating land ownership, annual income, as well as expenses and revenue of various activities of each household. There were significant differences in land ownership between different respondents. Most respondents (86.49%) owned less than 1 ha of residential land. Over 54.05% of respondents owned less than 1 ha of farmland, 8.11% owned 5 ha, 2.7% owned 4 ha, 13.51% owned 2 ha, and 5.41% owned no farmland.

During the project period, respondents' income mainly came from labor, rice, vegetables, animal husbandry, other sources, fruit trees, and non-timber forest products (NTFPs). The income from labor was high in the first and second years of the project as some respondents earned wages by participating in project activities, such as planting trees and other silvicultural measures. However, the income from labor decreased significantly in the third year due to the impact of the COVID-19 pandemic (Figure 3.13). The respondents' expenses were mainly spent on food, agriculture, gasoline, education, healthcare, transportation, and electricity (Figure 3.14).

The net savings of each household significantly increased in the second and third years of the project (USD 1,438 and USD 1,357, respectively) compared to the first year (USD 925), indicating that the project had a positive impact on improving residents' livelihoods (Figure 3.15). In 2020, the net savings mainly derived from vegetable cultivation and other incomes, while in 2021, that was mainly from animal husbandry and others.

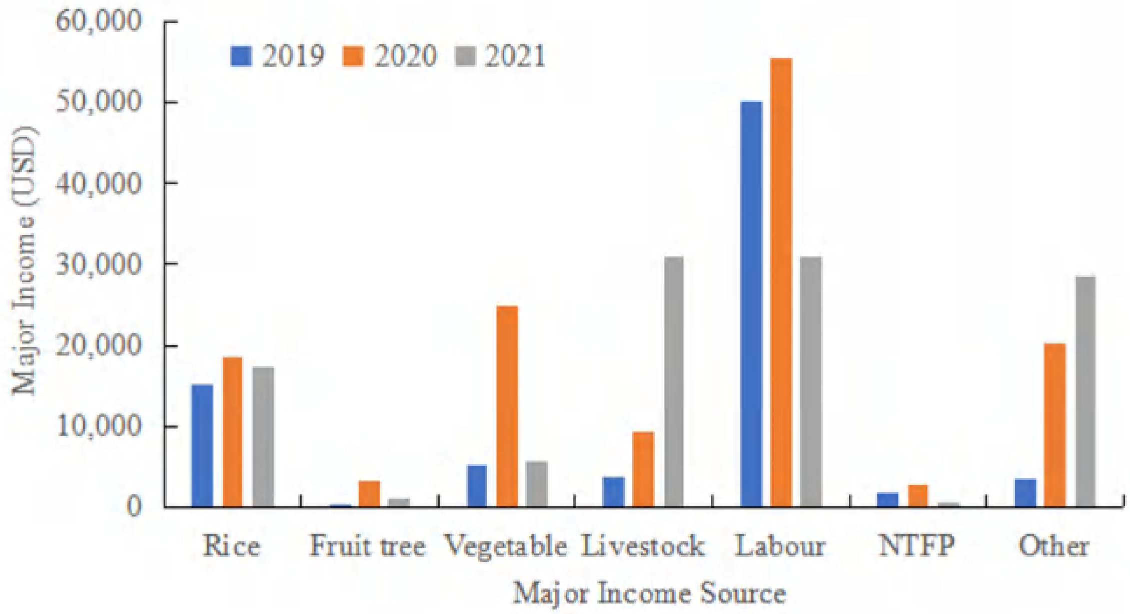


FIGURE 3.13 Annual income sources of all respondents

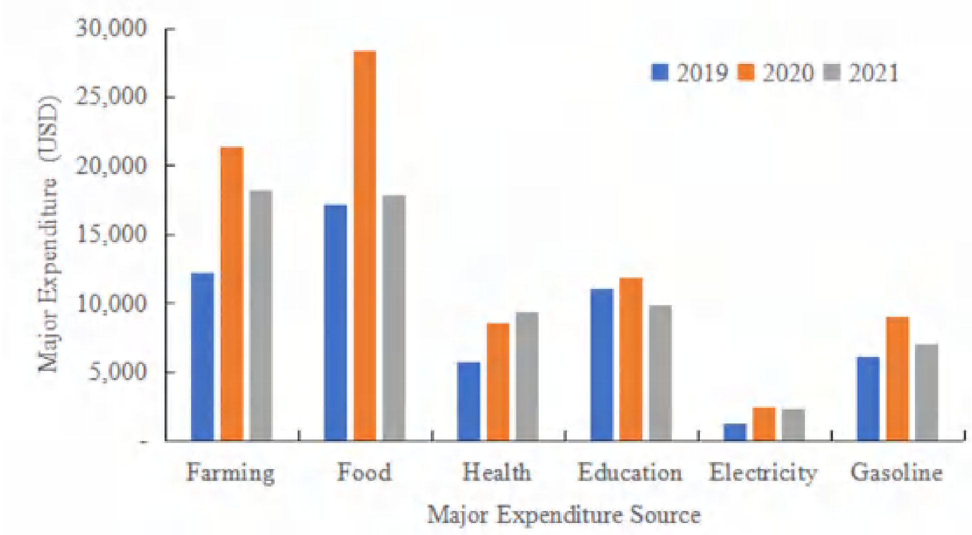


FIGURE 3.14 Annual household expenditure of all respondents

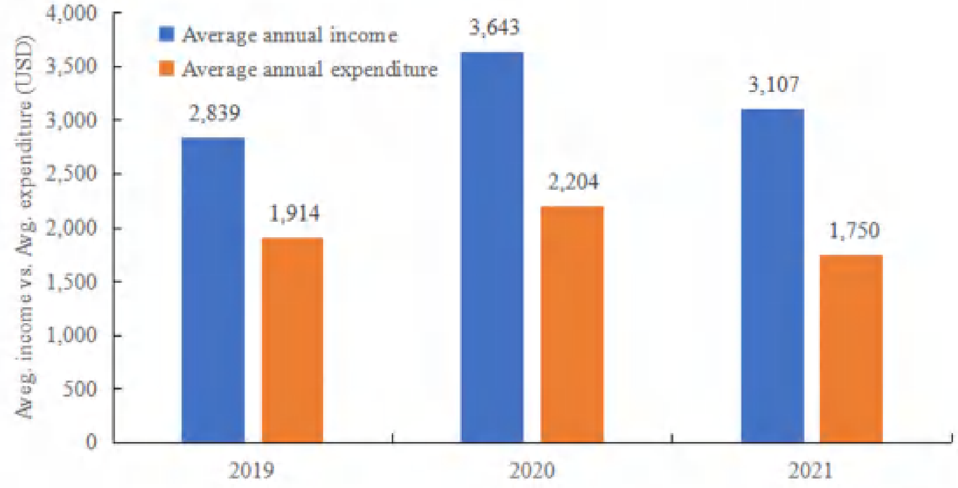


FIGURE 3.15 Changes in average annual net income

iii. PROJECT FUNDING SITUATION

The project has greatly improved local people's livelihoods by providing fruit trees, crops, solar energy, loans and wages for project-related labor. According to the results of the livelihood survey, 14 households received loans to invest in agriculture and livestock. All respondents received fruit trees for the project, which will generate additional income from the sale of fruit in the future. Eight of them received a solar system, saving each household $57 a year in electricity bills. Thirty families received vegetable seeds from the project, and each family earned $337 per year from vegetable planting (Figure 3.16). Some respondents were directly involved in project activities, such as marking tree selection, pruning, thinning, planting, and so on. They can also earn some labor wages to increase their annual incomes. The daily wage that a farmer received from the project is US 6.5 per day. It is estimated that each farmer get from USD 300 to USD 500 from the project per year.

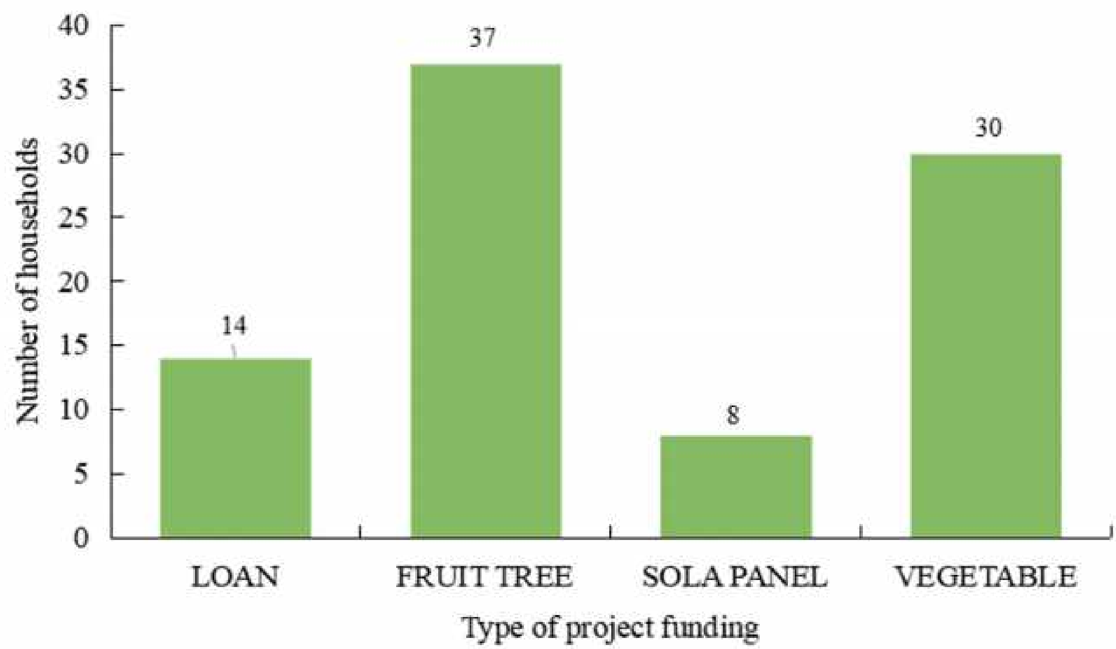


FIGURE 3.16 Number of households subsidized by the project

Chapter 4

IMPROVING AWARENESS AND BUILDING CAPACITY FOR FOREST RESTORATION

The project aimed to improve the technical proficiency in forest restoration and management of degraded forests in Bos Thom Village of Cambodia and raise awareness among local villagers on the importance of forest conservation. This was achieved through a variety of approaches, such as the organization of trainings, information-sharing workshops, the production of videos, and the publishing of technical manuals. At the end of the project, through field surveys and stakeholder interviews, it was found that the local community's awareness regarding the importance of protecting degraded forests had increased, and over 50% of the residents had participated in the restoration of degraded forests. This indicates that the knowledge of forest restoration has increased and best practices have been adopted and been practiced among the forestry community in the target area and farmers in nearby areas.

4.1 AWARENESS RAISING AND TRAINING COURSES/STUDY TOURS FOR CF MEMBERS, LOCAL FORESTERS AND FARMERS

In December 2018, the ECTF team went to Cambodia to coordinate a two-day technical training, including holding lectures and outdoor practices at nearby primary schools, teaching basic knowledge on afforestation and home garden construction techniques (Figure 4.1). Over 40 local people participated in the training, including forestry department management personnel, technicians, and community residents.

FIGURE 4.1 Indoor and outdoor *(background)* technical training

FIGURE 4.2 ECTF team providing technical counsel in Cambodia

In July 2019, the ECTF team went to Cambodia to survey the growth of the newly planted seedlings, to counsel on proper tending and other forest management techniques, as well as to offer to guidance on home garden construction (Figure 4.2). Due to the impact of the COVID-19 pandemic and the ensuing international travel restrictions, between 2020 and 2022, the ECTF team, which is based in China, had to relocate the technical support sessions to online platforms.

4.2 HOLDING SEMINARS & TECHNICAL DISCUSSIONS AND FACILITATING AN EXPERIENCE EXCHANGE BETWEEN CHINA AND CAMBODIA

The project kickoff meeting was held in Siem Reap in December 20 and 21, 2018. Fifty participants from APFNet, ECTF, IRD, local authorities, local communities, non-governmental organizations, and other stakeholders attended the meeting (Figures 4.3). The meeting shared information on current forest management practices and existing policies in Cambodia, best practices on degraded forest restoration and sustainable management, and also the alerted the participants to the availability of think-tank support for community forestry, sustainable management, and forest restoration. The participants were invited to visit the Bos Thom CF in Siem Reap, where they had face-to-face discussions with local residents about their views and expectations of the project. They recognized the project's importance for restoring and improving the quality of degraded forests in the area, and they were willing to participate in project activities.

FIGURE 4.3 Project kick-off meeting

On June 8th, 2022, the project team held an international symposium on Tropical Degraded Forest Restoration and Sustainable Management in China and Cambodia in an online-offline hybrid mode (Figure 4.4). Forty-six experts and young scholars from APFNet, IRD, Guangxi Academy of Sciences, Research Institute of Tropical Forestry, Henan University, and the Center for Tropical Forest Science participated in the conference. The symposium covered effective approaches for restoring tropical degraded forests and the potential advantages of sustainable forest management in responding to climate change, which promoted ASEAN forestry cooperation and regional economic development.

FIGURE 4.4 The China-Cambodia international symposium

4.3 COMPILING TECHNICAL MANUALS AND PROMOTIONAL MATERIALS TO SHARE BEST PRACTICES AND EXPERIENCES IN FOREST RESTORATION

Under the guidance of the expert committee, the project team compiled and distributed 300 copies of technical manuals written in Chinese, English, and Khmer to guide the technical activities of the project team and relevant personnel. In August 2022, the Chinese-English bilingual technical manual was officially published and distributed by the China Forestry Publishing House (Figure 4.5).

FIGURE 4.5 Compilation of technical manuals

In the severely degraded forest restoration demonstration areas and the project village, the IRD team installed six promotional signs and hired a local media company to produce a 12-minute short video (http://rlzx.caf.ac.cn/info/1251/3495.htm), which demonstrated the effectiveness of tropical degraded forest restoration (Figure 4.6).

FIGURE 4.6 Promotional signboards and videos of the project

The IRD team produced a project brochure and distributed 1,000 copies of it to promote the project (Figure 4.7). On June 15th, 2022, a project launch seminar on Promoting Community Forest Restoration and Sustainable Management through Multi-Tree Species and Agroforestry was held in Phnom Penh, Cambodia. During the conference, 100 brochures were distributed to the participants, and the remaining 900 copies were distributed or kept in the following ways:

- 300 brochures were distributed to local institutions in Bos Thom Village.
- 100 brochures were distributed to the Department of Agriculture, Forestry, and Fisheries in Siem Reap Province.
- 200 brochures were placed in the local forestry bureau library.
- 160 brochures were distributed to various subordinate departments of the Forestry Administration of Cambodia.
- 140 brochures were kept in the IRD library.

FIGURE 4.7 Project brochures

Chapter 5

SUMMARY

5.1 ACHIEVEMENTS

1. Fragmentation and habitat loss are major problems in Cambodia's tropical forests. The management strategy for tropical degraded forests in this project focused on the protection of forests while also encouraging a combination of natural and artificial restoration measures to accelerate forest succession. This will gradually restore the degraded forest ecosystem to a functional level and ultimately achieve a more resilient forest.

2. The project adheres to the principles of sustainable forest management and has designed three forest restoration strategies and techniques for different levels of degradation of tropical forests in Cambodia. This provides a good technical demonstration for the restoration of degraded forests in other tropical regions.

3. The project carried out various non-forestry livelihood activities, including building home gardens, providing micro-credits, and installing solar power equipment as an alternative source of energy. These activities have improved the livelihoods of community residents and have created favorable conditions for local communities to actively participate in forest restoration.

4. The restoration of degraded tropical forests is a long-term and complex process under the influence of various factors, including extreme weather, prevailing forest management practices, forestry policies and regulations, social and economic conditions, and others. Hence, these factors should all be considered to formulate science-based, feasible management measures for the restoration of degraded forests in tropical areas.

5.2 LESSONS LEARNED AND RECOMMENDATIONS

1. The three forest restoration models showcased by the project had great effectiveness. It is recommended to further promote and demonstrate these models in Cambodia and its surrounding regions. As the CNFM approach used in the project is a new technique with a relatively short history in Siem Reap Province, it is recommended to keep providing technical guidance and training for local forestry practitioners. It is also important to continue to roll out technical cooperation, demonstration, and research. Yet, strengthening forest restoration capacity building in Cambodia is crucial for promoting exchanges and cooperation between the forestry industries in China and Cambodia.

2. Home gardens are popular in Cambodia, so it is recommended to extensively promote the activity. Additionally, crops and Chinese medicine herbs that are adapted to future impacts of climate change and valued in markets are recommended in home gardens. Additionally, at least one expert to assist and guide local residents in the creation of home gardens should be hired.

3. Cambodia experiences seasonal droughts and water holding capacity is poor as the soil is fairly sandy. Water resources are a crucial factor that decides the potential use and value of a home garden. Therefore, it is recommended to construct water wells for impoverished farmers to provide sufficient water for agricultural purposes.

4. The project has only been implemented for a comparatively short time, and the forest stands are still mainly composed of small-diameter timber. Following the end of the project, it is recommended to continue funding and improving forest management and maintenance to boost the forest's ecological and economic value, Firstly, science-based soil improvement, water retention and fertilization measures should be adopted to resolve the challenges posed by the lack of water and soil nutrients on tree growth. Secondly, the newly planted trees in severely and moderately degraded forests should be tended by regularly and properly pruning vines and branches. Thirdly, in mildly degraded forests competitor trees should be removed and vines removed every 5 to 8 years.

5.3 CONCLUSION

Forests are of utmost importance in Cambodia as 80% to 85% of the population lives in rural areas and depends on traditional agriculture and forest resources. Forests provide local communities with NTFPs, such as fuel-wood, medicinal plants, bamboo, and food. They also serve as a source of drinking and irrigation water for agriculture, sustaining the livelihoods of local residents, and as a source of materials and goods for small business ventures.. Forests also fulfill the residents' spiritual and cultural needs of living in and being around forests. Since the project was launched, the project team has carried out activities in an orderly manner according to the initial design and annual work plan. Although the project was delayed for six months due to the COVID-19 pandemic, the results are satisfactory and the planned goals have been achieved. The project has established a 50-hectare demonstration forest for the restoration of degraded forests, which contributed to the restoration of ecosystem services in degraded tropical forests in Cambodia. The project has also established 19.94 ha of home gardens, installed 20 sets of solar power equipment, and provided USD 7,840 in revolving funds to 39 families. These activities have significantly improved the living standards of local residents. Additionally, the project team has provided technical training and guidance to local villagers, organized international symposiums, and compiled technical manuals to share exemplary practices and experiences in the restoration of degraded forests locally and internationally. This has improved the forest management techniques and capacities of Cambodian foresters and farmers, and will serve as an example and reference for the future restoration of degraded forests in surrounding areas and countries.

The project's goals align with and address national and international priorities for sustainable forest management, development and environmental protection. The project has made significant contributions to the restoration of degraded forests in the Bos Thom community of Cambodia, enhancing the ecological services of degraded forests, improving the living standards of local residents, promoting near-nature forest management practices, and raising awareness about forest conservation. Nevertheless, the protection of forests remains a challenging long-term task.

Even though people, cultures, economies, ecologies, and even locations can vary, many fundamental problems in managing degraded forest lands share a similar root. It is only through a thorough knowledge and techniques for these guiding principles that we will be able to offer people-respecting sustainable management to any area in need of it. We hope that by reading this report, the readers could gain an overview of these experiences and knowledge that they can use to forest restoration and sustainable forest management they may face.

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