Silvicultural Study for Coastal Restoration in Vietnam

Technical manual to the IKI-supported Project

"Ecosystem-based Adaptation (EbA) in the North Central Coast of Vietnam: Restoration and Co-management of Degraded Dunes and Mangroves"

UNIQUE forestry and land use

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"Ecosystem-based Adaptation in the North Central Coast of Vietnam: Restoration and Co-management of Degraded Dunes and Mangroves"

Authors

Nicolas Wittmann (UNIQUE, Germany)

Dr. Ho Dac Thai Hoang (IREN, Vietnam)

Le Thai Hung (Hue University, Vietnam)

Dr. Till Pistorius (UNIQUE, Germany)

Maximilian Roth (UNIQUE, Vietnam)

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ABBREVIATIONS

DBH	Diameter at Breast Height (1.3 m)
EbA	Ecosystem-based Adaptation
IUCN	International Union for Conservation of Nature
MoU	Memorandum of Understanding
NCC-VN	North Central Coast of Viet Nam
TTH	Thua-Thien Hue

1 INTRODUCTION

The coastline of the North-Central Coast of Vietnam (NCC-VN) is heavily affected by typhoons that often make landfall in this area. Some tropical storms have devastating impacts on the population of coastal areas, e.g. Typhoon Haiyan in 2013. Coastal forests on dunes and adjacent sandy areas, along with mangroves along estuaries, constitute a natural protection of resident local communities against such extreme weather events. However, most of these highly diverse forests on extremely difficult sites have vanished or are severely degraded. As a consequence, the poor rural population is more exposed to the impacts of tropical storms and typhoons, which in the context of climate change are expected to further increase in strength. In the worst cases, dunes can breach during storms and expose the agricultural land (mostly used for small-scale and subsistence agriculture) and the fresh water resources vital to the local population.

Figure 1: Breach in sand dune near Hue city in 2001 after tropical storm Eve

To date, damaged and fragile dunes, after typhoon events, have been 'repaired' by costly technical measures. Subsequent reforestation efforts focus on non-native species as Casurina and Acacia crassicarpa. Both species show significant disadvantages compared to the plethora of well-adapted native and endemic species of these habitats. Remnant patches and single trees still exist, providing opportunities for a close-to-nature restoration of the habitat, with the aim of ensuring the protective functions of these areas classified mostly as 'protection forests'[1] where timber extraction is not allowed. Sandy sites – i.e. the dune, adjacent sandy areas, and wetlands – show extreme stand conditions. They should be rehabilitated with diverse and site-adapted tree species and other vegetation in order to ensure the respective protection function.

[1] Note: Protection forests are not protected areas; they serve the provision of specific ecosystem services.

Project objectives

The project IKI-supported project "Ecosystem-based Adaptation in the North Central Coast of Vietnam: Restoration and Co-management of Degraded Dunes and Mangroves" has started in April 2018 and will run until March 2022. It aims at increasing the resilience and adaptability of the local population in NCC-VN to extreme weather events, in particular heavy typhoons, by restoring and improving the protective functions of degraded sandy sites and estuaries. One output of the project is to demonstrate the technical feasibility of specific ecosystem-based adaptation measures (EbA). The measures' impacts will effectively reduce the vulnerability of local communities and strengthen their livelihoods through sustainable business models for restored estuarine mangroves. In close coordination with various stakeholders, the project implements the restoration approach in an integrated co-management approach with selected local partner communities. The pilot activities in three provinces of the agro-ecological zone North Central Coast Vietnam – Thua Thien Hue, Quang Tri and Quang Binh – will serve as blueprints for scaling up to the landscape level, e.g. as part of other international programs focusing on effective coastal protection.

Meeting the challenge

In the past numerous programs have implemented reforestation and enrichment planting activities along NCC-VN's coastline with the aim of stabilizing sandy sites. The species commonly planted are *Casuarina equisetifolia* and *Acacia crassicarpa*. Both species are non-native to Viet Nam and perform poorly in the majority of plantings on sandy areas along Vietnam's coast.

The challenging site conditions are the main reason for the poor performance of past rehabilitation efforts: Surface temperatures on bare sand reach 60 – 70 °C during sunny days in the summer. The very sandy soil is very poor in nutrients, relatively salty, and provides only minimal water holding capabilities. The degraded and deforested sandy sites provide a very hostile environment for any restoration efforts and not well-adapted species.

In a pioneering approach this EbA project aims to restore 500 ha with a site adapted mix of species, all native to the sandy sites of NCC-VN. A number of them are IUCN Red List species. The site-adapted seedlings, produced from locally sourced seeds, will be planted in clusters in order to further increase their survival rate.

Figure 2: Poorly performing plantations of *A. crassicarpa* (top & left) and *C. equisetifolia* (right)

The existing experience with regard to reforestation with native tree species is very limited. In response and as a preparation for this project, existing expert and literature knowledge has been compiled and – making a virtue of a necessity – the most promising technical approaches were selected to be trialed as part of the project.

This study serves as a technical manual for other stakeholders that seek to replicate and further develop the approach. It compiles the practices realized for the implementation as well as for the monitoring of the success of the practices employed. Thus, it details the silviculture applied in the reforestation activities – i.e. seed collection, seedling production, planting, and tending practices. Special focus is given on the variations implemented in each step – i.e. the differences in and the different combinations of practices applied to each individual species.

2 AREA DESCRIPTION

The project area comprises of a total of 450 ha of terrestrial – i.e. sandy sites and 50 ha of aquatic – i.e. mangrove sites. The terrestrial sites are further divided in areas on the dunes themselves, sandy areas adjacent to the dunes, and wetlands that are temporarily flooded during the rainy season. The 50 ha selected for mangrove restoration cover estuaries and lagoon sites.

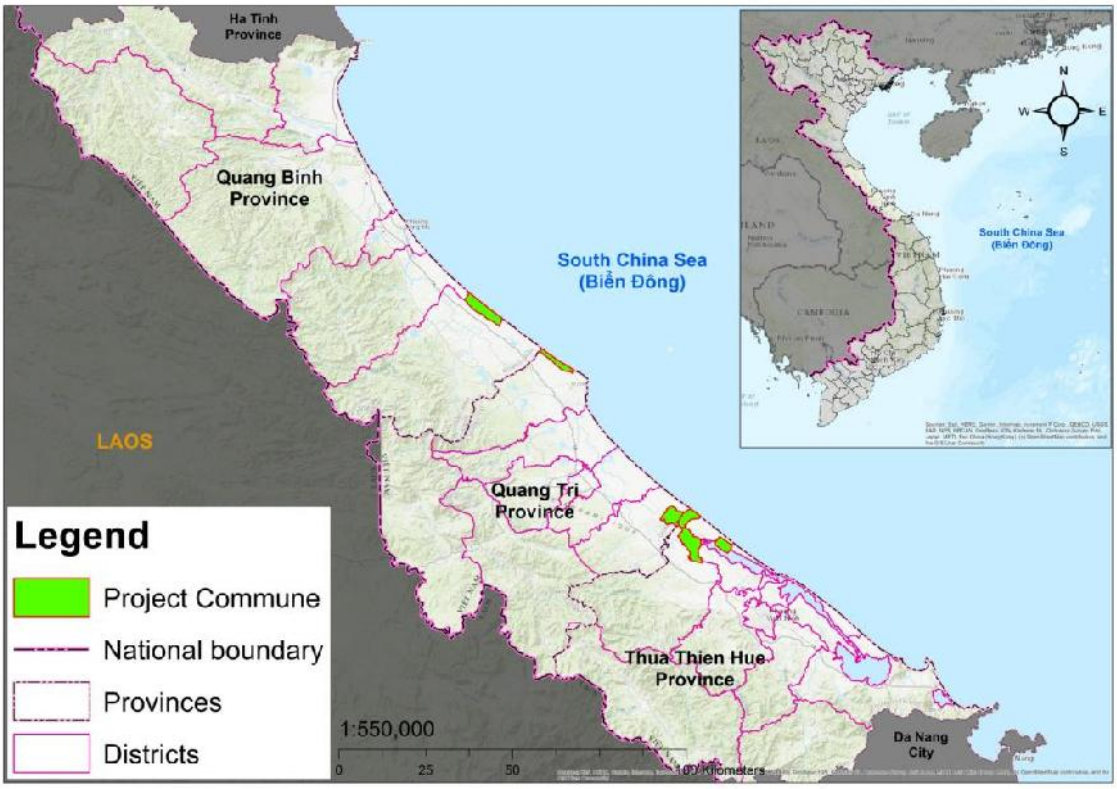

Figure 3: Selected project communes in NCC-VN

2.1 Sandy sites

More than 50% of the total sandy soils areas of Viet Nam are found in NCC-VN. They are located along the seashore in the form of sand dunes and adjacent sandy areas. Their extension inland varies from less than 5 km to about 10 km. Within the project provinces they cover a total of 117.860 ha and are inhabited by about 500.000 people. Figure 4 below details the distribution of sandy soils in the three project provinces.

Figure 4: Map of sandy soil areas along the coast of North Central Viet Nam

Table 1: Distribution of sandy soils in the project area

Province	Total area (ha)	% of land	Population	Coastline (km)	Districts involved
Quang Binh	35.840	4.0	110.000	116	Quang Ninh, Bo Trach, Quang Trach and Le Thuy
Quang Tri	38.058	8.0	100.000	75	Vinh Linh, Gio Linh, Trieu Phong & Hai Lang
Thua Thien Hue	43.962	8.7	300.000	120	Phong Dien, Quang Dien, Hương Tra, Phu Vang, Phu Loc
Total	117.860		500.000	311	13 districts

Source: Year books of Quang Binh, Quang Tri and Thua Thien Hue (various years)

In the past, these sandy soils have been covered by natural forests. Apart from small remnants however, these have been cleared. Striped of their vegetative cover NCC-VN's sandy site exhibit very challenging characteristics regarding potential reforestation efforts. Sand content is >80% resulting in only minimal water retention capacities, low nutrient contents, and high acidity levels. Salty water is carried inland by the wind adding salinity. Cation exchange capacity and water retention capacity depend largely on the organic matter content, which is typically low. In addition, present nutrients are exposed to leaching, due to the strong rains during the rainy season. During the dry season, the temperature on bare sand may rise to 60 – 70 °C on sunny days.

Figure 5: Surface fresh water stream in remnant of natural sandy site forest in Quang Tri province

It is the proximity to sweet ground water that allowed for the forest cover in the past as well as for the agriculture presently implemented on sandy sites. This is made possible by a largely impermeable layer of clay that separates the sandy top soil from a lower, also well drained, grit layer. On top of this clay layer fresh water currents flow towards the sea. Their depth may vary from many meters under the surface-to-surface streams (see Figure 5: Surface fresh water stream in remnant of natural sandy site forest in Quang Tri province above for an example). Figure 6 below shows a cross section of the dune in TTH province from North to South. It depicts the above describe soil layers typical for the project region as well as for other coastline regions of Viet Nam.

The soil depth before reaching moist layers is the main trait categorizing the three types of terrestrial sites found in the project area – i.e. i) sand dune, ii) wetland, and iii) other sandy area. Capillary motions elevate groundwater considerably above water-logged depths making it available to plant roots.

Figure 6: Poorly covered coastal dune (left); typical sandy site behind the dune (center); inundated wetland (right)

2.2 Mangrove sites

The total mangrove area in Viet Nam decreased from 400,000 ha in 1960 to only 73,000 ha in 1990. Up until 2015 intensive reforestation efforts increased the area again to 270,000 ha (FAO, 2015). The vast majority, more than 60% of Viet Nam's mangrove forests grow in the Mekong river delta. Another 18% are found in the northern region of the country. In NCC-VN 1,885 ha of mangroves are found (MFF – FOA, 2016). In addition, here, mangrove restoration activities have taken place in the recent past. In the three project provinces, approx. 500 ha have been planted between 2010 and 2018.

Figure 7: *Sonneratia caseolaris* planted in Cau Hai lagoon, TTH in 2018

The main mangrove site in the project region is Tam Giang – Cau Hai lagoon. It is characterized by a diurnal tidal cycle – i.e. it experiences one high and one low tide every lunar day. The elevation of the tide is relatively small: 0.35 - 0.5 m. Higher tides of up to 1 m are only observed in Tu Hien estuary in Cau Hai lagoon.

In Tam Giang – Cau Hai lagoon brackish water mixes with fresh water from rivers to the west and seawater from the east. Salinity levels in Lagoon rank between 5 – 18 ‰ depending on the distance to the estuaries. Due to the distance the lagoon's mouth, salinity levels in Dien Hai commune are lower than these average values, ranking between 0 – 8 ‰. 0‰ are recorded during rainy seasons and 8 ‰ in dry season. The salinity levels in Phu Dien commune are higher than average because of its proximity to Thuan An river's estuary. It ranks between 5 – 12 ‰ depending on the season.

The main soil type of in Tam Giang – Cau Hai lagoon is sand and fine sand. Organic material and silt is only found in the small bay or in ponds close to the bank. These areas however, may exhibit high organic material contents and high potential for the aquatic biome. The project will therefore concentrate its mangrove restoration efforts on such areas.

Mangroves are typical spawning grounds for fish and an ideal habitat for a number of shrimp, clamp, and crab species. In the medium term, the local communities on whose land the mangroves are planted will benefit from the restoration through the creation of rich fishing grounds.

Figure 8: Lagoon bank eligible for mangrove planting in Dien Hai commune, TTH province

2.3 Project sites

The project plans to implement its co-managed restoration approach on a total of 540 hectares of degraded coastal area within the three project provinces. The majority of the reforested sites classifies as dune area (435 ha). Other sandy sites and wetland areas make up 330 hectares and 40 hectares, respectively. Mangrove sites are comparably small, adding up to 50 ha. As of May 2019, the majority of these areas are confirmed by MoUs between the project and the respective communes (see Table 2 below for shares of confirmed/planned project area). The further description of this section focusses on the sites confirmed to date.

Table 2: Confirmed and planned project areas per site type and province (all in ha)

		Hue province		**Quang Tri**		**Quang Binh**	
		con-firmed	total planned	con-firmed	total planned	con-firmed	total planned
Sandy sites:	Dune area	100	115	100	110	110	120
	Wetland area	5	8	10	17	0	0
	Other sandy area	110	120	0	0	0	0
Man-grove area:		20	40	0	0	0	10
	Totals:	235	283	110	127	110	130
Sandy sites confirmed (planned) total: 435 (490)				**Mangrove sites confirmed (planned) total: 20 (50)**			

In TTH all main site types are represented on a total of 235 hectare of planting area. 100 hectares of sand dune sites are located in Dien Huong commune. There the typical mosaic of bare land, exotic species' plantation remnants and secondary shrub clusters can be found. The largest share (110 ha) consists of a number of plots of *other sandy sites* in Phong Chuong commune. Here the situation is similar, but the planting sites are further from the sea and therefore classify as other sandy sites. In Dien Hai a band of app. 3.5 kilometers along the seaside bank of Tam Giang Lagoon will be planted with mangroves (20 ha). Finally, small plots of temporarily inundated sites add up to 5 hectares of wetlands in TTH province.

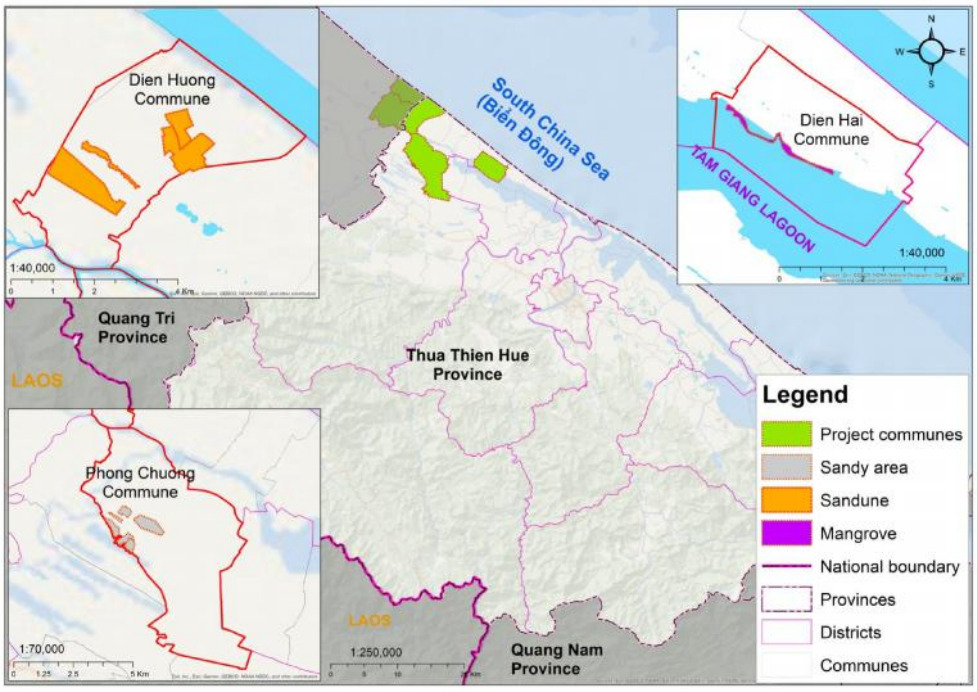

Figure 9: Confirmed project sites in TTH province

In Quang Tri the more than 90% of the project sites comprise of sand dune sites located in two communes (100 ha). In Quang Tri also the largest connected wetland site (10 ha) is situated. Only very few species tolerate water logged soils over a longer period time - i.e. weeks to months of inundation during the rainy season. A species proven to perform well under such conditions is *Melaleuca leucadendra*. Restoration efforts in wetland areas will therefore focus on this species (see also section 3.1.3 *Plant design*).

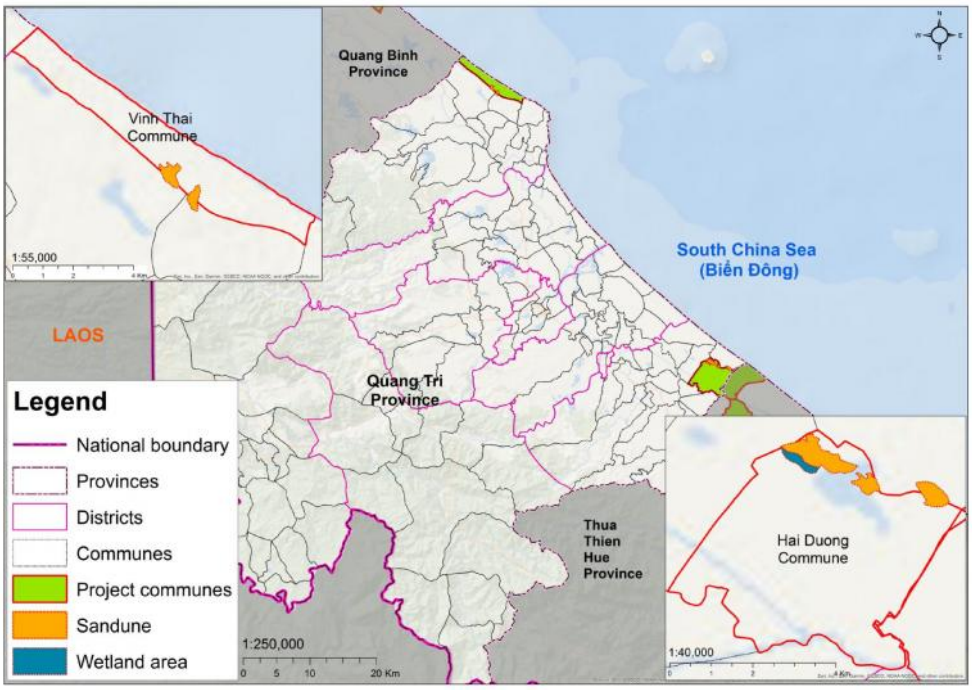

Figure 10: Confirmed project sites in Quang Tri province

In the last of the three project provinces, in Quang Binh, one connected 110-hectare site of dune area will be restored in Ngu Thuy Bac commune. The particularity of this site is its extensive cover with a native grass species. During the restauration activities, this cover will be affected to the least degree possible. Only spot weeding will be implemented to prevent the grass from outcompeting the young seedlings during the first months (see also section 3.1.3 *Plant design*).

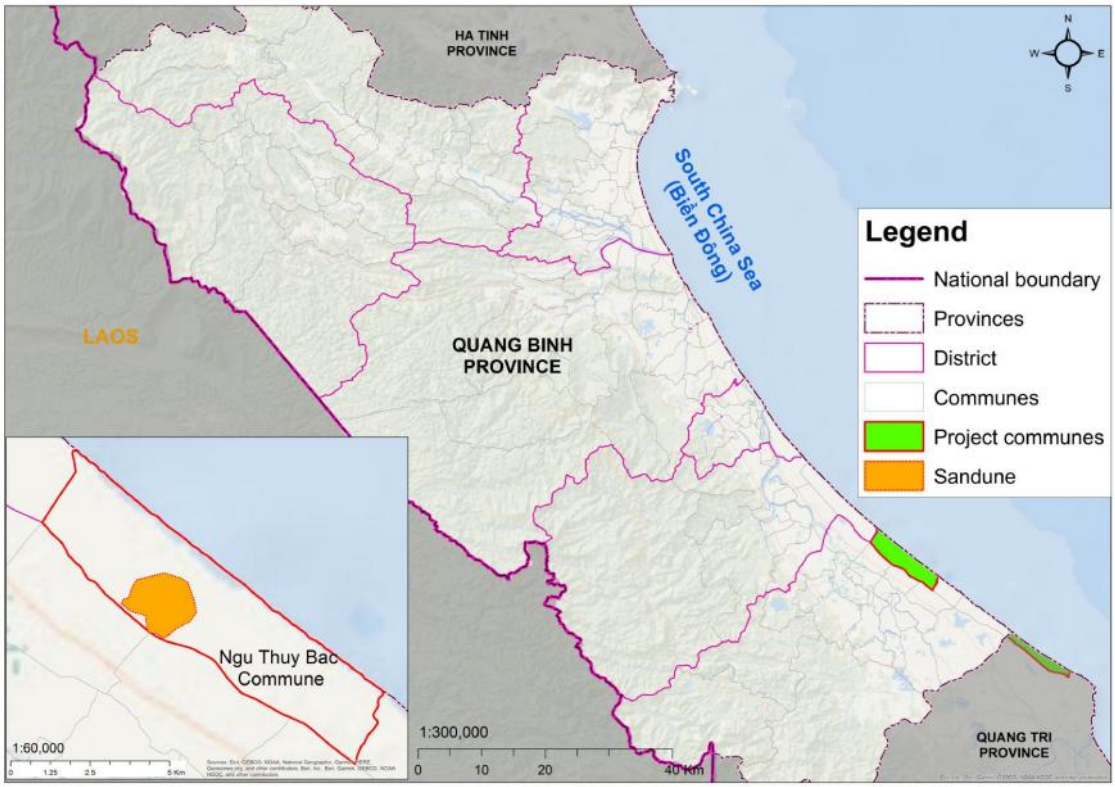

Figure 11: Project sites in Quang Binh province

3 SILVICULTURAL APPROACH

The point of departure for the restoration of sandy sites on the one hand and mangrove sites on the other are quite different. As mentioned in the introduction there is little experience with regard to successful reforestation using native species on terrestrial sites. Existing knowledge and promising approaches have been collected to be implemented in this project. In cases where more than one practice is promising, the different variations are trialed in order to identify and/or verify best practices.

In comparison, the practices implemented in reforesting the estuaries – i.e. mangrove sites – are well studied (e.g. Ha & Dinh, 2015; Tran & Nguyen, 2014; Tran & Ho, 2010) . The restoration efforts of the past ten years have created a wealth of knowledge with regard to the technical implementation.

3.1 Restoration on sandy sites

The main challenge is the survival of seedlings under the extreme conditions on terrestrial sites as described above. The project will meet the challenge by planting species native to the sites in question, produced from locally collected seeds (section 0). As most these species' seedlings currently do not have a market, the project contracted nurseries to produce its own seedlings and permanently supervised the production with a contracted expert from Hue University (section 3.1.2).

In order to further increase the survival rate, the plant design implemented mimics the vegetation clusters that naturally occur on sandy site. The seedlings will not be planted in lines, but in groups of nine individuals. The planting holes will be prepared in a way to give the seeds the best start possible (section 3.1.3). Finally, post-planting activities support the seedlings early development and monitor the success of the implemented practices (section 0).

Due to the little experience with regard to reforestation of NCC-VN's sandy sites, there are no established best practices the project could implement. To make a virtue of a necessity, the project trials a number a variations of the practices implemented as part of the project implementation. Hence, the project results may serve as a best practice guide for future upscaling of the approach (section 3.1.6).

The species the project works with are only introduced briefly in this chapter. Each of the twelve species planted requires its specific treatments. Thus, to increase readability, detailed information on each species and species-specific practices are presented on species fact sheets in the annex.

Table 3 lists the species used to reforest terrestrial sites by scientific name as well as their Vietnamese name. In a number of cases, the local names commonly used in the project area differ from those used in Vietnamese literature. Where this is the case, the local names are added.

Table 3: Terrestrial species planted in the coastal reforestation project

Scientific name	Vietnamese name	Vietnamese name in project region (where different)
Camelia sansanqua	Sở	Dầu sở in Quảng Tri
Casearia grewiaefolia	Nuốt cò ke	Cỗ ngỗng
Lithocarpus concentricus	Dẻ vùng cát	Dẻ lá bóng
Litsea glutinosa	Bời lời	Bời lời xanh
Melaleuca cajuputi	Tràm gió	n/a
Melaleuca leucadendra	Tràm lá dài, Tràm úc	Tràm
Shorea falcata	Chai lá cong	Sưng cát in Phú Yên & Khánh Hòa
Sindora tokinensis	Gụ lau, Gõ lau, Gõ dầu, Gõ sương	Cụ in Quảng Tri
Syzygium chanlos	Trâm trắng, Trâm nổ	Nổ in Quang Tri & Hue
Vatica mangachapoi subsp. obustifolia	Táu duyên hải	Nến in Hue and Southern Quảng Bình

3.1.1 Seed collection

A challenge with regard to seed collection is the limited (known) storing capability. It is therefore generally recommended to sow collected seeds as soon as they are ripe.

All the species used for reforestation on terrestrial sites are native to the coastal, sandy site forests of NCC-VN. The seeds for all but one species are also sourced locally, in the provinces of TTH and Quang Tri. The only exception is the IUCN Red List species *Shorea falcata*. It has almost been extinct in Viet Nam. Its last natural occurrences are in the provinces Phu Yen and Khanh Hoa. Therefore, the *S. falcata* seedlings used in the project had to be sourced from Phu Yen province.

The majority of the seed is collected in the coastal sandy areas of Thue Thien Hue province. In Quang Dien & Phong Dien districts, there are large areas of clustered secondary coastal sandy site forest. They are situated relatively close to one of the project's nurseries. This makes them the ideal sourcing ground for the project's seeds.

As mentioned above *Shorea falcata* can only be found in Southern Viet Nam. Its seedlings and therefore purchased there. *Sindora tokinensis* is the only other species that cannot be sourced in Thua Thien Hue province. The only remaining mother trees known are found in natural coastal forest remnants in the South of Quang Tri province. A total of five mature trees could be identified there.

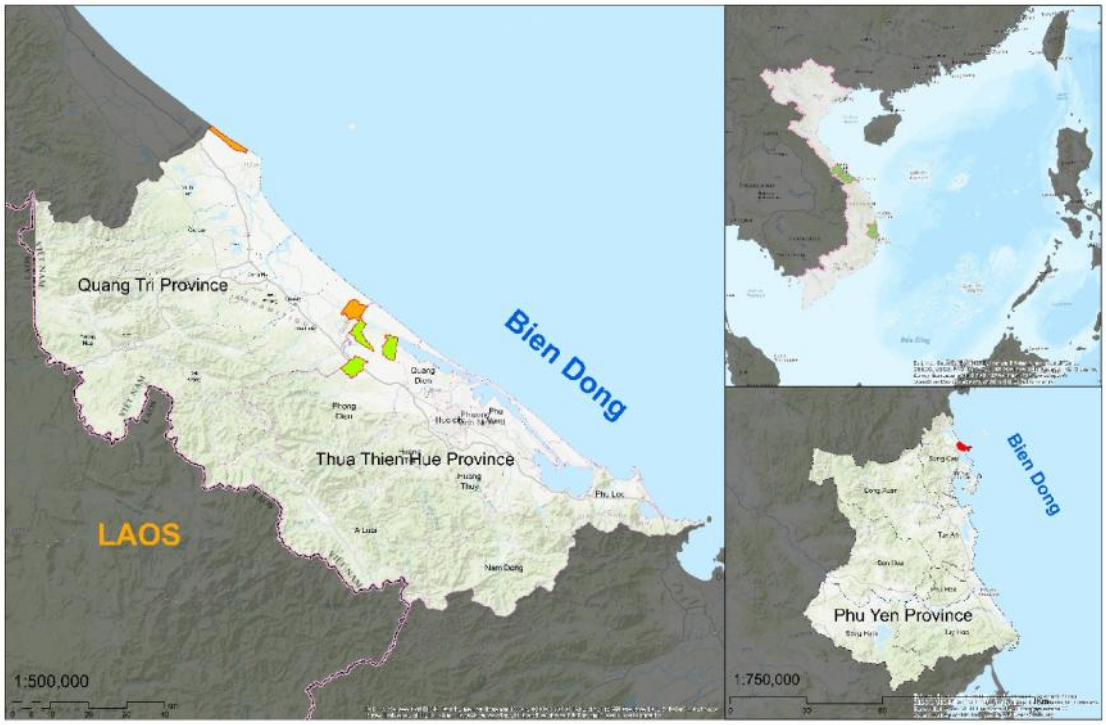

Figure 12: Main seed collection sites in clustered secondary forest in TTH (yellow-green), natural forest remnants in Quang Tri (orange), and Phu Yen (red)

The flowering and harvest periods are very species specific. As could be expected, most species flower once per year and develop ripe seeds during the following months. However, e.g. *Casearia grewiaefolia* flowers all year round, but its seeds can only be collected in September. In addition, the storing capabilities of the different species vary substantially.
Table 4 below gives an overview over the flowering and seed scattering times of the project species. For more detailed information on each species, refer to the species fact sheets in the annex.

The majority of the seeds or fruits respectively, are collected directly from the mother trees in the moment they are ripe. Wind dispersed seeds may otherwise be hard to find once they are scattered. Similarly, very small seeds are difficult to collect individually from the often sandy ground.

Table 4: Seed collection periods for terrestrial species. Species flower in yellow colored and scatter seeds in blue colored months.

Species	January	February	March	April	May	June	July	August	September	October	November	December
Camelia sasanqua												
Casearia grewiaefolia												
Lithocarpus concentricus												
Litsea glutinosa												
Melaleuca cajuputi												
Melaleuca leucadendra												
Shorea falcata							*		*			
Sindora tokinensis												
Syzygium chanlos												
Vatica mangachapoi												

** Shorea falcata mother trees are found in two provinces. In Phu Yen seeds ripe in August, in Khanh Hoa in September, October.*

Storing capabilities and storage trials

Few of the used species have a proven storability over longer periods – i.e. multiple months. Some of the species' seeds, e.g. Vatica mangachapoi, are known to have very limited storing capabilities. For others, save storing practices and periods are still unknown. It is therefore generally recommendable to sow collected seeds are soon as possible after collection.

3.1.2 Nursery approach

Four nurseries were contracted to produce the total of 500.000 seedlings needed for the reforestation of the terrestrial sites. Three of them are situated in TTH and one in Quang Tri. The main selection criterion for the nurseries was their former experience with native tree species breeding. The managers of all four nurseries are connected to the forestry department of Hue University. Professor Dr Duc, head of Hue University's forestry department is one of the leading experts in species native to NCC-VN's sandy sites.

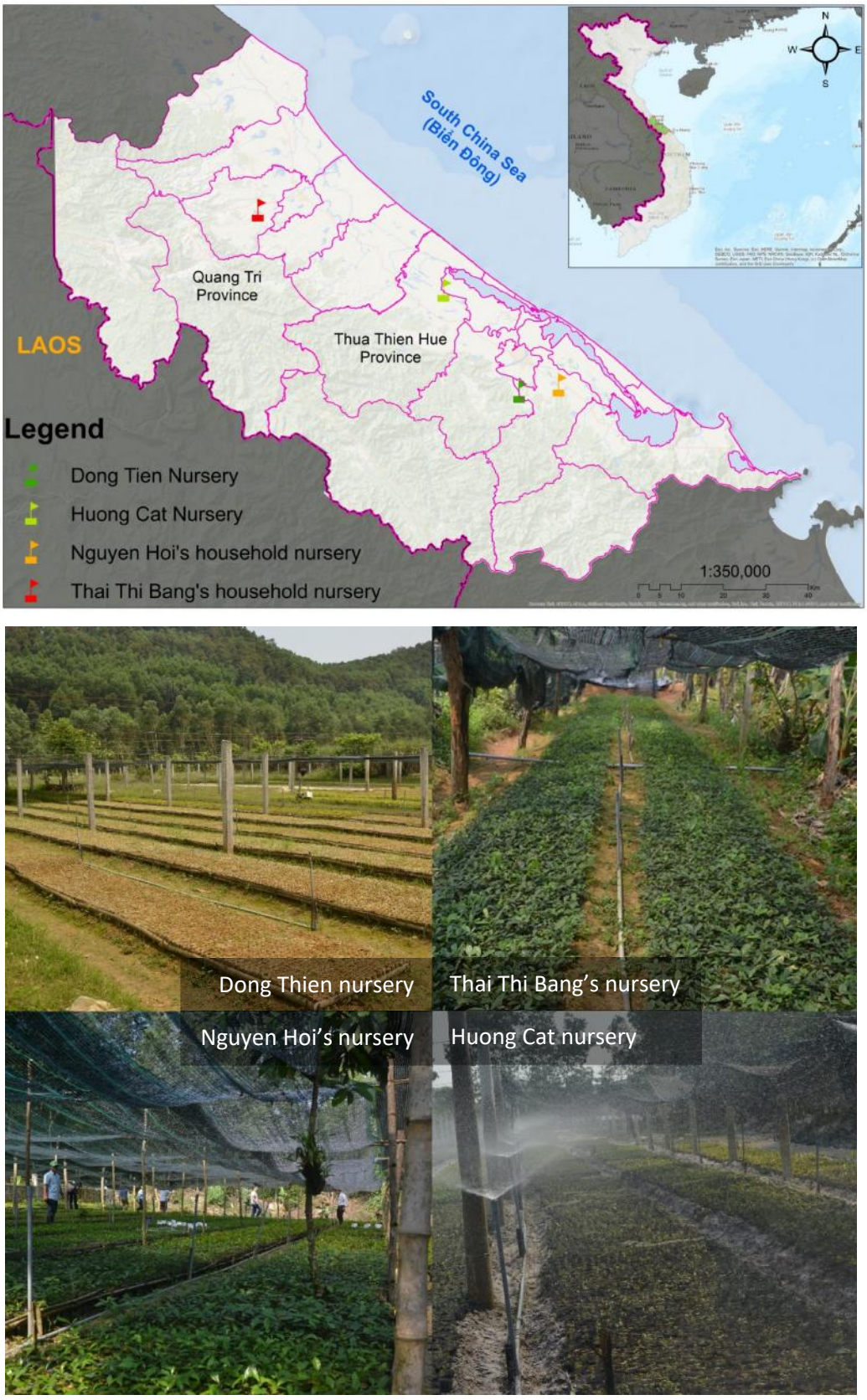

Figure 13: The four project nurseries

Germination

All species are germinated in germination beds and later transplanted into soil bags, rather than sowing them directly into the soil bags. The reason is, that prior to the project the germination vigor – i.e. the percentage of seeds that actually germinate – was unknown for most of the used species. From a germination bed, only vigorous and healthy seedlings are transplanted into soil bags. In case mortality rates are high this considerably lowers labor and space inputs compared to direct sowing into soil bags.

Figure 14: Typical straw cowered germination bed in Huong Cat nursery, TTH

The seedbeds consist of plain, fine sand. In order to germinate the seeds are sown into moistened sand. Individual seeds should not touch each other. They are then covered with sand. As a rule of thumb, the covering layer should be between 1 – 2 times as thick as the seeds' average diameter. Therefore, the smaller the seeds the thinner the layer of covering sand should be. It is crucial however, that the seeds do not dry up at any time during the germination process. The germination beds are therefore covered with a layer of straw. In addition, a layer of mesh is stretched over the germination beds in about 1.8 m height, providing partial shade and very fine sprinklers are used to maintain the seeds moist at all times.

Towards the end of the app. germination time, the seed are carefully observed. The right moment to transplant the seedlings into the soil bags is when they have developed the first pair of *real leaves*. These follow the first developed pair of *cotyledons*.

Soil bags

The soil bags used in the project measure 15 cm in length and 10 cm in diameter. This bag size is a compromise between available root space and costs for production and transportation. The substrate used to fill the bags differs from nursery to nursery. The main ingredient in all nurseries is loose, fertile soil. The exact mixtures are presented in the section 3.1.6 *Variations*, below.

Seedbeds & seedling age

The nurseries' seedbeds are simple construction on the ground. In design, they do not differ from the ones commonly used in the forestry nurseries in Viet Nam.

Figure 15: Seedbeds in Nguyen Hoi (left) and Thai Thi Bang (right) nurseries. The mesh cover provides partial shade.

The intended planting age is 12 – 18 months, counting from the transplantation of the seedlings into the seed bags. The seedling's height should be >30 cm at the moment of planting. In Viet Nam, native tree species seedlings are commonly planted at an age of 18 months. In an enrichment-planting context, these relatively old seedlings have the advantage of being comparably easy to relocate some months after planting for tending interventions. In the Coastal Reforestation project however, there is no need for seedlings to emerge high from surrounding vegetation. On the one hand, older seedlings have a stronger root system, which may increase survival rates on sandy sites. On the other hand, too old seedlings run the risk of developing a disadvantageous root to shoot ratio (see also Box on page 18). In addition, roots may *curl up* over time, as they do not find sufficient space in the seed bags. As a result of these considerations the project will trial different seedling ages as detailed in the section 3.1.6 *Variations in silviculture*.

3.1.3 Plant design for sandy sites

In the sandy areas of NCC-VN, secondary forests typically re-grow first in clusters of five to nine shrubs and/or trees. The plant design the project implements, mimics this clustered growth. The underlying rationale is that small groups of plants create a favorable microclimate with regard to moisture retention and biomass accumulation. Additionally, they are better protected against damage from drifting sand.

Figure 16: Typical clustered growth found in secondary forests in NCC-VN's sandy sites

Each planting cluster is composed by nine individual seedlings. One of them, the central seedling, is of a species with the potential to grow into a medium to large-sized tree. This central seedling is surrounded by a first ring of three seedlings of species that typically grow into shrubs. In the long-term they will occupy different crown strata, hence competition between these secondary species and the primary central specie is limited. The third and final ring is composed of pioneer species with a proven potential to establish themselves in the harsh conditions found on sandy sites. They are considered tertiary species.

On the typical dry sandy sites, *Melaleuca cajuputi* is planted. The species is commonly planted and managed for the essential oil that can be extracted from its leaves. Because of this common use, their ability to establish themselves on sandy sites is proven and the seedlings are readily available and propagation practices are well known in the project area. A different species that is very common in the area is *Camelia sansanqua*. It is of special interest as a high grade edible oil can be extracted from its seeds.

On wetlands – i.e. temporarily inundated sites primarily *Melaleuca leucadendra* is planted. Different to most species it tolerates water logged soils. It is the only species with such a known tolerance. On wetland sites, it will therefore be planted not only as tertiary, but also as secondary species.

Table 5: Species categories within planting clusters

Species cluster categories	Species
Primary species *grow into medium to large-size tree*	▪ *Lithocarpus concentricus* ▪ *Litsea glutinosa* ▪ *Shorea falcata*[2] ▪ *Sindora tokinensis*[2]
Secondary species *grow into shrub, shrub-sized tree*	▪ *Casearia grewiaefolia* ▪ *Melaleuca leucadendra*[3] ▪ *Syzygium chanlos* ▪ *Vatica mangachapoi*[2]
Tertiary species *species with proven reforestation potential on sandy sites*	▪ *Melaleuca cajuputi* ▪ *Melaleuca leucadendra*[3] ▪ *Camelia sansanqua*

The clusters are 2.5 meter in diameter and will be planted in lines of ten meters distance. Open space between two clusters is 7.5 meters – i.e. spacing between cluster centers is ten meters.

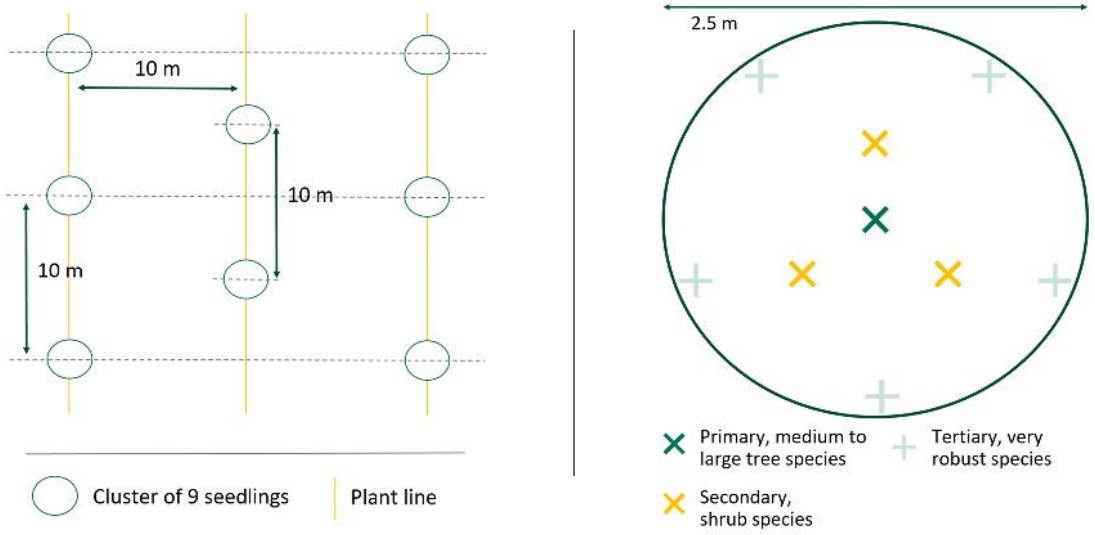

Figure 17: Clustered plant design (left) / cluster composition (right)

[2] IUCN Red List specie
[3] Planted primarily on wetland sites

3.1.4 Planting activities

Sandy sites need relatively little site preparation compared to other reforestation environments. Firstly, there is little competing vegetation and secondly existing vegetation cover will remain largely untouched and is only enriched by establishing planting clusters on the still bare share of the project sites. An exception is one local grass covered dune area in Quang Binh. In order to restore the natural dune forest, the plant clusters need to be protected from the grass' competition during the establishment phase – i.e. the first 12 to 18 months after planting. The planting cluster area plus a 0.5 m ring is therefore cleared prior to planting and cleared again in the post-planting weedings (see also 3.1.5 *Post-planting treatments*).

In the moment of planting, additional measures are implemented in order to support the seedlings in their efforts to establish themselves permanently in the sandy soil: Due to the sandy texture of the soil plant holes cannot be dug into the soil in advance, as it would usually be the case in a reforestation project. Instead, the holes are prepared in the moment of planting the seedlings. In a depth of approx. 50 cm a portion of mycelium penetrated straw[4] is buried. On top of the straw a dose of bio micro fertilizer (500 g) mixed with NPK fertilizer (50 g: 15:10:10) is added. The seedling is planted on top of the mycelium straw into the fertilizer.

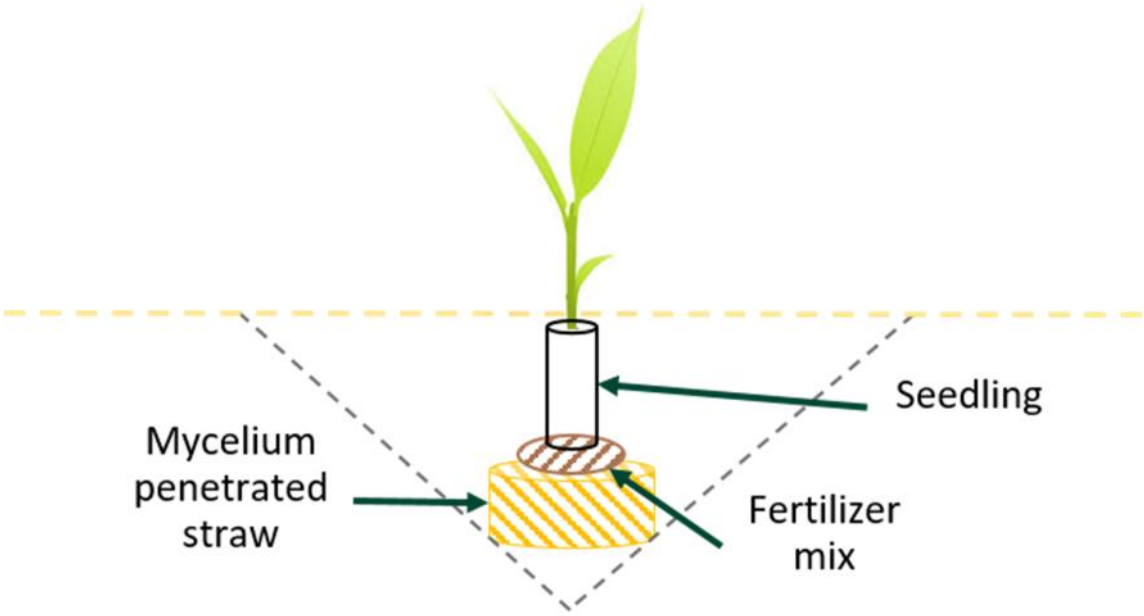

Figure 18: Details of plant hole design

To carry out the planting, local community members are contracted to the degree possible. In case there are not sufficient people available, planting staff from other districts will be contracted. As the plant design is comparably complex, pre-plating training is a priority activity. In each district, planting activities will start with a practical training course in the project area.

[4] Straw filled bags serve as substrate for mushroom farming which is very common in NCC-VN. After growing mushrooms for app. three months the straw / mycelium mix is usually discarded.

As planting trainers and supervisors, project nursery staff is contracted. Directly prior to the planting season 2019 / 2020, they participate in a multiple-day training of trainers course organized and implemented by UNIQUE & IREN experts. Its focus lays on the efficient & effective planning of the planting activities' logistics as well as on a thorough understanding of the planting itself. Both aspects are first taught theoretically and then implemented practically in the field. On the final day of the course the participants outline and plant the trial plots described in section 3.1.6 *Variations in silviculture & trial plot design*.

3.1.5 Post-planting treatments

The tending implemented after planting is comparably straightforward for two reasons:

1. There is no commercial production goal regarding any wood product – i.e. the survival of seedlings is paramount, but their form or growth rate is of lower importance
2. The intensity of weed growth is expected to be comparably low due to the harsh conditions found on sandy sites

Only one annual weeding is implemented at the beginning of the rainy season parallel to subsequent fertilizer application. This approach assures that the planted seedlings benefit from the fertilizer application and no other vegetation in their stead. However, a limited weed growth throughout the rainy season is anticipated and intended. During the dry season, these weeds will cover the soil and ameliorate the microclimate through retaining water.

A potential threat to newly established plantings is larger livestock owned by the neighboring communities. However, only few households own larger livestock such as cattle or goats in the coastal districts. As part of the implemented co-management approach, such livestock is identified and protection measures are discussed. Either the browsing grounds can be chosen in sufficient distance to the project area or the plantings need to be fenced. Once the trees and shrubs are well established, after app. two to three years, livestock can be reintroduced to the areas.

Seedlings that died will be replanted continuously throughout the first rainy season. Local communities' primary schools will be included in a continuous monitoring reporting of dead seedlings.

3.1.6 Variations in silviculture & trial designs

A central bottleneck to the successful implementation of the project is the little existing knowledge regarding the reforestation of the NCC-VN's sandy sites with native species. In response, the project trials a number of promising practices in order to identify best practices for future projects. Crucial in this context are the clear setup and consequent monitoring of the trials. This section presents the variations and combinations trialed as part of the project.

Substrate

Each of the contracted nurseries uses a slightly different substrate as filling for the soil bags. The bases in all nurseries are soils of favorable texture, nutrient content, and comparably low acidity. The soil is bought, delivered to the nurseries and loosened before it is filled into the bags.

In the process of loosening the soil manually using shovels, it is mixed with different additives:

Đồng Tiến nursery: 70% alluvial soils are complemented with 30% compost consisting of composted cow dung. To produce the compost, cow dung, mixed with straw is buried for about three month.

Hương Cát nursery: 90% alluvial soils are mixed with 10% micro organic fertilizer.

Nguyễn Hợi: Here only pure alluvial soil is filled in the soil bags.

Thái Thị Bang: 90% of ferrasols bazan soils are mixed with 10% micro organic fertilizer.

Wildlings vs. nursery seedlings

For a number of species, naturally germinated seedlings (wildlings) are found in large numbers in the vicinity of the mother trees. Where it was feasible, healthy wildlings have been collected and planted directly into seed bags. Table 5 lists respective species and the share wildlings represent of the specie's total seedling production.

Figure 19: Bare rooted *Litsea glutinosa* wildlings ready to be transplanted into soil bags

Table 6: Numbers and shares of wildlings per species where applicable

Species	Number of wildlings produced	Share of total production
Camelia sasanqua	10,000	26%
Lithocarpus concentricus	25,000	19%
Litsea glutinosa	21,000	51%
Vatica mangachapoi	35,000	43%

Planting trials will compare the survival rates and growth performances of wildlings vs. nursery seedlings for a number of these species.

Germination practice Lithocarpus concentricus

In most nurseries *Lithocarpus concentricus* seeds are germinated the same way as other seeds – i.e. sown and covered into moist sand. Nguyễn Hợi nursery however, implements a different germination technique.

The seed are first washed and floating nuts are discarded. Then they are soaked overnight (8 – 12 hours) in about 45°C hot water. 2 parts of boiling water are mixt with 1 part of cold water to reach this initial temperature. Afterwards the seeds are kept in closed large rice bags and washed once per day. Once the tips of the shoots become visible, after approx. 4 days, the nuts are planted into see bags.

Figure 20: *L. concentricus* seeds germinating in plastic bag after treatment. Some sprouts are visible (red arrows).

Seedling age

The ideal planting age is a topic of ongoing debate. On the one hand, an older seedling has a stronger root system and may therefore be more robust when planted. On the other hand an older seedling is more likely to show an unfavorable shoot to root ratio (see box below) and its root growths might have been impeded by the limited growing space inside the plant bag.

The project's seedling production cycle is closely linked to the natural availability of seeds. The majority of species do not allow their seeds to be stored over a longer period of time. A few

species, namely *Syzygium chanlos, Lithocarpus concentricus*, *Melaleuca spp*., and *Vatica mangachapoi*, can be collected also early. For these species, a second batch of seedlings will be produced. The majority of seedlings are planted at an age of 12 – 18 months. The aforementioned species will also be planted with an age of seven to nine months.

Clipping of seedlings

Species native to sandy sites often exhibit a strong root growth during the first months. The plants' resources are invested in establishing a connection to deeper, moister soil layers, rather than increasing its above ground biomass. During the dry summer months, it may then happen that the little-developed aboveground shoot dies back. However, with the first rains the plant regenerates itself from the nutrient reservoirs of its roots.

This natural survival strategy is mimicked by clipping young seedlings at the end of the rainy season in March following planting. The aboveground shoot is cut back, leaving only a stump of about 15 cm. Prerequisite for the success of this technique is the species' ability to re-sprout.

Trial implementation

A project area close to Hue city will be selected to implement the described silvicultural variation trials. The nurseries' staff will establish the trial plots as part of a planting training that is scheduled to happen just before the first planting season commences. The same people will also be in charge of follow-up measurements.

Root to shoot ratio for seedlings

If the above-ground biomass, the shoot, is too large in relation to the below-ground biomass (the root), the seedling is likely to suffer drought stress. I.e. the root is not large enough to support the shoot.

As a rule of thumb the height of the shoot should be no larger than two times the depth of the root in the moment of planting.

Figure 21: Very 'top heavy' *Hopea odorata* seedling showing a too long crown in relation to the poorly developed root

Table 7: Trial design

Substrate / Lithocarpus germination practice trials:

The aim is to test if the different substrates used in the different nurseries have an impact on survival rates and/or growth performance of the seedlings

All non-wildling Lithocarpus seedlings from Nguyễn Hợi nursery are germinated differently (as described above). Therefore this design will also test the different germination practices.

Species group	Specie	No. of seedlings	No. of plots	Comments
I	*Lithocarpus*	1	4	Except *Melaleuca* all species are grown in all 4 nurseries. Each plot shall be established using the seedlings from only 1 nursery. No wildlings are to be used.
II	*Casearia*	3		
III	*Melaleuca cajuputi*	2		
III	*Camelia*	3		

Wildling trials:

The aim is to test if collected wildlings or seedlings from seeds show higher survival rates and/or growth performances

Species group	Specie	No. of seedlings	No. of plots	Comments
I	*Lithocarpus*	1	4	2 nurseries are selected. From each of them, wildlings and nursery seedlings are used to plant 1 pure wildling and 1 pure nursery seedling plot.
II	*Vatica*	3		
III	*Camelia*	5		

Clipping trials:

It shall be tested whether clipping of the above-ground biomass at the end of the rainy season, increases the survival rate of the seedlings.

Species group	Specie	No. of seedlings	No. of plots	Comments
I	*Lithocarpus*	1	3	1 plot from each of the 3 nurseries growing *Vatica* seedlings.
II	*Vatica*	3		
III	*Melaleuca cajuputi*	2		
III	*Camelia*	3		

Seedling age trials:

Seedlings of different ages are compared in their survival as well as growth performance.

Species group	Specie	No. of seedlings	No. of plots	Comment
I	*Sindora*	1	3	Plant in 2019: ▪ 1 plot from the 2018 seedlings ▪ 1 plot from 2019 germinated seedlings Plant in 2020: ▪ 1 plot from the 2018 seedlings
II	*Syzygium*	3		
III	*Melaleuca cajuputi*	5		

3.2 Restoration on mangrove sites

In comparison to the reforestation on sandy sites, mangrove restoration involves well-known species and implements practices that have proven themselves on numerous sites of NCC-VN. In line with its EbA approach the project will put special emphasis on implementing minimal impact practices. Different to the restoration on sandy sites, seedlings for a number of well-adapted mangrove species are available from local nurseries. Therefore, the focus lies on a sound site-species matching and minimum impact planting activities.

3.2.1 Site-species matching

The species used in the project have proven their suitability for mangrove restoration in NCC-VN. Criteria for a successful site-species matching are:

- Bio-physical criteria: tidal inundation – i.e. the number of days per month a site is typically inundated, the soil type, and the salinity of the water
- Socio-economic criteria: for a successful restoration it is necessary to take into account the local population's needs and opinions with regard to the restoration activities

Three species were selected to be planted on mangrove sites. All of them have been planted before in the project region and are readily available from local nurseries in sufficient quantities and good quality:

Table 8: Mangrove restoration species' characteristics

Scientific name	Local name	Tidal inundation rage	Soil type	Salinity range
Rhizophora stylosa	Đước vòi	Every high tide; min. 20 d/m	Sandy rocky to coraline	10-25 ppt
Sonneratia caseolaris	Bần chua	min. 6 days/month	Silty clay	5-18 ppt
Aegiceras corniculatum	Sú	Needs daily dry periods (8-10 hours/day)	Silty clay	< 20 ppt

Source: OFSDP, 2010

In order to meet the socio-economic criteria, public consultations are held in all participating communities. All species have been selected for their suitability on project sites as well as for their potential positive impact on local livelihoods.

3.2.2 Plant design for mangrove sites

Also with regard to mangrove sites, the project aims to create favorable microclimates through the planting of relatively dense seedling clusters, similar to the design implemented on terrestrial sites. The gaps between the clusters serve as access routes for local fishing activities.

The distances in between cluster centers are 10 x 10 m. Each cluster consists of 6 - 9 seedlings and measures 2.5 m in diameter.

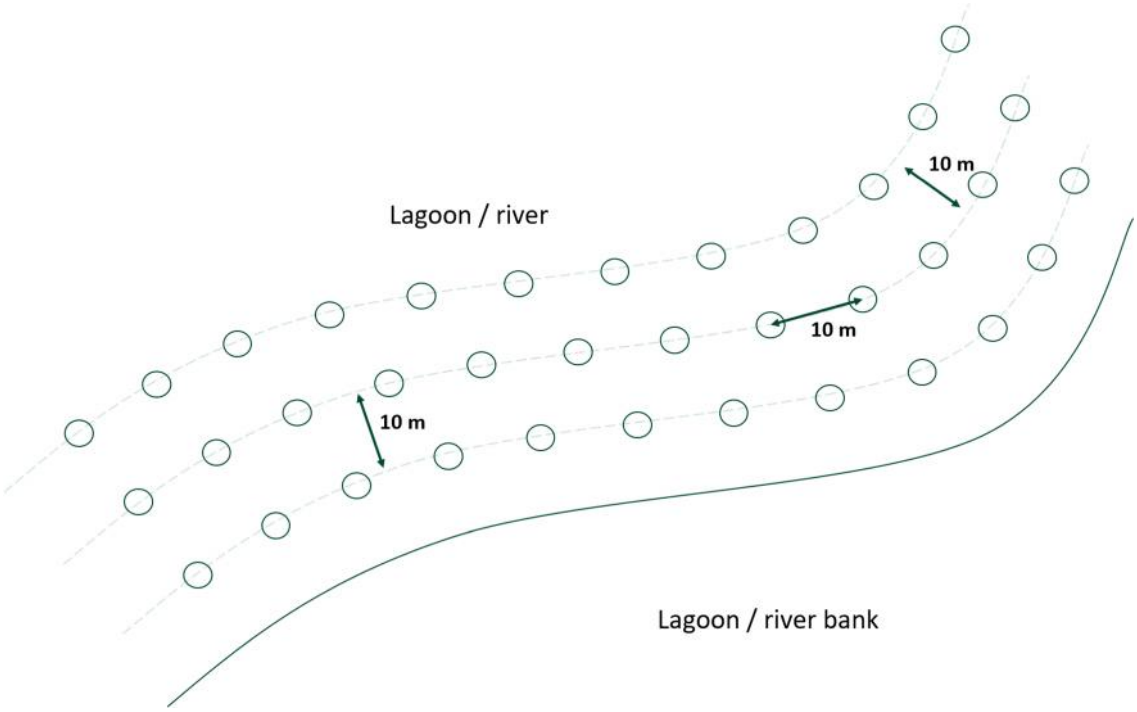

Figure 22: Mangrove plant design

3.2.3 Minimum impact planting

Mangrove planting projects in the past often used heavy machinery – i.e. excavators to prepare the mangrove planting sites. The impact to the site of these measures is substantial (pers. com.). In order to avoid such disturbances, the project targets the banks of estuaries and of the lagoon for its restoration efforts. Only comparably narrow bands along the banks are planted. The water depth at the time of planting should not exceed 60 cm. This way the planting can be carried out manually creating significantly less impact. It is planned in conjunction with the planting activities on terrestrial sites – i.e. people from adjacent communities are contracted and trained to carry out the planting. In case sufficient people cannot be found in the same district, they will be contracted from other district the project works in. Planting season is the rainy season starting in November, once major inundations have past.

3.2.4 Post planting treatments

A bamboo stick of 120 centimeters lengths will be placed next to every seedling planted. They serve two purposes. First, they act as a distraction for oysters, which are very common in parts of the project area. If too many of them settle on a young plant it is likely to break. Secondly, the sticks protect the seedlings against floating plastic bags. If these get washed onto the seedlings during tides they may as well break or suffocate young plants.

The bamboo sticks have to be cleaned of plastic and oysters for six weeks after planting. This will be done by the local population who will later benefit from the mangroves.

4 TRANSFERRABILITY

One of the aims of the coastal reforestation project is to serve as a feasibility study for similar activities in the future. An important consideration in this regard is the transferability of identified lessons learned to sandy and mangrove sites in other geographical regions.

Core factors in the context of the transferability of technical practices are i) the sites targeted – i.e. their suitability for the project species presented, ii) the application of practices not specific to certain species, and iii) the availability of the necessary, specific capacities in similar projects in the future.

Sites and species

The Vietnamese coastline stretches over 3,444 km and covers a latitudinal extension of 1,650 km (Sterling et al. 2006). As a result, site conditions may vary considerably between different sandy and mangrove sites throughout the country.

Site-species matching used for reforestation efforts needs to be carried out carefully. This is true for any reforestation attempt, but especially when dealing with sandy sites. Only the most vigorous and well-adapted species will be able to recover them. Information on the site requirements and the natural distribution of each species within Viet Nam is included in the annexed species fact sheets to the extent available. This shall facilitate the decision whether and which species presented may be of use in a given other project. It is not recommendable to use species towards the edges of their natural distribution, as it is likely that they will not perform to their full potential.

Non species-specific practices

A number of the silvicultural practices implemented are not species specific. Especially the measures taken during planting to minimize drought stress may be applied to any given species (e.g. adding mycelium penetrated straw or biochar).

Other practices may not be species-specific, but rather specific to a certain group of species. E.g. clipping of seedlings at the end of the first rainy season should only be applied to species with a proven capability to re-sprout – i.e. coppice.

Those practices that proved successful at the end of the project should be transferred to other projects, even if they work with different species.

Capacities

A key factor to the effective implementation of technical lessons learned is practical experience. The personnel of the contracted project nurseries as well as technical project staff will be valuable resource persons for any similar restoration projects.

Nursery trainings are taking place as part of the project, sharing practical experiences gained throughout the course of the project. Technical manuals such as the one present serve as valuable dissemination tools, but they cannot replace the practical knowledge of a technician who has implemented the described practices for two or three planting seasons.

5 OUTLOOK

Nursery training

Currently, in May 2019, the project's seedlings are growing in the four nurseries. The experiences and knowledge gained during their breeding will be disseminated in native species nursery training in Q3 of 2019 organized and implemented by IREN.

Planting training of trainers

In October 2019, at the beginning of the project's first planting season UNIQUE and IREN will jointly implement a multiple day training of trainers course on planting. It will cover theory and practice of planting logistics and the implementation of the plant design

Establishment of trial plots

On the last day of the aforementioned training of trainers, its participants will establish the project's trial plots. The most promising silvicultural variations identified are tested in order to maximize the knowledge gained regarding the restoration and co-management of degraded dunes and mangroves.

Planting season 2019 / 2020

From November 2019 to January 2020, 290 hectares of sandy sites and 10 hectares of mangroves will be planted in. The remaining 230 hectares will be planted in the project's second planting season 2020 / 2021.

Knowledge dissemination

In addition, in the future, the project will carefully document its progress and its lessons learned.

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7 ANNEX: SPECIES FACT SHEETS

Terrestrial species

- *Camelia sansanqua*
- *Casearia grewiaefolia*
- *Lithocarpus concentricus*
- *Litsea glutinosa*
- *Melaleuca cajuputi*
- *Melaleuca leucadendra*
- *Shorea falcata*
- *Sindora tokinensis*
- *Syzygium chanlos*
- *Vatica mangachapoi*

CAMELIA SASANQUA THUN.


Typical shrub form


Flower


Leaf and fruit

Family: *Theaceae*

Local name(s): Sở; in Quang Tri also Dầu sở

General description:

C. sasanqua grows to an evergreen shrub of 5 – 7 m height. The bark is smooth and brown. *C. sasanqua*'s leaves are simple and broad elliptic. The margins are finely serrated. The leaves are 3 – 7 cm long and 1.2 – 3 cm broad. Its flowers are white, reach diameters of 4 – 6 cm in diameter and have 5 – 8 petals.

C. sasanqua is native to China, Japan, Myanmar, India, and Vietnam. It grows in altitudes of up to 700 above sea level. C. sasanqua is naturally distributed mainly in northern Viet Nam down to Thua Thien Hue province. There are many successful models of afforestation C. sasanqua in Quang Ninh, Ha Giang, Nghe An, Quang Binh, Quang Tri and Thua Thien Hue province.

The species has been selected for reforestation projects of sandy coastal sites as well as interior hill sites - e.g. in Cam Lo, Vinh Linh district (Quang Tri), Le Thuy (Quang Binh), and Quang Dien (Thua Thien Hue). *C. sasanqua* nuts are used to produce essential oils.

Seed collection:

The flowering season is November to December. The fruits are scattered the year after in September to October and can be collected until November.

The fruits is a smooth, dry, globose capsule that is sometimes subdivided in up to three compartments. Each compartment contains up to three nuts. 500 nuts make 1 kg.

Pre-germination treatments

Freshly collected seeds do not need any pre-germination treatment. Seeds are only separated from the rest of the fruit.

When dried in the sun, seeds can be stored in dry and cool conditions for up to 6 months. Stored seed should be soaked in warm water for 24 hours before sowing.

Seedling production:

C. sasanqua nuts germinate slowly, they will need 1 – 2 months before they are ready to be transplanted into soil bags. The survival rates however are very high (>90%).

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Hoang Van Thang, Nguyen Quang Khai, Nguyen Ba Van, Nguyen Van Thinh and Bui Thanh Hang (2007): DEVELOPING TREE BREEDING AND INTENSIVE PLANTING MEHTODOLOGIES FOR CAMELLIA IN THE NORTH EAST, NORTH WEST AND CENTRAL NORTHERN VIETNAM. Forest Science Institute of Vietnam.

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CASEARIA GREWIAEFOLIA VENT.

Family: Flacourtiaceae

Local name(s): Nuốt cò ke; Cỗ ngỗng in Quang Tri, Thua Thien Hue, Quang Binh

General description:

C. grewiaefolia is evergreen and grows to shrubs or small trees of up to 8 m height. DBH of the trees does not exceed 30 cm. Branch tips typically grow in a curve. The bark is brown to purple. Leaves are simple and form blades of variable, oblong or oval, form. They grow 8 – 17 cm of length and 3 – 6 cm of width. Typical are circular and/or streaky oil dots on the leaves. They are usually visible to the naked eye. *C. grewiaefolia* flowers in dense clusters from leaf axils or leafless axils. The flowers are white or greenish yellow.

The species is native to China, Cambodia, Malaysia, Thai land, India and Viet Nam. It Viet Nam it occurs naturally in the coastal forests of central Viet Nam. It only grows in altitudes of up to 50 above sea level.

C. grewiaefolia is a fast-growing, natural pioneer species that provides food for several bird species. It is characteristic for Vietnamese coastal sandy site forests.

Seed collection:

The species flowers all year round. However, its ripe seeds can mainly be found in September and October. The fruits sub-globose to broadly ellipsoidal or oblong. They grow to 2 - 2.5 cm in lengths. The fruits are smooth and have a shining, orange-yellow surface. They are 3-valved. Inside a scarlet aril compresses 15 – 21 seeds. They are ovoid and measure approx. 5 x 3 mm. The seeds are ripe when the fruit starts to open. It is recommendable to collect ripe fruits with intact arils directly from the tree.

The seeds have a relatively short viability and should therefore be sown shortly after collection. Until sowing they need to be stored with care as they are much appreciated by ants.

Pre-germination treatments

The seed capsules are soaked in water for 12 hours. Afterwards capsule and seeds are separated manually.

Seedling production:

C. grewiaefolia seeds germinate after 7 days. The survival is very high (app. 90%).

References/further reading

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LITHOCARPUS CONCENTRICUS ((LOUR.) HJELMQ.)

Family: *Fagaceae*

Local name(s): Dẻ cát; also Dẻ lá bóng in the project region

General description:

Medium to large sized evergreen tree. It grows to 10 – 20 m of height and to 20 – 50 cm of DBH (up to 100 cm on excellent sites). The bark is smooth and of greyish brown color. Its branches are fine and glabrous. The simple leaves measure 8 – 12 cm in lengths and are also glabrous.

L. concentricus is native to India, China, Lao, Cambodia, and Viet Nam. It is a light demanding species and can be found in inland forests at elevations of up to 300 - 400 m above sea level. In sandy coastal areas it grows to altitudes of 50 above sea level.

Seed collection:

The species flowers twice per year. The first flowering occurs from April to May, the second from November to December. The fruits of the first flowering are scattered in October to November, the second generation of fruits reaches maturity from February to March in the following year. The fruits develop into nuts that look very much like oak acorns. In the process of maturing the cupule walls change from light green to light brown and yellow-brown. The nut itself measures between 0.8 – 1.2 cm and is globose and smooth.

The seeds lose their viability quickly if they are allowed to dry. For this reason they should be sown as soon as they are ripe. Seedlings produce a deep taproot and should be planted out into their permanent positions as soon as possible. Past experiences suggest that seeds sown in situ will produce the best trees.

Pre-germination treatments

Seeds can either be germinated in moist sand, like most other seeds. One nursery however, applies a different practice. The seed are first washed and floating nuts are discarded. Then they are soaked overnight (8 – 12 hours) in about 45°C hot water - 2 parts of boiling water are mixt

with 1 part of cold (room temperature) water to reach this initial temperature. Afterwards the seeds are kept in bags and washed once per day. Once the tips of the shoots become visible, after approx. 4 days, the nuts are planted into soil bags. The approach is promising, however, first evaluations of this germination practice show an increased risk of insect attacks (approx. 40%).

Seedling production:

L. concentricus seeds germinate after 20 – 25 days. Seeds that have been stored for a longer period, might take over 30 days to germinate. The survival rate after 1 month is comparably low (65%).

References/further reading

Tran Thi Han, Do Xuan Cam, Nguyen Truong Khoa (2015): Preliminary assessment of native tree Resources in Coastal Regions of Quang Tri province for Conservation and Forest sustenance. Report of the 6th national scientific conference on ecology and biological resources, ISBN: 978-604-913-408-1. Ha Noi.

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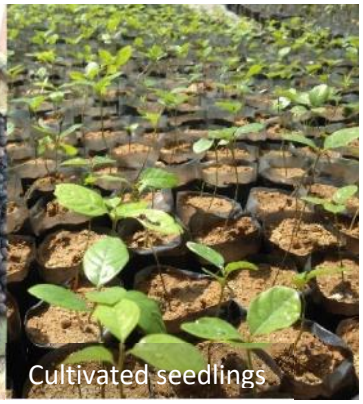
LITSEA GLUTINOSA (LOUR.) C.B.ROB.


Leaves & flower


Ripe fruits


Cultivated seedlings

Family: Lauraceae

Local name(s): Bời lời; also Bời lời xanh in project area

General description:

Small to medium-sized evergreen tree. It grows from 3 to 15 m of height. The DBH does not surpass 45 cm. Its branch tips typically grow in a curve. The bark is brown to purple. *L. glutinosa* has simple leaves that vary considerably in size (7 – 28 cm x 3 – 15 cm). Young leaves' undersides are covered with white, erect hairs that persist on the mature leaves or be almost entirely shed.

L. glutinosa is native to large parts of Southeast Asia, namely Southern China, Myanmar, Cambodia, Malaysia, Thai land, Laos, Indonesia, the Philippines, Vietnam, and also India. The trees grow in moist as well as in dry forests. They are mainly found in lower regions, but grow up to altitudes of 1,200 m above sea level. In sandy areas along the coast of NCC Viet Nam they are found up to elevations of 100 m above sea level.

Seed collection:

L. glutinosa flowers two times per year (Mar. to Apr. and Oct. to Nov.). The fruits are round, dark, reddish to blue-black berries and measure 5 – 6 mm in diameter. The main harvest season for the fruits is July to August. The fruits are collected directly from the tree when their color changes to black.

Pre-germination treatments

Soak the capsule in warm water for 8-10 hours.

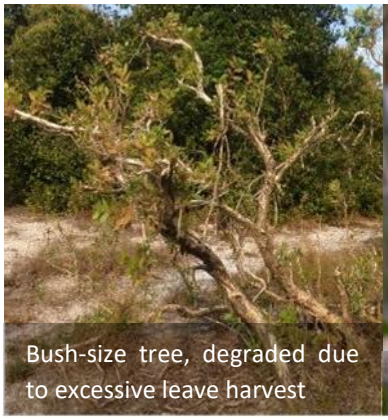
Seedling production:

L. glutinosa shows a high germination vigor. The seed will start sprouting within 5 - 7 days. The survival rate after 1 month is over 90%. The young seedling is often affected by leaf-miners.

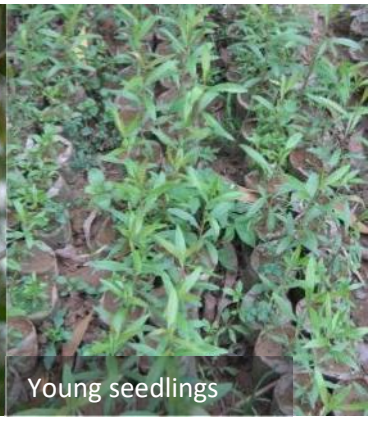
References/further reading

Pham Hoang Ho, 1999. An Illustrated Flora of Vietnam. Vol: full 2 volumes, Pages 320. Publisher: NXB Trẻ. Ho Chi Minh city.

MELALEUCA CAJUPUTI POWELL.


Bush-size tree, degraded due to excessive leave harvest


Ripe seed capsules


Young seedlings

Family: Myrtaceae

Local name(s): Tràm; Tràm gió in Quang Tri, Thua Thien Hue, Quang Binh province

General description:

Small evergreen tree. It usually grows to 2 – 4 m height, in rare cases however, it can grow up to 10 m. The DBH ranges between 0.4 and 10 cm. *M. cajuputi* has a white to pale grey bark that peels off in thin layers. Its elliptic leaf blades are more than seven times as long as wide and about 5 – 10 cm long. They show five longitudinal veins that are more prominent than the rest. Young shoots and twigs are covered in white or silver hairs.

The leaves are traditionally harvested to extract their essential oil which is used as a medicine.

M. Cajuputi is widely distributed and native to India, China, Cambodia, Malaysia, Indonesia, Philippine, Australia, and Vietnam. It grows naturally in coastal forests and coastal swamp forest in Quang Binh, Quang Tri, Thua Thien Hue as well as in Northern Vietnam. It can be found in altitudes of up to 100 m above sea level.

Seed collection:

The species flowers once per year in November to December. The seeds are then scattered in February to April of the following year. The fruits are sessile capsules. They are glabrous, globular, and measure 2.5+ mm in diameter. The seeds themselves are very small (approx. 2,700,000 seeds / kg).

Due to their size, seeds should be collected before they are scattered. The capsules are ripe when they become greyish brown. After harvest they are exposed to sun light for 2 -3 days. The seeds are extracted by sieving the capsules daily.

When kept in cool and dry conditions (5 – 10 °C) the seeds can be stored up to 5 years.

Pre-germination treatments

Prior to sowing the seeds should be soaked in warm (35 – 40 °C) water for 5-6 hours.

Seedling production:

M. cajuputi seeds germinate after 5 – 7 days. They should only be covered very lightly. The survival rate after 1 month is very high (>90%). The seed is very susceptible to fungus. The seed bed should therefore be sprayed with fungicide periodically (1 – 2 times / week).

References/further reading

Truong Thi Hieu Thao, Nguyen Khoa Lan, Ho Dac Thai Hoang (2015): Characteristics of plant communities at inner sandy areas in Thua Thien Hue province. Vol 108, 09, pages**:** *269-278*, ISSN 1859-1388. Hue University Journal of Sciences.

MELALEUCA LEUCADENDRA L.

Family: Myrtaceae

Local name(s): Tràm lá dài

General description:

M. leucadendra grows into medium-sized evergreen tree of app. 10 m of height. Under ideal site conditions it can reach 15 – 20 m. The tree's bark is papery and usually white. It may also exhibit cream or pinkish tones. *M. leucadendra's* leaves and young branches are covered with short, fine, white hairs. As they mature they become glabrous. The leaves are arranged alternately and lance-shaped. The flowers are colored cream to white. Usually they are arranged it groups of three individuals around young branches. The flowers emit a strong sweet odor.

M. leucadendra originates from Australia and is planted in southern Viet Nam. It naturally occurs mainly on flat and mild slopes, especially along river banks, along the coast or in seasonal swamps. The species grows on alluvial soil, muddy clay or muddy sandy soil. It rarely grows on land that lacks water. *M. leucadendra* tolerates temporal flooding for several weeks to a few months per year.

Seed collection:

The species flowers once per year from March to July. The seeds are then scattered in October to November of the same year. The fruits are sessile capsules arranged in groups of three. They are glabrous, globular, and measure 3 - 4 mm in diameter. The seeds themselves are even smaller than those of *M. cajuputi* (app. 20,000,000 seeds/kg).

Due to their size, seeds should be collected before they are scattered. The capsules are ripe when they become greyish brown. After harvest they are exposed to sun light for 2 -3 days. The seeds are extracted by sieving the capsules daily.

When kept in cool (5 – 10 °C) and dry (5 – 12 % rel. humidity) conditions the seeds can be stored up to 3 years.

Pre-germination treatments

Prior to sowing the seeds should be soaked in warm (35 – 40 °C) water for 5-6 hours.

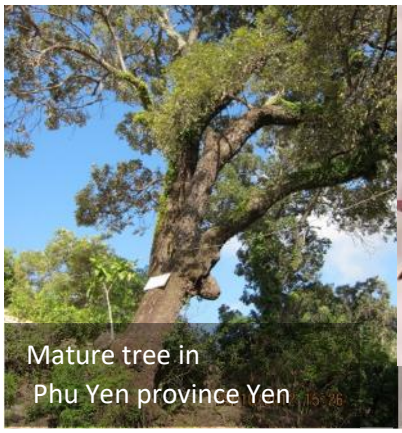
Seedling production:

M. cajuputi seeds germinate after 5 – 7 days. They should only be covered very lightly. The survival rate after 1 month is very high (>90%). The seed is very susceptible to fungus. The seed bed should therefore be sprayed with fungicide periodically (1 – 2 times / week).

References/further reading

Paul G.van der Moezel, Gladys V.N. Pearce-Pinto, David T.Bell (1991): Screening for salt and waterlogging tolerance in Eucalyptus and Melaleuca species. Forest Ecology and Management. Volume 40, Issues 1–2, 10 May 1991, Pages 27-37

SHOREA FALCATA J. E. VIDAL, 1962.


Mature tree in Phu Yen province Yen


Ripe fruits


Cultivated seedlings

Family: Dipterocarpaceae

Local name(s): Chai lá cong; Sưng cát in Phú Yên & Khánh Hòa province

General description:

Shorea falcata grows into a large, coastal evergreen tree. It grows to 15 – 20 m of height and up to 100 cm of DBH, making it one of the largest trees in coastal forests. Its wood has traditionally been used to build boats and ships, which decimated the species' natural occurrences. The bark is often greyish and young branches are pubescent. *S. falcata*'s leaves are ovate to elliptical, 8 - 10 cm long and 3 – 4 cm wide. The tree is monoecious and flowers in yellow panicles. The calyx show 5 oblong petals.

S. falcata can only be found in Viet Nam. Its last natural occurrences are in Song (Phu Yen) and Cam Ranh (Khanh Hoa). It grows in tropical forest on red sand near the coast, at altitudes of <100 m above sea level. The species is endemic to Vietnam. It is listed as red list species in Viet Nam (2007; CR A1c,d) and as an IUCN Red list species since 2018 (EX).

Seed collection:

As mentioned above, mother trees are only found in the provinces of Phu Yen and Khanh Hoa in Southern Viet Nam. The flowering season is in June in both provinces. However, in Phu Yen the fruits ripe considerably earlier (July), than in Khanh Hoa (September, October).

The fruit is a nut that is surrounded by the calyx. The calyx develops 5 wings, each 3 – 5 cm long. The seeds show a short viability and should be sown soon after they are collected. 1,200 – 1,500 seeds make one kilogram.

Pre-germination treatments

There is no special pre-germination treatment needed.

Seedling production:

S. falcata seeds germinate comparably quickly. Germination will start after only four days. The seeds show a high germination vigor and survival rates of over 90%.

References/further reading

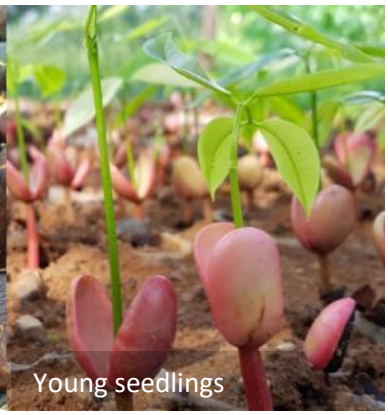
Ministry of Science and technology (2007): Vietnam's Red list – Part II. Plants, Publish house of Science and Technology, Ha Noi.

Hoang, V.S., Luu, H.T. & Rivers, M.C. (2018): Shorea falcata. The IUCN Red List of Threatened Species 2018: http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T33459A2836611.en (02-05-2019).

SINDORA TONKINENSIS A.CHEV. EX K.S.S LARS.


Fruit & seed


Seeds after pre-germination treatment


Young seedlings

Family: Caesalpiniaceae

Local name(s): Gụ lau, Gõ lau, Gõ dầu, Gõ sương; Cụ in Quang Tri province

General description:

Large deciduous costal tree. It grows to 10 – 15 m of height and to 40 – 60 cm of DBH. The stem is usually evenly round and of greyish red colour. Its branches are glabrous. The leaves are also glabrous and paripinnate with 4 – 5 leaflet pairs. Each leaflet measures 6 – 12 cm x 3.5 – 6 cm, they are asymmetrically ovate.

S. tokinensis is native to Lao, Cambodia, and Viet Nam. It is a shade baring climax species that will naturally only sprout under the closed canopy of forests. It grows well in wet, but deep sandy soils, tolerating low organic matter content. In the mountains it can be found in elevations of up to 600 m, at the coast only up to 5 m above sea level. *S. tokinensis* is listed as red list species in Viet Nam (2007; EN A1a, c, d + 2d) and as an IUCN Red list species since 2018 (EX). In the project provinces only five mother trees could be identified, they all grow in natural coastal sandy forest remnants in Southern Quang Tri province.

Seed collection:

The species flowers once per year in March to May. The fruits are then scattered in August to September. It is a circular to elliptic legume with a pointed apex. Legumes usually contain 1, seldom 2 – 5 seeds. The seeds covered by a hard black husk.

The seeds are very durable. Even though they are scattered in August and September, seeds that were covered with moist sand can be collected in the following months without losing their capability to germinate.

Pre-germination treatments

Due to their strong husk, it is necessary to treat the seeds before germination. The clean seeds are put in simmering water (90 – 100°C) for approx. 2 hours. The goal is to tear the outer husk. Once the seeds swell and the husk is teared they can be planted directly into plant bags.

The husk can be opened manually for seeds where it does not tear. Afterwards these seeds should be placed in warm water again until they swell.

Seedling production:

S. tokenensis seeds germinate after 7 – 10 days. Seeds that have been stored for a longer period, might take 10 – 15 days to germinate. The survival rate after 1 month is very high (95%). The seedlings develop very fast for the first 2 – 3 months. After that the development slows down significantly.

References/further reading

Tran Thi Han, Do Huu Thu, Le Tuan Anh, Nguyen Truong Khoa (2015): Diversity of flowering plants in the coastal sand region of Quang Tri province. Report of the 6th national scientific conference on ecology and biological resources, ISBN: 978-604-913-408-1. Ha Noi.

Le Duc Thang, Nguyen Thanh Tay (2014): Some characteristics of flora in coastal south land of Quang Binh. Science and Technology Journal of Agriculture & Rural Development (Ha Noi, Vietnam), ISSN : 1859-4581.Ministry of Science and technology, 2007. Vietnam's Red list – Part II. Plants, Publish house of Science and Technology, Ha Noi.

Pham Hoang Ho (1999): An Illustrated Flora of Vietnam. Vol: full 1 volumes, Pages 868. Publisher: NXB Trẻ. Ho Chi Minh city.

SYZYGIUM CHANLOS (GEGN.) MERR. & PERRY

Family: *Myrtaceae*

Local name(s): Trâm trắng; in the project area also Nổ

General description:

Syzygium chanlos grows into a shrub-sized evergreen tree of app. 5 – 10 m of height. Its bark is smooth and brown. S. chanlos' leaves are simple and oval. They are smooth and grow to about 5 – 8 cm in lengths and 2.2 – 3.5 cm in width. The flowers are grouped in axillary and terminal panicles, they are of white color and include numerous stamens. The flowers give off a typical smell.

S. chanlos is native to Viet Nam and Cambodia. It is naturally distributed along the coast line, where it grows in altitudes from 5 – 10 meters above sea level.

Seed collection:

The shrub flowers from August to September and scatters its fruits between December and January. The fruits are circular to ovoid. Unripe their skin is green. It develops an increasingly whitish color as it matures. The diameter is about 5 - 7 mm. The fruit is edible and has a lightly sweet taste.

Pre-germination treatments

After collection the outer skin of the fruits is removed and the seeds are dried in the sun. When kept in a cool and dry environment the seeds can be stored for several months. Stored seeds should be soaked in warm water for 3 – 4 hours before sowing.

Seedling production:

S. chanlos seeds usually germinate in 7 - 10 days. The seeds show a high germination vigor and survival rates of over 90%.

References/further reading

Truong Thi Hieu Thao, Nguyen Khoa Lan, Ho Dac Thai Hoang (2015): Characteristics of plant communities at inner sandy areas in Thua Thien Hue province. Vol 108, 09, pages: 269-278, ISSN 1859-1388. Hue University Journal of Sciences.

VATICA MANGACHAPOI SUBSP. OBTUSIFOLIA (ELM.) ASHTON


V. mangachapoi flower


V. mangachapoi unripe fruit


V. mangachapoi wildlings

Family: Dipterocarpaceae

Local name(s): Táu duyên hải; Nến in Southern Quảng Bình

General description:

V. mangachapoi is a coastal evergreen or semi-deciduous tree. It grows to 3 – 7 m of height (up to 10 m on very good sites) and reaches DBHs of 9 – 21 cm. Branches and leaves are often greyish green. Leaves are single and about 8 – 10 cm long and 3 – 5 cm wide. The tree flowers in white bunches, often at the tip of its branches.

V. mangachapoi is native to Brunei, China, Malaysia, Philippines, Thailand, and Vietnam. In Vietnam it is mainly found in coastal areas of the North Central region on elevations <10 m. The tree grows on deep white sandy soils characterized by low organic matter content and high aridity. In local sandy soils it usually develops clusters of 7 – 15 individuals and grows into shrubs only, due to the harsh site conditions. *V. mangachapoi* has strong vegetative regeneration capabilities – i.e. it readily produces root- and basal suckers. The species is considered as vulnerable under the IUCN Red List.

Seed collection:

Mother trees are common in the clustered secondary forests in Thua Thien Hue province. The species usually flowers from March and May (2nd flower in Oct. - Nov.). The fruits are scattered from July to September. Seeds of the second flowering are scattered in March and April of the following year.

The winged fruit is typical for *dipterocarpacaceae*. The two wings are 4-5cm long. The seed is about 0.5 cm in diameter and green. The wing color ranges from green to violet and (pale) yellow, indicating the degree of maturity. Ripe yellow seeds should be collected directly from the tree. As soon as there are scattered they easily drift away with the wind. In 2018 the ideal harvest period was from August 28th to September 15th.

Pre-germination treatments

The wings should be separated from the seeds in order to ease seed handling. To do so seeds are piled and exposed to direct sun light for 2-3 days. Afterwards seeds and wings can be easily separated.

Seedling production:

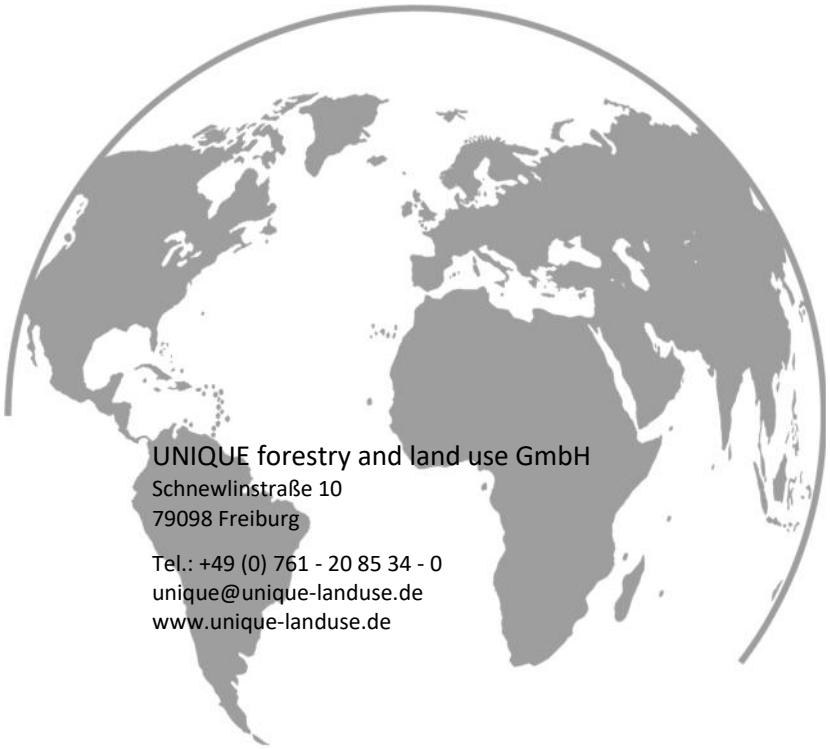
Due to the high oil content seeds become rancid after only a short time. Germination should therefore be initiated as soon as possible after seed collection.

V. mangachapoi seeds germinate comparably slow. It takes about two weeks until they develop secondary leaves. Also the initial growth in the seed bags is comparably slow and the mortality rate high (up to 40%).

References/further reading

Pooma, R., Barstow, M. & Newman, M.F. (2017): *Vatica mangachapoi*. *The IUCN Red List of Threatened Species* 2017: e.T32461A2819415.

Le Duc Thang, Nguyen Thanh Tay (2014): Some characteristics of flora in coastal south land of Quang Binh. Science and Technology Journal of Agriculture & Rural Development (Ha Noi, Vietnam), ISSN : 1859-4581.



UNIQUE forestry and land use GmbH
Schnewlinstraße 10
79098 Freiburg

Tel.: +49 (0) 761 - 20 85 34 - 0
unique@unique-landuse.de
www.unique-landuse.de