SPECIES FOR NATURAL FOREST RESTORATION IN VIETNAM - LOCAL AND INTERNATIONAL EXPERIENCE

Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet)

Silviculture Research Institute, Vietnam

Tran Duc Manh, Phan Minh Sang, Nguyen Thi Thuy Huong,
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1.1. General introduction

The Convention on biodiversity conservation, adopted at the global summit in Rio de Janero, Brazil, 1992, provided a definition for biodiversity: "the variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". This definition presents biological diversity at three levels: genetic diversity, species diversity, and ecosystem diversity, and refers to the space around and habitat of the organism.

Vietnam provides habitat for about 20,000 species of vascular plants on land and under water; about 10,500 species of terrestrial animals, including about 1,000 species of soil invertebrates, 7,700 insects, 500 species of reptiles and amphibians, 850 birds and 312 mammals, over 1000 species of invertebrates, about 1,000 species of freshwater fish; over 7,000 species of marine invertebrates, about 2,500 fish species and approximately 50 species of sea snakes, sea turtles and marine mammals. In addition, the number of known species in Vietnam (as above) is much lower than the actual number of species living in the wild, as there are certainly many other unknown wildlife species (National Report on Biodiversity, 2011).

Gymnosperms and angiosperms constitute Vietnam's valuable timber resource.

According to preliminary statistics, within the vascular plants group (in which of pine phyla and orchid phyla are the most species rich), there are over 12,000 species. There are approximately 2500 species that can be used for timber, and these species are distributed in the large tree families such as Rubiaceae, Euphorbiaceae and Fabaceae. There are other families that include only a few species, but have a high abundance, such as the species in Dipterocarpaceae, Lauraceae, Meliaceae and Rhizophoraceae. Among the gymnosperms, families such as Podocarpaceae, Pinaceae and Cupressaceae include species with high value timbers, characterized by beautiful wood grain, fragrance, durability (termite and decay resistant), as well as ease of processing. Many species grow in pure populations in the highlands, where the climate is tropical.

Many angiosperms are the subject of much attention by forestry experts and commercial interest, including the following families.

- Magnoliaceae has only five genera, and includes over 25 species with rare timbers, characterized by beautiful wood grain, fragrance and durability (termite and decay resistant). Some species have been widely planted for major timber production, and

economic benefit. Most species in this family are distributed in the northern highlands of Vietnam.

- Styracaceae has 4 genera and over 10 species that produce light wood, are easy to process, very durable and are widely used in processing industry. The species in this family grow widely from the midlands to the high mountains in the northern and central provinces. Some species have been planted in pure forests, which are highly productive because of their fast growth.
- Fagaceae only has five genera, but has 100 species which are large, and produce quite heavy, hard timber. This timber is used in construction of ferries and ships, and is also used in industrial products. This is a family typical of humid and cool climate areas in the highlands of the South, and central North.
- Families such as Sapindaceae, Meliaceae and Fabaceae also have many genera and species, characterized by large sizes and heights, fine veins, heaviness and durability. They are commonly used in everyday products such as family furniture, houses, and crafts. There are many species in this family which are becoming rare, and therefore need to be protected and sustainably managed. They characterize the wet evergreen jungles, with a tropical rainy season, from north to south.

- Dipterocarpaceae, with seven genera and 45 species, along with Rhizophoraceae with five genera and nine species, are large trees that characterize different types of forests (from mangroves to deciduous mountainous forests) in the southern provinces of Vietnam. The most common species also have a large number of individuals, creating forests that characterize areas with harsh climate and soil. Rhizophoraceae along with Verbenaceae, Sonneratiaceae, and Avicenniaceae form the unique coastal mangrove forest of Vietnam.
- The families with a large number of genera, such as Euphorbiaceae, Moraceae, Lauraceae and Rubiaceae, also have high numbers of timber species, including species with soft and light timber, and hard timber which are heavy, durable, and easy for processing. They are typical of tropical secondary forests on low hills and high mountains. Sometimes, they are the pioneers, which favour light, grow fast, and can be used for industrial production.

Today, despite the extensive development of other processing industries to meet our every need, the demand for using wood products is still increasing. Therefore, through understanding of plant diversity is required, on one hand to meet human needs, and on the other hand to protect and grow the timber resource, to ensure ecological balance, and

to maintain high yielding sustainable forests (Tran Hop, 2002).

1.2. Conservation and development

Faced with the decline of biodiversity, and with many species becoming endangered and extinct, conservation is critically important. Conservation of biodiversity has been a challenge for many countries in the world in recent years. Many international organizations have been established to supervise, support, and organize research and classification of species in order to best conserve endangered species.

Conservation Research

Plant Conservation: is the conservation of genetic variation existing between populations, families and individuals within each species; the maintenance of diversity and ensuring the survival of species through evolution, within which genetic variation is a decisive factor in adapting to changing environments. The more genetic variation there is in a population, the greater opportunity there is to select those individuals with the desired characteristics (Zobel & Tallbert, 1984). This has been understood since 1926, when a Russian scientist Vavilo, proposed collecting seeds of wild plants, the close relatives of crop species, to provide genetic variation to improve these species.

A number of countries and international organizations focused on the conservation and management of the genetic

resources of plants to deal with deforestation, climate change and the loss of genetic diversity. Regional networks of forest genetic resources have been established, such as the European Forest Genetic Resources Programme - EUFORGEN and the Forest Genetic Resources Programme Saharan Sub – SAFORGEN. In 2003, a Forest Genetic Resources - Asia Pacific Programme - APFORGEN was initiated, of which Vietnam is a member (Luoma-aho et al., 2004). Forest trees are often preserved as living collections, such as in Botanical Gardens, Botanic Gardens, and in (ex situ) areas for conservation of genetic resources. The advantage of this method is that trees continuously grow and develop, and are easy to observe and assess in the long term. However, the disadvantage of this method is the high cost for the construction and protection of such areas, and the risk of disease.

A *Botanical Garden* is the most common and oldest type of plant collections. There are, and have been, over 1500 gardens. Many botanical gardens are over 100 years old, like the Bogor Botanical Garden, Indonesia. This garden was established in 1817 and now has a total area of 87 hectares, with a huge collection, including a full collection of tropical plants from across the world, including 3504 species from 1273 genera and 199 plant families. There are also some collection / Botanic gardens dedicated to one or a few species. For example in Malaysia, the Botanic Garden of the

Forest Research Institute Malaysia (FRIM) has a living collection of *Shorea* species, a collection of rubber trees (*Hevea brasiliensis*) at the Rubber Tree Research Institute; and a collection of *Citrus*. The advantage of gardens is the gathering of genetic resources, but conservation can become difficult when there are changes in ecology of the species where it exists beyond boundaries of its original population.

According to Nguyen Nghia Thin and Mai Van Pho (2003), work towards conservation of biodiversity in Vietnam occurred before 1945. Under French rule, five comprehensive nature reserves and protection areas were developed, including two areas in Sa Pa, two areas in Ba Na, and the White Horse.

So far, the government and local authorities in Vietnam have established a system of special-use forests, including 130 with an area of 2.3952 million ha, in which there are 30 National Parks, 62 Nature Reserve Areas, 13 Habitat Reserve Areas, and 38 landscape-protecting forests (Nguyen Nghia Thin, 2005).

Nguyen Hoang Nghia (1996), in his project "Conservation of forest genetic resources", completed the following research:

- Evaluated the genetic diversity of the species that are now considered threatened.

- Assessed the threatened level of species according to the classification of the IUCN (2001), and proposed a list of threatened species.

- Proposed conservation plans/ solutions (in situ and ex situ) for specific species.

- Built conservation areas ex situ (Collection Garden, Botanical Garden and Conservation Populations).

To conserve biological diversity, Nguyen Quang Viet used a trip sampling method. The tree species composition was defined by strips 100 m from each other. Each strip was investigated in a width of 5 m or 10 m, and a plot area of 25 m^2. The first subplots were 4 m^2, the second 1 m^2, and were used to investigate regeneration (Do Dinh Sam & Nguyen Hoang Nghia, 2001). This method proved to be not sufficient for biodiversity research and conservation.

Nguyen Hoang Nghia's project, undertaken in 2006 and entitled, "Conservation of forest genetic resources" assessed the threat level for some rare species. This information was used to support efforts in protection, or making protection plans, for a number of valuable tree species in some areas. The species for which this was done include the two flat-leaf pine; the five-leaf pine in Da Lat; *Fokienia*, *Keteleeria* and some other species in Lam Dong; *Glyptostrobus pensilis* in Dac Lac; *Calocedrus macrolepis* in Ba Vi and Da Lat;

*Dacrydium pierre*i Hickel in Bach Ma National Park - Hue; and *Nageia fleuryi* in Cat Ba and Cuc Phuong National Park.

The Forest Inventory and Planning Institute (1987, 1999) also undertook research related to rare species which need protecting in Vietnam, including some species on limestone. The Indochina Forest Seed Project and the National Seed Joint Stock Company have also published research on resources, and conservation of some conifers in Vietnam (Nguyen Duc To Luu & Philiplan Thomas, 2004). Many agencies and scientists have undertaken some general research on biodiversity or classification (FIPI, 1996; KHKTLN Society, 2001; Nguyen Nghia Thin, 1997; Pham Hoang Ho, 1999; Tran Dinh Ly, 1993; Vu Van Chuyen et al., 1987), and have decided upon common conservation strategies for forest species such as: the action plan for biodiversity (Ministry of Science, Technology and Environment, 1995), the Vietnam Red Book, the plant sector (Ministry of Science, Technology and Environment, 1996), the Forestry Development Strategy (Ministry of Agriculture and Rural Development, 2001); and the System of National Nature Reserves (Government of Vietnam, 2003) (according to Nguyen Hoang Nghia, 2006).

The Solutions for Conservation

In parallel with the study of conservation, a series of documents regulating conservation was established, such as the Decree, Directive and Decision in order to limit maximal

decline of biodiversity in Vietnam:

- Decision No. 41-TTg on January 21st 1977 about the regulations of prohibited forests.

- Decree No. 17-HĐBT on January 17th 1992 of the Council of Ministers on the implementation of the Law on Forest Protection and Development.

A number of other documents have been adjusted and added, in which the most notable are two recent documents:

- Decree No. 48/2002 / ND-CP of the Government on April 22rd 2002 about amending and adding the list of forest vegetation.
- Decree No. 32/2006 / ND-CP on March 30th 2006 about the management of endangered and rare forest animals and plants. This has been attached to the list of endangered and rare flora and fauna.

- Biodiversity Law: law no. 20/2008/12 on November 13th 2008 with an effective date of July 1st 2009.

These are some documents on scientific and technological development in conservation. Notably, the Ministry of Science and Technology has officially issued the Temporary Regulations for conservation of genetic resources, which is the basis for the study of genetic conservation. Under this Regulation, the objects that need to be put into conservation and storage, include:

- Priority to rare genetic resources which are typical for Vietnam, and at risk of extinction.

- The genetic resources that have been evaluated according to biological criteria

- The genetic resources needed for research, breeding and training

- The genetic resources imported from abroad that have been stabilized and domesticated in Vietnam, and are important in production. (Source: Nguyen Hoang Nghia, 2006).

To prevent increasing exploitation, and illegal use of natural resources because of demand for local and export use, networks need to be created and support from international organizations sought. The Vietnamese Government has also participated in four of five International Conventions relating to the conservation of biodiversity and the management of conversation areas.

Assessing the effectiveness of reservation protection in Vietnam, Nguyen Ba Thu stated: “This action depends much on solving problems that exist in the buffer zones, including improving the life of local people; conversing or replacing their practices of using firewood and wood indiscriminately; improving techniques of farming and forestry; promoting intensive farming; improving crop yields; quickly giving up shifting planting and extensive farming; improving the understanding and knowledge of conservation; and the

rational and sustainable use of natural resource for local people (Nguyen Ba Thu, 1997).

In the research of indigenous knowledge in agriculture and natural resource management of highlanders, Hoang Xuan Ty and Le Trong Cuc confirmed the importance of indigenous knowledge in natural resource management. These local communities are the most profound people who understand the natural resources where they live, and how to deal with the socio-economic relationships in the communities. Presenting at the national conference in 1999, "For the life and the environment of highlanders are sustainable", Vo Quy said that, in order to sustain life, many people living in reservations must exploit natural resources, which then they ought to contribute to protection of the reserve. Therefore, in order to solve the above contradiction, the Government must to complicated socio-economic issues and find effective measures to improve the living standards of people, especially the poor; simultaneously, they need to raise the awareness of protecting nature and the environment, using rational, natural resources. Then the people would be entitled to decide on how to best use the resources for their lives and for the whole community (Vo Quy, 1999).

It was found that the participation of communities has contributed to the reduction in the conflict of interests in resource use. While studying the reservoir area in Da River,

Hoa Binh province, Vuong Van Quynh et al. (1998) showed that a lack of participation of the local communities did not properly resolve differences between the nation's interest and local communities' needs.

However, in order to have some concrete solutions to stabilize the socio-economic situation in local communities, there needs to be a reduction the dependence of people on forests. For this to occur, it is necessary to have specific research. Analyzing the difficulties, challenges, and risks, and proposing solutions in order to reduce the impact on forest resources will contribute to improving the conservation of rare flora and fauna.

1.3. Domestication and planting research

Native tree species are local flora. Therefore, planting native trees has a number of advantages. They are suitable for natural conditions which species have been adapted for many generations. However, most of the native trees are still in wild environment and have not been domesticated. They usually mix with other species to form complex and diversity compositions, structures and processes which many ones are still unknown. The domestication of forest trees t has not always been successful everywhere and every time. Restoration techniques for native trees include monoculture or mixed species planting.

Scientists have studied, propagated, and successfully planted many native trees to restore forests, which not only provide ecological services, but also produce large timber. According Tran Van Con (2011) promising tree species with fast growth rate have been selected for large timber on bare land and degraded secondary forests, including *Dipterocarpus alatus and Michelia mediocris* in the Central Highlands; *Aradirachta excelsa* in Central Coast Region; *Canarium album*, *Cinnamomum parthenoxylon* in the North West; *Manglietia conifera*, *Cinamomum obtusifolium*, *Toona sinensis*, *Lithocarpus fissus* in the North East. According to the author, to grow native tree species there are some issues need to be considered as below:

- Only growing trees on their suitable ecological regions and on degraded secondary forests.

- Planting method: Enrichment planting or improvement planting by strips or gaps.

- Seeds must be collected from recognized seed orchards or mother trees which have been selected from dominant trees for breeding.

- Seedlings for planting must be covered in the containers with height of at least 0.5 m and a root collar diameter more than 0.4 cm.

- Tree density and tending: Growing density is about 200 - 800 trees per ha, depending on the density and canopy cover

of the degraded forest. Tending forests regularly, density adjustment, space growth and phenotypic selection to foster targeted trees for large timber.

Ha Van Tiep (2011) studied the silvicultural techniques for planting *Fagraea fragrans, Cinnamomum balansae, and Dalbergia tonkinensis* for restoring the degraded forest in the North West region. Bui Trong Thuy and Le Van Binh (2011) evaluated the growth of some native broad - leaf tree species planted under the canopy of *Pinus merkusii and Pinus massoniana* in Dai Lai, Vinh Phuc province. The results showed that the native broad - leaf trees including *Erythrophleum fordii, Peltophorum pterocarpum, Michelia mediocris* Dandy, *Cinnamomum parthenoxylon, and Hopea odorata* grown under the forest canopy are well developed and are best grown in row planting.

Nguyen Thanh Minh (2011) studied planting techniques of *Maesopsis eminii, Terminalia calamansanai,* and *Parkia sumatrana* in the South Eastern for large timber. Pham The Dung, Phung Van Khen and Tran Van Thanh (2011) tested some native valuable tree species and planting techniques in dry land in Ninh Thuan and Binh Thuan provinces. 10 species which have high commercial value were tested on coastal sandy areas including *Sterculia foetida, Aradirachta excelsa, Spathodea campanulata, Tamarindus indica, Pithecellobium vietnamense, Anisoptera cochinchinenis, Dialium cochinchinensis, Afzelia xylocarpa, Shorea*

roxburghii, Shorea roxburghii, and Dipterocarpus condoensis. After two years seven tree species had positive results with survival rates higher than 50%, including: *Sterculia foetida, Aradirachta excelsa, Spathodea campanulata, Tamarindus indica, Pithecellobium vietnamense, Anisoptera cochinchinenis, Dialium cochinchinensis,* and *Afzelia xylocarpa*.

Growing trials of native trees including *Cinamomum obtusifolium, Machilus thunbergii, Lithocarpus ducampii, Toona sinensis, and Lithocarpus fissus* were carried out in the Central North region (Nguyen Thi Nhung *et al.*, 2011). *Lithocarpus ducampii, Lithocarpus fissus, Toona sinensis, and Cinamomum obtusifolium* grow well and stably. *Machilus thunbergii* grows more slowly than the four above species, but it is also promising for planting. Detailed results on growing native tree species can be found on different reports including "Research of intensive Silvicultural techniques of *Pinus carribaea* to provide large timber" (Dang Van Thuyet & Bui Trong Thuy, 2011), "Research of planting techniques of *Schima wallichii*" (Vo Dai Hai, 2011), "Research and select seeds of native *Melia azedarach*and and teak with high productivity" (Doan Thi Mai, Nguyen Thi Thom, & Quyen Phan, 2011) and "Research of selecting, breeding and planting techniques of *Michelia mediocris* and *Cinamomum obtusifolium"* (Nguyen Duc Kien & Ngo Van Chinh, 2011).

Mixed species models by native broad-leaved trees on degraded forest land in the Northern provinces were undertaken from 2000 to 2004 (Hoang Van Thang & Nguyen Ba Chat, 2006). Experiments on planting mixed species in lines at Cau Hai used four native species (*Canarium album, Cinamomum obtusifolium, Lithocarpus fissus*, and *Endospermum chinense)* with nurse trees (*Acacia mangium and Fallopia japonica)*. In Ngoc Lac - Thanh Hoa province *Canarium album, Michelia mediocris, Erythrophleum fordii, and Cinamomum obtusifolium* with nurse-crop trees such as *Acacia mangium*, and natural cover were tested. The results showed that model areas were dominated by nurse trees (Acacia), especially models of mixed species forests in program 327. The survival rate was about 80 - 93% in the models. The overall survival rate in the reseach model was over 90%. The highest growth belongs to *Lithocarpus fissus*, and *Endospermum chinense* (height growth rate is 1.33 m and 1.5 m per year repectively, in Cau Hai), and *Cinamomum obtusifolium* (height reaches 0.9 m per year in Ngoc Lac). Ho Duc Soa (2006) studied planting techniques and tending of *Paramichelia braiannesis*. Hoang Xuan Ty and Nguyen Duc Minh (2011) studied some of the physiological and ecological characteristics of *Tarrietia javanica, and Michelia mediocris* as the basis for developing the planting solutions.

Among indigenous trees that have been planted in Vietnam, there are some notable species as follows:

- In the northern provinces, the native tree species which are common and have a long planting history, include the *Styrax tonkinesis, Mangliatia glauca, Pinus merkusii, Cinnamomum cassia, Illicium verum, Vernicia montana V. fordii, Chukrasia tabularis, Liquidamba formosana, Canarium album, and Canarium nigrum*. In addition, there are a number of native bamboo species such as *Dendrocalamus membranaceus, Dendrocalamus latiflorus, etc.*

- In some central provinces (including coastal areas), number species is less as all common planting tree species are mainly large timber trees such as *Tarrietia javannica, Michelia mediocris and Michelia tonkinensis* while *Pinus merkusii, Cinnamomum, Gmelina Arborea* can be planted in some other areas. Researchers are currently testing some new species such as *Pterocarpus pendatus, Afzelia xylocarpa, and Dalbergia bariensis*.

- In the Central Highlands, plantations got attention after war (1975), especially in recent years forest cover has rapidly been reduced by over harvested and land use changes. Main species planted are tree species of *Dipterocarpaceae* family, *Pinus kesya, Litsea glutinosa, Aquilaria spp*, and a few other species of rare timber.

- In the Mekong river delta, the trees are mainly *Melaleuca leucadendron* on wetland.

- In coastal areas, some species widely grown are mangrove species such as *Rhizophora apiculata*, *Rhizophora mucronata*, and.*Rhizophora stylosa*. Also there are some species of other genera such as *Soneratia caseolaris, Xylocarpus spp, Candelia caldel, Bruguiera cylindra, etc.* However, timber of most mentioned species is not high value, except for *Rhizophora* and *Aegiceras corniculata*.

Beside native species, to meet forest restoration and reclamation requirement, as well as meet demanding of timber production, exotic species are also introduced in Vietnam. The exotic trees widely grown includes *Pinus massoniana, Pinus caribaea, Eucalyptus camaldulensis, Eucalyptus exserta, Eucalyptus urophylla, Casuarina esquisetifolia, Acacia auriculiformis, Acacia mangium, Acacia hybrid,* and Teak (*Tectona grandis*).

Each species has its own advantages. Acacia can plant in wide range of ecological conditions, simple techniques, fast growing rate for short rotation thus it's the most popular species for forest plantation in Vietnam. Acacias are considered successful not only for the aim of reclaiming land, re-greening bare hills, but also for the supply of raw materials for the timber processing industry. People have also gradually accepted acacia in agroforestry such as shading trees for tea, green fence and wind break for

instance practices in Dai Tu, Thai Nguyen province and Ba Vi, Ha Noi. Recently natural hybrid Acacias were found and rapidly copied by cutting propagation and planted widely in Vietnam. The selected hybrid genotypes has high growing rate in different site conditions and is becoming one of the major species is grown in the concentrated material areas. However, acacias also has some problems like diseases and weak stem structure resulted to tree's death and broken.

In sandy soil *Casuarina equisetifolia* is the most successful tree. Casuarina is planted in strips for wind and sand break, timber and firewood, and for improving soil and environment. Casuarina trees and forests contribute to landscape beauty of beaches.

One of the valuable trees planted earliest in Vietnam was teak. Although this species can live in all ecological regions in Vietnam. Most successful teak plantations are in the South Eastern provinces. Areas which have a temperate climate, no complex terrain - especially plateaus with basalt soil like Moc Chau (Son La), Dong Nai, Binh Duong & Binh Phuoc and the Central Highland provinces are most suitable for growing this species.

Pinus massoniana and *Pinus caribaea* are the two pines can grow quickly in Vietnam if grown in suitable latitude and altitude areas. These species have significantly contributed to log supply for mining industry, and diversifying the forest tree collection in Vietnam. On the other hand, high

commercial value resin can be extracted from *Pinus massoniana*. It contributes to increase the economic value from planting this species.

Other popular exotic species including *Cunninghamia lanceolata, Popolus spp* and recently *Cedrela ordorata*, *Michelia macclurei*, etc. *Cunminghamia lanceolata* has high photosynthetic efficiency and high commercial value. However this species can be grown in sub-tropical climate only. *Cunminghamia lanceolata* is mainly concentrated in some districts of Lao Cai, Cao Bang, Ha Giang, Lang Son and Bac Can provinces which have border with China. Native *Paulownia spp* of Vietnam are often difficult to grow by monoculture and have some disadvantages such as slow grow rate and has heart rot in stem. Imported *Paulownia spp* from China were tested over ten years ago. The initial results show that tested genotypes are not promising. Exotic *Popolus spp*, *Michelia macclurei*, *Cedrela ordorata* and a number of other species recently tested in experimental scales recently and initial results are just for basic evaluation.

Chapter 2: Tree species for forest restoration in Vietnam

Forest restoration can be carried out by planting seedlings, by direct seed sowing or by using cuttings. They are different between each other depending on the used material and thus planting techniques. Generally, there are three planting methods: direct seeding, seedlings, and cuttings.

2.1. Forest enrichment by seedlings

2.1.1. Forest enrichment techniques by seedlings

Tree seedlings for planting are nurtured in nursery. Using seedlings for planting is the most successful and popular reforestation method including restoration of degraded natural forests. This method has some advantages and disadvantages as below:

- Seedlings have stem, roots and leaves, are strong and can survive and grow in new planting environment and cope with droughts and weeds. This method can be applied in all terrain conditions.
- This method save seeds, reduces time and the time needed for tending.
- The major weakness of this method is the complicated production process which requires much more expense and labor. Due to seedling transportation, it has generally a higher price than

direct seeding. Also seedlings are vulnerable during transport and tree's base systems can be damaged.

The planting method by seedlings has some noticeable technical characteristics:

+ Type of seedlings: Seedlings used for planting can be divided into two types: i) seedlings grown from seeds or selected from natural regeneration saplings and, ii) seedlings from cutting of trunks, branches, roots, and leaves (grafting trees). Currently, the most widely used seedling type is the seedlings propagated from seeds and grow in the nurseries. Wild trees are rarely used because a number of trees that qualify for planting are small and are dispersed. Thus, they can only be applied to replanting in a small area.

+ Seedling quality standard:

Quality of planted forests like survival rate, initial growth rate and tree health depends on not only the terrain condition, planting technique and protection but also whether seedlings are qualified or not.

The seedling standard consists of two major aspects: quality and age.

Seedlings quality is mainly based on morphology which are expressed by root collar diameter and the stem height. Additionally, coniferous trees must have their tops. Broad-leaf trees have not pruned branches and there are

some other criteria such as pests and diseases free and non-physical damages.

Seedling's age which is suitable for planting are different depending on the planting purpose, technical requirements, species characteristics, site conditions and investment capacity in the growing area.

Reforestation by young seedlings needs less transport and tending in the nursery, but in general seedlings' has weak resistance to the droughts, weeds, and adverse weather. On the other hand, it usually takes time for tending and protecting them after planting.

Older seedlings are highly resistant to invasive weeds and droughts. Bigger seedlings can make closure of forest canopy quickly. Tending in plantation is less. However, older seedlings require longer nurturing time at the nursery, high transport cost, and seedlings are vulnerable to physical damage during transportation from nursery to planting sites.

In general, depending on site and economic conditions and growing purposes seedlings ages are defined differently for different species or for different planting conditions of the same species. Recently, mechanical are intensively used in reforestation, thus old seedlings are preferred to use.

+ Site preparation techniques for reforestation:

Site preparation is one of the basic reforestation techniques, which has significant impact on the quality of plantation.

The majority of land for reforestation in Vietnam is sloping, hilly areas with soil being dry, lacking nutrients. It can also be plain land, but is often fallow land or land with extreme conditions, where natural vegetation is often sparse, stunted, or dense. Therefore, the vital tasks of the site preparation for reforestation are improving site conditions, regulating the light and nutrition competition of natural vegetation, limiting erosion, retaining soil and water as well as ensuring the planting density as required.

The natural vegetation should be clear completely or partially before planting. Clear ratio depends on density and value of natural vegetation, ecological characteristics of plants, slope and erosion, planting method and planting density.

Figure 1 Forest enrichment with *Parashorea chinensis* Wang Hsie in APFNet's project, Phu Tho province

Vegetation clearing can be performed by strip or gap. The cutting strips must be parallel with the contour lines. The strip width is usually based on the slope, erosion intensity, ecological characteristics of planting species, vegetation density, and especially vegetation height which is

the most important factor. Advanced forestry countries have selectively used a number of chemical herbicides.

+ Season and weather:

The season and weather for planting is one of the vital factors determining the success or failure of reforestation. Planting season and weather have decisive impacts on survival rates and health and initial growth rate of young forests.

It is difficult to water seedlings after planting. Planted seedlings use rainwater and available soil moisture to restore the normal physiological processes of the plant. Forest soil in Vietnam is generally high acidity, thus to ensure a high survival rate and fast root-striking of planted seedlings, it is necessary to minimize the imbalance between the rate of evaporating water from leaves and absorption of water by tree's base system. In the first days after planting, due to the vulnerable root systems, they can only absorb a little water – they even temporarily stop taking water while seedling still has respiration.

The growth process of root systems, stems, branches, and leaves is closely dependent on weather. In spring, the under ground plant's parts begin growing before above ground ones. In autumn, the stem, branch and leaf end their growth, but tree's base system continues to grow. For deciduous trees, we can utilize these physiological

characteristics to select the best planting season, winter, when the parts on the ground stop growing but the ones underground continue. Planting at this time can minimize the imbalance of water and help tree grow roots quickly.

Base on climate, soil and biological characteristics of most tree species in Vietnam the main planting season is autumn or spring in the northern provinces, autumn in the Central and the areas affected by Foehn wind, and the rainy season in the southern provinces.

+ Seedling protection and treatment before planting:

As mentioned above, a high or low survival rate of planted seedlings depend on plant's water balance mechanism. To deal with this matter, it is necessary to minimize water loss before planting. Thus, a strict procedure for safely transporting seedlings from nursery to planting sites is necessary. On the other hand, to help seedlings have water balance, it is needed to treat seedlings before planting. These includes cutting seedling's branches and leaves, fertilizing tree's root system, watering container seedlings before planting and keeping seedlings in a cool condition with adequate moisture.

+ Planting techniques:

Base on the planting materials, this can be technically divided into two categories planting bare root or container seedlings. In each category, based on the tools used, it also

can be divided into: manual planting, by machine or by a combination of machine and manual approach.

For both container seedlings and bare root, digging holes for planting are the most popular method at present. Other methods are hardly applicable for production.

Bare root planting reduces transportation cost and plantation productivity might be higher but survival rates are lower than planting by container seedlings. Silvicultural techniques should focus:

- Protect tree's root system from drying and damage.
- Place the seedling in the middle of the pit thus the stem is upright, the primary root is not bent upward, horizontal roots and rootlets are distributed naturally and not clustered.
- The depth for filling up the pit is primarily based on the soil mechanical composition and soil moisture. Plant the trees on arable land, soil with mild mechanical composition and dry soil deeper than for fallow land, soil with heavy mechanical composition and wet land. In general, most of the species should put root's collar 2-5 cm lower than the ground.
- Soil and roots must be in contact with each other, so people should make soil porous, remove stones and weeds in soil.

Planting techniques for container seedlings needs to be consider the following important issues:

- Ensure use of appropriate grubbing technique in case seedlings are nurtured in nutrient containers: if the taproots go beyond the container to the ground, cut these roots before planting in 2-4 weeks.
- Place the container in the middle of the pit, thus the trunk are upright, and root' collar is 2 - 5cm below the ground. Fill with porous soil (remove stones and weeds) and press soil tightly around the container (not to break the container). If the container shell is made of polythene, tear up it before filling so that tree's bases can develop normally.

Figure 2 Enrichment planting with *Erythrophleum fordii* in APNet's project, Phu Tho province Vietnam

+ Forest tending and protection techniques:

Tending and protecting is one of the decisive measures for the success or failure of forest restoration. After planting to canopy closure, the most dangerous enemy of the planted seedlings at this stage is weeds, especially the ones with extraordinary adaptability, high resistance to the environmental conditions and are easy and fast reproduction.

These cause an intense utilization of water, nutrients, and light, making soil become dry. Weeds often live in dense populations, cause poor air circulation and easily bring pests, therefore seedlings are slow growth and even suppressed to death.

Tending measures for the plantation in the first few years after planting include weeding, removing the bush and climbers, turning up soil, fertilizing, and irrigating where possible in order to make the plantation have a high survival rate and higher growth rate.

Weeding and turning soil up are often two simultaneously activities, but each has different requirements. Hence, it should be based on specific conditions to make suitable decisions. Weeding and turning soil up can be conducted comprehensively on the whole or partly planting area. These activities are usually applied in whole area in flat terrain, agroforestry or dense bamboo forests. Mentioned activities can be done on strips or pits for enrichment planting or agroforestry.

Figure 3 Enrichment planting with *Dipterocarpus retusus* in APNet's project, Phu Tho province Vietnam

After planting, weeding and turning soil up must be done for several years. The number of tending years depends on the terrain condition, density, growth rate of the crop, weeds and production intensity. Generally, tending end after canopy closure which is normally from 3 – 5 years after planting.

Times of weeding and turning up soil for each year are subject to the specific situation. From the biological view, weeding should be as much as possible, but due to shortage of labor and limited funds, they should be suitable to meet certain requirements for the favorable growth of seedlings and available resources.

Along with tending, planting protection methods must be strictly implemented. These include prevention from fire, pests, livestock and human destruction. Practical experience over years has showed that with unscrupulous tending or protection after planting, plantations will have a low survival rate, poor quality and even will need replanting.

2.1.2.Ecological characteristics and Silvicultural techniques of some species for forest enrichment in Vietnam

The National Agriculture and Fishery Extension Center (2009) published a list of priority native species for forest restoration. Morphological, ecological characteristics and silvicultural techniques of common native species are presented as below.

(1) *Chukrasia tabularis* A.Juss

a/ Morphological and ecological characteristics:

**** Morphological characteristics:***

Chukrasia tabularis is an evergreen or deciduous large timber tree species, monoecious, medium-sized, sometimes fairly large tree up to 30 tall; with a diameter of up to 110 - 130 cm, without buttresses; bark surface rusty brown or deep brown, deeply fissured or cracked, with lenticels, inner bark reddish.

Leaves paripinnate, 30-50 cm long, with 4-6 pairs of opposite or alternate, entire, asymmetrical and acuminate leaflets (imparipinnate and lobed or incised when juvenile) with dentate margins, glabrous or with simple hairs.

Flowers unisexual, small, in axillary (sometimes appearing terminal) thyrses, tetramerous or pentamerous, up to 16 mm long; calyx lobed; petals free, contorted, reflexed in open flowers, white, in 10-30 cm long panicles.

**** Ecological characteristics:***

C. tabularis is usually found scattered in lowland evergreen forest or deciduous forest. It is a dominant tree, occurring in top canopy in natural forests. *C. tabularis* is photophilic, with rapid growth at young age and shade tolerance. The species has slower growing rate after 10 years old. *C. tabularis* requires moist and relatively high humus soil. It grows well on ferralsols soil which developed from granite and limestone.

Figure 4. ***Chukrasia tabularis***

Source: vafs.gov.vn

b/ Tending and Silvicultural techniques:

**** Planting season***: Planting at the beginning of the rainy season (spring or summer).

*__Planting Methods:__ Planting monoculture or mixture with other tree species; forest enrichment by strips or gaps mixing with other indigenous species.

* __Planting density:__

For monoculture planting: 1,100 trees per ha (3x3m) or 830 trees per ha (3x4m).

In infertile soil, *C. tabularis* needs to be mixed with nurse-crop trees. Planting density is 600 trees per ha for *C. tabularis*, 1000 trees per ha for nurse-crop trees, mixing by lines.

- Forest enrichment on strips: Planting density is about 420 trees per ha (8x3m).

- Agroforestry: Planting density should range from 200 to 250 trees per ha.

* __Seedling standard:__ Over 6 months of age, root collar diameter 0.5 - 0.6cm, height 35 – 40 cm on average, healthy, vigorously growing and free of pests and diseases.

* __Silvicultural techniques:__

- Site preparation: Choose deep, well drained and fertile soils for planting *C. tabularis*. Planting strips are prepared in contour lines on slopes and in straight lines on flat areas. Clearing weeds, digging holes with spacing of 3 m before planting about a month. Hole dimensions at least: 30 x 30 x 30 cm. 0.1 - 0.3 kg of NPK fertilizer is mixed with small

amount of soil and place the mixture in the bottom of the planting hole and then covers fertilizer by soil.

- Planting: After its polythene bag is removed, position the seedling in the hole with tree's base collar level with ground. Fill back with soil and firm with the foot around the seedling.

**** Tending***

- After planting 1 month, evaluating the ratio of survival trees, replanting died trees

- Tend for the first 3 years, two times every year in April - May and September - October.

- Weeding is recommended to remove climbers, creepers and vines, but less harmful weeds can be left in the field to maintain lateral competitions. For second tending each year soil is turned and earthed up around the base trees with 60 - 80cm in diameter, 3 - 4 cm in depth. NPK fertilizer is applied top dressing 0.1 - 0.3 kg per tree around the tree's base in the second tending of the first year. Integrating fire prevention and forest protection to make sure that the plant cannot be destroyed by people and cattle.

(2) *Erythrophloem fordii*

a/ Morphological and ecological characteristics

**** Morphological characteristics:***

- *Erythrophloem fordii* is a large timber, evergreen tree, which may reach a height of 37 - 45 m, with diameter of up to 2 - 2.5m. The stem is rounded with dark brown bark, which is square cracking, has many conspicuous lenticels and can be peeled off in scales. The base of the stem has a small buttress. Tree has many large branches. Foliage is thick and wide in an umbrella shape. There are many huge lenticels at youth.

- *E. fordii* has twice-pinnate leaf and apical racemose inflorescence. The oblong fruit is capable of reaching a length of 20cm, the width 3-4cm. The seeds are flat, dark brown and are layered over each other. They are firmly protected by a keratin layer on testa, and thereby can exist for a long time in soil and also be easily maintained.

***Ecological characteristics**

E. fordii is a photophilic species, shape tolerant at the youth stage, usually occuping the top forest floor. *E. fordii* grows in different soil types which develop in various types parent rock like sandstone, shale, mica schist. Soil's mechanical composition can be ranged from light to heavy. It usually grows with other broad leaf tree species in a multi storey forest environment, where vegetation is rich. *E. fordii* is able to grow well in yellowish red ferralsols which is fertile, thick and moist. It can be planted in the secondary degraded forests with canopy cover of 30 % - 70 %. *E. fordii* is mainly grown in the North provinces of Vietnam.

b/ Silvicultural techniques

Figure 5 *Erythrophloem fordii* seedlings of APNet's project, Phu Tho province Vietnam

**** Planting Season:*** Planted at the beginning of the rainy season, usually in Spring - Summer and Summer - Autumn in the North of Vietnam.

**** Planting Method:***

- Planting by seedlings in containers or by direct sowing.

- Monoculture or mixture in strips with other indigenous species in regeneration forests with scattered shrubs.

- Enrichment planting by gaps or strips on degraded natural forests.

**** Planting Density:***

- Monoculture: 1,100 trees per ha (3 x 3 m in distance)

- Mixture: 400 trees per ha (6 x 4m spacing), plant a row of indigenous tree species between two rows of *Erythrophloem fordii*.

- Forest-enrichment planting in gaps (4 x 4 m spacing) or in strips (10 x 3 m spacing) with other broadleaf indigenous tree species with the density of 330 trees per ha.

**** The seedling standard***

Seedling ages of 16 - 18 months, 30 – 40 cm in height, root collar diameter of 0.6 - 0.8 cm.

****Silvicultural techniques***

- Digging holes one month before planting with a size of 40 x 40 x 40 cm and in alternative arranged form.

- Filling up pits and basal fertilizer with 1 – 2 kg of

completely decomposed cattle manure mixed with 0.1-0.2 kg NPK per hole.

- Planting: Dig the holes to the level of the container height. Remove the container, place the seedling in the hole, tree's base collar level to the hole's mouth, fill up pit tightly and press firmly.

**** Tending***

- After planting 1 month, evaluating the ratio of survival trees, replanting died trees

- Tending for the first 3 years, 2 times each year.

- Tending methods: Weeding is recommended to remove climbers, creepers and vines, but less harmful weeds can be left in the field to maintain lateral competitions. For second tending each year soil is turned and earthed up around the base trees with 60 - 80cm in diameter, 3 - 4 cm in depth. Depending on soil's fertility, NPK fertilizer is applied by top dressing 0.1 - 0.3 kg per around the tree's base in the second tending of the first year. It is necessary to have measures to protect planted seedlings from fire and animal disturbances.

(3) *Peltophorum pterocarpum*

a/ Morphological and ecological characteristics

Morphological characteristic

Peltophorum pterocarpumis is large timber of 25 – 30 m height, and 50 – 60 cm diameter at breast height. The stem is straight with brownish bark which can be peeled off in scales. The base of the stem has small buttress roots. The branch has rust-colored hairs.

The leaves are bipinnate, even, dark green, with 7-16 pairs of secondary petioles. Each petiole has from 5-15 pairs of oval-shaped leaflets 1cm long and 4-9mm wide. Young leaves have rust coloured hairs and the stipules are deciduous.

Yellow inflorescence sprouts on the head of branch have a pyramid shape. The inflorescence has rust-coloured hairs and deciduous bracts and calyx 5, corolla 5, swayed anther. The flower stalk is 2-3 times longer than the flower bud. Hairy receptacles contain 3-4 ovules. The thin fruit is diamond shaped, 9-13 cm long, 2-3 cm wide, brown colour and has 2-4 seeds lying at an angle of 45^{o} with the hard testa.

Figure 6 *Peltophorum pterocarpum* leaves and flowers

(Source: vafs.gov.vn)

In natural forest, *Peltophorum pterocarpum* flowers at the age of 7 - 8 and fruits at the age of 15 - 20. The flowers bloom from April to May. The fruits are flattened and ripen from August to November. When the fruit ripens, the cover is darkish brown and sticks to the stalk tightly

Ecological characteristics

Peltophorum pterocarpum is primarily found in secondary forest below 700m in height in Northern provinces, Central regions and below 1000m in the Southern provinces, where the rainfall is 700-2500mm, the average annual temperature 20-25^{o}C, the average temperature of the coldest month is below 15 °C, is in goldish red ferralsols soil, red basalt soils, alluvial soils. It is a lucipetal tree and occupies the top floor of the secondary forest. It is capable of mixing with other tree species such as *Canarium*, *Castanea*, *Erythrophleum fordii*, *Gironniera subaequalis* planch, *Aphanamixis grandifolia* blume, *Ormosia pinnata*, *Symplocos laurina*, etc. Furthermore, it also can reproduce in clusters after slash-and-burn shifting planting, in large empty gaps in the forest or at the forest edge.

b/ Silvicultural techniques

P. pterocarpum can grow on fertile or infertile soil after slash-and-burn or grassland of shrubs with scattered timber.

Plant by strips or rows, for forest enrichment or by agroforestry methods. In particular, mixing with other tree species in rows such *Aschukrasia velutina*, *Cinnamomum obtusifolium*, etc. can be applied.

Plant seedlings from containers or bare root seedlings.

Plant on rainy days or shading days from April to August.

Plant with a density of 1,100 trees per ha, 3 x 3 m spacing, possibly sow rice, beans, peanuts between the 2 rows.

In degraded forest floors, cut shading tree species.

The hole size for planting can be from 30 x 30 x 30 cm to 40 x 40 x 40 cm.

Tending for the first three years:

- In the first year, to the tree species twice at the mid and the end of rainy season. Replant to replace dead trees, cut vines and grasses. Soil is turned and earthed up around the base trees with 60 - 80cm in diameter.

- In the second year, do the same as the first year. Besides, other targeted regenerating trees are also tended.

- In the third year, tending time is similar to that of the first and the second year. The tending activities include cutting vines, opening canopy for *P. pterocarpumand* and other targeted regenerating trees, soil is turned and earthed up around the base trees with 60 - 80cm in diameter, 3 - 4 cm in depth.

(4) *Manglietia conifera*

a/ Morphological and ecological characteristics

Morphological characteristics

Manglietia conifera is a large timber tree, 25-30m in height, and 30cm or even up to 50-60 cm in diameter at breast height. The stem is straight and round with silver-grey bark, fragrant, white sapwood, uniaxial and has a key pyramid-shaped top at youth. The stem part below the bough is 3/4 height of the tree.

Small branches sprout around the stem. Single leaves have long oval-shaped leaf blades, veins on the both sides and a thin petiole.

The bisexual flower which sprouts on the head of branch is big with a white yellow colour, and normally flowers from February to March. The dual fruit is cylindrical and ripens in August - September. The seed is red, has a glossy black inner layer and is fragrant. There are 25,000 seeds in a kilogram of fruit.

Ecological characteristics

Manglietia conifera is the endemic plant to the North of Vietnam. It is popular in many provinces such as Yen Bai, Ha Giang, Phu Tho, Thanh Hoa, and Nghe Tinh and is scattered in Quang Binh. *M. conifera* populations are pure secondary species restored after slash-and-burn and plantations. It is able to grow with other species such as *Cinnadenia paniculata, Michelia mediocris, Endospermum chinense, Dipterocarpus retusus, Burseraceae, Aphanamixis grandifolia, and Toona sinensis.*

Figure 7 **Manglietia conifera**

(Source: vafs.gov.vn)

M. conifera is distributed at elevation below 300 - 400m, in the low hills.

M. conifera is suitable to grow in areas where the average annual temperature is 22-24 ^{o}C, rainfall is over 1600 mm. *M. conifer* can plant in areas impacted by "foehn" but it must have rainfall of over 2000 mm per year and air humidity of over 80 %. Leaves or tops of seedlings just been

planted can be seriously withered if weather is frosty and cold.

M. conifera can develop in degraded forest soil, clearcutting forest, bamboo forest, bamboo forest with scattered shrubs, or goldish red ferralsols soil which is deep, moist, drained, rich in humus on clay christ, mica christ, or gnai.

It is impossible to plant *M. conifera* on soil with remaining *Imperata cylindrica* and on bare hills.

M. conifera is a photophilic species and requires low light at the youth stage. In the summer, with strong light, the plant is able to grow well when provided with proper canopy cover. At older age, it needs more light to grow. Tree's base system grows quickly with a 2 - 3 m long taproot. The horizontal root has many branches sprouting in different directions, and is primarily distributed in topsoil (top 10 – 30 cm). Natural regeneration seldom occurs, only found in sparse, fresh vegetation. Buds are strong capable of reproducing.

Flowers normally bloom in February - April, the fruits ripen in August - September.

b/ Silvicultural techniques

The most appropriate season to plant *M. conifera* is Spring since soil is moist and the rainfall is higher than the evaporation.

It should be planted in autumn from August to the beginning of October, especially in shady, rainy and moist days. It is suggested not to plant *M. conifera* on hot and heavy rainy days or even days with a high evaporation rate.

Site clearing can be carried out in low terrain, below 20^o of slope hills with deep and thick soil. When using this method, it is crucial to plant other supporting tree species such as *Fallopia japonica or Indigofera spicata*.

The areas with above 20^o of slope, especially in mountainous areas and high erosion, thin soil and strong evaporation planting sites are cleared by strips. *M. conifera* is planted in cutting strips following the contour lines.

The remaining strips are maintained to leave natural regeneration trees. This is the optimal method because it maintains the forest and forest soil conditions and forest protection.

The width of the remaining strip is 8 – 12 m, and the width of the cutting strip is 25 – 40 m. Holes are dug with the dimensions of 40 x 40 x 40 cm. Fill up the holes with porous soil about a half of month before planting. Remove weeds.

Tree density is 1,660 trees per ha (3 × 2 m) or 2,000 trees per ha (2.5 x 2 m). If planting on strips, the distance between two trees is 2 m and between 2 rows is 2.5 m.

Seedlings should be watered on the previous day before planting. Containers must not be break during transportation to planting fields. Remove the containers, place the seedlings upright, cover with a small amount of soil to 2 – 5 cm higher than tree's base collar and press moderately.

Tending is conducted for the first three years after planting, twice or three times each year. Weeding, turn over soil around sapling's base to a width of 80 - 100 cm. It is necessary to cut vines and gradually remove it to give the tree species proper light. Strong light may lead to high evaporation resulted to withered leaves. In contrast, the light shortage can restrict growth of a young tree.

Pests and diseases are needed to monitor frequently to prevent their occurrence. *M. conifera* is commonly damaged by leaf - eating bees. Depending on each case, apply different prevention levels.

Mild impact: Turn over soil and exterminate cocoons around the tree species that have signs of pets and diseases. Soil is turned up to a depth of 6 - 7cm, and to 20 – 50 cm wider than the canopy projection once or twice per year during February to the first 10 days of March.

Severe impact: Spray 666 pesticide powder with a concentration of 6 % of 20 – 25 kg per ha for ages 9 - 10; 15 - 18 kg per ha for ages 6 - 8; 10 - 12 kg per ha for ages under

6. Canopy is spray directly in the early morning (at 5-7 o'clock).

(5) *Michelia mediocris*

a/ Morphological and ecological characteristics

Morphological characteristics

Michelia mediocris is a large timber evergreen of 25 - 35m in height, and 80 - 100 cm in diameter at breast height. The stem is straight and evenly round with brown and flat bark. Sapwood is yellowish brown, soft, thick and slightly fragrant. Young twigs have hairs, white lenticels and round leaf scars. The single leaf is long, oval, flat, short nosed at the apex, light green, glossy, 8-15cm long, and 3-5cm wide. There are 10 to 16 pairs of veins on a leaf. The stipules have hairs on the outer side.

Figure 8 *Michelia mediocris* seedlings of APNet's project, Phu Tho province Vietnam

The flowers sprout on the head of the branch with hairy peduncles and white petals. The fruit is 6-10cm long and contains red seeds in the shape of an avate or ellipsoid.

Ecological characteristics

Michelia mediocris can be found in mountainous areas with elevation below 700m in broadleaf natural forests. This species is distributed from Lao Cai, Yen Bai, Phu Tho, and Nghe An provinces in the North to the Central Highlands.

M. mediocris grows fast in deep, moist, and well-draigned soil. They can also grow in many kinds of ferralsols soil on gnai, micasit, clay schist, mica schist and macma acid. *M. mediocris* can be mixed with *Peltophorum pterocarpum, Ormosia balansae, Gironniera subaequalis* (in the North) or *Dialium cochinchinensis, Dacrycarpus imbricatus, Canarium album, Endospermum chinense, and Platanthera yosemitensis* (in the Highlands). *M. mediocris* is a photophilic species, has relatively fast growth and seed natural regeneration. Young tree species are light shade tolerant.

Flowering season is from March to April with fruits ripening from September to October. There are 4,500-5,000 seeds/kg. With good seeds and proper techniques, it is easy to get over 2,500 tree species/kg.

b/ Planting

Michelia mediocris is planted at regions with average annual temperature of 20 to 25^{o} C, average annual rainfall of 1,500-2,500 mm, and elevation not more than 1000m. *M. mediocris* grows well in reddish yellow, yellowish red, and yellowish grey ferralsols soil on sandstone, magma stone, mica schist, or areas remaining forest cover with depth, moisture, drainage, over 40 cm soil layer, humus content of 4 - 5%, and K_2O digestion of over 10mg/100g soil. *M. mediocris* can plant on degraded forest (IIIA1), secondary

regeneration forests (IIa), or in scrub land with scattered timber species.

The most suitable season for planting *M. mediocris* is in Spring or the beginning of the Summer crop from March to June in Northern provinces; from October to November in North Central region; and from June to August in South Central Coast and the Central Highlands.

M. mediocris can grow for forest enrichment or plantation for large timber on degraded forests, young secondary forest, over exploited forest or forestry land after slash-and-burn. *M. mediocris* can be planted by strips or in gaps for forest enrichment.

Planting *M. mediocris* for forest enrichment by strips: It is applicable to poor secondary forests which deficiency of regeneration and young secondary forest after slash-and-burn. Strips are designed to East–South or following the contour lines of the terrain with a slope of above 15^{o}. In forest with tree height of 8 - 10 m clear strips is about 5 - 6 m and remaining strip is 8 – 10 m. In forest with tree height of 12 - 15 m, clear strip has width of 7 – 8 m, remaining strip is 10 – 12 m in width. Clear strip's width is 7 – 8 m, and remaining strip width is 10 - 12 m in forest which tree layer height over 15 m. On the clear strips, vegetation must be cut closely to tree's bases, then leave on targeted regeneration trees, economic tree species. Non-commercial tree species with a diameter of above 10cm will be cut.

Holes with dimensions of 40 x 40 x 40 cm are dug one month before planting. Holes are filled up 10 - 15 days before planting. *M. mediocris* is planted strip with 4 m spacing between trees.

Forest enrichment by planting M. mediocris in gaps: Applying to poor forest, young secondary forest with a minimum gap area of 200m^2. In the gaps, vegetation is cut closely to tree's base, chopped into small pieces, cleared out. Non-economic trees with diameter of over 10 cm must be cut or killed. Commercial regenerating trees are kept. In the forest clusters around the gaps, clear vines or non-economic tree species which have a large canopy and affect tree species in the clusters. Dig pits with a dimensions of 40 x 40 x 40cm at least one month before planting. Pits are filled up 10-15 days before planting. In the clusters, arrange tree species with an even spacing by 4 x 4 m.

Michelia mediocris plantation establishment for supplying large timber: Apply to scrubland after slash-and-burn and forest land after over-exploitation. Mix *M. mediocris* with *Acacia auriculiformis or Acacia mangium*. Each row of *M. mediocris* mixes with a row of *Acacia*. In the relatively flat terrains, planting rows is designed by East–West direction. In the areas with a slope of over 15^o, planting rows is following contour lines, with strips 4 m wide. Vegetation is clear, cut, chopped into pieces and left on the ground. Only regenerating trees and commercial trees

are left. Holes with dimensions of 60 x 60 x 60 cm are dug in the flat area. Pits with dimensions 40 x 40 x40 cm are dug on slope over 15^{o}. Holes should be dug one month and fill up 15 days before planting. On each strip, *M. mediocris* is planted in a row in the middle with spacing of 4 x 4 m and mix with with *Acacia* with spacing of 3x3m.

Containers are removed before planting. Containers must not break during transportation. Seedlings are placed into pits carefully, press around tree's base collar.

One month after planting, inspect the site to replant dead tree species. If the survival rate is over 90% planting is successfully.

Tending forest within 5 continuous years:

- The first year: after 2-3 months, clearing vegetation, vines, and shrubs around tree species; weeding; turning up soil around tree's base within 1 m in diameter from tree base.

- The second year: 3 times tending. The first time is in Spring: cut vines. The second time is in the beginning of the rainy crop: turning up soil around tree base within 1 m, applying NPK (5:10:3) at a rate of 200 g per tree. The third time is at the end of rainy season: vegetation, vines, and shrubs are removed around the trees.

- The third year: twice tending: The first time is at the beginning of the Spring: clear vegetation and vines. The

second time: do the same as the second time the second year.

Two to three years after planting, density of nurse-crop species, *Acacia*, should be adjusted if its canopy affects the growth of *Michelia mediocris*.

The fourth and fifth year: tending once each year. Vines, shrubs and bushes, remove diseased tree species and non-targetted trees with large canopies which negative affect the development of other trees in the strips are removed.

(6) *Canarium album*

a/ Morphological and ecological characteristics

*** Morphological characteristics**

Canarium album is a large timber with 25 m in height. The trunk is round and straight with grey-white bark which is peeled off in small scales at old, opaque white resin with fragrance.

The leaves are pinnate. The leaflet is oval or ovate shape, 6-10cm long, and has a gradual pointed apex, slanting tail, and smooth edge with plenty of white waxy flakes on the underside.

The inflorescence is usually described as extra-axillary with clusters in leaf axils. The fruit is oval; yellowish when ripening. The seeds have 6 sections, gradual pointing at two heads.

*** Ecological characteristics**

- Climate: *Canarium album* is a photophilic species and fast growth but requires shade tolerance for the first two years. It grows well in region with rainfall between 1,500 – 2,000mm, and elevation between 100 – 750 m asl where the average temperature is 22^0 C.

- Soil for planting: *Canarium album* can grow in different soil and can be planted in hills, alluvial soil, river banks with pH 4.5-5, and in sites which forest soil properties are remained.

Figure 9 ***Canarium album***

Source: vafs.gov.vn

b/ Silvicultural techniques

- Season: Spring in February - March, Autumn in August - September.

- Soil: planting density is 1,000 trees per ha, spacing of 5 x 2m; or 400 trees per ha with spacing of 5 x 5 m. Holes have dimensions of 40 x 40 x 40 cm; applying NPK fertilizer and composting manure.

Planting: Planting by container seedlings; *Canarium albumcan* is mixed with *Cacia auriculiformis or Ananas comosus* (2-3 *Ananas comosus* rows then insert a *Canarium album* row).

If it is planted for protection forest, *Canarium albumand* mixed with with *Acacia auriculiformis and Eucalyptus camaldulensis*. Two rows of *Acacia auriculiformis* or *Eeucalyptus camaldulensis* mixed with a row of *C. album*.

- Tending and protection: it is necessary to keep planted seedlings with shade for the first 2 years and tending for the first 3 years. Tending techniques are the same between mixed species.

(7) Cinnamomum cassia

a/ Morphological and ecological characteristics

*** Morphological charateristics**

Cinnamomum cassia is evergreen timber species with 10-20m of height, and 25-40 (70) cm of diameter. It has thick and smooth bark when young, but scabrous and grey-brown bark when old. The buds have brown hairs. The tree grows elongated leaves that are 8 – 25 x 4 - 8.5 cm in

dimensions. Leaf is oval and have sleek hairs when young. Leaves are alternate, sometimes opposite with a single blade. The leaves have an elongated base and pointed tip with a big leafstalk 1.5-2cm long. The upper surface of leaf is darkish green, glossy and smooth with strips. The lower surface is ashy-grey and exposes many main veins, 3 in an arch shape. Also, there are many small parallel veins.

Inflorescence axillary panicles are 7 - 15 (18) cm long, have smooth hairs on the outer side that are small and white or yellowish.

The fruit is oval or ovate, 1-1.5cm long that ripens and becomes black or dark violet, surrounded by a cup like perianth. The seed is ovate, 1 cm long, and is dark brown with a light stripe.

* **Ecological characteristics**

Cinnamomum cassia is found in tropical rainforest, at an altitude below 800m.

Cinnamomum cassia is a photophilic species, but it still needs proper shade at the young stage (1 - 5 years old). It requires full sun light for the growth at older age. The more light there is, the faster *Cinnamomum cassia* can grow, thus its oil quality is better. *C. cassia* grows quickly in a hot and humid climate. The most suitable temperature for its development is 20-25^{o}C. However, it can also be planted in areas with a low temperature (10^{o}C-0^{o}C) or high

temperature of up to 37 - 38^{o} C. Suitable annual rainfall for growing is between 1,600 and 2,500 mm.

Cinnamomum cassia is suitable for a variety of soil types which have different soil parent materials (sandstones, schist...) or moist and porous soil rich in humus; red, yellow, or sandy soil; mountainous soil, high pH (4 - 6) and infertile soil, but good drainage.

Cinnamomum cassia has a large root system with a deep taproot. Trees from seeds are able to attain the average height of 2.2 m (maximum 2.7 m) after 3 - 5 years at A Luoi (Quang Tri). A 9 – year - old tree may reach 6.9 - 7.0 m in height and 20 – 21 cm in diameter. It has the ability to regenerate young shoots from the base of the trunk. Therefore, after cutting down the base of the trunk will be kept for coppice. It is possible to keep and tend a coppice for the second rotation. *C. cassia* flowers in April - August, the fruits ripen in October - December or January – February the next year.

b/ Silvicultural techniques

Cinnamomum cassia should be planted on sites with slope of not more than 35 %, thick and porous soil and rich in humus, pH: 4 - 5, little windy. Suitable elevation for planting in the North is 300 – 700 m and 1,000 - 1,500m Kon Tum, Quang Nam, Quang Ngai provinces in South Central Coast Vietnam.

The most suitable soil for *C. cassia* planting is fertile and moist soil, rich in humus and other nutrients. Trees grow well in soil with mechanical composition of medium loam or heavy loam, thick soil layer and drainage.

Sandy soil, soil on limestone and soil with shallow groundwater level and thin layers are inappropriate for growing *C. cassia*. *C. cassia* can grow on soil which has moist-demanding shrubs and drought-resisting shrubs but it has low productivity.

It is impossible to plant *Cinnamomum cassia* in areas covering with grasses *Rhodomyrtus tomentosa, Melastoma dodecandrum* Lour. These tree species indicates very infertile and acidity soil.

The best planting season is in Spring (in the North) or at the beginning of the rainy season (in the South). The Dao ethnic people planting *C. cassia* in Spring (right after Lunar New Year). Ca Tu and Kor ethnic people in Quang Nam and Quang Ngai provinces plant *C. cassia* in September and October to avoid the hot summer.

Holes of 30 x 30 x 30 cm are dug and composting manure and phosphoric fertilizer are applied. Planting density is defined depending on soil fertility. It is possible to monoculture with 2 x 2 m or 1 x 1 m in spacing. Plantation is then thinned gradually. In some regions, *C. cassia* are mixed in agroforestry plantations with sugar cane, cassava

and tea species to maximize soil's production, and enable higher income in the first years.

In the first few years, it is essential to clear weeds, vines, shrubs and shading trees of *C. cassia*, then remove gradually. This tending includes pruning low branches and applying with NPK fertilizer (about 40 – 100 kg per ha; depending on the age of the plant and soil fertility) at the same time. Fabaceae species such as *Tephrosia candida* are able to be mixed with *C. cassia* to provide shade for *C. cassia*, cover land and improve soil properties for the first several years.

"Squid tentacle" disease on *C. cassia* has been found in Tra My, Quang Nam province. This is a serious disease but knowledge of this disease is still limited. According to Hoang Xuan Ty (1998), cause of the disease is C. cassia is planted in the low mountainous areas of Western Quang Nam may come from the hot temperature.

Occasionally, root collar rot disease by Fusarium is affected in young trees. Older trees can be attacked by harmful bacterium like *Phytophthora cinnamomi, Corticium salmonicolor, Fomes lignosus, Aecidium cinnamomi, Glomerella cingulate.*

Some pests such as *Chilasa clytia, Acrocercops spp, and Sorolopha archimedias và Gryllotalpa spp* can also damage to the development of young trees.

Silvicultural techniques: Due to young *C. cassia* needs shade (canopy cover of 50 % - 70 %), it is suggested to plant *C. cassia* mix with with agricultural crops for the first 3 years. For instance, *Cinnamomum cassia* is mixed with with *Manihot esculenta* in order to generate minimum canopy cover and attain a high survival plant rate.

Site preparation:

Vegetation are cut in December. Site are then clear in February - March of the solar calendar. Seedlings are planted in Spring. Holes with dimensions of 40 x 40 x 40 cm are dug one month before planting. The planting density is about 5,000 - 10,000 trees per ha (1 x 1 m).

Seedlings should be sufficiently watered before planting. Seedlings must have straight trunks. Seedlings' tops should not be young. It is better to plant *Cinnamomum cassia* with a full density to limit branches development. It contribute to increase trunk development and bark quality.

The first tending should be carried out a month after planting. Cassava is planted in March – April with density of 5,000 - 7,000 tree species per ha to mix with with *C. cassia*. Similar mix with should be conducted for the second and third years. Two tending per year by weeding and turn up soil around tree's base for both *C. cassia* and cassava. Cassava provides shade for *C. cassia* saplings during summer season. It is unnecessary to plant with other

agricultural crops from fourth year. The forest plantation canopy should be closed by this time.

During tending, regeneration species such as bamboo and herbal tree species should be kept in order to form a mixed multi storey forests with high economic and ecological values.

Thinning:

Cinnamomum cassia plantation can be gradually thinned from age of 7 - 8 years old when trees have diameter over 9 cm and over 7 m in height. If entire density at thinning time is 5,000 trees per ha (1 x 2 m in spacing on average), 2500 trees should be thinned. Thinned *C. cassia* are material for oil distillate and fire wood.

At the age of 15 - 16 years old, second thinning of plantation is conducted. The remaining stocking is 1,250 trees per ha.

Thinning principle: Different to many other plantations for timber, *C. cassia* trees for thinning are biggest trees and located evenly in the stand. After thinning remaining trees have much larger growing space and can grow quickly, especially the first 2 – 3 years after thinning.

Main harvesting: If targeted products is second grade oil and bark the plantation can be clear cut at 14 – 15 year old. Remaining stumps are kept for coppice rotation.

If highest quality of oil and bark and big timber are targeted the plantation should be clear harvested by age from 25 – 30 years old depending on site quality. Coppice rotation is also generally practiced.

(8). *Machilus bonii*

a/ Morphological and ecological characteristics

Morphological characteristics

Machilus bonii is evergreen large tree species, 25 - 30 m in height, 60 - 70 cm in diameter at breast height. It has straight trunk which has thin fragrant bark.

The single leaf are alternate, reverse ovate, wedge-shaped apex, fragrant, 4-6cm wide, 14-15cm long with flat green upper side and white lower side.

The flowers are borne in inflorescences that usually arise from the base of branchlets. The perianth has short hair on the outer. 6 perianth lobes which are equal and elongated. There are fertile stamens, 9 in 3 series, 6 outer stamina non-glandular, anthers with 4 cells, and 3 inner series of 2 stamina glandular on receptacles. The fruits are globose, 1-1.5 cm in diameter, calyx and enlarged on the fruiting pedicel. The ripe fruits are dark violet, white powder, and have a pale coloured pedical.

Figure 10 ***Machilus bonii***

(*Source: vafs.gov.vn*)

Ecological characteristics

Machilus bonii is distributed in Laos, Cambodia, and Vietnam in a wide ecological range. In Vietnam, it is scattered in secondary and primary forests in Lang Son, Bac Giang, Bac Can, Thai Nguyen, Thanh Hoa, Nghe An, Quang Binh and Gia Lai provinces. Generally, it grows in plant communities with *Castanea sativa*, *Canarium*, *Cinnamomum obtusifolium, Erythrophleum fordii and Ormosia pinnata* species.

The most suitable conditions for growth this species is humid tropical monsoon climate with annual rainfall of 800 - 2,500mm, and the average annual temperature of 20 -

27^{o} C. *M. bonii* is able to grow well in yellowish red or reddish yellow ferralsols soil on magma rock, sandstone, or schist.

Machilus bonii is a photophilic species and grows well on thick soil layer, rich humus and good drainage. It has light shade tolerance at youth; however; in order to attain a high growth rate, it is necessary open canopy for full sun light when it's older. Its growth can reach 1 m in height and 1 cm in diameter on average. Natural seed and coppice propagation well. *M. bonii* is suitable to mixed with some other broad leaf native species thus it's promising for forest enrichment by this species.

b/ Silvicultural techniques

Machilus bonii has a wide ecological amplitude, thus it is able to grow in the many Northern, Central and Southern provinces with an average rainfall of 1,500 -2,500 mm per year and average temperature of 20-27^{o} C.

The tree species favour a variety of soil types, therefore it is able to grow on good forest soil, reddish yellow or yellowish red ferralsols soil on acid magma or sandy, and some infertile soil.

Monoculture planting

Site preparation is conducted before planting up to 2 months by cutting, chopping vegetation.

Holes with dimensions of 40 x 40 x 40 cm are dug, then filled up the holes with composting manure 3-5 kg per hole or NPK fertilizer (5:10:3) with 0.1 - 0.15 kg per hole applied. Fertilizer is mixed with soil.

Suitable planting densities recommended is 1,100 trees per ha (3 x 3 m in spacing), or 1,330 trees per ha (3 x 2.5 m) or 1,660 trees per ha (3 x 2 m).

It is able to be mixed with with agricultural crops for the first 2 years. Legume species like *Fallopia japonica* should be mixed in the first few years to improve soil fertility. Use seedlings with containers to plant, remove containers, place seedlings upright in the mid pits, fill up pits to root collar, and press soil firmly.

Plant season is in the spring, February – April, and in the autumn, August –September, on cloudy days.

Tending for the first 3 - 4 years:

+ The first year: if it was planted in spring, it should be tended twice, May - June for the first time, including removing weeds, shrubs and vines; September-October for the second time, including cutting shrubs, vines and turning up soil around tree bases by 1 m wide. If it was planted in autumn, it should be tended for only once in October-November by cutting the weeds and vines only.

+ The second year: Two tendings includes clearing vegetation in planting strips and turning up soil around the

tree bases in February - March and July - August and clearing vegetation only in November.

+ The third and fourth years: tending twice per year, clearing vegetation in planting strips and turning up soil around the tree bases in February – March. The second tending in August - September only weeds are cleared.

Mixed planting:

There are number of indigenous species which can be mixed well with *Machilus bonii* like *Lithocapus ducampii, A.Camus, Erythrophleum fordii, Betula alnoides, and Lithocarpus fissus*. *M. bonii* can plant mixed with *Acacia mangium*.

Depending on each density - mixture procedure, it is suggested to plant with density of 1,100 trees per ha (3 x 3 m) distance or 1,660 trees per ha (3 x 2 m).

Species can be mixed in row or between rows. Tending is similar to monoculture planting.

Enrichment planting by strips:

M. bonii is used for enrichment of secondary degraded forests. Planting strips are cleared 6 – 8 m in width and remaining strip is 4 m. In planting strips vegetation are cleared. Holes with dimensions 40 × 40 x 40 cm are dug for planting.

Tending: Applying similar techniques like monoculture plantation for planting strips. In addition, it also need open canopy of trees around seedlings planted to facilitate growth of them.

(9) *Lithocarpus ducampii*

a/ Morphological and ecological characteristics

Morphological characteristics

Lithocarpus ducampii has a diameter at breast height of 50-60cm, is up to 30m tall with straight stems which have brown bark with a buttress at the tree base, a deep crack along the stem and rays that are conspicuous on the stem. The foliage is wide, and green all year around.

The single leaf is an alternate, lanceolate leaf 10 - 12cm long, 3-4cm wide with deciduous stipules; petiole of 1cm long, veins exposed on both sides, and rust hairs on the lower side in a star shape.

The inflorescence is a panicle. The male flower has 10-12 pistils, and a long and thin filament. The female flower grows in clusters, each cluster is formed from 2-5 flowers. The flowering season is May-June. The fruit without pedicel, long 1.5-2 cm and 1-1.5 cm in diameter forms the cluster of 3 flowers with many pointed scales. The fruiting season is in November - December.

Ecological characteristics

Lithocarpus ducampii found natural distribution in Laos, Cambodia, Vietnam and South China.

In Vietnam, it is distributed in primary and secondary forests in Lang Son, Bac Can, Thai Nguyen, Tuyen Quang, Ha Bac, Quang Ninh provinces. This species is rarely found in natural forests in the South of Vietnam. In the forest, it coexists with many trees such *as Erythrophleum fordii, Madhuca pasquieri, Vatica odorata, Cinnadenia paniculata, Cinnadenia paniculata, Canarium, Ormosia pinnata* and other Fagaceae such as *Fagus sylvatica, and Lithocarpus*.

In its distribution area, *Lithocarpus ducampii* grows in various soils and the finest soils are yellowish red or reddish yellow ferralsols on acid magma or clay schist.

The species can grow well in tropical monsoon climate with an average rainfall of 1,500-2,500mm annually and average temperature of 22 - 27^{o} C.

Regeneration by seed is good under a sparse forest canopy. The plant is lucipetal and needs a little shade at young age. The rotation is only 25 - 35 years because it grows fast. *L. ducampii* can be planted by monoculture or mixture and forest enrichment.

b/ Silvicultural techniques

Due to the wide ecological amplitude, it is easy to plant *Lithocarpus ducampii* in Northern provinces which have average rainfall of 1,500 - 2,500 mm/year, and average

temperature of 22-27^{o} C. It grow well in areas which have fertile forest soil. The most suitable soil for growing are fertile and light clay, but yellowish red or reddish yellow ferralsols soil on acid magma or clay schist.

Monoculture planting

Vegetation should be cut and chop before planting 2 months.

Planting holes have dimensions of 40 x 40 x 40 cm. 15 days, filled up holes with composting manure (3 - 5 kg) or 100-150 g NPK fertilizer (5:10:3) with per hole; mixed fertilizer with soil.

A suitable planting density is 1,100 trees per ha with spacing 3 x 3 m, or 1,330 trees per ha (3 x 2.5 m) or 1,660 trees per ha (3 x 2 m).

This tree species can grow with other crops for the first 2 years.

Use container seedlings age over 04 months to plant, tear out containers, fill up holes to reach tree's base collar, press soil firmly, and place seedlings upright in the mid pits.

Plant in the spring (February - April) and the autumn (August – September) on cool weather days.

It is vital to Carefully tend seedlings planted for the first 3 - 4 years.

+ The first year: if it is planted in the spring, it should be tended 2 times, May-June for the first time, including removing weeds, shrubs and vines; September-October for the second time, including cutting shrubs, vines and turning up soil around sapling's base to 1m wide. If it is planted in the autumn, it should be tended for only one time in October - November.

+ The second year: Three tending times, including weeding and turning up soil around sapling's base twice in February - March and July - August and weeding in November. Tending techniques are the same as in the first year.

+ The third and fourth year: two tending times each year, including weeding and turning up soil around sapling's base in February - April and weeding in August - September. Tending techniques are similar to the first year.

Mixture planting:

There are varieties of indigenous timber species which can be planted with *Lithocarpus ducampii* such as *Machilus bonii* Lecomte, *Cinamomum obtusifolium* A.Chev, *Erythrophleum fordii, Betula alnoides, Platanthera yosemitensis, Lithocarpus fissus* Champ. It can be mixed in rows and in patches with *Acacia mangium and Acacia auriculiformis.*

The suitable density is 1,100 trees per ha or 1,660 trees per ha using 3 planting methods including:

Mixture in rows

Mixture between rows

Mixture in patches.

Applying tending techniques like for monoculture plantation.

Enrichment planting by strip:

Applying to enrich natural degraded forest. Planting strips width 6 – 8 m are cleared, remaining strips width 4 m. Vegetation in planting strips are cleared. Holes are dug in planting strips with spacing of 2.5 – 3 m, hole's dimensions 40 × 40 x 40 cm.

All planting and tending techniques are similar to monoculture planting. Additional activities includes cutting branches in remaining strips to open space for planted seedlings, facilitating natural regeneration.

(10) *Melia azedarach*

a/ Morphological and ecological characteristics

*** Morphological characteristics**

Tree is up to 20-25m tall with a straight stem and sparse canopy. The bark is grey-brown and flat. The young branches have hairs.

Leaf has two or three times compound (odd-pinnate), alternate with hair on the petiole. Small leaves are ovate or lanceolate.

Bisexual, even flowers grow in clusters which sprout in axil.

Fruit has a drupe with lean outer testa, and woody inner testa. There are 4 - 5 cells and each cell contains one seed.

Ecological characteristics

Melia azedarach has a wide range distribution tropical to subtropical climate, but the most suitable climate is a hot and humid climate with rainfall above 1,000mm and elevation below 500m.

It can grow well in various types of soil from acidic to slightly alkaline or saline soil.

It is a lucipetal species, with seasonal growth and has a deciduous leaf in winter, and buds sprout in spring. The taproot is the strongest growth in tree's base system. Regeneration ability from shoots and roots is very strong.

It grows fast and has short rotation thus it's not suitable for growing for large timber. It can achieve harvestable size after 5 – 6 years planting. However, to achieve saw log timber size it needs rotation 10 – 15 years.

Currently there is high demanding of *Melia azedarach* timber. The species has wide ecological zone. Thus *M. azedarach* have been planted in many provinces in Vietnam

b/ Silvicultural techniques

* Planting conditions:

Most suitable planting areas have average annual temperature of 16 - 22^{o}C, annual rainfall of 1,700 – 2,000mm, and elevation less than 500 m above sea level.

It should plan on soil after slash-and-burn, alluvial soil with an average mechanical component, drainage, and slight to average acidic soil (pH 5-6.5).

It can be planted as plantation species and as scattered trees in farm from delta to mountainous areas.

* Planting season

Planting in the spring at the beginning of spring.

Plant container seedlings, bare root, cuttings or direct seeding. Direct seeding has been applied in mountainous areas, people often remove vegetation, burn, hoe and direct seed.

* Planting density:

Planting density 1,100 trees per ha (spacing: 3 x 3 m).

Planting density 1,600 trees per ha (2 x 3 m).

* Site preparation:

+ clearing vegetation around pits within 1 - 2.2 m in diameter. In monoculture or mixed plantation clearing all vegetation before digging holes and planting.

+ Digging pits following contour lines on sloping land. If direct seeding, hole has dimensions of 30 × 30 × 30 cm. For intensive plantation, dig pits with dimensions of 40 × 40 × 40 cm. When digging holes, put upper and lower soil on different sides and dig pits 1 - 1.5 months before planting.

+ Fill up pits: Fill up 2/3 pit with fresh, topsoil mixed with composting manure (2 – 5 kg) or 0.2 kg NPK per pit. Fill up pits 10 - 15 days before planting.

- Silvicultural techniques:

+ Use hoe to dig up soil to the middle of hole so that there is enough space to put container seedlings in, then Carefully remove container by knife, finally put the seedling in the mid pit. If seedling is bare rooted, keep tree’s base shape.

+ Select shade or light rainy days thus soil is moist enough to plant.

+ Fill up soil gradually and press soil firmly around container (or root) to 1 - 2 cm higher than tree’s base collar. After that, keep tree’s base moist by covering with garbage or cut weeds.

+ Direct seeding: seeds that have been processed through combustion is sow (1-2 seeds in each pit, then fill up seeds with porous soil 2 – 3 cm in thick.

- Replanting:

+ Replant dead seedlings 8-10 days after first planting.

+ Direct seeding: 20 to 25 days after germination, collect seedlings in pits to grow in any holes which have no seed germinated. Choose shade days and moist forest soil to replant. Seedlings for replanting must need to meet the requirements like seedlings for first planting.

4. Tending and protection after planting

- Tending for 3 consecutive years.

+ For planting with seedlings:

The first year, tending two times:

The first time is after planting 1 - 2 months. Weeding and turning up soil around sapling's base to a width of 80cm.

The second time is in October and November. Weeding and turning up soil around sapling's base to a width of 1m.

The second year, tending 3 times:

The first time is in March-April; carrying the same activities as the first year, with dressing fertilizer – 200 g NPK or 500g microbial organic fertilizer per tree.

The second time is in July and August; clear vegetation in the hole area, weed to a width of 1m around sapling's base.

The third time is in October and November, remove vegetation around tree's base to a width of 1 m.

The third year, tending 2 times:

The first time is in March or April; remove vegetation in the pit area, branches pruning to a height level of 1.5-2m. Weed around tree's base to a width of 1m, use dressing fertilizer twice as for the first time, but manure to a width of 40-50cm from tree's base.

The second time is in July or August; cut the vegetation in the pit area, cut diseased tree species, weed around sapling's base.

After 4 - 6 years, the forest canopy should be closed; thinning first time at age 6 - 7 (depend on density). Thinning intensity of 30 – 50 % of current number of trees in the plantation stand.

+ Planting forest by direct seeding:

After 15-days of germination, turn up soil, fill up tree's base and re-sow to the pits without any germination.

Tending 2 times per month with the main tasks are weeding, turning up soil around tree's base to a 0.8-1 m diameter. Remove vines, shrubs within 2 m diameter. Leave a strong seedling at each pit at the end of the first year. Apply the same tending techniques for seedling planting in the second and the third year.

The rotation is 10 - 15 years.

Protection: commonly focus on people and cattle from destroying the tree species.

(11) *Styrax tonkinensis*

a/ Morphological and ecological characteristics

Morphological characteristics

Styrax tonkinensis is an average timber, 18 – 20 m tall, 20-25 cm in diameter at breast height with relatively round, white stems which have thin bark. The foliage is thin and sparse. The taproot grows weakly, whereas the secondary root system grows quickly and distributes above 80% on 0 – 20 cm top soil layer. As a consequence, fertility of the topsoil layer has significant impact to the growth of *Styrax tonkinensis*.

Ecological characteristics

Styrax tonkinensis is an endemic species of the North, Vietnam in evergreen broadleaf forest with broken foliage or in the forests mix with *Bambuseae, Bambusa nutans and*

Schizostachyum aciculare. It is widely distributed in mountainous provinces of the North West, North East to the North Central - Thanh Hoa and Nghe An. It is very popular in Yen Bai, Tuyen Quang, and Phu Tho, and also distributed in Lang Son, Bac Can, Thai Nguyen, Cao Bang, Ha Giang, Lao Cai, Lai Chau, Son La, Hoa Binh, along the upper part of Hong, Lo, Da and the Ma river basin. Additionally, it has been grown in the Central region of the North, Vietnam for a long time.

Normally, *Styrax tonkinensis* naturally regenerates after slash-and-burn or on bared forestry land which has just been deforested. It can grow well in areas which are remaining good soil. *S. tonkinensis* is suitable with soils with different parent rock, except for limestone. *S. tonkinensis* naturally regenerate in monoculture or mixture with *Neohouzeaua dullooa* (Gamble) A. Camus and scattered other timber trees.

Styrax tonkinensis is a pioneer species, light-demanding, relative high cold tolerant but has low heat and drought tolerance (especially young trees). Thereby, it is only found in humid areas and fertile soil. It grows fast with a short rotation of 10 - 12 years.

During leaves falling off, *S. tonkinensis* stops growing, i.e. from November - December to the next January - February. Its deciduous feature and sparse canopy are the basic weakness of *S. tonkinensis* in terms of environmental

protection. There are 2 kinds of *S. tonkinensis*, including one with high resin which grows on uplands and one of low resin which grows in lowlands for timber.

Suitable climate of *S. tonkinensis* is average annual temperature of 19 - 23^{o} C, annual rainfall of 1,500 - 2,000 mm, dry months no more than 3 in number and there is no influence of a Foehn wind which is dry and hot.

S. tonkinensis is capable of growing in reddish yellow ferralsols soil on low sloping lands with a thick weathering soil layer and relatively heavy mechanical components of soil, parent materials of gnai, mica and philit schist, neogene sediments, pocphiarit, and acient alluvial. *S. tonkinensis* grows well on deep and moist soil. It's not suitable to plant on limestone soil, not drainage soil, gley soil; and weak growth on degraded soil, sandy soil and laterite soil.

b/ Silvicultural techniques

Depending on the degradation levels of forest soil under national standard TCVN 3131 - 79 issued by Decision No.657 dated on 27/12/1979 by the State Science and Technology Committee, forest soils for planting *Styrax tonkinensis* are divided into 6 classes. It depends on the characteristics of soil and the vegetation profile which indicates the levels of soil degradation. Of which, soil thickness plays a key role.

Class I: Intact forest soil and slight degraded forest soil (a soil layer is above 15cm thick, above 4% humus, porous);

Class II: Mildly-degraded forest soil (A soil layer is above 10cm thick, 3.5-4% humus, porous);

Class III: Average degraded forest soil (A soil layer is above 10cm thick, 3-3.5% humus, properly porous);

Class IV: Quite-severely-degraded forest soil (A soil layer is above 5cm thick, 2-3% humus, poorly porous);

Class V: Severely-degraded forest soil (A soil layer is below 5cm thick, 1-2% humus, tight);

Class VI: Very-severely-degraded forest soil (A soil layer is not available, below 1% humus).

It is difficult to plant *Styrax tonkinensis* on soil of class V and VI.

Soil of class I: The planting density is 1,600 trees per ha (2.5 × 2.5 m spacing) to 2,000 trees per ha (2.5 x 2 m). Soil of class II: the planting density is 2,500 trees per ha (2 x 2 m). Soil of class III: the planting density is 2,500 - 3,300 trees per ha (1.8 × 1.8 m or 2 ×1.5 m).

On the low slope hills, clear whole planting area. The hills with slope of above 25^{o}, leave a forest strip on the top of at least 10m wide on each side. The areas with a steep slope of over 100 m in length, leave forest strips of 6 - 10m width along the contour lines and forest remaining strips far

from each other 50 – 60 m. Clear and burn the vegetation 10 - 15 days before digging holes.

Depending on crops and soils as well as conditions, seed of *S. tonkinensis* can be directly sowed, plant container seedlings or stumps; direct seeding, however, has become the popular method in production sector.

The seed quality must meet the requirements under the Decision at national standards No. 3127-79, TCVN 3128-79, TCVN 3129-79 and TCVN 3130-79 issued in conjunction with Decision No.657/QD dated on 27/12/1979 by the State Science and Technology Committee.

- Direct seeding:

Dig pits with dimensions of 20 x 20 x 30 cm. Then, seed as soon as possible. Sow 5-6 seeds in each pit, 5cm apart. Fill up the seeds with soil thick layer 2 cm.

Seeding time: from October to December, do not sow too late, until February of the solar calendar.

- Planting with container seedlings:

Dig pits with dimensions of 30 x 30 x 30cm.

Planting duration: January, February, and March. Tear out containers and carefully not to break containers.

- Planting with the stumps:

The stumps are taken from the seedlings in the nursery with ages 10 to 12 months, are 1.2 - 1.5 m tall, and 1 – 2 cm in diameter. Cut the stem, leave the segment that is 3-5cm tall from tree's base collar.

Dig pits 35-40cm wide, and 30cm deep. Plant in January-February. When planting, be Careful not to make tree's base twisted, fill up soil close to tree's base collar, and only leave the stem on the ground that is 2-3 cm tall.

After 7-10 days, the tree species sprout new shoots. for a month. If the survival rate is no more than 85%, replant right after the seeding season. Replant with container seedlings.

Tending for 3 consecutive years:

- Tending 4 times in the first year:

The first time: after 15-20 days, the container seedlings have 3-5 leaves. Break the scum and mildly turn up soil around pits. Prune and leave 1-2 strong seedlings.

The second time: when the seedlings attain 25-30m in height. Clearing weeds. Depending on the weather and growth level of the seedlings, decide whether to have a strong or weak level of clearing. Leave regenerating broadleaf tree species, *Aganonerion polymorphum*, and *Schizostachyum* which are unaffected in their growth, continue to prune and only keep the strongest shoots.

The third time: when they are 60-70cm tall, clear weeds and vines. Thin and leave a plant per pit if direct seeding.

The fourth time: remove weeds, vines, and shrubs in October-November. Turn up soil up to 10-15cm deep, 60cm diameter and fill up tree's bases.

- The second year: the planted trees are nearly close the canopy must be tended 2 times. Tending includes cutting vines, shrubs, turning up soil around sapling's base to a width of 60cm and filling up tree's bases.

- The third year: cut the vines, gradually thin to reduce the density (if necessary). Cut diseased tree species, but leave all of regenerating trees that are unaffected in their growth. Turn up soil around sapling's base to 60cm wide and fill up tree's bases.

(12) *Aquilaria rugosa* L.C.Kiet & PJ

a/ Morphological and ecological characteristics

*** Morphological characteristics**

Aquilaria crassna Pierre ex Lecomte is an evergreen timber, 20-30m tall, 60-80cm in diameter with a straight brown stem which sometimes has hollow strips. Tree's base has a buttress 2m long. The bark is flat and grey-brown with a crack along the stem, easily peels and there is stripping upside down from tree's base. The sapwood is white, quite

rich in fibre (celluloz). The branches are thin, twisted, brownish, hairy or flat with sparse canopy. The single leaves are alternate. The petiole is 4-6mm long, with dimensions of 8–15x2.5–9cm. Oblong leaf blades in ovate or oval, papery thin or nearly chewy as skin with glossy green upper side and greenish hairy smooth lower side. The leaf base is pointed or quite square. The apex is oblong, pointed, and sharp at the top. The secondary veins have 15-18 pairs, erratically change, clearly-exposed veins on the lower side. Inflorescene is umbel or cluster, sprouting in the axil or the head of branch. The stalk is thin and 2-3cm long. The flower is small, sample 5 with sepal formed in the lower part which is bell-shaped, yellow-green, pale white or yellow-brown and has thin hairs on the outer side. There is an almost flat inner side with 10 clear veins. Five perianth tubes are oblong and ovate. They are 12-15 mm long, attached near the sepal throat; stamina 10; the ovary has an ovate shape, 2 menus, dense hairs and the ovary base has nectar glands. The capsule is nearly opposite ovate, pear-shaped, 4cm long, from 2.5 to 3cm in diameter and has soft short hairs. When dry, it cracks into two pieces and usually has only one seed per fruit.

*** Ecological characteristics**

A minority community of *Aquilaria malaccensis* are found in the tropical evergreen forest, primary or secondary forest, or on mountainsides or ground with an altitude of 50

– 1,000m (-1,200 m) above sea level. In Vietnam, *Aquilaria malaccensis* is scattered in mountainsides with low slope and drainage.

Figure 11 *Aquilaria rugosa*

(Source: vafs.gov.vn)

A. crassna favour typical ferralsols soil, weathered from rocks, slate or granite. The topsoil layer is usually thin, quite moist, acidic or near-neutral (pH ranging around 4-6).

Aquilaria malaccensis also grows in small quantities in Malaysia and Northeast India with about 2.5 individuals/ha. In Northeast India, it is also scattered in areas up to 200-700 m, even up to 1000m high. Additionally, it is capable of growing in areas with rainfall ranging from 1,500–6,500mm, and maximum average temperature of 22–28^{o}C. According to the observation results in Northeast

India, this plant has a broad distribution in humid evergreen or evergreen forest, and is rarely found in semi-deciduous forest. Nonetheless, it is a fact that before and after producing *A.malaccensis*, it is possible to grow it well in the areas with an altitude of about 40 m above sea level.

A.malaccensis is able to adapt to soil weathered on lava, denatured rocks, as well as soil weathered from sandstone.

b/ Silvicultural techniques

*** Dig pits**: The dimensions are 40x40x30cm. When digging pits, put topsoil on the one side. Dig pits a month before planting; fill up pits with topsoil mixed with fertilizer NPK at 0.3-0.5kg/pit mixed with composting manure at 1kg/pit.

*** Planting density:** 800 trees per ha**:** 2.5 x 5 m in spacing; 1,160 trees per ha (3 x 3 m). If mixed with coffee, cashew, logan or pepper the *A.malaccensis* density is only 250 - 500 tree species.

*** Silvicultural techniques:** The seedlings must meet the requirements; planting after rainy days in the beginning of the rainy season. The best condition to plant is light rainy days with cool and moist weather. Planting by contour lines to prevent soil erosion. Remove the plastic container, place the container 1 – 2 cm deeper than natural soil layer. Balance the seedlings in the mid pit, fill up the pit and press firmly, fill up tree's base to 2-3cm higher than the

surrounding area. After mixing with, weed, scarify around sapling's base to 1-1.2m in diameter. Fertilizing two times in the first and second year with 100 g NPK per tree. Afterwards, there is only a need to weed, scarify, and prune branches to stimulate the growth.

2.1.2. Species for natural forest restoration in Vietnam

Indigenous tree species have been planted for forest restoration in Vietnam. Below are summary

1/ Forest-enrich model with Chukrasia tabularis, Ormosia balansae, Toona suremi, and Cinnamomum parthenoxylon.

- Location: forest enrichment model in Doan Hung district, Phu Tho province (Nguyen Van Thong, 2005)

- Implemented in an area of 10.9ha in 1993, allocated to households for long-term protection;

- Degraded forests for enrichment is in status IIIA[1] which has completely degraded forest structure, insufficient quantity of native timber species (less than 1000 trees per ha), regenerating trees have uneven distribution in the stand.

- Methods:

+ Adjustment highest tree layer sof the forest: remove poor quality trees (twisted, diseased, noncommercial trees)

+ Openning strips with 2 m – 4 m width, the remaining strips will be 3 m width.

+ Digging planting holes with the dimensions of 40 x 40 x 40 cm.

+ Planting: on the clear strip of 4m, planting *Chukrasia tabularis, Ormosia balansae, Peltophorum pterocarpum, Toona suremi, Cinnamomum parthenoxylon* (lucipetal trees). On the remaining strips (2 m width) planting *Michelia mediocris* Dandy, *Cinnamomum parthenoxylon* (less light demanding tree species).

+ For the remaining strip: natural regenerating trees (height > 2 m) are tended as same as planted trees.

* Achievements:

+ Available natural regenerating tree species are kept to combine with adding high economic & ecological value trees. This method is enhancing forest composition for higher economic and ecological values.

+ Forest enrichment with 3 species, including *Lithocarpus fissus* Champ, *Michelia mediocris* Dandy and *Cinnamomum parthenoxylon* are successfully.

* Limitation:

Three native timber species, *Toona suremi, Chukrasia tabularis and Ormosia balansae* were trialed but not successfully.

The dimensions of strips is inappropriate. It is suggested to research more on the dimensions of strips, seedling

standards for planting, and ecology of enrichment tree species.

2/ Forest enrichment with Michelia mediocris

- Location: Kon Ha Nung Forest Research Station, Gia Lai province, the Central Highlands (Ho Đuc Soa, 2004).

- Objects: degraded natural forest after over-exploitation or uncontrolled exploitation with standing volume of timber < 120m^3 per ha; number of trees with DBH > 8 cm is only 200 – 300 trees per ha; Only 30 - 40% trees are commercial tree species; Natural regeneration capacity is weak with only 1,000 – 2,000 regenerating trees per ha in which number of regenerating trees belong to commercial species are only 30 - 40 %. Forest is significantly occupied by vines, lianas and creepers.

- Experimental model:

At the Forestry Experimental Station of Kon Na Hung, *Michelia mediocris* Dandy has been tested in two methods in 1982-1985:

+ Plantting strip: 5 m wide, remaining strip 10 m wide. Enrichment planting density is 300 trees per ha.

+ Planting by group after forest has been selectively logged.

+ *Michelia mediocris* were planted since 1986. Measurement results in November, 2000 (after enrichment 14 years) showed that: trees planted on cutting strip has

survival rate of 70 - 80 %, diameter increased by 0.7 cm per year and height increased by 0.8m per year. A vegetation cut in the seventh year (1993), reduced the canopy cover of strips by 0.3-0.4 helped to increase diameter and height faster than that of the unopened canopy: D increased by 0.9cm/year, H increased by 0.92m/year. Planting in gaps with a density of 500 trees per ha has survival rate of 80%, diameter increased by 0.9 5cm per year, and height increased by 1 m per year.

3/ Forest improvement with Terminalia chebula

- Location: Forest Science Centre of Central of North Vietnam

- Area: 10.9 ha of forest was contracted to local households for long-term protection;

- Vegetation types: a mixture of *Neohouzeaua dullooa* (Gamble) A. Cams and *Saccharum spontaneum*, scattered with some regenerating trees. Clearing the strips 3 m wide, leaving regenerating commercial tree species, and totally remove other tree species.

- Hole are dug, dimensions 40 x 40 x 40 cm.

- Planting density: 1,000 trees per ha (5 x 2 m spacing)

- Seeding: in April 1989, plant in September 1989

- Survey results in December 1998 showed that: After enrichment and maintainance the survival rate was 95% with

the average diameter 15.0 cm, average top height 12.2 m, average canopy diameter 3.7 m, and average height under the biggest living branch 7.41 m. The forest has numerous regenerating trees, primarily including high valuable timber species *Erythrophleum fordii*, *Diospyros kaki*, etc. These new regenerating trees need to be monitored and tended to create new forest canopy layer for replacement of degraded forest canopy. Remarkably, *Terminalia chebula* grows very well, rapidly exceeding shrubs on the forest floor, has quick canopy closure, and a good ability for killing and restraining invasive bamboo and grasses *Schizostachyum aciculare* and *Saccharum arundiraceum* Retz. It is recommended to carry out more research and experiments to improve the forest soil by using similar vegetation.

4/ Forest improvement with Prunus arborea, Cinnamomum parthenoxylon, Quercus platycalyx

- Location: Forest Science Centre of Central of North Vietnam

- Area: 7.7 ha land was allocated to households for long-term protection;

- Vegetation: there are shrubs, vines, lianas creepers and scattered regenerating trees. Clear cut vegetation but leave regenerating valuable tree species.

- Digging holes with dimensions of 40 x 40 x 40 cm

- Planting density: 625 trees per ha (8 x 2 m spacing)

- Seeding season: *Prunus arborea* and *Cinnamomum parthenoxylon* are sowed from January to February in 1990, and in April 1990 for *Quercus platycalyx*

- Result: current forest density of 1,100 trees per ha, survival rate 50 %

- Result of growth: *Prunus arborea* and *Cinnamomum parthenoxylon* have grown well, particularly their diameter. *Quercus platycalyx* is average growth. Regenerating trees are growing well. It is possible to plant all above three native tree species to improve the forests.

5/ Forest enrichment with indigenous tree species such as Lithocarpus ducampii, Machilus bonii, and Erythrophleum fordii

- Location: Luong hamlet, Bac Thai (Vu Quang Nam, in 1992)

- Silvicultural methods:

+ Local vegetation removal (2 m width strip)

+ Holes were dug with dimensions of 40 x 40 x 40 cm and 50 x 50 x 50 cm.

+ Seedling height < 0.5m (in container); height > 0.5m (bare root).

+ Planting density and distance; 330 trees per ha; 500 trees per ha (5 x 6 m)

+ Tending 6 times per 3 years (First year 3 times; second year: 2 times and third year: 1 time)

- Growht of trees in the model (*Lithocapus ducampii* + *Erythrophleum fordii* + *Machilus bonii* Lecomte) after 13 years.

+ Entire stands have H = 13.85m

D = 14.25cm

V = 92.38m^3 (7m^3/ha/year)

+ Additional tree species v = 37 m^3 (2.8m^3/ha/year)

+ Natural regeneration trees v = 55.38m^3 (4.2m^2/ha/year)

The study revealed that the improvement and enriched model of natural forest state Ib by strips with *Lithocapus ducampii, Erythrophleum fordii, and Machilus bonii* Lecomte at the experimental zone of the Luong hamlet is a good model which can be extended in areas with similar natural conditions.

6, Forest enriched with Cinamomum obtusifolium:

+ The seedlings are made from seeds and can be planted at an age of 6 - 7 months (or a year), when 30-50cm (or 50-65cm) tall.

+ Planting soils: poor forest soil, secondary forest, soil with shrubs, soil layer is thicker than 100 cm.

+ Planting and land treatment method: with poor forest soil, remove vegetation in the strips; extend strips to 2 - 2.5 m wide, the distance between the strips is 6 m, the distance between the tree species 3 m. It is able to mix with with other tree species which having similar ecological characteristics such as *Michelia mediocris*, *Paramichelia braiannesis*. They can also be mixed with *Cinamomum obtusifolium*. When tending the vegetation, people must ensure that the seedlings in the first phase are not exposed into hot a temperature. Dig pits with dimensions of 30 x 30 x 30 cm. Planting density is 250 trees per ha, 500 trees per ha or 1,100 trees per ha.

+ Planting season:

Spring crop: February - April

Autumn crop: July - September

+ Tending and maintenance:

Plant in poor forest with shrubs, Tending for first 3 continuous years. Limit vines and creepers negative impacts seedlings as much as possible. Tending 2 times in the first year if it was planted in autumn. Tending 4 times if enrichment trees is was planted in spring. Remove vegetation twice per year, scarify and fill up roots. Fill up roots twice before and after the rainy season. The second and the third year do the same tending as above. In the third

and fourth year, planted trees are 3 - 4m tall and can merge into the secondary forest.

They are harvestable and use when they attain 30 - 35 cm in diameter, 20 - 25 m in height at age of 20 - 25.

In Cau Hai, after planting for 3 years, the survival rate is 85 – 90%. Tree species grow evenly with average height 4 - 4.5m, and average diameter 4 - 5 cm. This is one of the best species in trials in Cau Hai. Additionally, *Michelia mediocris Peltophorum pterocarpum, Gmelina arborea* and *Toona suremi* are also promising for enrichment planting.

7, AKECOP project

The project sponsored by ASEAN-Korea Environmental Cooperation Project (AKECOP) was implemented in Hoa Binh and Phu Tho provinces, North Vietnam. Two research components were designed in the project, including:

(1) Restore degraded secondary forest by silvicultural techniques. The total area of 15 ha was set up by 2 formulas, not replicated at the two locations.

a/ At Tu Ne, Hoa Binh province: 7.5 ha, including:

+ 5 ha trial model for promoting natural regeneration with additional planting in strips, and

+ 2.5 trial model ha for promoting of natural regeneration with additional planting in gaps

b/ At Cau Hai, Phu Tho province: 7.5ha, including:

+ 5 ha trial model for promoting natural regeneration with additional planting in strips; and

+ 2.5 ha trial model for promoting of natural regeneration with additional planting in gaps

(2) Restore degraded forest land by using an agroforestry system: the total area of 5ha, including:

a/ At Tu Ne: 2.5 ha trials includes enrichment Planting formulas:

(1) Cinamomum parthenoxylum + Manihot esculenta + Tephrosia candida

(2) Cinamomum cassia+ Tephrosia candida

(3) Dimocarpus logan + Pandanus tonkinensis+ Tephrosia candida

b/ At Cau Hai: 2.5 ha trials includes enrichment Planting formulas:

(4) Acacia hybrid + Arachis hypogaea+ Tephrosia candida

(5) Acacia hybrid + Vigna cylindrica + Tephrosia candida + Lithocarpus fisssus

(6) Acasia hybrid + Manihot esculenta+ Tephrosia candida + Castanopsis phuthoensis

These experiments mainly focused on technical performance rather than experimental research. Thus, the expert group who evaluated the mid-term of the project criticised that the experimental design was unclear and illogical. They also recommended amending and supplementing experiments so that comparison with different techniques could be undertaken. Basically, the project-implementing group carried out additional experiments in the second year for both the two researching components, including:

(1) Component 1: restore secondary forest with silvicultural techniques

a/ Set up the forest-restoring experiment with 5 formulas and with two replicates at Tu Ne:

Formula 1: Promote natural regeneration with additional planting of indigenous broadleaf tree species in strips 8 m width;

Formula 2: Plant indigenous broadleaf tree species with *Acacia hybrid* as the auxiliary tree;

Formula 3: Plant indigenous broadleaf tree species with *Fallopia japonica* by direct seeding as the supporting tree;

Formula 4: Plant indigenous broadleaf tree species under shrub canopy;

Formula 5: Plant indigenous broadleaf tree species under available *Acacia* forest canopy

b/ Set up the experiments with 4 formulas at Cau Hai with 2 replicates:

Formula 1: Plant indigenous broadleaf tree species on vacant land;

Formula 2: Plant indigenous broadleaf tree species under shrub canopy;

Formula 3: Plant indigenous broadleaf tree species with one-year-old *Acacia hybrid* as the supporting tree

Formula 4: Enrich the indigenous-tree forest in gaps

(2) Component 2: restore degraded forest soil with an agroforestry system: set up 2 ha in both places:

a/ In Tu Ne with following formulas:

Formula 1: *Cinamomum cassia* – Control experiment

Formula 2: *Cinamomum cassia + Canarium album*

Formula 3: *Cinamomum cassia + Canarium album + Manihot esculenta*

Formula 4*: Cinamomum cassia + Canarium album + Manihot esculenta+ Tephrosia candida*

b/ Cau Hai with the following formulas:

Formula 1: *Acasia hybrid* + *Peanut* + *Tephrosia candida*

Formula 2: *Acasia hybrid* + *Manihot esculenta* + *Tephrosia candida*

In the trials of forest enrichment technique, the two most important factors defined are species selection and light adjustment. To carry out these studies, 4 experiments have been implemented as follows:

+ Experiment 1: Promote natural regeneration by planting indigenous broadleaf tree species in strips.

+ Experiment 2: Promote natural regeneration by planting indigenous broadleaf tree species in gaps.

+ Experiment 3: Utilize the available vegetation's canopy to adjust the light for planting indigenous tree species.

+ Experiment 4: Plant indigenous broadleaf tree species with other supporting tree species such as *Acacia hybrid* and *Allopia japonica*.

These experiments have been set up in Tu Ne and Chan Mong with two or three replicates. Experiment 1 and 2 are aimed at: (1) to identify the growth rate of natural regeneration species and enriched tree species depending on the dimensions of the strips and gaps; (ii) to evaluate species diversity over time, which was conducted by the system of

temporary standard plots arranged in the research area. Set up 20 standard plots, each plot of area 900m^2 (30 x 30 m) and count the tree species with DBH > 10 cm and also the targeted regenerating trees.

Experiment 3 is aimed at developing forest enrichment techniques on the sites with the available shrub vegetation where forests are severely degraded. Experimental plots were set up in the areas which there was a lack of mother trees for sowing seeds and weak ability of natural regeneration. Strips were opened to Eas t –West with a width of 4, 8 and 10 m subject to height of existing vegetation. The distance between strips was 10m; two sets of gaps with different dimensions were tested, including gap < 50 m^2 and gap > 100 m^2 with number of gaps 5 - 9 per ha. There were different indigenuous tree species trialed such as *Cinamomum parthenoxylum, Canarium album, Peltophorum pterocarpum, Lithrocarpus fissus and Erythrophloem fordii*.

The purpose of experiment 4 was to examine the capability of silvicultural techniques on planting native species on bare land with supporting tree species. *Cinamomum parthenoxylum* was planted using 4 different formulas: (1) *C.parthenoxylum + Acacia auriculiformis*; (2) *C. parthenoxylum + Tephrosia candida* (direct seeding); (3) *C. Parthenoxylum* was planted under *Acacia auriculiformis* canopy which was pruned; and (4) *C. Parthenoxylum* was planted on bared land without supporting tree species

(control). These experiments were in a randomly arranged in complete block and repeated three times.

The main research findings

- Poor secondary forest in the research area has remained an impediment to natural regeneration; however; in some cases regeneration seedlings were insuffucient due to seed tree shortage; or the natural conditions were unfavourable for seeds to approach soil as well as germination. Then, it is needed to use technical solutions in order to promote natural regeneration by adding indigenous tree species in strips to restore these poor-forest areas.

- Bare land/ scrub land can possibly be restored by planting indigenous tree species with the support of rapid growing tree species such as *Acacia auriculiformis, Acacia mangium, Acacia hybrid, Tephrosia candida.*

- The main problems of forest restoration by indigenous species are light adjustment and species selection. Light adjustment is based on light demand of specific species at different development stages.

- The reseach identified three tree species with different light demands in the first stage, including: (1) natural lucipetal species need 75 - 100 % natural light such as *Cinnamomum parthenoxylon* and *Peltophorum pterocarpum*; (2) neutral light demanding species require 75 – 85 % natural light such as *Canarium album and*

Lithocarpus ducampii; and (3) shade-tolerant species which is suitable with 50 - 75% natural light such as *Erythrophleum fordii.*

- Adjusting light and moisture for indigenous tree species to enrich secondary forest and shrub land can be based on current forest floor conditions or planting of fast growing supporting species.

8/ Pham The Dung (2014) presented the evaluation result of pilot planting of some fast growing tree species mixed with indigenous commercial species in South Eastern Vietnam.

According to the research, *Erythrophleum fordii, Senna siamea, Khaya senegalensis, Swietenia macrophylla and Terminalia chebula* are used for forest enrichment.

The experiments were carried out in 1999 at subplot 9, Compartment 382 under the economic forest management board in Tan Lap - Binh Phuoc province. Degraded secondary forest was treated in strips 4 m width following East – West direction, the distance between strips is 6m.

The result of this research showed that:

- Over 8 years, *Senna siamea, Terminalia, Erythrophleum fordii and Swietenia macrophylla* were indentified as most promising species. The average annual growth in diameter of this species is not less than 1 cm per

year and the average annual growth in height is not less than 1 m per year. *Terminalia chebula*, however, has a low survival rate, and thus it is not recommended for planting.

- Natural forest quality on remaining strips: forest has been classified into two distinct layers including the upper tree layer and the lower tree layer. The upper one has an average height of 15 m and canopy cover 20 – 30 %. The main tree species on the remaining strip are *Lagerstroemia speciosa, Shorea vulgaris, Sindora cochinchinensis Baill, Leucaena leucocephala, Peltophorum pterocarpum and Adenanthera microsperma*. Average height of lower trees is 11 m, the canopy cover is 70 – 80 % with the main tree species being *Cratoxylum formosum, Aporosa tetrapleura, Lagerstroemia speciosa, Leucaena leucocephala, Ingerophrynus galeatus* and *Garcinia oblongifolia*.

- The canopy cover of enriched tree species on strips reaches 95%. Planted tree species have an open capony and mixed with the regeneration species to creat forest stand. There are four trialed species has high growth rate, including *Cassia siamea, Terminalia chebula, Erythrophleum fordii* and *Swietenia macrophylla*. This model is promising for extending because it's trial scale 20 ha and taken 8 years to observe. The forest stand structure is relatively stable. Only two species of *Canarium albumand and Parashorea chinensis* are considered unsuccessful owing to their low survival rate.

9/ Forest enrichment by planting Dracontomelon duperreanum

* Planting spacing: 4 x 3m (between rows spacing is 4m and between tree spacing is 3 m)

* Duration: planting a spring or autumn crop

* Digging holes

- Hole dimensions: 40 x 40 x 40 cm

- Holes following contour lines

- Put topsoil on one side when digging hole

- Digging holes 1 - 2 months before planting

* Fill up holes with applying fertilizer

- Digging topsoil around the pit mouth. Then fill up the pit with topsoil. Finally, fill up the remaining soil layer.

- Pits must be filled, the middle pit is 5cm higher than the pit mouth

- Fill up the holes at least 15 days before planting

* *Forest enrichment by planting Dracontomelon duperreanum*

- Plant in shade, cool, light rainy weather

- Remove plastic containners with a small sharp knife or razor

- Turn up soil on the mid pit and dig a small pit 3 - 5cm deeper than the container height. Put in the seedling in the middle pit with the container surface balancing the pit mouth. Fill up tree's base with small amount of soil, then press firmly by hands or legs. Finally filling up tree's base with a small soil layer on the top, 1 - 2 cm wide.

*Techniques, tending and nurturing of plantation

- The first year:

Planting in the spring crop:

+ Tending times: two times

+ Duration: July - August and October - November

+ Techniques:

- The first time: clear vines, weeds, shrubs to 1 m width on strips combined with preparing new planted seedlings.

- The second time: clear vines, weeds, shrubs on strips to 1m width and fill up tree's base to 0.8m in diameter.

- Replant dead tree species.

Plant in the summer-autumn crop:

+ Tending time: one time

+ Duration: Octorber - November

+ Techniques:

- Clear vines, shrubs in strips to 1 m wide.

- Fill up tree's base to 0.8m in diameter.

- Replant dead trees.

- The second year.

+Tending times: 3 times

+ Duration: February - March, June - July, October - November.

+ Techniques:

- The first and second time: remove vegetation strips, leave good regenerating trees. Scarify around sapling's base to 1 m in diameter.

- The third time: remove vegetation on strips and cut tangled branches, shrubs on the remaining strips.

- In remaining strip: cut vines, creepers and diseased trees. If targeted regenerating trees are competed by other non commercial trees or scrubs it is needed to remove these plants and mark targeted trees for tending.

- The third year:

+ Carry out the same activities as tending in second year: cut vines and diseased tree species.

+ Replant dead seedlings.

+ If targeted regenerating trees are strongly competed by non-purpose tree species and shrubs, it is necessary to remove these plant.

- The fourth year:

+ Tending times: two times.

+ Duration: April - May and October - November

+ Tending techniques:

- The first time: Weeding on planting strips, cutting shading branches on *Dracontomelon duperreanum* saplings.

- The second time: Weeding on planting strips and turning up soil around tree's base, fill up tree's bases within a diameter of 1 m.

- Clearing vegetation and tending regenerating trees.

* Young forest tending and protection:

- Prevent buffaloes and cows from destroying forest plantation

- Fire protection

- Adjust nutritional space for purpose regenerating trees, cut or thin trees/branches which compete with targeted tree species.

* Forest tending and nourishment in the next phase:

- In this phase, people should mainly focus on fire prevention in areas with dense vegetation. Clear the vegetation before the dry season.

- Adjust growing space, remove shrubs or non-purpose regenerating trees which affect the crop growth.

- Cut vines, creepers and branches of remaining strips to open light for the crops for forest enrichement.

- Remove twisted tree species, diseased tree species, topless tree species, multi-stem trees and stunted trees.

9/ APFNet project: Performance of the ability of sustainable forest restoration in Vietnam, carried out in Thanh Son and Tan Son – Phu ho province

Technical design for establishing forest enrichment pilot models

Basis for species selection to be planted

- The project's objectives;
- Expectations of smallholders involved in the project ;
- Species' characteristics in terms of biology, ecology and silviculture;
- Land area of the project areas and natural conditions;
- Field survey results;
- Project's plan and progress.

The following species were selected to be planted in the project's models:

* High-value timber species:

    - Erythrophleum *fordii*
    - Michelia *mediocris* Dandy
    - Parashorea *chinensis*
    - Dipterocarpus *retusus*
    - Manglietia *conifera* Dandy

* NTFP species

    - Dracaena *ensifolia*
    - Desmodium *styracifonium* (Osbeck) Merr
    - Calamus *tetradactylus* Hance
    - Erythropalum *scandens* Blume
    - Morinda *officinalis*

Species allocation to each block

There are 17 blocks in each commune: Thuong Cuu and Thu Cuc. The specific information on area, species to be planted and number of seedlings in each block was presented in the table 3.1.

Techniques for establishing planting models are presented in details in attached annexes.

Table 1 Information of each NTFP model block in Thu Cuc commune

Compart-ment	Sub-compartment	Block No.	Total area	Net area	Species	Number of seedlings
204	7	5	6.85	6.85	Calamus *tetradactylus*	6,850
		6	1.0	1.0	Dracaena *ensifolia*	16,000
		7	0.7	0.7	Dracaena *ensifolia*	11,200
		8	2.0	2.0	Morinda *officinalis*	4,000
		9	1.8	1.8	Morinda *officinalis*	3,600
		10	3.0	3.0	Desmodium *styracifonium*	48,000
		11	3.04	3.04	Erythropalum *scandens*	12,160

Compart-ment	Sub-compartment	Block No.	Total area	Net area	Species	Number of seedlings
		12	2.16	2.16	Desmodium *styracifonium*	34,560
		13	2.75	2.75	Dracaena *ensifolia*	44,000
		17	1.7	1.7	Morinda *officinalis*	3,400
		Bamboo cuttings will be planted along streams and surrounding blocks at foot-hills				250
Total			**25.00**	**25.00**		**184,020**

Table *2* Information of each NTFP model block in Thuong Cuu commune

Compa rt-ment	Sub-compartm ent	Block No.	Total area	Net area	Species	Seedlin gs numbe r
327	10	14	1.7	1.7	Dracaena *ensifolia*	27,200
		3	1.12	1.12	Morinda *officinalis*	2,240
		5	0.8	0.8	Erythropalum *scandens*	3,200
		6	3.8	3.8	Dracaena *ensifolia*	60,800
		7	3.8	3.8	Desmodium *styracifonium*	60,800
		8	4.2	4.2	Calamus *tetradactylus*	4,200

		9	1.2	1.2	Erythropalum *scandens*	4,800
		13	4.0	4.0	Desmodium *styracifonium*	64,000
		1	1.2	1.2	Morinda *officinalis*	2,400
		16	3.18	3.18	Morinda *officinalis*	6,360
		Bamboo cuttings will be planted along streams and surrounding bloks at foot-hill				250
Total			**25.0**	**25.0**		**236,250**

Table *3* Species composition and seedlings of each species are planted in pilot block in Thu Cuc commune

Block	Total area	Net area	Species composition	Total of seedlings	Number of seedlings for each species				
					P. *chinensis*	D.us *retusus*	E.um *fordii*	M. *conifera*	M. *mediocris*
1	7.9	7.9	Parashorea *chinensis* (20%), Michelia *mediocris* (20%), Erythrophleum *fordii* (20%), Dipterocarpus *retusus* (20%), Manglietia *conifera* (20%)	2,175	435	435	435	435	435
2	2.5	2.5	Parashorea *chinensis* (20%), Michelia *mediocris* (20%),	690	138	138	138	138	138

Block	Total area	Net area	Species composition	Total of seedlings	Number of seedlings for each species				
					P. *chinensis*	D.us *retusus*	E.um *fordii*	M. *conifera*	M. *mediocris*
			Erythrophleum *fordii* (20%), Dipterocarpus *retusus* (20%), Manglietia *conifera* (20%)						
3	5.06	5.06	Parashorea *chinensis* (25%), Erythrophleum *fordii* (25%), Dipterocarpus *retusus (25%)*, Erythrophleum *fordii* (25%)	1,392	348	348	696		
4	2.5	2.5	Erythrophleum *fordii* (25%), Michelia *mediocris (25*,	688			344	172	172

Block	Total area	Net area	Species composition	Total of seedlings	Number of seedlings for each species				
					P. *chinensis*	**D.us *retusus***	**E.um *fordii***	**M. *conifera***	**M. *mediocris***
			Erythrophleum *fordii* (25%), Manglietia *conifera* (25%)						
15	2.54	2.54	Parashorea *chinensis* (20%) Erythrophleum *fordii* (20%), Dipterocarpus *retusus* (20%), Michelia *mediocris* (20%), Manglietia *conifera (*20%)	690	138	138	138	138	138
16	2	2	Parashorea *chinensis* (25%), Erythrophleum *fordii* (25%),	552	138	138	276		

Block	Total area	Net area	Species composition	Total of seedlings	Number of seedlings for each species				
					P. *chinensis*	**D.us *retusus***	**E.um *fordii***	**M. *coniferra***	**M. *mediocris***
			Dipterocarpus *retusus* (25%), Erythrophleum *fordii* (25%)						
14	2.5	2.5	Parashorea *chinensis (50%)* Dipterocarpus *retusus (50%)*	688	344	344			
Tot	**25.0**	**25.**		**6,875**	**1,541**	**1,54**	**2,0**	**883**	**883**

Table *4* Species composition and seedlings of each species to be planted in each block in Thuong Cuu commune

Block	Total area	Net area	Species composition	Total of seedlings (including 10% restocking)	Number of seedlings for each species				
					P. *chinensis*	D. *retusus*	E. *fordii*	M. *conifera*	M. *mediocris*
2	4.37	4.37	Parashorea *chinensis* (20%), Michelia *mediocris* (20%), Erythrophleum *fordii* (20%), Dipterocarpus *retusus* (20%), Manglietia *conifera* (20%)	1,205	241	241	241	241	241
4	3.29	3.29	Parashorea *chinensis* (25%), Erythrophleum *fordii* (25%), Dipterocarpus *retusus (25%)*, Erythrophleum *fordii* (25%)	907	227	227	453		

Block	Total area	Net area	Species composition	Total of seedlings (including 10% restocking)	Number of seedlings for each species				
					P. *chinensis*	D. *retusus*	E. *fordii*	M. *conifera*	M. *mediocris*
10	3.37	3.37	Manglietia *conifera* (33.33%), Erythrophleum *fordii (*33.33%), Michelia *mediocris* (33.33%)	927			309	309	309
11	4.63	4.63	Parashorea *chinensis* (50%), Dipterocarpus *retusus* (50%)	1274	637	637			
12	4.99	4.99	Manglietia *conifera* (33.33%), Erythrophleum *fordii (*33.33%), Michelia *mediocris* (33.33%)	1374			458	458	458
15	2.12	2.12	Parashorea *chinensis* (20%), Manglietia *conifera* (20%) Erythrophleum *fordii* (20%),	585	117	117	117	117	117

Block	Total area	Net area	Species composition	Total of seedlings (including 10% restocking)	Number of seedlings for each species				
					P. *chinensis*	**D. *retusus***	**E. *fordii***	**M. *conifera***	**M. *mediocris***
			Dipterocarpus *retusus* (20%), Michelia *mediocris* (20%),						
17	2.24	2.24	Parashorea *chinensis* (25%), Erythrophleum *fordii* (25%), Dipterocarpus *retusus (25%)*, Erythrophleum *fordii* (25%)	616	154	154	308		
	25.01	25.01		6,886	6,888	1,376	1,376	1,886	1,125

Table 5 Total of high-value timber seedlings to be planted in the two communes

No.	Species	Number of seedlings (tree)		
		Thu Cuc	**Thuong Cuu**	**Total**
1	Parashorea *chinensis*	1,541	1,376	2,917
2	Dipterocarpus *retusus*	1,541	1,376	2,917
3	Erythrophleum *fordii*	2,027	1,886	3,913
4	Manglietia *conifera*	883	1,125	2,008
5	Michelia *mediocris*	883	1,125	2,008
	Total	6,875	6,888	13,763

Table 6 Number of NTFP seedlings and bamboo cuttings are planted in the two communes

No.	Species	Total number of seedlings (tree)		
		Thu Cuc	**Thuong Cuu**	**Total**
1	Calamus *tetradactylus*	6,850	4,200	11,050
2	Dracaena *ensifolia*	71,200	88,000	159,200
3	Erythropalum *scandens*	12,160	8,000	20,160
4	Morinda *officinalis*	11,000	11,000	22,000
5	Desmodium *styracifonium*	82,560	124,800	207,360
	Total	**183,770**	**236,000**	**419,770**

Detailed technical design in blocks

Location: Compartment 327, Sinh tan hamlet, Sub-compartment 10, blocks: 2, 15 ***Compartment 204, Que hamlet, Sub-compartment 7, blocks 1, 2, 15***
Total area in the two communes: 19.43 ha
Forest cover: 0.4
Vegetation: almost pioneer species such as Liquidambar *formosana*, Ormosia *balansae*; average height of 7 – 9m
Species to be planted: Michelia *mediocris*, Parashorea *chinensis*, Dipterocarpus *retusus*, Manglietia *conifer*, Erythrophleum *fordii*.
Initial stocking: 625 tree/ha (only planting tree on cleared strips)
Planting model: Michelia *mediocris* + Parashorea *chinensis* + Dipterocarpus *retusus* + Manglietia *conifer* + Erythrophleum *fordii*.
Layout: trees are planted as mixed alternatively of species on each cleared strip. Cleared strips and non-cleared stris are alternated with 8mx12m in size. Trees are planted in holes.

Hole size is 40x40x40cm. - On each strip two lines of trees will be planted. On each line there are 5 species will be planted alternatively i.e. one tree of Michelia *mediocris*, one tree of Parashorea *chinensis,* one tree of Dipterocarpus *retusus,* one tree of Manglietia *conifer,* and one tree of Erythrophleum *fordii*. - Planting space: line by line as 4m, tree by tree as 4m.
Location: Compartment 327, Sinh Tan hamlet, sub-compartment 7, blocks: 4, 17 ***Compartment 204, Que hamlet, sub-compartment 7, blocks: 3, 16***
Total area in the two communes: 12.59 ha
Forest cover: 0.6
Vegetation: uncommercial small timber species with average height of 4 – 6m.
Species to be planted: Parashorea *chinensis*, Erythrophleum *fordii*, Dipterocarpus *retusus*
Initial stocking: 650 tree/ha (only planting tree on cleared strips)
Planting model: Parashorea *chinensis* + Erythrophleum

fordii + Dipterocarpus *retusus* + Erythrophleum *fordii*
Layout: trees are planted alternatively of species on lines on cleared strips. On each line the species are planted alternatively i.e. one tree of Parashorea *chinensis*, one tree of Erythrophleum *fordii*, one tree of Dipterocarpus *retusus*, one tree of Erythrophleum *fordii* (Erythrophleum *fordii* 50%, Parashorea *chinensis* 25%, Dipterocarpus *retusus* 25%). Hole size is 40x40x40cm. Planting space: line by line as 4m, tree by tree as 4m.
Location: Compartment 327, Sinh Tan hamlet, Sub-compartment 10, block 11 ***Compartment 204, Que hamlet, Sub-compartment 7, block 14***
Total area in the two communes: 7.13 ha
Forest cover: 0.65
Vegetation: almost pioneer species such as Liquidambar *formosana*, Ormosia *balansae*; average height of 6- 8m
Species: Parashorea *chinensis* + Dipterocarpus *retusus*
Initial stocking: 625 tree/ha (only planting tree on cleared strips)

Planting model: mixing of Parashorea *chinensis* and Dipterocarpus *retusus* on strips
Layout: trees are planted alternatively of species on each cleared strip. On each strip two lines of trees will be planted. On each line there are 2 species will be planted alternatively i.e. one tree of Parashorea *chinensis* and one tree of Dipterocarpus *retusus*. Cleared strips and non-cleared stris are alternated with 8mx12m in size. Hole size is 40x40x40cm. - Planting space: line by line as 4m, tree by tree as 4m.
Location: Compartment 327, Sinh Tan hamlet, Sub-compartment 10, blocks: 10, 12
Total area: 8.36 ha
Forest cover: 0.58
Vegetation: Ormosia *balansae*, Schizostachyum *leviculme*, Liquidambar *formosana* with average height of 4- 5m
Species: Manglietia *conifera*, Erythrophleum *fordii*, Michelia *mediocris*
Initial stocking: 625 tree/ha
Planting model: Manglietia *conifera* + Erythrophleum *fordii*

+ Michelia *mediocris*
Layout: trees are planted alternatively of species on each cleared strip. On each strip two lines of trees will be planted. On each line there are 3 species will be planted alternatively i.e. one tree of Manglietia *conifera,* one tree of Erythrophleum *fordii* and one tree of Michelia *mediocris* . - Planting space: line by line as 4m, tree by tree as 4m.
Location: Compartment 204, Thu Cuc commune, Sub-compartment 7, block 4
Total area: 2.5ha
Forest cover: 0.5
Vegetation: Liquidambar *formosana*, Schizostachyum *leviculme* with average height of 2- 4m.
Species: Erythrophleum *fordii*, Michelia *mediocris*, Manglietia *conifera*
Initial stocking: 650 tree/ha
Planting model: Erythrophleum *fordii* + Michelia *mediocris* + Manglietia *conifera*
Layout: trees are planted alternatively on the whole area i.e. one tree of Erythrophleum *fordii*, one tree of Michelia

mediocris, one tree of Manglietia *conifer (1:1:1).* - Planting space: line by line as 4m, tree by tree as 4m.
Location: Compartment 327, Sinh Tan hamlet, Sub-compartment 10, Blocks: 7, 13 ***Compartment 204, Que hamlet, Sub-compartment 7, Blocks: 7, 10***
Total area of the two communes: 12.96 ha
Forest cover: 0.3
Vegetation: average height of *0.5-3m.*
Species: Desmodium *styracifonium*
Initial stocking: 40,000 seedlings/ha
Planting model: planting only Desmodium *styracifonium* on the whole area
Layout: Pure Desmodium *styracifonium* will be planted. Distance: lines by lines as 0.5m, seedling by seedling as 0.5m Hole size: 40x40x40cm
Location: Compartment 327, Sinh Tan hamlet, Sub-compartment, Blocks 8.

Compartment 204, Que hamlet, Sub-compartment 7, Blocks: 5
Total area of the two communes: 11.55 ha
Forest cover: 0.4
Vegetation: uncommercial small timber species with average height of 1.5 - 2m.
Species: Calamus *tetradactylus*
Initial stocking: 2,500 seedling/ha
Planting model: Pure Calamus *tetradactylus* will be planted on the whole cleared strips
Layout: Hole size is 30 x 30 x 30cm. Four lines of Calamus *tetradactylus* will be planted on a cleared strip. Planting space: lines by lines as 2m, seedlings by seedlings as 2m. Holes are digged alternatively.
Location: Compartment 327, Sinh Tan hamlet, Sub-compartment 10, Blocks: 3, 16, 1 ***Compartment 204, Que hamlet, Sub-compartment 7, Blocks: 9, 17, 7***
Total area of the two communes: 11 ha

Forest cover: 0.3
Vegetation: uncommercial small timber spcies with average height of 5- 7m.
Species: Morinda *officinalis*
Initial stocking: 5,000 seedling/ha (2x1m)
Planting model: Pure Morinda *officinalis* will be planted on the areas or planted under plantations' canopy
Layout: lines by lines as 2m, seedlings by seedlings as 1m. Hole size is 30x30x30cm
Location: Compartment 327, Sinh Tan hamlet, Sub-compartment 10, Blocks: 5, 9 ***Compartment 204, Sub-compartment 7, Blocks: 11***
Total area of the two communes: 5.04 ha
Forest cover: 0.3
Vegetation: uncommercial small timber spcies with average height of 1.5 - 2m.
Species: Erythropalum *scandens*
Initial stocking: 10,000 seedling/ha

Planting model: Pure Erythropalum *scandens* will be planted on the whole cleared areas
Layout: lines by lines as 1 m. Hole size is 20x20x20cm
Location: Compartment 327, Sinh Tan hamlet, Sub-compartment 10, Blocks 14, 6 ***Compartment 204, Sub-compartment 7, Blocks 6, 7***
Total area of the two communes: 9.95 ha
Forest cover: 0.3
Vegetation: uncommercial small timber spcies with average height of 1.5 - 2m.
Species: Dracaena *ensifolia*
Initial stocking: 40,000 seedling/ha
Planting model: Pure Dracaena *ensifolia* will be planted on the whole cleared areas
Layout: seedlings are planted on lines on cleared strips with lines by lines as 0.5m
Planting bamboo cuttings along streams and surrounding blocks at foot-hills

Species: bamboo cuttings
Number of cuttings: 500
Planting model: planting bamboo cuttings surrounding blocks at foot-hills and along streams
Layout: bamboo cuttings are only planted surrounding blocks at foot-hills and along streams as 5m in planting space.

Forest planting, tending and protecting techniques of each model as well as model layout were presented in the annex 02.

a. Results of the project

According to forest resources inventory of the project before and after project activities in demonstration models, it is found that this project has positive impacts on forest restoration and sustainable forest management in the province. Forest restoration has improved species composition, increase proportion of high valuable timber species, quantity and quality of the regenerating trees, and the diversity of non-timber forest products.

Figure 12 One-year-old* Dipterocarpus retusus *in APFNet's project pilot model, Phu Tho, Vietnam

Positive impacts of the project can be summarized in the following points:

The first positive impact must be mentioned is silvicultural techniques selected to apply to the project: The techniques chosen are simple but highly effective. As a result, it is easy to be extend project's practices to local households, and communities which have limited access to technology and capital. The silvicultural techniques for restoration of degraded forests is enrichment planting by indigenous trees in clearing strips.

The second successful lesson is *species selection.* Species chosen for forest restoration is native species which has high economic and ecological value. Local people and communities are interested in indigenous non-timber forest product species which has high economic value. High survival and growing rates prove that the selected species and silviculture approaches are successfully. The project selected many valuable indigenous species such as: *Parashorea chinensis, Erythrophleum fordii, Dipterocarpus retusus, Michelia mediocris* Dandy, *Manglietia conifera* Dandy, *Desmodium styracifonium* (Osbeck) Merr, *Dracaena ensifolia, Morinda officinalis, Calamus tetradactylus* Hance *and Erythropalum scandens* Blume. Silvicultural techniques of these tree species have been researched and rigorously tested.

The third positive impact is *participation of ethnic minority communities in project areas:* this is one of the most important factor in the project's success. Due to their participation, the project models were implemented and remain in place.

The project applied the method that local people can participate in all steps such as selecting the species, planting, tending, harvesting and utilization of the products. Local people also develop their community forestry management plan and applying to their forest management.

The final efficiency is *establishment of a local micro institutional framework.* This is an essential factor to ensure sustainable forest management, particularly in natural forest. A micro institutional framework comply with local and national legal framework is the basis for effective forest management.

After training courses, community meetings and the process of developing village's regulations on forest management, the awareness of local people and local officials about sustainable forest management is enhanced. This awareness has been applied to forest protection and development of village regulation on forest management and development.

Local communities have also been learned about their roles in management of their own forests, rights and restrictions under Government policy. Farmers are keen on to improve their degraded secondary forests to have better high-valued timber tree species composition and valuable NTFP under forest canopy. This contribute to sustainalbe forest mangement of project's communes. Involvement of project implementation and get payment for larbor cost and the initial products from short term NTFP contributed to increase income of local households and proverty alleviation.

Through implementation of the project, local people, project counterparts, Phu Tho authorities and Vietnam forestry sector has learned about APFNet and raised recognition on the contributions of APFNet on forestry development, sustainable forest management in Vietnam.

2.2. Species for direct seeding

2.2.1. Enrichment planting by using direct seeding methods

Using this method, seeds are directly sowed on forestry land without the nursery phase. Compared with other methods, the direct seeding technique has some advantages and disadvantages as follows:

Advantages:

+ The direct seeding method is the most biologically appropriate way to establish new forest because young seedlings have high growth capacity in such an environment to which they can biologically adapt.

+ The seedling root system has been fully developed and is stable. Compared with using seedlings, when grubbing up trees, it is unavoidable to have physical injures. As a result, roots usually are deformed and tend to develop unusually, reducing the performance of the young forest.

+ With a large number of seeds being sown, expect a large number of seedlings. Then, it is easy to accomplish both natural and artificial selections; only good quality seedlings are retained, contributing to increased plantation quality.

+ Seeds can be spread by aircraft on wide and sparse population areas in order to accelerate the afforestation progress and lessen investment by reducing labour and costs.

Disadvantages:

+ Compared to seedling afforestation, the broadcast seeding method requires many more seeds and has a longer tending duration. After seeding, germinating seeds have

more risk of being harmed by birds, ants, weeds and unfavourable weather.

+ Afforestation tends to be restricted by many factors, including seed available, seed storage techniques, soil conditions, and the biological charateristics of species.

There are some issues when using direct seeding for afforestation:

Sowing area selection: People need to seed by hand in small areas, choose moderate climate conditions and porous soil (moist, porous) with little harm from weeds, birds and animals.

Aircraft seeding sowing:

* Natural conditions:

Sowing area must be large enough (according to an empirical guide from Chinese technical development; the smallest area is 2,500 ha or at least enough for a flight turn). The topography needs to be convenient for aircraft operation. Soil needs to have a thick depth, be fertile, porous and moist for germination and give rise to strong seedlings. Vegetation: weed species composition, density and cover have a significant influence on the efficency of forest regeneration. Vegetation also affects seeds ability to reach into soil, and the germination process and seedling growth.

* Socio-economic condition:

The land use rights need to be clearly defined; forest protection and fire prevention activities and slash-and-burn need to be thoroughly implemented. Local people support and recognise the benefits of forest regeneration.

+ Seeding duration:

Generally, direct seeding forest regeneration times are similar to the time in the nursery. However, watering seeds and seedlings is strongly dependent on weather conditions compared with watering in the nursery. Hence, selecting seeding duration and weather are crucial factors for the success of forest regeneration which needs to be based on factors to determine seeding duration that ensure the survival of seeds and seedlings from drought and natural damage.

Sufficient water is the most important condition for the germination and survival of seedlings. Seeds need water and primarily depend on rain to germinate. There is a reality that afforestation by direct seeding in arid regions with little rainfall has a lower efficiency than in higher rainfall areas. Thus, it is a vital principle to follow the rainy periods of the local climate to identify seeding duration.

Temperature also is a necessary factor for germination and growth of seedlings. The extreme conditions of temperature, too hot or too cold, are not conducive to germination. For most forest tree seeds, the suitable temperature for germination is 20-25^{0}C. Therefore, both moisture and temperature conditions are needed when considering the seeding duration.

In addition, seedlings undergo a long growth period. Only strong seedlings having deep roots can resist unfavourable conditions like drought, heat, and frost. Hence, the determination of seedling duration needs to be based on all weather and climate conditions in the area.

In the Vietnam northern provinces, excepting some areas affected by hot dry southwest winds (foehn winds), seeding usually starts at the beginning of spring. However, there are some species that need to seeded at other times to get a high rate of germination and better growth from the seedlings. For example, a suitable season for *Tectona grandis* is summer, *Styrax tonkinensis* is autumn, and *Cinnamomum camphora* is winter. In central Vietnam, all provinces have southwest winds and less rainfall during the time from mid-spring to early-autum and the middle of autumn is the most suitable time for seeding. Regarding the southern provinces, there are two distinct seasons in a year,

the dry and rainy seasons, so people can only seed at the beginning of the rainy season (May and June).

+ Seeding procedure and method: There are two methods of afforestation by direct seeding: spot and broadcast seeding.

Broadcast seeding: broadcast seeding involves scattering seed by hand or mechanically, over a relatively large area. It is normally applied by using aircraft on already-harvested forest, burned-out forest, or large unplantingd land with limited transportation capacity and a shortage of labour.

The major disadvantage which leads to the rare use of this method is seed wastage.

The spot seeding method is seeding on a piece of land, and is divided into two methods: row and cluster seeding.

Row seeding (band seeding): soil can be tillaged in strips or bands. Then, the rows are made to follow a certain distance. Seeds will be sown on rows continuously or interruptively. This method is easy to apply mechanically in seeding and tending. It also the highly recommended method because of the economic use of seeds.

Cluster seeding: at every certain distance, dig a hole with dimensions of 20 x 20 x 20 cm, 30 x 30 x 30 cm or larger of 1x1m or 1x2m. In each hole 2-5seeds will be sown.

In Vietnam, cluster seeding have been widely applied for *Melia azedarach*, *Vernicia montana*, *Camellia sasanqua*, *Styrax tonkinensis*.

+ The seeding density:

Suitable seeding density is the key factor for the success of the highest possible forest regeneration. The young forest will take a long time to get closed canopy with sparse seeding density. Also, it would need more tending time and longer time for each tending duration. In contrast, high density seeding will waste seeds, but will lead to the forest being differentiated from one that grows weakly. In short, seeding density must be based on two major factors: the species' ecological traits and site characteristics.

Seed qualities, seed dimensions and other factors also affect the seed germination rate and the survival of seedlings.

In general, seed for wood supply purposes in suitable weather conditions, and for light shade species with good seed quality. Carefully tillage, seed, tend and protect; the seeding density should be sparse and of high density for contrary cases.

+ Seed quality and seed treatments before seeding:

It is important to test seed qualities of germinatiton rate, purity, etc. Only the seed lots meeting the standard can be used for sowing. In general, seeds used for seeding have to have qualities similar to the seed that is used by nurseries. However, due to the hash condition of afforestation land and occasional tending, seeds used for seeding should have higher and stricker quality requirements.

Seeds must be shown to be antidotal to chemicals such as *methylrosaniline* chloride or ceresan before sowing. Depending on the real condition, sometimes seeds must be treated for germination, or swelled (for seeding by aircraft). In dry weather, seeds should not be stimulated for sowing, seeds will naturally germinate when they meet suitable conditions of temperature and moisture.

+ Sowing

+ Soil backfill:

After seeding, backfill soil instantly to prevent bird and ant damage. The thickness of the backfill soil on the seeds will significantly affect the germination period and seedling vitality. Hence, this thickness should be based on the species' biological characteristics, seed dimensions, planting, seasonal cycles, weather and soil and site condition.

Use porous fine topsoil to fill over the seeds before covering with a layer of leaves or dead weed on the topsoil layer.

+ Protection and tending after seeding:

Protect seeds and seedlings from insects, birds and animals, especially for oily seeds. Also, it is necessary to make a protection plan to prevent dryness in order to create favourable conditions for germination and to protect seedlings from drought and frost.

Tending and protection methods after seeding are of decisive significance to the success or failure of plantation forests. In Vietnam, using direct seeding for plantation of *Styrax tonkinensis* and *Melia azedarach* showed that the forests grew well and met the standard density if they were tended and protected Carefully. In contrast, in conditons of never or seldomly tending, it is difficult to achieve desired results. Consequently, failure of plantations, low forest quality or high forest price can be easily understood.

2.2.2. Species of direct seeding used for forest restoration in Vietnam

In Vietnam, some timber species such as *Melia azedarach*, *Vernicia montana*, *camellia sasanqua*, and *Styrax tonkinensis* have been successful after application of

the direct seeding method. Lessons from the practice show that a combination of planting season, tending and protection methods drives the survival rate and the success of direct seeding techniques. Species charateristics of morphology ecology and suitable Silvicultural techniques will be presented in section 2.1 of this chapter.

1. Research on direct seeding of Acacia mangium plantation in central - north Vietnam

The most successful direct seeding model using for *Acacia mangium* species has been conducted in the Ham Yen Distict, Tuyen Quang Province by planting two times in February and April on 105 ha with five treatments with eight replicates.

The collation of ecological characteristics of *Acacia mangium* and the natural conditions in Ham Yen District showed that it was suitable for applying the direct seeding of A. Mangium in Ham Yen.

The research result showed that the seed germination rate must reach up to more than 90% with 30% average germination. The seed quality from the plantation forest or nursery must be recognised as being of decent quality. Seeding in March-April which is the beginning of the rainy season with gradual increasing humidity can get a higher success rate than in February of the lunar calendar. In

February, cold weather, little rain, low humidity and dry soil are the causes of weak germination.

Treat seed in boiling water for a minute, and incubate to pullulate, then seed or burn dry leaves on ground (seeds without treatment in boiling water can bring about a higher germination rate than formulations without seed treatment). Tree species sown in the forest can attain better growth in terms of height and diameter than container seedlings (seeding these two categories at the same time), because tree species directly seeded can have better adaptability with the forest environment.

Compared to afforestation with container seedlings, it is easily found that forestation by the direct seeding method costs just 50% of the cost of creating seedlings and there is no cost for any seedlings or transport.

However, this project has just been tested in Ham Yen-Tuyen Quang in February and April of the solar calendar. More testing is required.

2. Research on direct seeding with 3 indigenous species including Erythrophleum fordii, Peltophorum tonkinensis and Cassia siamea under the restoring forest crown after slash-and-burn in northern mountains of Vietnam

a. The study area

This study has been conducted at Chieng Bom District, Son La Province, located in the northwest mountainous region of Vietnam, between 21°55'N and 102°02'E. Chieng Bom had 33.00 ha of forest land, in which 1.200 ha was natural forest. These natural forest areas mainly are distributed in remote areas, usually on the peak of mountains. The rest of the forest land is secondary forest which was rehabitated after slash-and-burn planting with the age of the forest varying from 1 to 30 years. The forest is characteristic evergreen broadleaf forest with 98 species of species composition. In Chieng Bom, the rainy season begins in mid-May and ends in late September; the average annual rainfall is between 900-1,100 mm (80% of the total rainfall comes from the rainy season); the average temperature during rainy season is between 22-26°C. The dry season is from November to March of the following year, the temperature occasionally goes down to 7°C.

The study area has undergone a long period of slash-and-burn planting. The secondary forest rehabitated after slash-and-burn (from 1 to 15 years), and the topsoil layer has been eroded, resulting in poor fertility and dissappearance of the forested microclimate characteristic. The common natural regeneration tree species are *Schima wallichii*,

Betula alnoides, and *Wendlandia paniculata*. In regards to the older secondary forests, soil moisture and soil fertility have improved; the microclimate condition has been gradually meeting the forested microclimate characteristics. Especially, the forests have the presence of indigenous species such as *Litsea cubeba*, *Camellia sp*, *Quercus sp* and *Castanopsis sp*. Despite the high number of species, the number of individuals is not enough for the forest to perform regeneration naturally without assistance.

b. Experimental design

* Tree species (S): This study conducted experiments on three species of indigenous trees, including Erythrophleum fordii Oliv (sign S1), Peltophorum tonkinensis (Pierre) Gagnep (sign S2) and Cassia siamea Lamk (sign S3). These species were chosen for the following reasons: (1) The seed source is available and can be maintained for a long time while maintaining a high germination rate. 2) They distribute natually at the study area. 3) Seed treatment techniques are available, and 4) They are the species with high economic value that the locals prefer. The germination rate of these species is tested regularly.

* Vegetation treatment was conducted locally at the seeding area (30 cm of radius) by removing all weeds. Dig holes

with dimensions of 20 x 20 x 20 cm, soil in holes to facilitate germination.

b.1 Experiment 1 (E1): The effect of treatments on germination and growth of seedlings

* The object of restoring the forest; E1 is being conducted with a restoring-forest objective after slash-and-burn with canopy cover of 35-50% (measured by using a Luximeter SM-700 located at a height of 1 m above the forest floor). The extent of this shade is chosen because in the nursery condition, these species have the greatest germination and seedling growth at this canopy cover.

* Formulas of treatment, including following three formulas:

+ Pretreatment seedlings (PTS); PTS1, the seeds will be treated the same as in the nursery under current processing techniques and control for formula-untreated seeds. The base to implementing this experiment is because the seeds are treated before seeding, they will therefore obtain a higher germination rate after planting in favourable weather with moist soil and suitable air temperature. Otherwise, if weather conditions are unfavourable, the seeds will die.

+ Cover the seeds after seeding (SCL); after placing the seeds into holes, the seeds will be covered with a thin layer of fine soil of around 0.5-1.2cm thick. Then, use leaves to

cover the holes (3-5cm long) which is called SCL1; on the contrary, holes are not covered with leaves SCL0 called control leaves SCL0. The base to carry out this experiment is that the holes covered with leaves can protect soil moisture in holes and create favourable conditions for germination.

+ Seeding duration (SD); seeds will be sown at 3 different times, in July from days 5 to 20, signed SD1 (around 15 days before the rainy season); in August from days 10 to 16, signed SD2 (around 15 days after the rainy season) and in September from days 27 to 29, signed SD3 (1 month after the end of rainy season).

* Experiments in the location include three species (S) x 3 seeding duration (SD) x 2 seed treatment (PTS) x 2 seeding measures (SCL), repeated 3 times with a total of 108 experimental plots. The experimental plots were laid out in a fully randomised block (see figure of experimental design number 1).

* The size of the experimental plots and number of seeds: each experimental plot has an area of 64m^2, total area of a block is 2.304m^2 for a block (48x48m). In each experimental plot, the seeds are planted in the centre point with dimensions of 5x5m (25m^2) at 36 seeding points. Each point sows five seeds.

b.2. Experiment 2 (E2): Effects of canopy cover on germination and seedling growth.

* Three canopy cover levels (CCL) are selected for study including below 35% (sign CCL1), 35-50% (sign CCL2), and higher than 50% (sign CCL3)[CCL are measured by the SM-700 Luxmeter at the elevation of 1m above the the forest floor]. All of them will be tested three times with seeding similar to that of experiment 1. All seeds are treated and holes are covered with leaves.

* The experimental design for each level of shading has three species (S) x three seeding duration (SD) x a seed treatment (PTS) x a coverd hole (SCL), repeat 3 times and experiment for the 27 plots with a fully randomised block design. The total of three cover levels have 81 experimental plots (see the drawings of experimental layout 2 for more details).

* The size of the experimental plot and the number of seeds are similar to that in experiment 1.

Though the report on the study results has not been produced, the project has been relatively successful right from the first step.

2.3. Species for other restoration approaches

2.3.1. Forest restoration techniques by using asexual tree species

This method is based on the asexual natural regeneration capacity of tree species, the materials using for forest regeneration could be the structural sections of trees like trunks, branches and roots.

The method has some advantages, trees grow and develop faster, leading to shortened years for flowering, fruiting and wood harvest. In addition, forest stands have good genetic traits that are inherited from their parents. However, being old very quickly, a tree lifespan is shorter and smaller as for the trunk diameter.

This method is recommended to be applied for species which have nutritious organs with the ability to sprout roots. Besides, planting with cuttings is only implemented in relatively good site conditions (climate and soil).

Silvicultural techniques with ***asexual tree species*** can be divided into two cases:

Plant cuttings fed in the nursery when sufficiently struck and rooted, and use leaves similar to seedlings made

from seeds; Silvicultural techniques are similar to afforestation with seedlings.

Use cuttings to plant directly on forest soil, without experiencing phases in the nursery, in this case, people should apply technical measures of selecting cuttings, and planting them as described in the nursery section. Techniques of tillage, afforestation, tending and protection are the same as that of planting with seedlings. However, people should pay much attention to soil selection. At the first stage, the cuttings have not yet sprouted roots, water absorption is done through the mouth of the cuttings, so soil must have the required proper humidity. In general, planting cuttings on discrete and arid, sandy, rocky soil. Low-lying land increases the risks of dry and rotten cuttings so that it is difficult to directly plant cuttings on afforestation land.

+ Techniques of mother trees and cuttings selection, root stimulation, crops are similar to the section on asexually planting in nurseries.

+ Protection and Tending techniques are similar to forestation with seedlings.

2.3.2. Biological characteristics and Silvicultural techniques of some asexual tree species

Tectona grandis has been primarily used for

enrichment with cuttings

a/ Morphological and ecological characteristics

Morphological characteristics

Tectona grandis is a decidious evergreen plant, 30m tall, 60-80cm in diameter, and has grey-yellow bark with lenticels which are cracked into small long narrow species. Tree's base has a buttress and strips and the sapwood is fibrous. Young branches have rusty hair. The leaves are ovate-elliptic to ovateor round with a pointed apex. The upper side is flat. The lower side is yellowish in a star shap and are 20-60 cm long, 20-40 cm wide, with secondary veins of 30-60 pairs.

The hairy petiole is 2.5–5cm long in a star shape.The opposite flowers grow in clusters with 3 branches. The sepal has dense hairs, forming a tube, and margin with teeth on the red outer side. The corolla is white, forming a tube, 5-6 round lobes on the above, hairy outer. 5 to 6 pistils are slightly protruding. The dense ovary which is divided into 2 parts has a conical shape and short taps. The fruit is a spherical shape, has thick hairs, is 2 cm in diameter, and is covered on the outside with yellow calyx.

Ecological characteristics

Tectona grandis prefers a tropical, rainy climate. Its

cold tolerance is weak and it is entirely a lucipetal species, even at youth. Natural regeneration of buds and seeds are good. It is capable of resisting pests and forest fire and it flowers in May-June or July-August and fruits in November-December or December-January.

b/ Silvicultural techniques

* Conditions of plantation forest

+ Climate:

Select areas that satisfy the following conditions:

- The climate is hot and humid with two distinct seasons: rainy and dry.

- The average annual temperature should be 20-27^{o}C and the lowest temperature not below 2^{0}C; the maximum average temperature of the hottest month is 40^{0}C and the average minimum temperature of the coldest month is 13^{0}C.

- The average annual air humidity is 80-90%. The average rainfall is 1250-2500mm / year. A year has 3-5 dry months (rainfall <40 mm / month)

+ Soil

- Plant *Tectona grandis* on well-drained soil, with a 50cm thick layer. Good soil, particularly soil with remaining forest soil.

- *Tectona grandis* is appropriate to grow on light loam, sandy soil, and quite rich in humous. Soil is slight acidic or alkaline. Soil has pH = 6.5-7.5

- Choose relatively flat land with the slope $<25^0$, generated on basalt parent rocks, granite, alluvial, alluvial along rivers and antique alluvial.

- Plant forest on laterite soil, sandy soil, laterite soil (eroded soil with gravel and stone)

- Do not plant forest on wetland forests in the rainy season.

+ Planting season

Plant in the spring-summer crop after heavy rain or plant in summer-autumn. Depends on each region to decide.

+ Remove vegetation

At the end of the year, before digging holes, remove vegetation and divide into many small parts for burning. Burn under the regulations of fire protection.

+ Dig holes

Dig holes with dimensions of 40 x 40 x 40 cm; put topsoil on the one side.

Fill up holes a month before planting, Fill higher than the mouth of the hole.

+ Method of forestation

Using a stump for forestation is the most effective method

+ Planting method and density

- Monoculture or mixture of agricultural tree species

- Plant with agricultural tree species using agroforestry methods. The density is 1100 trees per ha (3x3m in distance). It can mix with tree species such as: Glycine max, Oryza sativa, Carica papaya, Nicotiana tabacum, Anacardium occidentale L and Indigofera spicata.

- Duration for mixture: 2 years

- Monoculture: 1700-2200 trees per ha (density of 3mx2m; 3×1.5m)

+ Silvicultural techniques

Use hoe to mix soil evenly in the hole, add soil, then hoe small hole 20cm deeper, put stump upright, fill up root, press firmly; stump protrudes 2cm from the ground.

+ Tending plantation forest

Continuously tend for 3 years:

* *The first year*: Tending for at least 3 months from planting day. The contents of tending are removing

vegetation, weeding and hilling up tree's base to 1m long. If planting in spring-summer, tending 2 times in quarters 3 and 4. If planting in summer-autumn, Tending once. Besides, replant in the first year to ensure the former density.

* *The second year*: tending 2 times with the similar content as the first year

* *The third year*: tending 2 times with the similar content as the second year

+ Tending and protecting plantation forest

- Prevent from forest fire, set fire separation, and remove inflammable material on the forest soil before the dry season.

- Prevent pests

- Prevent damage from cattle and people

2.3.2. Lessons learned from facts

Enrich the poor dipterocarp forests with *Tectona grandis*

a/ Select the positions for enriching the poor dipterocarp forests with *Tectona grandis.*

Select dipterocarp forests which have been seriously affected by exploiting and cutting with a sparse density of natural tree species and too many large gaps.

- Select areas which are well-drained, not flooded in the rainy season, and avoid local wetlands in the forest when having long, heavy rains.

- Topsoil is usually from 30cm upwards. Avoid areas which are exposed to a lot of gravels and rocks where even indigenous species have trouble growing.

b/ Procedures and methods of forest enrich

- Planting procedures: mix with *Tectona grandis* in empty gaps in poor and sparse dipterocarp forests, do not affect tree species in the dipterocarp forests.

- Planting method: plant with a stump is the most effective method which is not only economic but also convenient.

Figure 13 Mix withing* Tectona grandis in *poor dipterocarp forest

- The density of the enriched forest depends on the dimentions of current forest tree species and empty gaps; the density of *Tectona grandis* can range from 500 to 800 trees per ha. The distance beween *Tectona grandis* and current forest tree species is 4–5m and the distance between *Tectona grandis* in the empty gaps is 3–4m.

c/ Seed resource of *Tectona grandis*

If people have to buy the seedlings because they have not created a nursery, the seedlings must meet the requirements of quality and origin. Seed and seedlings have to come from recognized seed sources by relevant authorities.

Figure 14 Stump of Tectona grandis

- Obtain the stumps from a nursery with ages of 12-15 months, root collar diameter of 1cm, healthy tree species without diseases.

- The upper parts are cut on a bevelled angle of 30-45^{o} in a vertical manner, far from tree's base collar of 2-3cm and do

not use broken roots. Get the taproot in its entirety (ranging from 15-20cm), prune away the secondary roots. Be Careful not to damage the stems and roots in the transport process.

d/ Planting and tending techniques

- Remove vegetation in March-April, before digging the holes. Vegetation is cleared, chopped and mixed with soil.

- Digging holes in April, the number of holes are mentioned above. Indentify hole locations in the area before digging by measuring the distance and plugging with bamboo stakes. The dimensions are 40 x 40 x 40 cm. When digging holes, put topsoil (15 - 20 cm) on a side, underlying soils are put on the other side.

***Figure 15 Digging holes to plant* Tectona grandis**

Source: vafs.gov.vn

- Fill up holes: in May, fill up holes a month before planting. Mix topsoil with 3kg of composting manure or 1kg of microbiological fertilizers, then fill up holes. After that, rake topsoil around holes and continue to fill up holes, 15–20cm higher than hole mouth. Tectona grandis prefers alkaline soil with pH from 6.5 to 7.5. Soil from dipterocarp forests is slightly acidic, so it is necessary to blend into each hole 100-200g of lime to improve soil pH.

- Planting: after transport, the stumps must be planted as soon as posible, otherwise, put them in the shade, cover and water to keep them fresh for several days. Use hoes to dig a small deep hole, place the stump in the middle, fill up tree's base and press firmly. After that, fill up tree's base to about 10cm tall in tortoise shells shapes to prevent from being flooded in the rainy season, causing stagnated water in the holes. The length of stump on the ground is about 2cm.

- Crop: plant in the beginning of the rainy season (June-July)

- Tending plantation: continuity of Tending in the first 3 years.

+ The first year: after planting for at least 3 months, tending techniques must be conducted, including the following tasks: remove vegetation, weed, turn up soil around the base to 1m. In the beginning of the dry season, people must implement Tending by removing vegetation covering tree's bases, regularly prevent fire by cutting and collecting vegetation around Tectona grandis to deter from burning to tree's base. Otherwise, replant to ensure the original density.

- The second year: tending 2 times with the same content as the first year.

- The third year: tending 2 times with the same content as the second year.

People can manure 25-50g NPK fertilizer/root in the first year, manure fertilizer with a higher mount in the next year.

Tectona grandiscan can have fire resistance from the third year, if it is burned in the first or second year. The plant is capable of shoot natural regeneration but it is weak. Thereby, fire prevention within the first two years is very necessary.

e. Forecasting the efficiency of dipterocarp forest enrichment with Tectona grandis

* Forecast cycle and productivity *Tectona grandis* mixed with in dipterocarp forest

- Business cycle, harvest time: It is is expected that after 15 years, Tectona grandis is available to harvest in small wood form with an average diameter of about 15cm, and height of 13m.

- Yield: Enriching 1 ha of poor dipterocarp forests with Tectona grandis can provide timber yield of approximately 40m^3/ha from about 500 tree species.

***Figure 16 One-year-old* Tectona grandis**

(Source vafs.gov.vn)

* Forecast of economic efficiency

- Total fees of dipterocarp forest enriched with Tectona grandis for 15 years is 17.6 million dong/ha.

- Total income for 15 years with the price of 8 million Vietnam dong per m^3 saw log timber, productivity of 1 ha is $40m^3$ and value at 320 million dong per ha.

* Social impact.

- Planting *Tectona grandis* in dipterocarp forest has opened a new effective direction for manufacturing businesses in dipterocarp forest, especially for some households allocated forest land for this purpose.

- Create jobs and income which result to livelihood improvement and stable economic and social conditions.

- Provide timber for processing industry.

- Maintaining the status of dipterocarp forests also contributes to raising people's income from non-timber forest products such as *Lentinus edodes, Nicotiana tabacum, Bambusa spp*, etc.

* Forecast of environmental efficiency

- Dipterocarp forest enriched with Tectona grandis aims to enhance the quality of dipterocarp forest, avoiding the risk of transforming poor dipterocarp forest into the planting of other trees. The development of dipterocarp forests has contributed to biodiversity conservation, particularly for large mammals.

- The environmental value of dipterocarp forests is improving and will be calculated from payments for environmental services such as CO_2 sequestration, and watershed protection in the future.

Chapter 3. The common tree species used for natural forest restoration in neighbouring countries

3.1. Restoration of natural forest in the region

Facing deforestation and forest degradation, a lot of efforts have been paid to study of natural forest restoration especially in South East Asia countries. Natural forest restoration, in general, includes two major techniques: forest enrichment and assisted natural regeneration.

3.1.1. Forest enrichment

Forest enrichment is the approach to improve tree species composition but not clear existing vegetation. It can also be carried out in an area that is lacking in natural regeneration of a certain number of species that are precious and with high economic value. There are a number of forest enrichment methods based on different types of forest and the availability of resources, including forest enrichment in a patch and forest enrichment in bands.

*Forest enrichment in patches

Conduct additional planting in areas of at least 2,500m^2 without trees. Density: planting trees as a quincunx (equilateral triangle), an edge of the triangle is equal to ½ diameter of the canopy of a mature tree (tree by tree). Plant trees inside the forest 2 to 4m distance at least from the

edge.

* Forest enrichment in bands

This method only applies for regeneration forests after slash and burn planting (young forest), it is not applied to forests with big trees such as poor forest, medium forests and old forest because there is a lack of sunlight for development of small trees in these forests.

Make rows for planting trees: the width of rows depends on the characteristics of each species (trees favour light or shade) and the width of the area between rows; this is to ensure sufficient sunlight for young trees. The rows should face the east-west direction to receive the maximum sunlight. The width of rows normally ranges from 4 - 8m.

The width of the area between rows: this area will not be used for planting trees, weeds or shrubs should be cleared; the width is about 8 - 12m.

The distance between trees: each row has one row of trees only, the distance between trees is usually equal to ½ diameter of the canopy of a mature tree.

Selection of species for forest enrichment - Criteria for selection of trees: - Species should be local trees or originally come from the same ecological conditions, have a high economic value, be easy to plant, and have quick

growth especially in height thus be able to compete for light with weeds and shrubs. The criteria of species depends on each species in terms of height, root system and vigorous appearance. Height should normally reach at least 0.8 to 1m to reduce the competition of weeds and shrubs.

Season for forest enrichment: The preparation for forest enrichment such as clearance of weeds and shrubs, clearing soil is conducted in the dry season. Planting of trees is made in the rainy season. It depends on labour resources and local conditions to enact the forest enrichment plan.

Preparing rows, patches for planting trees: Weeds should be cleared in rows or patches, all shrubs and trees with low economic value should be cut, leaving trees that have potential for timber and NTFPs.

Preparing holes and planting trees: The size of the hole depends on each species; it is normally 40x 40x40cm. Surface layers with lots of organic substances and nutrients should be used for planting. Litter and dry leaves should be collected to put around the tree's base.

Tending young trees: Animals might eat leaves of young trees, so it is necessary to make fences around trees. Weeding should take place regularly in the first 2-3 years after planting.

3.1.2. Assisted Natural Regeneration

Seed regeneration

- Objects: Natural regeneration promotion by seed is applied to the degraded forest, forest after clear cutting, fallow agriculture land, savanna and shrubs, and alluvials which have regeneration/ regenerative ability to form a natural forest.

- Techniques:

Depending on the specified conditions, apply one of the following methods:

1. Treat partial land by a manual method, hoeing or plowing seeds to bury in soil, to allow early germination to avoid the destruction of insects and animals. This is suitable for pipe species, some lucipetal species with light and numerous seeds such as *Helicia grandifolia*, *Schima wallichii* and some species of oil palm.

2. Remove fresh shrubs when valuable but impacted productive trees and regeneration trees are available but crowded out. This treatment is performed once or twice in one to two years until productive trees overcome the inhibition of fresh shrubs. This method is applied for savanna and shrub and fallow milpa.

3. In some special situations, it is possible to burn and cut fresh shrubs before the seed falling season, but fire spread should be controlled.

4. Some species with early blossoming and fruiting and numerous fruits and seeds, have easy natural regeneration and trees or clumps of trees are scattered or on convenient positions after seed dispersal for natural regeneration promotion.

For degraded forests, if high layers do not have enough purpose trees, but there are available seeds, it is necessary to decline the canopy level of the high tree layer, cut liana and fresh shrubs in bushy areas, and create the conditions for seed to germinate and develop. When there are enough regeneration trees, the forest nourishment mode will be transferred.

Coppice regeneration

* Applied subject:

Coppice regeneration is applied to forests which have species with regeneration ability through foot buds and root buds. The main aim is to produce small wood or types of other timbers which are suitable for wood quality due to bud natural regeneration.

This method will be taken advantage of for species with bud regeneration ability to shorten the business cycle, and lessen the cost of reforestation.

* Forest which utilizes coppice regeneration has to meet all standards:

1. In age with the ability for bud natural regeneration.

2. Natural mixed forest without the same age, forest types from young forest, degraded forest or more.

3. Plantation or natural forests with the same age must have at least 800 trees per ha evenly distributed on the area.

* Mode and cutting method:

Selective cutting and clear cutting by strip or gap for degraded natural forest. Must clear cut totally under the even age planted forest or natural forest; at least 800 trees per ha have to be evenly distributed across the area.

The logging will be performed 4 months before the growing season..

Height of cut roots of trees is 1/3 of tree’s base collar diameter or 40 - 50 cm depending on the type of species and commercial purposes.

Roots of tree should be free of cracking, denuding or scratching.

Cut roots need to be smoothed and repaired and have a tilt for drainage.

* Coppice forest tending

- Filling of blanks: When bud trees have not enough quantity or are distributed unevenly, it is necessary to promote seed natural regeneration for mixed natural forest without the same age such as the forest state of a young forest, degraded forest and over and replanting in tending times. In the first year of plantations or natural forests with the same age, there must have be at least 800 trees per ha evenly distributed across the area.

- Coppice thinning: Depending on the business purpose, keep from one to three buds. Big and strong buds growing above or under the slopes or under the main wind direction are prioritized for retention. In the case where the cut root is 1/3 of diameter, retain buds where possible that are close to the ground.

The first thinning starts when the tree is 30- 50 cm in height. Thin and retain buds whose quantity is much more than buds for feeding 1-2.

The second thinning is executed when the bud tree is 1-1.2 m in height; thin and only keep enough quantity to grow.

Coppice forest are tended in first 2 - 3 years. Tending techniques o is similar to planted forest. Especially, in the case where height of cut root is 1/3 of diameter, and it is necessary to fully fill up tree's base of new-growing bud trees.

* Nurturing the coppice forest

a/ Natural mixed forest without an even age; if the forest state is of a young forest, or a degraded forest or worse, apply the following:

- If there are enough purpose trees with good quality in the high tree layer, the object is tending this plant storey. The technical impact has the following provisions:

1. Removing trees techniques

a- Select tree species for nourishment: select tree species which is healthy and growing well in the group of commercial trees.

b- Select auxiliary trees: Choose the less valuable trees, but with no expression of blocking nourished trees.

c- Chop down harmful trees: including the gnarled trees, diseased trees, trees of poor quality, tightening necrotic tree, and low commercial tree species blocking nourished trees.

2. Cutting intensity is a reasonable result, but it does not reduce forest cover to less than 0.5.

3. Time: Cutting 1-2 times since the forest has formed a canopy until reaching middle age.

4. Only hack harmful vines; fresh shrubs do not need to be hacked.

- If the tall trees layer of the forest does not have enough purpose trees with good quality, but they are in the low tree layer with required density, nourished objects are the layers of regeneration trees and commercial timber in the low layer. Use techniques according to the following provisions:

1/ First time: Reduce canopy of tall trees layer down 0.2 to 0.3 in the order of hacking harmful trees to auxiliary trees until reaching a suitable canopy

2/ Hack harmful vines and fresh shrubs blocking purpose trees.

3/ The amount of cutting is 1-2 times until the regeneration tree layer reaches middle age.

Artificial forest or natural forests with an even age, must have at least 800 trees per ha evenly distributed on the area

- Purpose:

Nourishment of artificial and natural forests with even age must reach the following targets:

1. Adjust and create a reasonable composition for mixed forest in each nourished phase.

2. Remove trees with bad quality, diseased trees, blocking trees.

3. Adjust and create the suitable density for each age period so that the forest gains yield and high commercial value.

4. Shorten the business cycle without much effect on the final yield.

5. Take full advantage of the intermediate products corresponding to investment and ensure the requirement of sustainable land use.

- Remove trees:

1. Nourished objects are tree species with normal growth, good quality, balanced leaf canopy, few big knotty branches, no disease, and even distribution.

2. Removed trees are trees with bad growth, excreted trees, gnarled and diseased trees, topless trees, less commercial trees, trees with many branch knotties blocking purpose trees.

- Intermediate cutting must be carried out in accordance with the following requirements:

1. The best cutting time is before the plant's growing season. The amount of cutting since a young forest has formed canopy until logging: for a forest of big wood, the cutting times are 1 - 3 times and 1 - 2 times for a forest with small wood. In special cases, it is unnecessary to conduct cutting for a forest with short business cycles.

2. Ensure that the forest has the appropriate density, the canopy of purpose trees have enough nutritious space but do not create big gaps in each thinning.

- Cutting intensity under 3 levels follows:

Strong level: The distance among remaining trees is diameter of tree canopy at the major logging age

Average level: Distance among remaining trees is 1/2 of diameter of the tree canopy at the major logging age.

Weak level: The distance among the remaining trees is 1/3 of diameter of the tree canopy at the major logging age.

- The time, frequency and density of cutting must be specified under the ecological characteristics of tree species, site conditions, and density and production targets.

Particularly, light-demanding tree species with fast growth and straight tree-trunks need to be trimmed early and strongly.

It is strictly prohibited to take advantage of intermediate cutting for abusive exploitation of forest products

3.1.3. Forest restoration

- Object:

Areas have good productive capabilities (elements of natural conditions, favourable biology).

- Techniques:

+ Average time for forest to recover and close canopy (0.5 of canopy) is 7 - 8 years and natural regeneration of purpose trees under the forest canopy is approximately 1,000 trees per ha.

+ After the recovered forest closes the canopy, it then needs to be applied nourishment or enrichment solutions. When the defined deadline comes and forests have not still recovered, but still have good condition, forests will be applied the plantation solution.

3.1.4. Forest reclamation

Forest reclamation is approach which entire vegetation will be replaced by new vegetation to increase productivity and quality. Similar to forest enrichment, forest reclamation can rely on the old vegetation to adjust light for planted trees and keep commercial tree species of entire forest. However, differences between forest enrichment and forest reclamation are intervention intensity and the difference between the new forest and old forest. In forest enrichment, the original vegetation is only supplemented by commercial tree species, whereas in forest reclamation, there is a completely replacement of the old forest. In many cases, forest reclamation also means reforestation after clear harvest.

- Objects:

Targetted areas for forest reclamation include severely degraded forests, which have low natural regeneration, consist of mainly uncommercial species and where there are large gaps in the forest.

- Techniques:

Clear existing vegetation and re-plant by native or introduced tree species which is high commercial value and can grow faster. In this case, the applied techniques will be similar to plantation techniques. The differences between

forest reclamation and reforestation on non-forested land show at the points:

+ The logging and clearing of the existing forest takes a lot of work and the cost is usually higher than the sale value of harvested products because these forests were degraded and little commercial timber. To improve the productivity and efficiency of the vegetation treatment, a mechanical method must be applied. However, this site preparation method has environmental problems such as destroying the soil structure. Cutting trees is conducted by chainsaw; non-commercial trees will be collected, chopped or burned on the area.

+ Soil fertility of these sites are better than that in grassland.

Tree coppice can grow rapidly but require better tending in comparison with normal reforestation.

If site for planting is prepared as planting strips (clear vegegation) and reserved strips (keep vegetation) the reclamation technique is similar to forest enrichment.

3.2. Thailand

As for some Southeast Asia countries, Thailand has clear policies for improving large regeneration forest soil by native planting (Blakesley et al., 2002). There have had

some success. In many research experiences, the purpose of Framework Species Method and multiplication with native seed to improve the forest area, defines their ability to master ecological conditions and the socio-economic conditions. The selected Framework Species are based on their ability to live for a long time, fast growth, to live well under herbaceous tree species' shadow and have the ability to attract birds to scatter seed in plantation areas or nest places. The ability to attract birds to scatter seeds of many tree species in plantation areas increases the restoration of the biodiversity. Besides, the Framework Species should be easy plantings from nurseries. A list of the Framework Species in evergreen forests in northern Thailand consist of 36 species from 19 families including pioneer species such as Melia toosendan and climax species such as Hovenia dulcis. The important families include Moraceae (4 species), Meliaceae (2 species), Beans Leguminosae (2 species) and Fagaceae (6 species) (Blakesley *et al.*, 2002). 10 species have been selected for the restoration of seasonally dry tropical forests in northern Thailand including Castanopsis acuminatissima, rimosa Dalbergia, Diospyros glandulosa, albiflora Eugenia, Ficus glaberrima var.glaberrima, Lithocarpus craibianus, Melia toosendan, Prunus cerasoides, Quercus semiserrata and Spondias axillaris (Elliott *et al.*, 2002). The different species make seeds at different times of

the year and often have different growth rates. Their germination range from 38-89% and the time to reach the standard size for planting from 119 days to 609 days. By studying and testing for reforestation programs using Spondias axillaris Roxb (Pakkad *et al.*, 2003) the selected parent tree species met the criteria of the selected tree parents for good seeds: survival rate of seedlings over 70%, 100 cm seedling height or more after the first growing season, the percentage of germination in the nursery more than 40%, and survival rate of seedlings in the nursery more than 70%. The study results also showed that Spondias axillaris has more potential than other species because its survival rate and initial growth rate are very high.

The following summary presents the biology and engineering used to tree species used in reforestation, mainly in Thailand

1. *Spondias axillaris* (Roxb.) (Burtt & Hill, 1937)
   Morphology

Figure 17 Spondias axillaris

Trees are large, deciduous in the dry season, wide umbrella-shaped canopy, height of 15-25m, a diameter of 40-60cm or more, straight trunk, brown or grey-brown, thick, lengthwise cracked and flaking bark, looks like a slice of flowers; pink flesh shell thickness of 2cm, with grey plastic; and black or brown-purple brown shoots with light brown packaging giant. Leaves are odd-pinnate, serrated margins, 30 to 40cm long with 7-15 leaflets. Leaflets grow on, 5-10cm long, 2 to 4.5cm wide, ovate, or oval-shaped label, stump falls slightly,

head tapered, serrate leaves or not, short-stalked, and 5-6mm long. The flower is complicated, unlike the original. Male flowers are red purple pseudo hermaphrodite, grow in inflorescences in axillary or terminal spikes, 4-12cm long. Female flowers are solitary, grow at the axillary; sepals 5; petals 5; stamen 5 cells.

Lean fruit is round or spherical, measuring 2-3cm by 1-1.5cm, yellowish brown when ripening, with edible flesh. Solid seeds have 5 holes on top, and consist of 2-4 property pollinated embryos.

Distribution

Spondias axillaris is distributed in South Asian countries such as India, Nepal, and Southeast Asia in Thailand, Malaysia, Indonesia, Laos, Cambodia, Vietnam and the southern provinces of China, such as Guangdong and Guangxi.

Biological features

Trees are scattered in both primary and secondary forests at an altitude below 1,000m, and concentrated in an altitude of 200-500m elevation. Trees grow in sub-tropical climates and tropical regions, with rainfall of 1,500mm/year and seasonal distribution. It is easy to find them on hillsides that have a sloping gentle terrain, drainage, places with a

kind of forest soil that is less acidic, moist, deep, thick, red or yellow on land above shale, sandstone and limestone. They are a light demanding species, but at less than 3 years old they tend to grow under shadow; grow rapidly, especially in the period up to 1.5 years old. The average growth in height is 1.5-2 m/year and 1.5-2cm diameter growth/year. A 5-year-old tree can reach a height of 7-8m and a diameter of 7-10cm; 10-year-old trees can reach a diameter of 20cm. Then the growth rate decreases. Roots mainly are cluster roots, spread over a diameter of 3-4 metres and a depth of 50-70cm. They easily regenerate by seeds and shoots. 7-year-old tree species start blooming.

Methods and techniques for growing

Depending on the conditions, the following methods of planting are possible:

- Plant mixed species and supplement a bunch of holes. Combine with regeneration, promotion of natural regeneration, and reforestation after planting.
- Plant mixed species and supplement strips, enrich degraded secondary forests that have a shortage of trees for regeneration purposes.
- Plant comprehensively tamed species instead of shrubs, grasses and scattered trees or after planting support trees, acacia, fences, etc. in vacant and less

degraded land.

Planting density

Supplement by planting clusters or enrich by planting sparsely with a density of 400-500 trees per ha, at a distance of 5x5m or 4x5m. Support trees like Sapindaceae, and Acacia need to be more thickly planted at a density of 1,000-2,500 trees per ha, at a distance of 5x2x2m or 4m.

Vegetation treatment

Clear vegetation in strips 1 m wide, on the contour. When clearing poor secondary forest trees, leave the regenerating valuable timber trees. Many worthless trash trees with a height of 5-7m on the floor need to be cut down to for wood and easier clearing operation.

Site preparation

Dig holes of size 30 x 30 x 30 cm or 40 x 40 x 40 cm. Holes are in the cleared strips. Planting supporting species between two *Melia toosendan* rows.

Planting

Select a qualified tree, shed their cover and put into a hole. Fill up and press around tree's base and then cover with soil 4-5cm above the hole.

Tending

Replanting dead trees in autumn after planting. In the first three years, 1-2 times tending times are conducted per year. It includes removing invasive tree species, and heap up soil around tree's bases in the beginning and end of the rainy season. In the fourth and fifth year, only one tending is conducted every year. It mainly removes shrubs, vegetation, and adjust the canopy cover and keep canopy cover approximately 0.2 - 0.3.

2. *Melia toosendan* Sieb. et. Zucc

Melia toosendan Sieb. et. Zucc, *Meliaceae families*.

Description: Trees measure 10m or more in height, wigs are grey-black or grey-red. The leaf is odd-pinnate leaves 2 times, alternate, 5-12 cm peduncle, and soft-bristled. Each first peduncle consists of 4-5 pairs of leaflets. Leaflets grow alternately. Their shape are oval-lanceolate, 4-8cm long, 2-3 are 5cm wide, long spiky top, wedge-shaped corner, round edges, sides leaves are hairless, and 12-14 double-ribbed sides. Inflorescences are at the top of the small petal 6-15cm long, half the length of the leaf. Hermaphroditic flowers are white or purple, thick. Sepals are long, hairy, 1-1, 3cm long spatulate-shape, hairy on the outside. Stamens focus on the tube with 10-12 teeth; oval anthers; 6-8 cells. Nuts are big, quite spherical, 2.5-4cm long, 2-3cm wide, pale yellow when ripe.

Living habitat and harvest: This species is distributed in Japan, China, Thailand, Laos and Viet Nam.

How to plant seedling from seeds

Collect yellow fruit on the land from October- December. Dried fruits are separated to get seeds. These seeds are sown shallowly under the light with 1:1 of the rate of forest land and sand land to prevent from humidity loss. They rapidly sprout. Transplant tree after it grows the first real time (best in January). Implement measures to prevent insect, butterfly and fungal infections and do not prune or fertilise (unless there are signs of a lack of nutrients for development).

Seedlings grow rapidly reaching 30cm in height in the first growing season after the grain harvest (time in the nursery is 7-8 months). Ensure robust and healthy trees to plant under sunlight and reduce watering in the 6 weeks before planting.

How to plant and tending seedling?

Seedlings are extremely sensitive and require special tending during transport. They can grow well with a minimum tending condition, but the best growth is with cardboard.

3.3 Malaysia

It seems to be extremely difficult to perform tropical rainforest restoration and it often grows species with fast

growth such as Eucalyptus with its original from Australia, long leaf pine from USA and Acacia mangium. These exotic species grow very fast in the early stages. From then, they grow in a canopy layer, but they more easily bring dry air, strong winds and destructive pests. Afforestation with these species is not always successful (Miyawaki, 1999).

Miyawaki tested to select species from potential natural vegetation in the area; tree species in the Dipterocarpaceae family, including *Hopea, Shorea and và Dipterocarpus*. 91 species that are planted mostly in tropical rainforest communities can be used to create the natural biodiversity of ecology. This may be the newest method in replanting forest in the world (Miyawaki, 1999).

Applying the even methods, the authors also show the success in restoration, preventing tree species from disaster and giving enviromental protection.

Now, the Malaysia Ministry of Forestry has been studying and researching other species for reforestation that provide significant timber to meet dosmetic and export wood demand. From the mid-1980s, rubber wood has become an important timber source for manufacturing furniture products (Krishnapillay et al. 2007).

Aside from rubber wood, many other species are also being researched on a large scale including *Tectona grandis* and

Azadirachta excelsa and so on. Teak used to be grown only on the dried regions of northwestern part of Malaysian Peninsular, but now it is also planted on a small scale in the wetter southern areas. They have good growth, with the only downside being that there is no closed growth cycle. Therefore, the timber quality is not high. Other species are also planted like Khaya ivorensis, Khaya senegalensis and Swietenia macrophylla and some tree species of the dipterocarp family (Krishnapillay et al. 2007)

3.4. Indonesia

Species are often used for reforestation as monoculture plantation include a number of exotic species with faster growth and native species such as *Acacia mangium, Acacia auriculiformis, tectona grandis, Swietenia macrophylla, Swietenia mahagony, Peronema canescens, Eucalyptus spp, Gmelina arborea, Agathis borneensis, Pinus merkusii, Shorea spp., Lapopetalum spp, Intsia bijuga, etc*. (Ani Adiwinata Nawir *et al.*, 2007).

Forest restoration projects through utilising plots established in Eastern Kalimantan, have been performed and the result is the planting of Peronema canescens which are a fire tolerant species used for fencing. Then the main species used for forest restoration are dipterocarps species because they are native species. In addition, species with slow,

average and fast growth are also selected to reduce the risks and ensure biodiversity. Two exotic species are also planted such as Gmelina arborea which is used for artificial barriers and *Paraserianthes Falcataria* which is grown for shade trees. This tree is part of the oil family.

Plantation activities in the project are carried out in areas where planting has occurred and have burned strongly, by planting species *Peronema canescens, Gmelina arborea, Tectonia grandis, Swietenia mahagony, Duabanga moluccana, and Antocephalus cadamba* and tree species of the palm families. Forest enrichment also is conducted in areas where the forest has burned strongly or at an average level by using 15 different species and different methods including planting under trip, row and clearance (Ani Adiwinata Nawir *et al.*, 2007).

According to Kuswata Kartawinata (1994), the Indonesian Ministry of Forestry, has selected a list of native species including fast-growing trees for forest restoration from degraded forest land. They are *Albizia falcataria, Acacia mangium, and Eucalyptus urophylla và Pinus merkusii*. In addition, studies have used valuable pioneer species and secondary species like *Cratoxylum arborescens, Duabanga moluccana, Macaranga spp., Trema orientalis, Peronema canescens, Pometia pinnata, and Cananga odorata which*

grow in the first stage of succession in plant communities (Kuswata Kartawinata, 1994).

Chapter IV. The way forward

4.1. Technical gaps

4.1.1. Natural forest

Sivilcultural solutions applied to natural forests and production in forests have been guided by Norm QPN 14-92 attached to Decision No 200/QD-KT issued on March 31st, 1993 by the Ministry of Forestry. Some technical problems were generated and the solutions are discussed below.

a. Selective logging

The most important technical issue in the selective *logging* system is the regulation of a minimum logging diameter. A minimum logging diameter is defined by Statutory Instrument (Decision No.04/2004/QD-BNN-LN issued on February 2rd, 2004 and adjusting and supplementing the Decision No. 40/2005/QD/BNN by the Ministry of Agriculture and Rural Development) and is implemented according to various wood groups for different ecological areas. These regulations show a number of inadequacies and do not have a sufficient scientific basis. Athough civilcultural solutions must be executed before and after logging as defined by statutes, in fact this has not been executed in a serious and strict manner (Nguyen Thanh Xuan, 2004; Do Dinh Sam et al., 2006).

Maximum logging production has been defined, but in

fact this production has often been abused and exploited at higher levela than permitted. The main reasons for this phenomena are: (i) In most rich natural forests (major logging objective), a number of trees with over minimum diameter are exploited too much on a relative basis; (ii) Estimates of forest production are higher than the real production. This can be caused by errors in investigation but it cannot be excluded that forest owners and designated officials have consciously colluded to increase production to increase their exploitation; and (iii) The state does not have the ability to control illegal logging.

In fact weaknesses in the execution of regulations of natural forest logging are mentioned in many scientific research projects. Actually, the selective logging system is the harvesting wood method, but in terms of a civilcutural solution it has not gained its desired effectiveness. This is caused by some of the following limitations:

- The regulation of a minimum logging diameter has not focused on the differences in the growth speed of species leading to wrong decisions in deciding diameter exploitation of some species;

- Lack of attention in the investigation of factors such as reserves, structure of the components of forests, and species of components of the forest after harvesting. In addition, erroneous assumptions about diameter distribution leading

to the expectation that after logging the forest will regenerate, has not be achieved;

- Regulation on the number of trees left after logging for each diameter size is a technical problem that needs to be addressed rather than have a regulation on the minimum logging diameter. It means that it is necessary to change fully the concept of selective harvest methods without them being based on the minimum allowable diameter. Selective harvesting methods should be based on the structure of distribution purposes under diameter of the tree. Also, it means that the operators may be permitted any diameter size.

- In fact, logging designs only focus on economic factors, meaning that only trees with high commercial value are selected and cut (as long as they reach the defined minimum diameter). The issue on hygienic cutting has not been addressed. As a result, forest quality after logging is extremely poor.

b.Forest maintenance

Natural forest maintenance is a sivilcultural technical method for adjusting density and creating a suitable composition for the forest at each development stage by rejecting trees with bad quality, disease, hollow trunks or a tree blocking purpose tree to shorten the business rotation, increase productivity and product quality. The technical

aspects for this solution have been defined in detail in the QPN 14-92; however, in the business practice for natural forests, compliance with technical regulations in forest nourishment is not strictly executed because:

- Forest owners have not spend enough money on execution; in common with others, expenditure on forest nourishment is performed under a plan which is assigned by Senior authorities.

- There has not been a mechanism implemented to compel forest owners that they must deduct a part of their business capital to implement natural forest nourishment

c. Forest enrichment

The most important technical issue in forest enrichment is tending and protecting the planted tree; tending and protecting trees for enrichment in natural forest is not as homogenous as tending and protecting trees for afforestation; but in fact, tending and protecting trees for enriching forests are still applied under a process and the rules for forest plantations; it takes only 2-3 years of tending after planting. Many examples of the enriched model have failed because forests are not tended for after the tending time ends (3 years after planting). As a result, tree species for enrichment are covered by the canopy (it is often called "planting in the pipe") and do not have enough light to grow. tending and treating for enriching natural forests need to

resolve issues such as how often tending takes place and for how many years after? Does the impact of tending bring economic benefits? Important impacts of tending enrichment tree species are the layer of high tree treatment, light adjustment for tree species by thinning in strips, filling non-purpose tree blocking planted trees, cutting liana, thinning capony on the above layer. These activities waste much time and require much expense, so in fact, they are not always done.

d. Assisted natural regeneration

This technical solution is commonly applied to natural forest recovery because it is the cheapest solution. Restoration that promotes natural regeneration started in the early 1960s and has had many extremely important innovations and many technical advances proposed which have guided work that is in process. However, the systems used have not implemented all the parts to this very well. Forest owners like households, private people, mountain hamlets and hamlet communities have been handed forests as part of forest regeneration process. In this situation, forest management is based on communities who have not been trained on techniques to apply for extensively assisted natural regeneration approaches. Morever, assisted natural regeneration is mainly applied in forest restoration and special-use and protection forests, rarely to forest

production. This is because natural regeneration trees are mostly pioneer species which favour light, and are not of high quality.

According to Nguyen Xuan Quat (2004), natural regeneration in recovering forest has many issues which have not been resolved. Two of the most pressing issues relate to effectiveness and the stable development in which forest is regenerated and recovered: (i) *Firstly:* All of the things relating to the quality of restoration forest, such as which object should be chosen for development in the forest so as to be quickly effective. Also, how to make the forest a nurturing forest or how to choose methods for each affected object which are easily done and cheap and applied so the forest can remain stable under sustainable development. (ii) *Secondly*: All of these things relate to the rights of people planting directly in the forest, especially farmers and communities who live in the forest or on the forest's edge. How to attract them to participate and become fond of the restored forest? How top resolve long-term rights to use land and forest; the right to use products from the forest in order for them to have a present and daily living source?

4.1.2. Bare land and shrub land

Current plantations on vacant land and shrubland still focus on the purpose of greenery planting; project 327

(former) and 661 only invests in planting protection forest and special use forest. Production forest plantations on bare land/shrubland are still limited, especially, for the poor forest owners. In terms of technical aspects, there are some essential issues:

- Select planted species: The Ministry of Agrilculture and Rural Development have issued a list of the main force tree species for production in forests for 9 forest ecoregions. However, the application of this list actually causes more confusion for the forest owner and the project owner. This limitation is because: (i) The scientific and technical basis to offer a list of tree species is researched at the macro level, the relationship between the tree and site on a micro scale has not been researched Carefully. (ii) Lack of a socio-economic basis, so products can be used by local people; (iii) A lot of species in the proposed list do not have a planting process or technical guidance; (iv) There is little information about native species.

- Trees for afforestation now are mainly introduced tree species with fast growth such as *Acacia auriculiformis* and Eucalyptus. Very few native tree species are used for economic plantations. Although there have been many advances in the field of genetic improvement, generally species used in afforestation are still poor quality leading to

low yield and quality of plantations. There is a lack of high-quality nurseries to provide seedlings for planting in Vietnam, especially native species.

-Fire and pest and disease still have been serious issues which reduce the effectiveness of plantation efforts

- There is still too many gaps in the knowledge of planting native trees on bare land/grassland dust.

4.2. Social – economic problems on species selection for forest restoration

4.2.1. Natural forest

The most prominent social-economic issues relating to restoration are: (1) The participation of local communities; (2) Poverty; and (3) Lack of a main work force. Sociological studies have shown that restoration projects are often planned from the top–down, so they have not attracted the active participation of local communities (Tran Van Con, 2001). The active participation of communities in restoration projects are limited by poverty, commonly in the mountains. If restoration projects do not embrace the urgent and essential issues of local people, then there will not be community, leading to indifference, nonchalance or even estrangement within communities. The farmers usually prefer to use their time on activities which bring directly benefits because of their daily needs of existence. Therefore,

people’s initial economic needs must be of concern when conducting restoration projects. Projects must create opportunities to increase income and contribute to the livelihood of the community. Efforts at restoration in remote areas have been limited because of lack of a workforce.

One of the necessary requirements for effective restoration is issue-solving for the benefit of indigenous communities. When local people need forests to survive, the forests must be used. All restoration projects with long-term targets will not allay people’s concerns unless they are clearly explained in terms of the profits/ benefits people can receive. This requires authorities to research forest use and the dependence on forests by comununities living in the forest and nearby. Studies have to be combined with strategic balancing of people's needs. Local people must actively participate in designing and planning and have rights to use the land and forest. To increase the effectiveness of indigenous people’s involvement, it is necessary to do the following:

+ Enhance local people’s participation: It is necessary to convince local people to cooperate as much as possible; encourage local people to actively participate in planning, implementing and evaluating activities of the program. To encourage this participation, the activities must bring pratical material and spiritual benefits to meet people’s real

needs .

+ Strengthen local community organizations: The development of community organisations needs to be based on available organisations in localities.

+ Build faith and create cohesion between people: This is a basic issue for performing successful forest restoration programs in the ethnic mountainous areas, especially in areas where local people still have a skepticism and negative attitude towards policies and external officials. This negativity can be overcome by showing concern, helping them enthusiatically to resolve their daily problems and having an effusive and public communication style to avoid misunderstanding.

+ Bring independence into play. It is necessary to have the finance needed to support the project so that local people can receive new technologies for the development, but the project must try to create the independence of the community from outside funding.

+ Associations and mergers: A complex problem requires mixed solutions. Therefore, the development should be planned by the program with the association and merger of many sectors and economic components to limit the antagonistic and contradictory interests.

+ Synchronisation and comprehensiveness: Any programs, projects of any type also need to be considered as

a part of the developing socio-economic general program and should not always be separated from other areas.

4.2.2. Bare land and shrubland

As we know, bare land and shrubland can be restored into secondary forest by succession and natural regeneration. However, forest restoration by natural regeneration is difficult to be done sucessfully in many bare land and shrub land areas, especially areas used for farming and people's living activities. Therefore, this type of restoration needs the application of different solutions such as agroforestry, lumped forest plantations, and small-scale plantations. These strategies of forest recovery in the mountainous areas also have a lot of limitations from a socio-economic aspect. A number of issues emerge here like: (1) Low infrastructure; (2) Lack of local people's technical abilities; (3) Lack of seedlings; (4) Lack of manpower in organising production and consumption markets for the goods; and (5) The lack of capital for investment and support.

Policy / institutional aspects

Natural forests: Regarding to the policy and institutional aspects, there are some problems about natural forest restoration: (i) The current policies overlap or even contradict each other; (ii) The right to use land and forest resources has not been consistent; (iii) The agriculture and forest encouragement is weak; and (iv) Lack of field staff to

support forest owners. Research and evaluation of systems and policies related to protecting forests now show that there are too many issued policies, but the majority of these policies overlap, and are even contradictory because too many offices have been involved. According to current policies, the rights to use forest and forestry land were allocated for 50 years, and propagation and explanation have not enabled people to clearly understand their rights and obligations. Because there are still thoughts that the Goverment could withdraw land/forest at any time, they do not feel secure to invest in forest restoration because it takes a lot of time for a tree to be productive. Moreover, the force for encouraging people in the mountainous areas is too thin and weak. In addition, forest owners are farmers, when they receive land or forest, they have insufficient technical capacity to develop a forest business efficiently so as to bring real benefits.

Bare land /grasslands, shrub: As presented in parts of the natural forest, the current policies have not created motivation to encourage landowners to plant an economic forest, particularly small-scale plantations. The problem which needs resolving firstly is the forest owner's autonomy in determining exploitation and consumption of products from their plantation forest. Current policies (forest ranger procedure) have too many constraints on forest owners when

they want to exploit and sell products.

4.3 Ecological problems

4.3.1. Natural forests

The types of soil under the ground of natural forests is very diverse with different physical, chemical and biological characteristics. Soil under the ground of natural forests or under plantation forests, under shrubland or grassland, can be classified into groups: acid soil, alkaline soil, salinity soil, stony soil, leached soil, mining soil, drainage and sewerage hard soil and so on. Therefore, the expedience of forest restoration measures needs to be identified so that they can be combined with the inherent problem characters of each soil type. Adaptation of a tree species using restoration depends on the nutriment providing ability of soil and other physiological requirements of the species. Thus, the overarching recommendations on how to select trees to plant on different sites is a solution to the issue about the rate of survival and growth of trees on the site. Normally, selecting tree species pays more attention to market demand (economic value) and the ability to provide seedlings of the species. While the rates of survival and growth are greatly influenced by the land, planting trees on degraded lands is trying to have an influence on soil properties. This can be done through various mechanisms such as nitrogen fixation

and symbiotic fungus, weathered minerals due to activated roots, supplementing the quantity and quality of carbon compounds in soil, improving soil, etc. Many people believe that forest plantations on degraded land can improve soil fertility and the nutrition cycle. However, it is necessary to have more research to verify this. The number of these studies in Vietnam is still very limited. Infertile conditions of degraded forest land requires the application of soil improvement measures such as fertilizers, microorganisms and lime to ensure the success of reforestation. However, the application of these soil improvement measures on a large scale in restoration activities is often limited by the lack of appropriate technology and budget constraints.

4.3.2. Bare land, grassland and shrubs

Planted forest establishment on bare land/shrub usually creates an artificial ecosystem which is far different from the original ecosystem. There are many studies about the effects of planted forest in tropical regions on the environment, but in Viet Nam, information about planted forest impacts, especially introduced species has many limitations and is not homogeneous. For example, the different perspectives on the impact of eucalypt forests on soil fertility; the acidity of soil and on vegetation under canopies (Do Dinh Sam, 2005). Issues related to nomoculture planted forest with fast

growth, short cycle, and the sustainability of soil fertility are also controversial. There is a lack of research on the productivity of planted forest in the next rotation cycles. Currently, there are two different viewpoints about the effects of nomoculture planted forest on the sustainability of soil fertility. (1) The first view was that monoculture plantations with short cycles are unstable ecosystems, and have bad effects on soil fertility and the ecological environment in the next rotation. According to this view, the long-term purpose of planted forest established on bare land and shrub land is a mixed species forest with not same age but with the same structure as natural forest. Planted forest with domesticated species is only a temporary solution when the site is too bad, and native tree species cannot be used. When the site has been improved by former tree species, monoculture forests will be tranferred into a mixed forest through assisted natural regeneration and/or supplementary planting of native tree species. This view does not allow clearcutting planted forest to replant the second rotation. Representative of this view are the German experts when implementing forest plantation projects funded by their Development Fund (KfW). (2) The second view is that focused/ concentrated intensive and dosmeticated species in a business forest plantation using clearcutting and then replanting during the following cycles are necessary to

supply materials for industry. However, it is necessary to research the problems on soil fertility and forest productivity for the next cycle. According to this view, the problem of nutrition management in intensive forest plantation is the key to the sustainability of the site. In fact, planted forest businesses in Australia have demonstrated the feasibility of this view and it has been transferred to Vietnam by Australian specialists via small projects funded by CARD. In our opinion, Vietnam needs to further research the use of planted forest on bare land /shrubland in terms of both the technical approaches that depend on the natural and socio-economic conditions of each particular region.

4.4. Selection of species combining economic and ecological purposes

Large tropical forest areas have been degraded, but there are no suitable measures to recover the biodiversity of these areas. Managers usually must choose small scale planting of various species, or replace to recover productivity on a large scale by planting a number of tree species of a species. In fact, there are many choices and we need to review some projects to promote forest recovery on a larger scale as well as achieve a balance of other factors to gain the best combination. Planting many trees with high density brings promising results. However, it is usually

difficult to execute on a large scale because of difficulties in collecting enough seedlings of many trees and the high cost. A solution is planting less species with the same density. This solution avoids difficulties in seed and normally costs will decrease if seeding is sown directly. Then biodiversity can be recovered when the process starts if primary forest is near and plant and animal species from these regions have the ability to move into areas in which trees are planted. The third solution is planting an economic forest with a monoculture economic forest. In this solution, traditional sivilcultural techniques usually are not concerned with biodiversity development (Lamb, 2011). But planting cross-timber species or cross-economic trees under the forest canopy are measures that can bring economic efficiency, improve productivity, as well as give a few possibilities about biodiversity and landscape. Finally, it is possible to plant trees for forming forests on large degraded scale by thinly planting under the way of "planting trees for birds" that is often applied in many deserts. If the surroundings of these regions still have natural forest, seeds of the tree species will be dispersed by birds and will start invading. Each of the above approaches has advantages and disadvantages which depend on the major ecological conditions and social conditions for forest restoration.

The scale of forest degradation and the loss of biodiversity in tropical forests over the world has been widely studied (Brown & Lugo, 1994; Eliott et al., 1995; Grainger, 1988; Lugo, 1988; Prarrof, 1997a; Uhl, 1988, Lamb, 2011). In some regions, primary forests completely disappear and are replaced with grass. In other regions, many species initially can remain in the region, but the biomass structure of forests basically changes. There are a few common agreements about some types of forest restoration executed in these degraded lands. However, there is little agreement about how to conduct these types of reforestation. In some situations, communities have conducted a number of activities supporting natural regeneration such as plucking up weeds, setting up methods of soil reservation and building walls or barriers against animals (Bhattachrya, 1998; Coh, 1995; Gilmour, 1990; Gilmour et al., 1990). In some regions, larger scale forest recovery has been suggested with the purpose of resetting the biodiversity and initial features of the ecology (Goosem & Tucker, 1995; Kooyman, 1996; Miyawaki, 1993; Murphy, 1997). Several approaches to afforestation above bring positive promising results but in fact they are too expensive when performed on large areas. Normally, afforestation not only is performed by monoculture plantings to restore productivity and gain some economic income but also to

provide some benefit in protecting the watershed (Appanah & Weinland, 1993).

However, the third solution is a combination of the two above solutions. It is the restoration of not the entire original biodiversity and productivity improvement of degraded soils. This change brings the recovery ability of at least a part of the biodiversity which has been lost on a more larger scale (Lamb, 1998).

These solutions may represent a choice among multiple combinations of the two factors. There are a number of species used for plantations and the density of the individual can grow. The advantage of planting a larger number of species (e.g., the high rate of initial biodiversity) in the regions where there is a lack of diversity of species increases rapidly and the development of the forest structure is boosted. This may make the recovery of previous wild biodiversity areas increase. But the use of large numbers of different species may present difficulties in obtaining seeds of tropical forest tree species and planting a large number of seedlings. Moreover, the high species diversity may reduce the commercial productivity or economic income because it reduces output per hectare of the most popular tree species with high economic value. The advantage of the plantations is that it is easy to clear weeds quickly and to bring a higher

initial yield. But high density also brings higher planting prices.

In all cases, the necessary precondition for restoring the forest is that assumptions must be accepted by land owners or the land user and harmful activities (burning, grazing, logging, etc.) must be stopped or banned. After that, the regeneration of the land through the normal succession or speed of recovery can be speeded up by replanting. In this, there is a need to review some of the main features of the regeneration solutions which accelerate the recovery process of the degraded tropical land. There may need to be changes in the number of tree species and planting density through considering different situations and the remaining problems needing solutions.

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