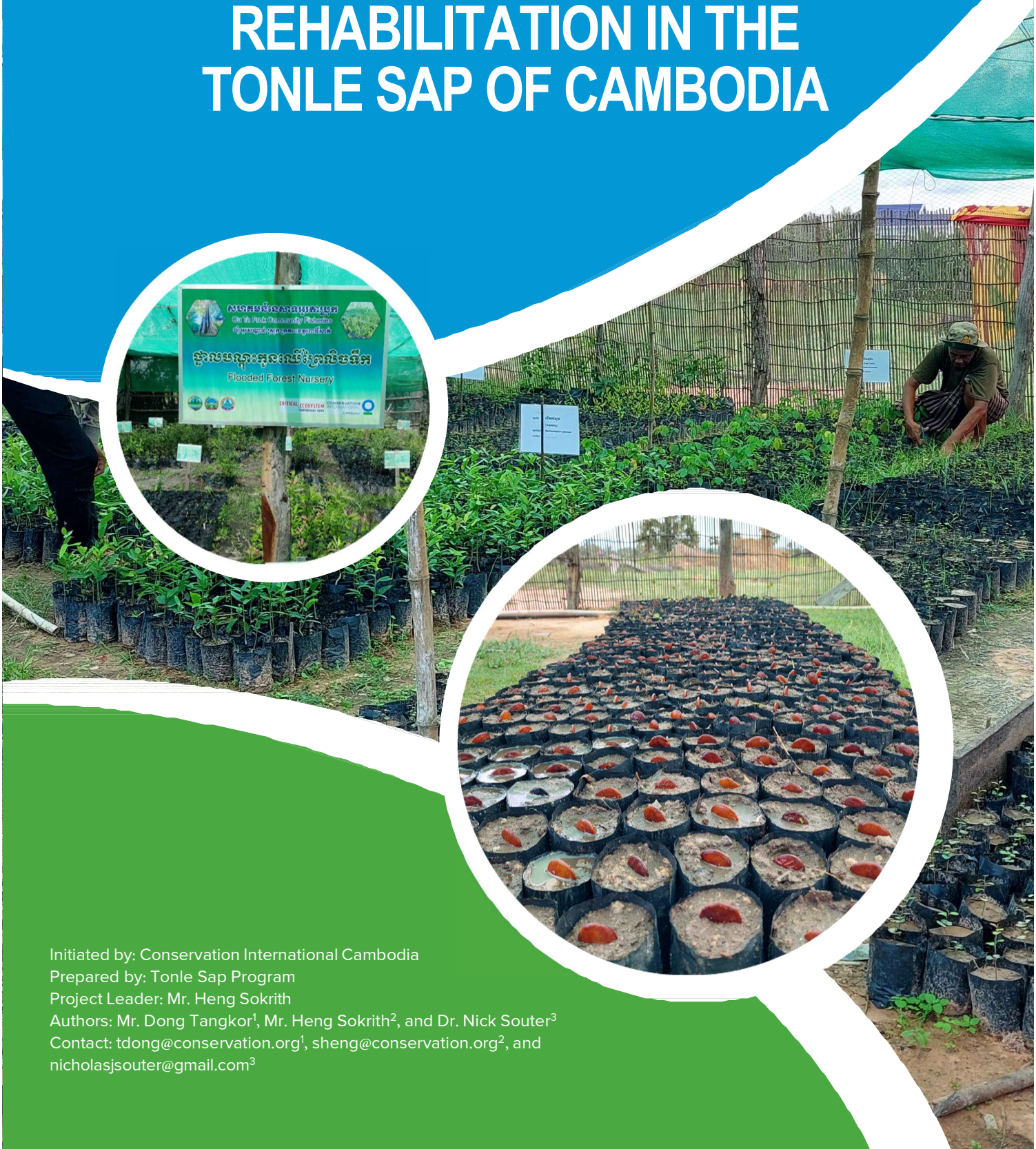
A GUIDE TO FLOODED FOREST REHABILITATION IN THE TONLE SAP OF CAMBODIA



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About Conservation International : People need nature — and for over 30 years, Conservation International has worked to protect it around the planet. Through cutting-edge science, innovative policy and global reach, we empower people to protect the nature that we rely on for food, fresh water and livelihoods. Since our inception, we've helped to protect more than 6 million square kilometers of land and sea across more than 99 countries. Currently with offices in 29 countries and 2,000 partners worldwide, our reach is truly global.

Our Mission: Building upon a strong foundation of science, partnership and field demonstration. CI empowers societies to responsibly and sustainably care for nature, our global biodiversity, for the well-being of humanity.

Conservation International Cambodia is part of a global nonprofit organization that has worked with local communities, the government, and key partners in Cambodia since **2001** to maintain and protect some of the country's most vital remaining ecosystems and unique biodiversity — for the benefit of the planet, and for the people of Cambodia.

Country Objective

In partnership with Indigenous peoples, local communities, and government, Conservation International (CI) Cambodia aims to improve and protect Cambodia's terrestrial and freshwater ecosystems by supporting improved protected area management and the development, management, and access to nature positive livelihood opportunities and markets through private and public financing opportunities related to Reducing Emissions from Deforestation and Forest Degradation (REDD+), climate, and freshwater to secure biodiversity hotspots and critical freshwater systems and ensure cohesive, sustainable development for the country.

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Content

Introduction

Flooded forests are an integral part of Tonle Sap Lake and its floodplain. Flooded forests provide a range of benefits to local communities. They are a shield from storms, provide firewood for household fuel, and wild fruits for food and income. The flooded forest also provides important habitat for a range of endangered species and provides important fish habitat. At least 200 species of shrubs and trees have been found around the lake (CNMC et al., 1998; Triet, 2002). The trees are between 7-15 meters tall, with some growing to 20 meters. These trees are on the shorelines of ponds, lakes, and rivers. The inundated shrublands are shorter, no taller than 2-4 meters, and they are found between the flooded forest and the grasslands (Campbell et al., 2006) and cover almost 80 % of the lake's floodplain.

The Tonle Sap's flooded forest is being increasingly degraded by a range of human activities. The forest has been converted to agricultural lands, cleared for human settlement, and felled for fuel wood (Bonheur and Lane, 2002) and timber (Campbell et al., 2006). Forest fires, which commonly occur between March and June, have recently become more widespread and severe (IUCN, 2016).

Since 2010, Conservation International Cambodia (CI) has been collaborating with various community fisheries (CFis) and Community Protected Areas (CPAs) in the Tonle Sap Lake and the Fisheries Administration (FiA) and Provincial Department of Environment (PDoE) to restore degraded flooded forests. With technical and financial support from CI and community partners in the lake, we've successfully restored approximately 1,000 hectares of these critical ecosystem areas in Pursat and Kampong Thom provinces.

Based on our practical experience and local knowledge, CI has developed a comprehensive Guide to Flooded Forest Rehabilitation. This guide covers all stages of the restoration process, including the initial planning, site selection, seed collection, nursery establishment, seedling planting, and seedling survival rate limitation. Each stage details the implementation process and the methodologies required to complete it. The manual aims to assist local communities and partners with limited experience in understanding and replicating CI's successful model throughout Cambodia as well as within the regions related with flooded forest restoration.

Procedure for Restoring Flooded Forest

The restoration of flooded forests involves six key components: Initiating Planning, Site Selection, Seed Collection, Tree Nursery Establishment, Seedling Planting, and Seedling Survival Rate Limitation. The main criteria for each of these procedures are included as follows:

Initial Planning

- Stakeholder Consultant

Site Selection

- Replanting Site Selection
- Replanting Site Demarcation

Seed Collection

- Species Selection
- When to collect seeds?
- Seed Collection Techniques
- Seed Storage Techniques
- Species ecological,Seed collection and Storage techniques

Tree Nursery Establishment

- Nursery Location Selection
- Nursery Preparation
- Soil Preparation
- Seedling Propagation
- Tree Seedling Propagation by Species
- Seedling Protection and Care

Seedling Planting

- Timeframe
- Pre-treatment before transporting
- Transporting Seedlings
- Gridline Tree Replanting
- Seedling Planting
- Maintainence Replated Trees

Seedling Survival Rate Limitation

- Species Selection
- Replanting Techniques
- Forest Fire
- Natural Disasters

I. Initial Planning

A pre-replanting consultation meeting with stakeholders is a critical step for a successful project. These preliminary discussions ensure that everyone involved is aligned and can contribute to a well-organized replanting effort. Inclusive participation is essential for gathering diverse ideas and solutions (Figure 1). The stakeholders to be included are:

- Community Fisheries (CFi) Committees and members,
- Community Protected Areas (CPA) Committees and members,
- Local authorities such commune council and the village chief,
- Local government institutions like Fisheries Administration officers in provincial (FiA) and Provincial Department of Environment officers (PDoE)
- NGO partners (optional)

The main purposes of pre-discussion meetings are:

- To discuss the replanting plan with involved people, gather feedback, and address concerns,
- To identify key people responsible for different aspects of the replanting work, ensuring clear leadership and division of tasks.
- To determine the most suitable degraded flooded forest areas for replanting
- Identify the potential tree species and available tree species for restoration in the community.

Replanting consultation meetings should be hosted in the available places, such as:

- Community stations,
- Public pagodas,
- Public schools

Figure 1: Consultation meeting to discuss on replanting project between local community and relevant stakeholders.

II. Site Selection

2.1 Replating Site Selection

It is essential to consult and gather ideas from the local communities and relevant stakeholders at the beginning of the replanting process. This ensures that the best site is selected and fosters a sense of ownership within the community over both the replanting process and its success. The restoration site should be selected based on the community management plan, aligning with the commune or government plan, where applicable. Generally, replanting site identification falls under community protection and within the boundary of community management areas. We understand that replanting site selection focuses on available locations, which are recommended as follows:

- The degradation of flooded forest areas that have been cleared due to agricultural land encroachment or forest fire (Figure 2).
- Public degraded areas are allowed and agreed upon for replanting by local communities, local authorities, and relevant governmental institutions.
- Large areas belong to the states where many trees can be planted without conflicts, and
- The sites belong to the local community fisheries (CFis) and Community Protected Areas (CPA) management areas.

Sites with the following characteristics are **less suitable** for revegetation:

- Frequently burned grasslands as fire may kill the seedlings.
- Dense grasslands, as the grasses can smother the young plants.
- Small areas where few trees can be planted; and
- Tenured or private land, or disputed land.

Figure 2: The flooded forest burned site is suitable for restoration.

2.2 Replating Site Demarcation

To ensure successful replanting efforts across large areas, site demarcation is crucial. By visually delineating planting zones, local communities can accurately transplant seedlings within designated areas, preventing confusion and maximizing efficiency. Various demarcation techniques can be employed, including the installation of wooden poles, the attachment of rice bags or garments, and GPS-based boundary marking. Local communities around Tonle Sap Lake are familiar with using rice bags or garments attached to wooden poles or existing trees as visible markers for replanting (Figure 3).

Figure 3. The selected restoration area is demarcated to be visible for replanting activity avoiding site confusion.

Introducing digital tools to the local community can significantly enhance their understanding on new technology with the replanting project. Digital maps on Avenza*** or Google Earth provide a clear visual representation of the replanting boundaries. This is especially helpful compared to relying solely on physical markers, which might be temporary or difficult to see in dense vegetation. Community members can easily validate the boundaries by comparing the digital map with the physical location. This fosters transparency and reduces confusion.

****Avanza is an offline application that works with digital maps (PDF files) and can display the user's current location. This feature makes it easy for planters to navigate to their desired destinations, especially within specific boundary areas. While Google Earth offers similar functionality, it requires a KML file and internet access, making it an online application. If internet connectivity is available, Google Earth is generally easier to use than Avenza.*

III. Seed Collection

Seed collection is crucial stage that must be well-organized and timely; otherwise, tree seeds will disappear or be destroyed naturally or by insects after falling from mother trees. There are three main points to considered in this stage.

3.1 Species Selection

When selecting plant species for replanting, a range of factors must be considered, including site characteristics; tree height, rare species, and the benefits they provide to both the ecosystem and local communities. It is important to consult with local communities when selecting tree species as they are likely to have valuable knowledge about species' ecology and benefits to both ecological systems and people. The gallery tree species typically selected for replanting includes eleven recommended flooded forest species, *Crudia zeylanica, Homalium brevidens, Terminalia cambodiana, Barringtonia acutangula, Diospyros cambodiana, Xanthophyllum lanceatum, Cynometra ramiflora, Mallotus plicatus, Combretum trifoliatum, Garcinia cochinchinensis,* and *Elaeocarpus lanceifolius* (Table 1 in Appendix). These species offer a range of benefits to both local people and the lake ecosystem.

3.2 When to collect seeds?

Flooded forest plants in Tonle Sap Lake exhibit varying reproductive timelines, with each species commencing flower and fruit production at different times. Based on research and observation, the selected flooded forest species for replanting show diverse flowering and fruiting periods (Table 2 in Appendix). Seed collection timelines vary significantly among species. While some species, like *Barringtonia acutangula* and *Combretum trifoliatum*, produce fruit almost year-round, others have more specific fruiting seasons. For instance, *Crudia zeylanica* typically produces seeds between August and October, although some trees may produce seeds as early as March.

3.3 Seed Collection Techniques

Seed collection is a crucial stage for nursery operations. Seed collectors must be aware of the seed production timeline of their target tree species. Two main approaches are typically used to collect seeds from mother trees, 1) Fallen Seed Collection and 2) Direct Seed Collection.

3.3.1 Fallen Seed Collection

A common practice for seed collection involves gathering seeds from the ground beneath mother trees after fallen (Figure 4). To facilitate this, it's essential to clear the ground of weeds, leaves, and branches. However, this method may not be feasible for certain species in floating communities during flood periods. To overcome this challenge, techniques such as spreading plastic sheets, cloth, canvas, or mesh nets beneath mother trees can be employed to capture falling seeds (Figure 5). Alternatively, seeds can be collected directly from the water's surface as they fall and float.

Figure 4: The common practice of seed collection on ground beneath the mother trees.

Figure 5: Spreading mesh nets beneath mother trees for collecting the falling seeds during flooding season.

3.3.2 Direct Seed Collection

Direct Seed collection refers to gathering seeds directly from mother trees. This technique is particularly effective at Tonle Sap Lake, where many flooded forest species produce fruit while submerged (Figure 6 & 7). This approach allows collectors to gather seeds before they fall into the water. However, it can be challenging to collectors to distinguish between unripe and ripe fruits while they are still on the mother trees.

Figure 6: Seed collection was carried out directly from mother tree of floating community.

Figure 7: Seed collection directly from the mother tree at the Tonle Sap Lake.

3.4 Seed Storage

Seed storage is essential for preserving seeds for future nursery cultivating and restoration efforts. Seed storage protocols differ based on the specific tree species. Two primary techniques are utilized by local communities in the Tonle Sap Lake region for flooded forest seed storage: dried seed storage and water soaking storage.

3.4.1 Dried Seed Storage

Drying seeds before storage is a common practice widely employed by planters. Seeds are dried to reduce moisture content, inhibits germination and fungal growth. However, it is crucial to consider the specific seed species, as excessive heat exposure can compromise viability. Once sufficiently dried, seeds are typically stored in various containers, such as cotton sacks, net sacks, or cotton boxes.

3.4.2 Water Soaking Storage

Water-soaking storage is a technique specifically suited for flooded forest species. Soaking seeds in water is commonly used to break dormancy and induce germination. Certain tree species in flooded forests produce seeds that naturally remain submerged after falling from the mother trees. This natural soaking period serves as a form of seed storage. Rather than drying the seeds, local communities have adapted this natural process by submerging the seeds in water until they are ready for nursery planting (Figure 8). While this method is effective for short-term storage, it is not suitable for long-term preservation. Extended soaking can lead to seed decay or deterioration.

For long-term storage, seeds must be dried, typically using sunlight, which often results in a lower germination rate for some species. Therefore, careful consideration is needed when selecting storage methods based on the duration and intended use of the seeds.

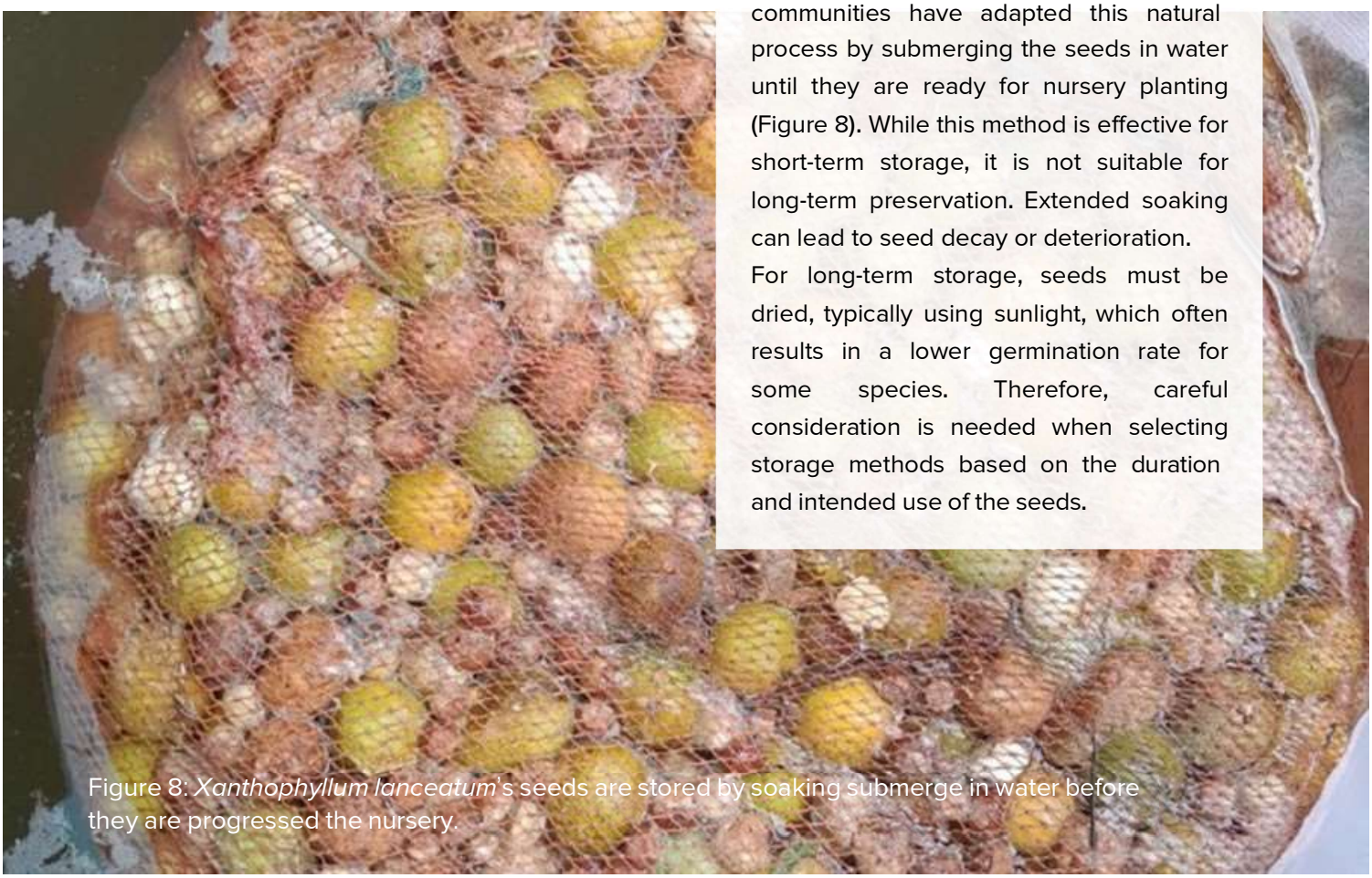
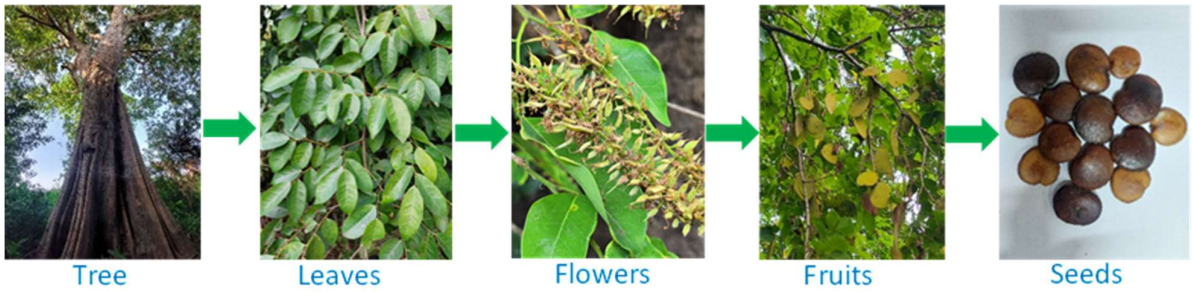


Figure 8: *Xanthophyllum lanceatum*'s seeds are stored by soaking submerge in water before they are progressed the nursery.

3.5 Species ecological, Seed collection and Storage techniques

3.5.1 *Crudia zeylanica* (Sdey)



Species ecology and status: *Crudia zeylanica* (Sdey) is a tall tree residential to gallery forests, reaching heights up to 30 meters. This species is listed as Critically Endangered (CR) on the IUCN Red List.

Flowering and Fruiting: *C. zeylanica* typically begins flowering between March and April, with fruiting occurring in May, although some trees have been observed to fruit in November. The optimal time for seed collection is between August and October, as this period coincides with peak seed production (Appendix 2). However, seed collection can also be done in March for certain trees.

Fruit and seed Shape: *C. zeylanica* produces flat, elliptic fruits measuring 5-6 cm by 3-4 cm. The seeds are coin-shaped or suborbicular to elliptic, brown in color, and measures 3 cm by 2.5 cm (Appendix 1). Each fruit contains a single seed enclosed within a hard shell. Seeds are released when the fruit shell opens.

Seed collection methodology : Fallen seed collection is a suitable method for gathering seeds for future restoration. Seeds can be collected from the ground beneath parent trees or by spreading garments or nets to catch fallen seeds, especially in flooded areas.

It is crucial to collect *C. zeylanica* seeds promptly after they fall, as they are susceptible to insect damage or spoilage if left uncollected (Figure 9).

Seed Storage: *C. zeylanica* seeds are best stored after drying for a short period in cotton sacks or other secure containers, with a maximum storage duration of one month. Avoid exposing seeds to direct sunlight for drying for storage or soaking them for prolonged periods, as this can damage and increase their susceptibility to insect damage and rot.

The most effective approach is to collect seeds directly from or beneath mother trees and promptly process them for nursery planting. This minimizes storage time and reduces the risk of insect damage or rot associated with drying or soaking.

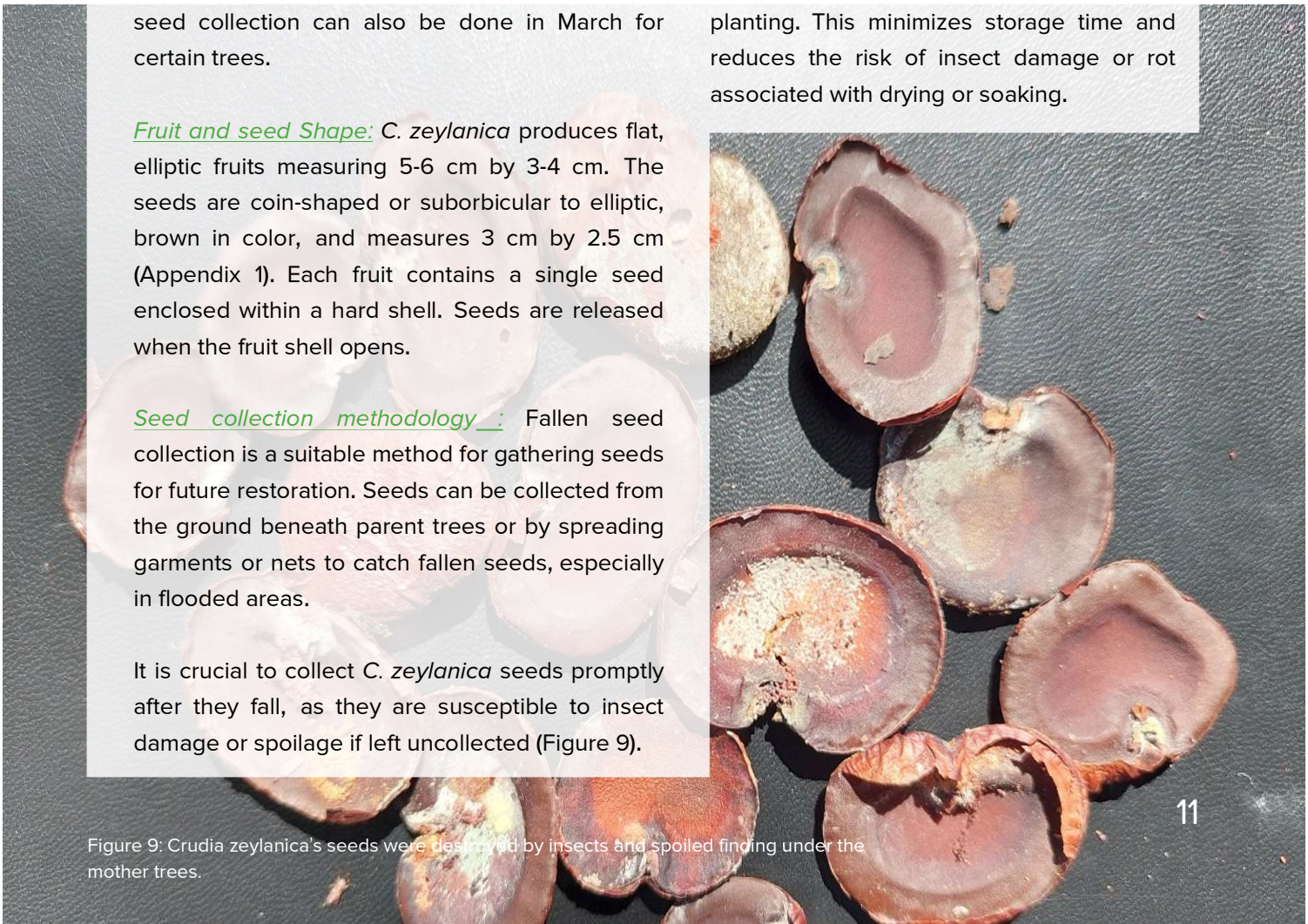


Figure 9: Crudia zeylanica's seeds were destroyed by insects and spoiled finding under the mother trees.

3.5.2 *Homalium brevidens* (Roteang)

Species ecology and status: *Homalium brevidens* (Roteang) is a tall tree native to gallery forests, reaching heights of up to 30 meters. This species is listed as Endangered (EN) on the IUCN Red List.

Flowering and fruiting: *H. brevidens* typically begins flowering in between July and September, with fruiting occurring from August and September. Seed production follows the ripening of the plant's flowers. The optimal time for seed collection is between September and November (Appendix 2).

Fruit and seed Shape: *H. brevidens* naturally produces small fruits that are difficult to distinguish from its flowers. Similarly, the seeds are extremely small and challenging to identify (Appendix 1).

Seed collection methodology: The most effective seed collection technique involves direct collection. Collectors can gather fruits or seeds directly from parent trees or by spreading garments or narrow mesh nets beneath the trees and shaking the branches to dislodge the seeds.

Seed Storage: *H. brevidens's seeds* are typically stored in cotton sacks or narrow-mesh net bags or other containers after indirect sun drying in the safe place. Nursery experiments have shown that direct sun drying significantly reduces or eliminates seed viability. Storing seeds for extended periods can decrease their ability to germinate successfully.

3.5.3 *Terminalia cambodiana* (Ta Ou)

Species ecology and status: *Terminalia cambodiana* (Ta Ou) is a tall tree originally to gallery forests, reaching heights of up to 30 meters. This species is listed as Vulnerable (VU) on the IUCN Red List.

Flowering and fruiting: *T. cambodiana* naturally begins flowering between March to June, with fruiting occurring between June and August. The best time for seed collection is between August and October (Appendix 2).

Fruit and seed Shape: *T. cambodiana* produces oval-shaped fruits with a thin, waxy skin that can be green, dark yellow, or dark brown or black when dried or after prolonged exposure to water. The fruit exhibits 4-5 distinct ridges running down its sides and contains a single seed (Appendix 1).

Seed collection methodology: The most effective seed collection technique involves collecting fallen seeds from the ground beneath parent trees. Given that this species often produces seeds during the flooding season, spreading nets under the trees can be a useful approach to capture fallen seeds on the water's surface. Seeds can be collected immediately beneath mother trees on the water surface or after the water level recedes.

Seed Storage: Two primary storage methods can be employed for these seeds: 1) storing dried seeds and 2) storing seeds after soaking in water. While drying facilitates easier storage and handling, prolonged drying and storage can significantly reduce germination rates.

Water soaking in net bags is another effective storage method. Soaking seeds in water from their natural habitat (lakes or ponds) can provide familiar nutrients and improve long-term storage viability. This technique is particularly useful only for pre-nursery storage (2-3 months), as it can enhance germination rates.

3.5.4 *Barringtonia acutangular* (Reang)

Species ecology and status: *Barringtonia acutangular* (Reang) is a tall tree fundamental to gallery forests, reaching heights of up to 25 meters. This speciesis listed as Least Concern (LC) on the IUCN Red List.

Flowering and fruiting: *B. acutangular* starts flowering in April to May, with fruiting peaking between June to July. The optimal time for collecting seeds is between August to October (Appendix 2). However, the B. acutangular is observed bearing fruits almost year-round.

Fruit and seed Shape: *B. acutangular* produces oval-shaped fruits with a thin, waxy skin that can be green, dark brown or black when dried or long stay in water. The fruit exhibits 3-5 distinct ridges running down its sides and contains a single seed (Appendix 1).

Seed collection methodology : The most effective technique for collecting *B. acutangular's* seed is gathering fallen seeds. Fallen seeds can be collected from the ground beneath the parent trees or by spreading nets beneath the trees to catch seeds before they sink into the water during the flooding season.

Seed Storage: Common storage methods include drying seeds and soaking them in water. Short-term storage typically results in higher germination rates. Practical experience suggests that storing seeds in net bags and soaking them in water from their natural habitat (lakes or ponds) promotes higher germination rates. This method exposes the seeds to familiar nutrients and conditions, reducing damage from insects and improving germination compared to traditional drying methods.

3.5.5 *Diospyros cambodiana* (Ptoul)

Species ecology and status: *Dyospyros cambodiana* (Ptoul) is a tall tree primary to gallery forests, reaching heights of up to 25 meters. This species is listed as Not assessed on the IUCN Red List.

Flowering and fruiting: *D. cambodiana* typically flowers between May and July, with fruiting occurring between August and September. Peak fruiting and seed collection periods are between October and November (Appendix 2).

Fruit and seed Shape: *D. cambodiana* produces oval or circular-shape fruits with a thin, waxy skin that can be green or dark brown when dried (Appendix 1).

Seed collection methodology : Fallen seed collection is the most effective method for gathering high-quality seeds. Spreading garments or narrow-mesh nets beneath the parent trees can facilitate seed collection by capturing fallen fruits, especially for small seeds that may be difficult to locate on the ground.

Seed Storage: Common methods include dried seeds storage and water soaking. However, our practical experience indicates that storing seeds in net bags and soaking them in water sourced from their natural habitat (lakes or ponds) can significantly improve germination rates. This method exposes the seeds to familiar nutrient-rich conditions, reducing insect damage and promoting optimal germination compared to traditional drying methods.

3.5.6 *Xanthophyllum lanceatum* (Kanseng)

Species ecology and status: *Xanthophyllum lanceatum* (Kanseng) is a tall tree native to gallery forests, reaching heights of up to 25 meters. This species is listed as Least Concern (LC) on the IUCN Red List.

Flowering and fruiting: X. *lanceatum* naturally flowers between February and April, with fruiting occurring between May and July. Peak ripening fruits and seed collection periods are between August and September (Appendix 2). Seed collection for this species sometimes begins earlier for certain trees.

Fruit and seed Shape: X. *lanceatum* produces circular-shaped fruits with an average diameter of approximately 1.5-2 centimeters. Each fruit contains a single, coin-shaped seed (Appendix 1), which is revealed after the fruit shell is removed or decayed.

Seed collection methodology : Fallen seed collection is the most effective method for gathering high-quality seeds. Spreading garments or narrow-mesh nets beneath the parent trees can facilitate seed collection by capturing fallen fruits, especially during the flooding period.

Seed Storage: Common methods include dried seed storage and water soaking. Our practical experience demonstrates that storing seeds in net bags and soaking them in water from their natural habitat (lakes or ponds) can significantly enhance germination rates, whereas storing dried seeds typically results in lower germination rates. This method exposes the seeds to familiar nutrient-rich conditions, reducing insect damage and promoting optimal germination compared to traditional drying methods.

3.5.7 *Cynometra ramiflora* (Chompring)

Species ecology and status: *Cynometra ramiflora* (Chompring) is a tall tree native to gallery forests, reaching heights of up to 25 meters. This speciesis listed as Least Concern (LC) on the IUCN Red List.

Flowering and fruiting: *C. ramiflora* flowers in May, with fruiting occurring in June. Peak ripped fruit and seed collection periods are between July and September (Appendix 2).

Fruit and seed Shape: *C. ramiflora* produces kidney-shaped or cylindrical fruits (Appendix 1). When the fruits ripen and fall, they generate seeds.

Seed collection methodology : Fallen seed collection is the most effective method for gathering high-quality seeds. Spreading garments or narrow-mesh nets beneath the parent trees can facilitate seed collection by capturing fallen fruits, especially during the flooding period.

Seed Storage: While dried seeds are typically easy to store for most tree species, *C. ramiflora* seeds present a unique challenge. They are difficult to dry effectively and exhibit poor storage longevity. Practical experience indicates that seeds fallen on the ground and dried are suitable for storage. However, seeds that fall into water readily germinate upon removal. Consequently, the recommended storage method involves water soaking. Alternatively, for short-term storage, seeds should be processed immediately for nursery establishment.

3.5.8 *Mallotus plicatus* (Chrakeng)

Species ecology and status: *Mallotus plicatus* (Chrakeng) is a tall tree native to gallery forests, reaching heights of up to 25 meters. This species is listed as Data Deficient (DD) on the IUCN Red List.

Flowering and fruiting: *M. plicatus* naturally flowers from May to June, with fruiting occurring between June and July. The peak period for ripe fruit and seed collection falls between August and October (Appendix 2). In some cases, fruit ripening may continue into December depending on the individual tree.

Fruit and seed Shape: *M. plicatus* produces distinctive, triangular fruits with three pointed tips (Appendix 1). Each ripe fruit contains a single seed. The seed remains intact within the fruit shell until the shell decays.

Seed collection methodology : Fallen seed collection is the most effective method for obtaining high-quality seeds. Spreading garments or narrow-mesh nets under the parent trees can facilitate seed collection by capturing fallen fruits, particularly during flooding periods. Seeds can be collected from the ground beneath the parent trees, especially after floodwaters recede.

Seed Storage: Common storage methods include drying seeds or soaking them in water. While drying is a suitable method for storing seeds of many tree species, *M. plicatus* seeds face a unique challenge. Dried seeds typically exhibit low germination rates. In contrast, soaking seeds in water or collecting seeds after they have fallen during or after flooding periods generally results in higher germination rates. Although water soaking can be effective for immediate planting, it is not a suitable method for long-term seed storage.

3.5.9 *Combretum trifoliatum* (Tros)

Species ecology and status: *Combretum trifoliatum* (Tros) is a woody vine native to forest shrublands, typically reaching heights of up to 4 meters. However, when it grows alongside and climbs other species in gallery forests, it can match the height of the species it is climbing.

Flowering and fruiting: *C. trifoliatum* naturally flowers from March to May, with fruiting occurring between June and July. The peak period for ripe fruit and seed collection falls between August and October (Appendix 2). In some cases, individual trees of this species may flower and fruit almost year-round.

Fruit and seed Shape: *C. trifoliatum* produces oval-shaped fruits with a thin skin that can be green, dark brown, or black when dried or long stay in water (Appendix 1). The fruit exhibits 3-5 distinct ridges running down its sides and contains a single seed.

Seed collection methodology : Fallen seed collection is the most effective method for obtaining high-quality seeds. Spreading garments or narrow-mesh nets under the parent trees can facilitate seed collection by capturing fallen fruits, particularly during flooding periods. Seeds can be collected from the ground beneath the parent trees, especially after floodwaters recede.

Seed Storage: Common storage methods include drying seeds or soaking them in water. While drying is a suitable method for storing seeds of many tree species, *C. trifoliatum* seeds face a unique challenge. Dried seeds normally exhibit low germination rates. In contrast, soaking seeds in water or collecting seeds after they have fallen during or after flooding periods generally results in higher germination rates. Although water soaking can be effective for immediate planting, it is not a suitable method for long-term seed storage.

3.5.10 *Garcinia cochinchinensis* (Sandan)

Species ecology and status: *Garcinia cochinchinensis* (Sandan) is a tall tree dominant in gallery forests, reaching heights of up to 15 meters. This species is listed as Endangered (EN) on the IUCN Red List.

Flowering and fruiting: *G. cochinchinensis* naturally flowers from February to May, with fruiting occurring between March and August. The peak period for ripe fruit and seed collection falls between September and October (Appendix 2).

Fruit and seed Shape: *G. cochinchinensis* produces ovoid or plum-sized fruits, approximately 5 cm x 4 cm, with a thin green or yellowish skin (Appendix 1). Each fruit contains at least 6 to 10 seeds, which remain encased within the fruit until it decays.

Seed collection methodology : Fallen seed collection is the most effective method for obtaining high-quality seeds. Spreading garments or narrow-mesh nets under the parent trees can facilitate seed collection by capturing fallen fruits, particularly during flooding periods. Seeds can be collected from the ground beneath the parent trees, especially after floodwaters recede.

Seed Storage: Dried seed storage is the most common and effective method for this species. According to the experience, *G. cochinchinensis* does not work by storing in the water, soaking, as it results lower germination rate.

3.5.11 *Elaeocarpus lanceifolius* (Romdenh)

Species ecology and status: *Elaeocarpus lanceifolius* (Romdenh) is a tall tree dominant in gallery forests, reaching heights of up to 15 meters. The conservation status of this species is unknown.

Flowering and fruiting: *E. lanceifolius* naturally flowers from February to May, with fruiting occurring between May and July. The peak period for ripe fruit and seed collection falls between September and November (Appendix 2).

Fruit and seed Shape: *E. lanceifolius* produces ovoid-shaped fruits, approximately 2-4 cm in length, with a thin green skin. Each fruit contains a single seed, which size about 1-2 cm (Appendix 1). Seeds will become visible once the fruits have fallen, and their skin and flesh have decayed.

Seed collection methodology : Fallen seed collection is the most effective method for obtaining high-quality seeds. Seeds can be collected from the ground beneath the parent trees. Spreading garments or narrow-mesh nets under parent trees is an ideal way to collect fallen fruits.

Seed Storage: Dried seed storage is the most effective method for preserving the *E. lanceifolius* species. Seeds should be dried in indirect sunlight to prevent damage to their germination potential. Once dried, seeds can be stored in various containers, such as cotton sacks, to maintain their viability.

IV. Tree Nursery Establishment

Establishing a tree nursery aims to produce healthy seedlings and nurturing them in a controlled environment for future planting. Nursery-based seedling production is a practical approach to ensure that sufficient and high-quality seedlings are available for upcoming reforestation or transplantation plans.

4.1 Nursery Location Selection

When selection an appropriate nursery location, consider the following factors:

- **Suitability for Plant Production:** The nursery area should be sloped, fertile, and well-drained.
- **Accessibility:** The areas should be well connected by various means and easily accessible.
- **Protection:** The nursery should be well protected, ideally located near villages or household buildings, community stations, community conservation areas, or replanting restoration sites.
- **Proximity to Irrigation:** The site should be near irrigation or other water sources to ensure an easy water supply

We have found that nurseries next to CFi conservation ponds are ideal. This location makes it easy for Community Fisheries Committee members to care for the seedings and conserve fish species during the spawning season.

4.2 Nursery Preparation

4.2.1 Timeframe

Nursery preparation can be carried out at various times depending on local needs and conditions. For the Tonle Sap Lake region, the ideal time to establish a tree nursery is between January and March, when the water recedes and land becomes available for nursery setup. Seedlings should be raised in the nursery for at least 4 to 5 months before being transplanted to the replanting site. Transplantation typically takes place during the rainy season, with the optimal period for the Tonle Sap area occurring between May and July. Delays in nursery preparation can negatively impact seedling development and reduce overall planting success.

4.2.2 Nursery Proposal

It is important to design the nursery prior to its construction. The first thing to consider is its size, which varies according to the number of seedlings that are to be raised.

For example, a 10 x 10 m nursery is large enough to raise 25,000 seedlings. The nursery must be covered by a roof of blue or green mesh netting to provide shade and reduce the impact of heavy rainfall. The nursery should be surrounded by a fence to prevent livestock from entering. A three-meter-high wooden plank fence is recommended (Figure 10).

Figure 10: This is the format of flooded forest nursery facility was constructed for seedling production.

4.3 Soil Preparation

4.3.1 Type of soils

Figure 11: Compost soil mixture for growth the seedlings

Soil plays a vital role in seedling production during the nursery stage. Seedlings need a well-draining yet moisture-retentive growing medium. A good mixed soil provides essential nutrients and promotes healthy root development. Compost is an excellent source of organic matter and nutrients for seedlings (Figure 11). The standard valuable compost soil should be mixed with soil, husk ash, coco peat, cattle manure, and other materials, including composted hay or leaves, as detailed below. However, some components, like coco peat or rice husk ash, might be difficult to find or expensive in some local communities around Tonle Sap Lake.

The components of compost soil that improve tree root system growth well.

Photos	Compost soil Components	Percentage (%)
	Soil	30
	Husk Ash	30
	Coco Peat	20
	Cattle Manure	10
	Hay/Leaves	10

Alternatively, soil from the flooded forest is also suitable for establishing nursery beds and placing seedling in plastic bags. The following recommendation should be considered:

- **Source Soil from the Replanting Site:** This ensures the new plants encounter familiar conditions, including beneficial microbes already present in the soil.
- **Match Soil Characteristics:** If collecting from elsewhere, try to find a location with similar characteristics, such as texture (sandy, loamy, clayey), drainage, and organic matter content (Figure 12).
- **Utilize Similar Flooded Forest Soil:** Soil from a similar flooded forest environment likely contains the natural nutrient profile that the target tree species are adapted to, which can significantly benefit seedling growth and development.

Figure 12: Mature soil is collected from a similar flooded forest environment at the Tonle Sap Lake.

Note: *Practical experience has shown that unfertile soil from rice fields or mainland areas might not be ideal for a flooded forest nursery. Rice field and mainland soils might often have different textures and drainage characteristics compared to flooded forest soil. These differences could impact root development and water availability for the seedlings. Therefore, a soil environment that mimics the natural habitat of the flooded forest trees gives seedlings the best chance of thriving, developing strong root systems, and growing faster (Figures 13 and 14).*

Figure 13: Soil collected from rice fields can sometimes impact the root system of seedling and reduce their growth

Figure 14: Mature soil collected from a similar flooded forest environment consistently promotes healthy seedling growth.

4.3.2 Soil Preparation

Black plastic nursery bags are commonly used for planting seedlings. These bags should be at least 15 cm deep and 10 cm wide, with punched holes at the bottom to allow for drainage. They are available at district and provincial markets, making them accessible to local communities.

Once fertilizer soils are collected and mixed, it's time to fill the nursery bags and organize them in rows for efficient seedling propagation (Figure 15).

Figure 15: Mature soil was filled in the nursery bags for seedling production.

4.4 Seedlings Propogation

Seedling production is a crucial stage in growing tree seeds in a nursery until they are ready for planting at replanting sites. Selecting suitable methods for seedling propagation is essential, as it optimizes growth and maximizes the success of replanting efforts. Four seedling propagation techniques are commonly used to produce tree seedlings: 1) cutting for propagation, 2) direct seed germination, 3) seed sowing in seedbeds, and 4) natural seeds/seedlings nursery. Among these, three techniques–placing seeds in nursery bags, sowing seeds in seedbeds, and collecting naturally germinated seeds/seedlings for the nursery–are widely practiced by the local communities.

4.4.1 Cutting for propagation

Cutting for propagation is an effective method for plant species that are difficult or impossible to grow from seeds. While cuttings are genetically identical to the mother plant (clones), this method can still support genetic diversity and future resilience if done thoughtfully. To maintain genetic variation within the cutting stock, take only a few cuttings from as many different mother plants as possible, rather than many cuttings from a single plant. The basic materials used for this process include nursery bags, baskets, pruning shears, knives, rooting hormone, a mini greenhouse, shovels, and a hoe.

Selecting Branches for Propagation

Mature branches are cut from healthy mother trees (Figure 16). Branches are selected based on criteria:

- Healthy branch that is at least 1 year old,
- Branch has a diameter of about 0.8 to 1.5 cm,
- The branch should be positioned at a 45-degree angle,
- Length of sample branches is about 25 to 30 cm,
- Leaves and buds should be removed from the bottom of the cutting,
- After cutting, dip the base of the branch in a water tank or cover it with wet cloths.

Figure 16: Terminalia cambodiana's branches were cut from mother trees at the Tonle Sap Lake for propagation experiment using cutting technique.

Selecting Branches for Propagation

Sample branches are started to propagate using the following process:

- Select healthy tree branches and make them uniform in length,
- Remove the outer bark from the tree branches about 3 centimeters in length,
- Mix 5 ml of liquid hormone with 1 liter of water in a tank, and soak sampling branches in the hormone mixture tank for about 30 minutes.
- Make a hole at the center of the plant nursery bags,
- Place tree branches into nursery bags filled with compost soil, one by one, until all are completed. Store them in a suitable site (greenhouse if possible),
- Spray water twice a day and monitor growing progress (Figure 17).

Figure 17: Process of branch cutting for propagation

Note: The cutting propagation technique is applied to tree species that are impossible to produce seedlings from seeds or when seeds are not available for collection. This technique is applicable for *Homalium brevidens* species, as its seeds are not available for the nursery. For other species like *Terminalia cambodiana*, *Crudia chrysantha*, *Barringtonia acutangular*, *Diospyros cambodiana*, *Xanthophyllum glancum*, *Cynometra (inaequifolia)*, *Mallotus plicatus*, and *Combretum trifoliatum*, this species is not recommended because seeds are available for collection.

4.4.2 Direct Seed Germination

Available seeds can produce viable seedlings in the nursery. Direct seed germination involves planting seeds directly in nursery bags. Planters can use this method to produce tree seedlings for their specific needs.

a. Pre-treatment of Seeds

Tree seeds require pre-treatment to increase germination before being planted in a nursery. This pre-treatment typically involves soaking the seeds in water at least 24 hours. This process also allows planters to select high-quality seeds by removing any that are damaged or spoiled before planting them in nursery bags. Seeds that have already been stored in water do not require additional pre-treatment, as the soaking period has already prepared them.

b. Place Seeds in Nursery Bags

Placing seeds in nursery bags is an effective method for producing seedlings. After pre-treatment, the treated seeds are placed in the nursery bags filled with composted soil. Below is the process of placing seeds in planting bags in the nursery:

- Pre-treat seeds by soaking them in water to improve germination success.
- Thoroughly water nursery bags filled with good quality compost soil mix before planting seeds.
- Sow 1-2 seeds per bags.
- Water the nursery bags twice daily.
- Control and remove weeds and insects.

4.4.3 Seed Sowing in Seedbed

Sowing seeds in a seedbed is an effective method for seedling production. This approach ensures uniform growth of seedlings in the nursery. There are two main steps1) sowing seeds in seedbed, and 2) transferring geminated seeds or young seedling into nursery bags.

a. Seedbed Preparation and Seed Sowing (Figure 18):

- Clear ground surface in well-drained areas.
- Fill the cleared ground surface with compost soil to a height of at least 5-centimeter.
- Sow seeds on the top surface of the seedbeds.
- Cover the seeds with a thin layer of composted rice straw.
- Water twice a day.
- Manage weeds and insects that can disturb and destroy seeds.

Figure 18: Process of seedbed preparation for sowing seeds before transferring them into nursery bags.

b. Transferring Germinated Seeds or Seedlings to Nursery Bags (Figure 19):

- Gently remove germinated seeds or juvenile seedlings,
- Use a finger or stick to make a hole in plant nursery bags, comfortably accommodating the seedlings' root systems,
- Plant the germinated seeds or seedlings immediately in nursery bags to prevent them from drying out in the sun's heat,
- Place the seedling into the hole and gently press the surrounding soil to secure it.
- Arrange plant nursery bags in rows, and water newly seeded plants twice a day.

Figure 19: The process of transformation seed germinated or juvenal seedlings into nursery bags.

4.4.4 Natural seed/seedlings nursery

A natural seeds/seedlings nursery involves a thoughtful process of collecting naturally germinated seeds or seedlings from the wild and nurturing them in the nursery before replanting them in their natural habitats. This method is commonly practiced by local communities around Tonle Sap Lake and focuses on tree species focuses tree species such as *Barringtonia acutangular, Diospyros cambodiana, Xanthophyllum lanceatum, Cynometra inaequifolia, Mallotus plicatus, Terminalia cambodiana,* and *Combretum trifoliatum* are commonly found as germinated seeds or young seedlings beneath their mother trees or nearby areas. However, it is not recommended for rare species such as *Crudia zeylanica and Homalium brevidens* due to their low regeneration rates in nature.

The process involves two main steps: collecting wild seeds/seedlings and transplanting them into nursery bags.

First, healthy mother trees are identified when they produce fruit. Seedlings are then located on the ground beneath or near these trees, carefully removed by hand or with a spade, and placed in a basket or water tank to prevent drying out (Figure 20). The seedlings are transported to the nursery shed, soaked in water, and then planted in nursery bags.

Figure 20: Process of removing natural seedlings to nurture in the nursery for seedling production.

Second, transplanting seeds/seedlings in nursery bags: After collecting wild germinated seeds/seedlings, they are immediately transplanted into nursery bags to minimize damage from sun exposure, especially to the root system. This process is like transferring seedlings from a seedbed to nursery bags, such as:

- Select Healthy Seedlings: Choose seedlings that have just been removed from natural regeneration,
- Create Holes in Nursery Bags: Use your finger or a stick to create a hole in each nursery bag before placing the seedling.
- Place Seedlings in Bags: Carefully place each seedling into the hole of each nursery bag and gently press the surrounding soil to secure it (Figure 21)
- Prepared Nursery Bags: Arrange the planted seedling bags as a nursery bed, and water twice a day.

Figure 21: The process of planting natural young seedlings into the plant nursery bags.

Note: *When collecting wild seedlings, it's best to focus on those that have germinated or are in their juvenal stages. These seedlings have smaller, less developed root systems, making them easier to extract with minimal damage (Figure 22). A healthy root system is crucial for their survival after transplanting into nursery bags. Conversely, removing older seedling or sapling with larger, deeper root systems is not recommended. (Figure 23). This practice can disrupt natural regeneration and cause significant damage, making it difficult for these plants to establish themselves after transplanting.*

Figure 22: wild Juvenal seedling with less root system (Recommended).

Figure 23: Wild seedling with long root system (Not recommended)

Here are some tips for successful transferring young seedlings from a nursery bed or wild transplanting in nursery bags:

- **Watering Adjustment:** Reduce or stop watering seedlings in the seedbed a day before removal. This will make the soil less sticky and easier to remove seedlings.
- **Timing is Key:** Choose cooler times of the day, such as early morning or late afternoon, for transferring and transplanting. This minimizes stress on the seedlings from sunlight.
- **Minimize Root Disturbance:** Carefully remove seedlings from nursery beds or the wild and plant them into their nursery bags immediately to minimize root disturbance.
- **Post Transplanting Care:** After planting the seedlings in nursery bags, place them in a shaded area for 2 or 3 days. This allows them to recover from transplanting and develop their root systems before being exposed to full sunlight.

4.5 Tree Seedling Propagation by Species:

Flooded forest species have different ecological requirements. Most of the selected species grow in gallery forests, but they do not germinate or grow under the same conditions in a nursery. Some species' seeds germinate easily and grow quickly, while others are difficult to germinate and grow very slowly. The table below shows the germination and growth conditions in the nursery:

4.5.1 *Crudia zeylanica* (Sdey):

C. zeylanica is generally easy to germinate and grows quickly in a nursery. The tree seedling production is processed as below:

- *Pre-treatment of seeds*: Seeds require pre-treatment by soaking in water for about 24 hours before sowing. If seeds are collected from beneath water, pre-treatment is not necessary
- *Seedling production Method:*

- **Direct Sowing:** Seeds are typically sown directly into nursery bags. This method is both effective and efficient for achieving successful germination.
- **Nursery Bed:** Alternatively, seeds can be sown in nursery beds and later transplanted into nursery bags. However, this method can sometimes damage the roots during transfer, as the taproots develop quickly and grow long.
- **Wild Seedling Collection:** C. zeylanica exhibits low natural regeneration, making the collection of wild seedlings for nurturing in nurseries a rare practice.
- **Cutting Propagation:** C. zeylanica does not respond well to cutting propagation techniques.

Key Tips for Planting Crudia zeylanica Seeds in Nursery Bags:

- **Identifying the Radicle Side:** Due to the seed's unique heart shape, it is crucial to plant the Crudia zeylanica seed with the flat radicle side facing down into the compost soil.
- **One Seed per Bag:** It's recommended to plant only one Crudia zeylanica seed per nursery bag due to large size of each seed.
- **Shallow Planting Depth:** The planting depth should be shallow, ideally not exceeded 40% of the seed's total size (Figure 24).

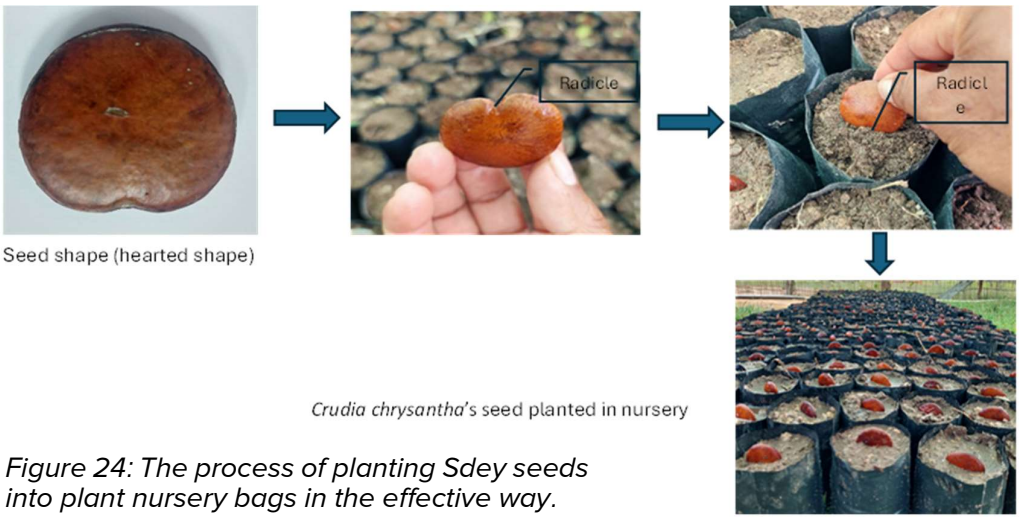


Figure 24: The process of planting Sdey seeds into plant nursery bags in the effective way.

4.5.2 *Homalium brevidens* (Roteang)

Little known about *H. brevidens* progressing in a nursery. Based on experience, seedling production from seeds has a critically low germination rate, and the seedlings develop slowly. The seedling production is processed as below:

- ***Pre-treatment of seeds*:** If seeds are dried and stored for months, pre-treatment is required at least 24 hours before nursery progression. However, if seeds are collected from the surface of water, pre-treatment is not necessary.

- ***Seedling Production Method:***

  Direct Sowing: Seeds are typically planted directly into nursery bags. This method is not feasible for *H. brevidens* because of the low gemination rate.

  Nursery Bed: Seeds are commonly sown in nursery beds and later transplanted into nursery bags. This method appears suitable for these tiny seeds, as it allows juvenile seedlings to establish and continue growing successfully in the bags after transplantation.

  Wild Seedling Collection: *H. brevidens* presents low natural regeneration, making the collection of wild seedlings for nurturing in nurseries a rare practice.

  Cutting Propagation: This is a viable option for producing tree saplings, especially for species that are difficult to find or rare to collect seeds from mother trees. However, the survival rate of saplings through this technique is observed to be very low after the leaves have developed and grown for some time.

4.5.3 *Terminalia cambodiana* (Ta Ou)

T. cambodiana is generally easy to produce seedling from seeds and grows quickly in a nursery if provided well-cared. The seedling production is processed as below:

- ***Pre-treatment of seeds*:** Dried seed required pre-treatment at least a week before processing in a nursery because the seeds' shell is normally hard when dried. If seeds are stored by soaking in water, pre-treatment is not necessary.

- ***Seedling Production Method:***

  Direct Sowing: Seeds can be placed directly in nursery bags. This method provides both effectiveness and efficiency.

  Nursery Beds: Seeds can be sown in nursery beds and then transferred to the nursery bags once germinated. This method is also effective and efficient for *T. cambodiana*.

  Wild Seedling Collection: Seeds can be sown in nursery beds and then transferred to the nursery bags once germinated. This method is also effective and efficient for *T. cambodiana*.

  Cutting Propagation: This is a viable option for producing tree saplings, especially for species that are difficult to find or rare to collect seeds from mother trees. However, the survival rate of saplings through this technique is observed to be very low after the leaves have developed and grown for some time.

4.5.4 *Barringtonia acutangular* (Reang)

B. acutangular seedlings are germinated easily from seeds, grow quickly, and have a high survival rate when nurtured in a nursery. The seedling production is processed as below:

- ***Pre-treatment of seeds:*** *Dried seeds require pre-treatment for at least 24 hours, while seeds stored by soaking in water do not required pre-treatment.*
- ***Seedling Production Method:***

  Direct Sowing: Seeds can be placed directly in nursery bags. This method is feasible for this species with effectiveness and efficiency.

  Nursery Bed: Seeds can also be sown in nursery beds and then transferred to a nursery bag once germinated. This method significantly enhances seedling production for *B. acutangular* more effective.

  Wild Seedling Collection: Seedling production can be generated from collecting naturally germinated seeds or young seedlings from the wild, as they commonly grow in abundance beneath the mother trees after water recedes. This method is also crucial for seedling production and is normally used by local communities at the Tonle Sap Lake.

  Cutting Propagation: This technique is not recommended for B. acutangular, due to the availability of seeds for collection and abundant geminated seeds in nature.

4.5.5 *Diospyros cambodiana* (Ptoul)

Seedlings production of D. cambodiana species can be generated from seeds and tend to growing quickly, but low geminated rate in nursery. The seedling production is commonly processed as below:

- ***Pre-treatment of seeds:*** Dried seeds require pre-treatment for at least 24 hours before nursery progressing. However, if seeds are stored by soaking in water, pre-treatment is not necessary.
- ***Seedling Production Method:***

  Direct Sowing: Seeds can be directly planted into nursery bags to produce seedlings in the nursery. This method is particularly suitable and effective for Diospyros cambodiana. However, it is crucial to collect high-quality seeds to ensure a high germination rate and avoid the need for seed replacement later.

  Nursery Beds: Seeds can be sown in the nursery beds and then transferred to nursery bags once germinated. The method is also effective for *Diospyros cambodiana*.

  Wild Seedling Collection: Seedlings can also be produced by collecting naturally germinated seeds or young seedlings from the wild, as they commonly grow in abundance beneath mother trees after water recedes.

  Cutting Propagation: This technique is not recommended for D. cambodiana due to the availability of seeds for collection.

4.5.6 *Xanthophyllum lanceatum* (Kanseng)

Seedling production of *X. lanceatum* is generally straightforward in a nursery setting. Seeds typically germinate well and grow quickly. The seedling production is processed as below:

- ***Pre-treatment of seeds:*** Dried seeds require pre-treatment for at least 24 hours before nursery progressing. However, if seeds are stored by soaking in water, pre-treatment is not necessary.
- ***Seedling Production Method:***

  Direct Sowing: Seeds can be directly planted into nursery bags to produce seedlings in the nursery. This method is particularly suitable and effective for X. *lanceatum*. However, it is crucial to collect high-quality seeds to ensure a high germination rate and avoid the need for seed replacement later.

  Nursery Bed: Sowing seeds in nursery beds and then transplanting young seedlings into nursery bags is rarely practiced for this species, as it is time-consuming. Directly planting seeds in nursery bags is more effective and works well for this species.

  Wild Seedling Collection: Collecting naturally germinated seeds or young seedlings from the wild for nurturing in a nursery is feasible for *X. lanceatum*. However, seedlings have never been produced through wild seedling collection. This may be due to the fact that the species is readily available for seed collection, and seed germination in the nursery is also high, and growing faster.

  Cutting Propagation: This technique is not recommended for *X. lanceatum* due to the availability of seeds for collection.

4.5.7 *Cynometra ramiflora* (Chompring)

The production of *C. ramiflora* seedlings is generally straightforward in a nursery setting. The seeds typically germinate well but grow slowly in the nursery. The seedling production is processed as below:

- ***Pre-treatment of seeds:*** The seeds of *C. ramiflora* are typically stored by soaking in water after being collected from beneath the mother trees. Therefore, it is not required for pre-treatment. **(**Note: These seeds naturally fall into the water when they ripen. Once collected, they should be stored in water before processing the nursery; otherwise, they will begin to germinate immediately after being harvested from the water.**)**
- ***Seedling Production Method:***

  Direct Sowing: -Directly planting seeds in nursery bags is the most effective method for producing seedlings of *C. ramiflora*, as the seeds begin to germinate once removed from the water within a short time.

  Nursery Beds: Sowing seeds in nursery beds and then transplanting young seedlings into nursery bags is also feasible, but rarely practiced for this species.

  Wild Seedling Collection: Alternatively, seedlings can be generated by collecting naturally germinated seeds or young seedlings for nurturing in a nursery, although finding these in their natural habitat can be challenging.

  Cutting Propagation: This technique has never been experimented with, and it is not recommended for *C. ramiflora* due to the availability of seeds for collection.

4.5.8 *Mallotus plicatus* (Chrakeng)

M. plicatus seedlings generally perform well in the nursery. Seedlings are produced through seed germination, although the germination rate is relatively low. However, once the seeds do germinate, the seedlings grow quickly. The seedling production is processed as below:

- ***Pre-treatment of seeds:*** Soaking seeds in water is the most effective method for pre-treatment. For dried seeds, this process should be carried out at least 24 hours before nursery processing. However, if seeds are stored by soaking in water, pre-treatment is not required.
- ***Seedling Production Method:***

  Direct Sowing: Directly planting seeds in nursery bags is a good method for producing seedlings of *M. plicatus*. However, this species has a low germination rate when using stored seeds, especially dried seeds. Therefore, it is essential to practice appropriate pre-treatment and select high-quality seeds to improve the germination rate.

  Nursery Bed: Sowing seeds in nursery beds and then transplanting young seedlings into nursery bags is the optimal method for this species. This approach allows for the selection of only the germinated seedlings to be placed in nursery bags, ensuring better care and management afterward.

  Wild Seedling Collection: Alternatively, seedlings can also be produced by collecting naturally germinated seeds or young seedlings for nurturing in a nursery. This method is feasible for *M. plicatus* species and is a practical approach commonly used by local communities due to the low germination rate of seeds.

  Cutting Propagation: This technique has never been experimented with, and it is not recommended for *M. plicatus* due to the availability of seeds and young seedlings for collection.

4.5.9 Combretum trifoliatum (Tros)

C. trifoliatum seedlings generally grow well in a nursery after germinating. However, the dried seeds typically do not germinate well compared to seeds that are stored by soaking in water. The seedling production is processed as below:

- ***Pre-treatment of seeds:*** Soaking seeds in water is the most effective method for pre-treatment. For dried seeds, this process should be carried out for a longer period than other species (at least a week) due to the hard shell that forms when the seeds dry. However, if seeds are stored by soaking in water, pre-treatment is not required, and the seeds will germinate well and faster.
- ***Seedling Production Method:***

  Direct Sowing: Directly planting seeds in nursery bags is an effective method for producing seedlings of *C. trifoliatum*. However, this species has a low germination rate when using stored seeds, especially dried seeds. Therefore, it is essential to practice appropriate pre-treatment and select high-quality seeds to improve the germination rate.

  Nursery Bed: Sowing seeds in nursery beds and then transplanting young seedlings into nursery bags is the best method for this species. This approach allows for the selection of only the germinated seedlings to be placed in nursery bags, ensuring better care and management afterward.

Wild Seedling Collection: Alternatively, seedlings can also be produced by collecting naturally germinated seeds or young seedlings for nurturing in a nursery. This method is feasible for *C. trifoliatum* species.

Cutting Propagation: This technique has never been experimented with, and it is not recommended for *C. trifoliatum* due to the availability of seeds and young seedlings for collection.

4.5.10 Garcinia cochinchinensis (Sandan)

Seedlings of *G. cochinchinensis* are generally challenging to cultivate in a nursery due to their low germination rate. Typically, dried seeds are used for producing seedlings. According to local community experience, longer-stored dried seeds are more feasible for germination than fresh ones. The seedling production process is as follows:

- ***Pre-treatment of seeds:*** Soaking seeds in water is a common method for pre-treatment. For dried seeds, this process should be carried out in two steps: 1) soaking the seeds in water for at least 24 hours, and 2) keeping the wet seeds in a damp cloth until they start germinating. However, if seeds are stored by soaking in water, only step 2 is required.
- ***Seedling Production Method:***

  Direct Sowing: Directly planting seeds in nursery bags is an effective method for producing seedlings of *G. cochinchinensis*. However, pre-treatment of seeds using the two steps mentioned above is required to improve the germination rate and ensure efficient effort.

  Nursery Bed: Sowing seeds in nursery beds and then transplanting young seedlings into nursery bags is the optimal method for this species. This approach allows for the selection of only the germinated seedlings to be placed in nursery bags, ensuring better care and management afterward. If this method is applied, only step 1 of the pre-treatment process mentioned above is required.

  Wild Seedling Collection: Seedlings can also be produced by collecting naturally germinated seeds or young seedlings for nurturing in a nursery. However, this method is not recommended due to the limited natural regeneration of this species.

  Cutting Propagation: This technique has never been experimented, and it is not recommended for *G. cochinchinensis* due to the availability of seeds.

4.5.11 Elaeocarpus lanceifolius (Romdenh)

E. lanceifolius seedlings generally grow well in a nursery after geminating. Seeds are typically used for producing seedlings. The germinated seeds or seedlings of this species usually grow quickly, and the survival rate is high in the nursery. The seedling production process is as follows:

- ***Pre-treatment of seeds:*** Soaking seeds in water is a common method for pre-treatment. This process is generally carried out at least 24 hours before nursery processing.

- ***Seedling Production Method:***

  Direct Sowing: Directly planting seeds in nursery bags is an effective method for producing seedlings of *E. lanceifolius*. High-quality seeds must be selected to improve the germination rate and enhance the effectiveness and efficiency of the seedling production effort.

  Nursery Bed: Sowing seeds in nursery beds and then transplanting young seedlings into nursery bags is the optimal method for this species. This approach allows for the selection of only the germinated seedlings to be placed in nursery bags, ensuring better care and management afterward.

  Wild Seedling Collection: Seedlings can also be produced by collecting naturally germinated seeds or young seedlings for nurturing in a nursery. However, this method is rarely implemented due to the limited natural regeneration of this species.

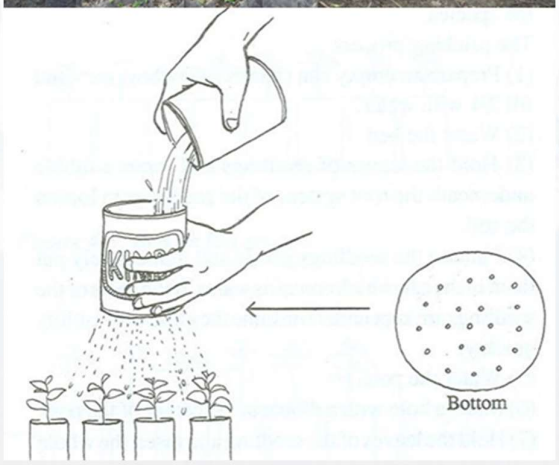
  Cutting Propagation: This technique has never been experimented with, and it is not recommended for *E. lanceifolius* due to the availability of seeds.

4.6 Seedling protection and care

Once the seeds have germinated and begin to grow, they need to be cared for and will remain in the nursery for around three to four months. During this time, several activities need to be carried out:

- **Watering:** The seedlings need to be regularly watered, ideally twice a day, in the morning and the evening. As the seedlings grow larger, they will require more water. A watering can, which can be purchased from local markets, or a self-made watering tin should be used (Figure 25).

Figure 25. Watering can (left) and self-made watering tin (right, from Ruvuga et al. 2002). ©CI Cambodia/ Dong Tangkor



- **Weeding:** Weeds can hinder the growth and the survival of plants or seedlings by competing for nutrients, moisture, light, and attracting insects. Gently pull out weeds by hand and compost them for future use.

- **Fertilizer:** Enhance seedling growth by applying organic fertilizer such as composted livestock manure. Ensure the manure is properly composed before use.

- **Livestock and wild animals:** Protect seedlings from browsing animals with a sturdy fence around the nursery. Maintain cleanliness inside and around the nursery to reduce damage from mice and rats.

- **Insects:** Various insects can harm seedlings. Termites and tree worms may attack roots and stems, while grasshoppers and crickets target young leaves. Hand removal is the best method for managing these pests.

V. Seedlings Planting

Transplantation of seedlings marks the final stage of the restoration process. When seedlings reach three to four months of age, they should ideally be between 50 and 80 cm in height. With proper care, some young plants can even grow up to 100 cm. Achieving the optimal height of 50-80cm is crucial for successful transplanting as it facilitates easy transportation and minimizes root disturbance, ensuring the seedling fits well in standard nursery bags.

5.1 Timeframe

Seedlings should be planted at the beginning of the rainy season, typically between May and July, on the Tonle Sap floodplain. It's crucial to wait until sufficient rain has soaked the soil, as this significantly enhance the trees' chance of survival. Transplanting seedlings at the start of the rainy season allows them 2 to 3 months to establish and grow before the rising lake floods the area.

5.2 Pre-treatment before transporting

Pre-treatment is essential for ensuring high survival rates of seedlings after planting. This process involves hardening off the seedling, making them stronger as they'll face after planting. Pre-treatment often includes lifting the seedlings from the nursery bed and placing them back in the same position (Figure 26). This temporary root disturbance encourages the development of new feeder roots, helping the seedlings adapt to the new environment. Adequate watering is crucial during pre-treatment. Pre-treatment typically begins at least 2 weeks before transplanting.

Figure 26: Local community is practicing pre-treatment seedlings before transplanting.

5.3 Transporting Seedlings

Transporting Seedlings from the nursery to the planting site requires special care. A variety of vehicles can be used, including trucks, ox carts, motorcycles, mechanical mules, manual tractors, and boats (Figure 27). To prevent damage, seedlings should not be piled on top of one another. Instead, place them in boxes or baskets for safe transport. Additionally, avoid watering seedlings the day before transport to keep your vehicle clean.

Figure 27: Means for transporting seedling during planting in replanting site.

5.4 Gridline tree replanting

Planting seedlings is a crucial stage in the restoration of the flooded forest. Seedlings should be planted approximately four meters apart, as recommended by both our experience and FiA officers (Figure 28), resulting in a density of 450 plants per hectare. To prepare the soil, cultivate a hole no larger than 40 cm in width x 40 cm in length x 40 cm in depth, and loosen the soil to allow the roots to penetrate easily and quickly.

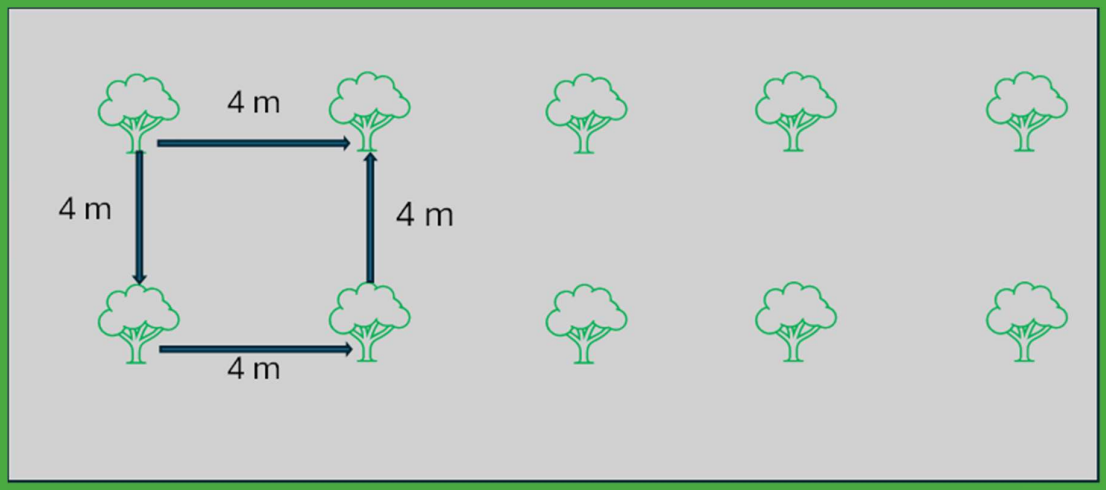


Figure 28: The technique to planting seedlings in replanting site by practicing 4 meters from each seedling and each row.

The following steps need to be taken when planting seedlings:

- Choose strong and healthy seedlings;
- Excavate a 40 x 40 x 40 cm hole;
- Re-fill ¼ of the holes with wet soil around the holes, or with the soil removed when preparing the holes;
- Remove the plastic bag from the seedlings and their soil by tearing or cutting;
- Put the seedling in the center of the hole and cover it with the top layer of soil
- Use your hands or feet to firm the soil carefully around the seedling (Figure 29).

Figure 29: The process of tree seedling transplanting in replanting area.

5.5 Maintaining Replanted Trees

Once planted, seedlings need proper maintenance to ensure high survival rates, preferably between 50% and 70 %. To achieve this goal, the community should focus on regular watering, removing weeds to prevent competition for resources.

5.5.1 Seedling Replacement

Replacing dead or loose seedlings is crucial to address the mortality rate after replanting. For the flooded forest, the replacement typically occurred a year after replanting, as the area remains flooded for about seven months. It is recommended to plan to replace at least 20% of the total seedlings at each site to maintain the 4 x 4 m grid spacing when some of the trees die, replanting the positions where the trees have died. This activity should be carried out at the beginning of the rainy season, with May to July being the optimal time for replacing the new seedlings.

5.5.2 Invasive Species Control

Mimosa pigra and grasses (Thvang and Rompheak Toek) pose significant threats to replanting sites in the Tonle Sap floodplain due to their rapid growth and dominance. These invasive species can smother replanted native vegetation and contribute to fire risks during the dry season. Early control of *Mimosa Pigra* is crucial. Removing young plants *M. Pigra* or cutting them before the annual flood helps prevent their spread (Figure 30). Controlling the dense and widespread grass (Thvang and Rompheak Toek) is more challenging due to its high density and prevalence across replanting sites (Figure 31).

Figure 30: The activity of Mimoza pigra removing at the replanting site.

Figure 31: Grass cutting at the replanting site before planting and fire break creation

5.5.3 Fire Prevention

Dense grass dominated the replanted seedlings, creating a significant fire hazard, especially during the dry season, which can easily kill young trees. Removing dry grass around the base of seedlings at the beginning of the dry season significantly reduces the fire risk (Figure 32). However, this task is challenging on larger replanted sites due to the higher labor and time costs involved.

Figure 32. Removing floodplain grass from around planted seedlings to reduce the risk of fire damage. ©Dong Tangkor

Tips for successful transplanting:

- **Select healthy seedlings:** Ensure seedlings that are healthy and have been nurtured for at least 3-4 months, reaching a height of at least 0.5 meters.
- **Pre-treatment seedling before transplanting:** About 1-2 weeks before transplanting, gently lift the seedlings from the nursery bed and place them back, watering as usual. This temporary root disturbance encourages the development of new feeder roots and helps seedlings adapt to the new environment.
- **Timing:** Transport seedlings during cooler parts of the day, such as early morning or late afternoon, to minimize stress from sunlight. The best time for transplanting is during the rainy season when the soil is naturally moist.
- **Replanting techniques:** Ensure seedlings are planted following the recommended guidelines and techniques.
- **Minimize root disturbance:** Carefully remove the nursery bag to avoid disturbing the root system and breaking the soil around the seedling.
- **Post-transplant care:** After planting the seedlings in replanting sites, ensure the sites are protected from threats such as fire or damage by cattle or buffalo.
- **Maintenance:** Replace any dead or loose seedlings after a year to ensure the survival and replanting effort.

VI. Survival Rate Limitation:

Replanting efforts are influenced by four primary factors: species selection (Species Ecology), replanting techniques (nursery care, transportation, and transplantation), forest fire, and natural disasters (drought, flash floods, and heat).

6.1 Species Selection

Species selection is a crucial factor in determining the survival rate of replanting efforts. The ecology of the selected species must be considered to ensure they are planted in habitats where they naturally thrive.

For tree species selection:

- **High Survival Rates** ***Barringtonia acutangular*** has demonstrated higher survival rates, followed by ***Diospyros cambodiana and Combretum trifoliatum***. These species can grow in various habitats throughout the flooded forest area.

- **Lower Survival Rates** ***Xanthophyllum lanceatum, Cynometra ramiflora, Mallotus anisopodus, Terminalia cambodiana, Garcinia plicatus***, and ***Elaeocarpus lanceifolius*** have exhibited lower survival rates after planting in general habitats. These species require specific locations or habitats.

- **Unknown Survival Rates** The survival rates of ***Crudia zeylanica*** and ***Homalium brevidens*** are unknown. It is known that ***Crudia zeylanica*** has the highest seedling survival rate in nurseries, while ***Homalium brevidens*** has the lowest. These species rarely regenerate naturally, even beneath their mother trees.

To maximize restoration efforts, species with high germination and survival rates should be prioritized and increased numbers for transplanting in degraded flooded forest sites.

6.2 Replanting Techniques

Replanting techniques significantly impact the survival rate of planted seedlings. These techniques encompass the nursery process, seedling care in nurseries, seedling transportation to replanting sites, and seedling transplanting.

Inappropriate nursery practices can result in low-quality seedlings, while unsuitable transportation methods can weaken or kill seedlings before planting. Improper planting techniques can significantly reduce survival rates. These include using weak or low-quality seedlings, planting during periods of insufficient rainfall, or exposing seedlings to immediate flooding after planting. Other factors, such as digging shallow planting holes, failing to remove plastic from seedlings before planting, not adding compost to the base of seedlings, or applying improper soil pressure around the seedlings, can also contribute to poor establishment and survival.

To minimize these risks, planters must carefully follow the guidelines and techniques for each stage of the replanting process in flooded forest projects.

6.3 Forest Fire

Forest fires pose a significant threat to the survival of replanted seedlings. Replanting sites dominated by long grass can smother the seedlings and increase the risk of forest fires. Areas that have been burned by forest fires typically exhibit low seedling survival rates and slow growth rates.

To mitigate these risks, planters must implement effective forest fire prevention measures to enhance seedling survival. This includes:

- **Clearing Long Grass:** Regularly clearing long grass around replanting sites to reduce fuel for fires.
- **Creating Firebreaks:** Establishing firebreaks to prevent the spread of fires.
- **Monitoring and Early Detection:** Implementing monitoring systems for early detection of fires.
- **Community Awareness:** Raising awareness among local communities about fire prevention and control measures.

By taking these precautions, the chances of seedling survival can be significantly improved.

6.4 Natural Disaster

Natural disasters are indeed uncontrollable and unpredictable, posing significant challenges to the survival of planted seedlings. Factors such as drought, increased sun heat, flash floods, long grass dominance at replanting sites, and forest fires can all contribute to the low survival rate.

- **Extended droughts or Increased Sun Heat:** These conditions can cause seedlings to dry out and die after planting.
- **Immediate Flash Floods:** These can drown and kill some seedlings shortly after landing.
- **Dominant Long Grass:** This can smother planted seedlings and increase the risk of forest fires.
- **Forest Fires:** Prolonged drought, increased sun heat, or dominant long grass can easily lead to forest fires, which can disaster planted seedlings.

To minimize these risks and mitigate damage, it is crucial to plan and prepare effective prevention strategies.

Appendix 1

The selected tree species, their conservation status, and productivity of each flooded forest species.

Scientific Name	Local Name	Trees	Flowers	Fruits	Seeds
Crudia zeylanica (Gallery species, Height: up to 40 meters) *Critically Endangered (CR), IUCN 2020*	ដើមស៊ី (S'dey)				
Homalium brevidens (Gallery species, Height: up to 35 meters) *Endangered (EN), IUNC, 2023*	ដើមរ៉ៃ (Roteang)				
Terminalia cambodiana (Gallery species, Height: up to 30 meters) *Vulnerable (VU), IUCN, 2023*	ដើមតូ. (Ta Ou)				
Barringtonia acutangular (Gallery species, Height: up to 25 meters) N/A	ដើម ង (Reang)				
Diospyros cambodiana (Gallery species, Height: up to 25 meters) N/A	ជ្រៃ. ល (Ptoul)				
Xanthophyllum lanceatum (Gallery species, Height: up to 15 meters) *Least Concern (LC), IUCN, 2022*	ដើមកែន ង (Kanseng)				
Cynometra ramiflora (Gallery species, Height: up to 20 meters) *Least Concern (LC), IUCN, 2022*	◌ ពីង (Chompring)				
Mallotus plicatus ((Gallery species, Height: up to 25 meters) N/A	ដើម ចែកង (Chrakeng)				
Combretum trifoliatum (Shrubland forest species, Height: up to 4-5 meters) N/A	ដើម តស់ (Tros)				

Garcinia cochinchinensis (Gallery species, Height: up to 15 meters) Endangered (EN), IUNC, 2023	**ដើមសន់ (Sandan)**				
Elaeocarpus lanceifolius (Gallery tree species, Height: up to 15 meters) N/A	**ដើមរដេញ (Romdenh)**				

Appendix 2

The best timeframe for seed collection of selected Flooded Forest species across the Tonle Sap Lake.

Scientific Name	Local Name	Flowering	Fruiting	Fruit ripening	Peak time for Seed collection
Crudia zeylanica	ដើមស៊ី (S'dey)	Mar-Apr	May/Nov	Aug-Oct/ March	August to October and March
Homalium brevidens	ដើមរាំង (Roteang)	Jul-Sep	Aug-Nov	Sep-Dec	September to November
Terminalia cambodiana	ដើមតូ" (Ta Ou)	Mar-Jun	Jun-Aug	Aug-Oct	August to October
Barringtonia acutangular	ដើម ង (Reang)	Apr-May	Jun-Jul	Aug-Oct	August-October
Diospyros cambodiana	ដើមទ្រុល (Ptoul)	May-Jul	Aug-Sep	Oct-Nov	October-November
Xanthophyllum lan ceatum	ដើមកែនង (Kanseng)	Feb-Apr	May-Jul	Aug-Sep	August-September
Cynometra ramiflora	ើ ពីង (Chompring)	May	Jun	Jul-Sep	July-September
Mallotus plicatus	ដើម ចែកង (Chrakeng)	May	Jun-Jul	Aug-Oct	August-October
Combretum trifoliatum	ដើម តស់ (Tros)	Mar-May	Jun-Jul	Aug-Oct	August to October
Garcinia cochinchinensis	ដើមសន្ទន់ (Sandan)	Feb-May	Mar-Aug	Aug-Nov	September-October
Elaeocarpus lanceifolius	ដើមរដេញ (Romdenh)	Feb-May	May-Jul	Aug-Nov	September to October

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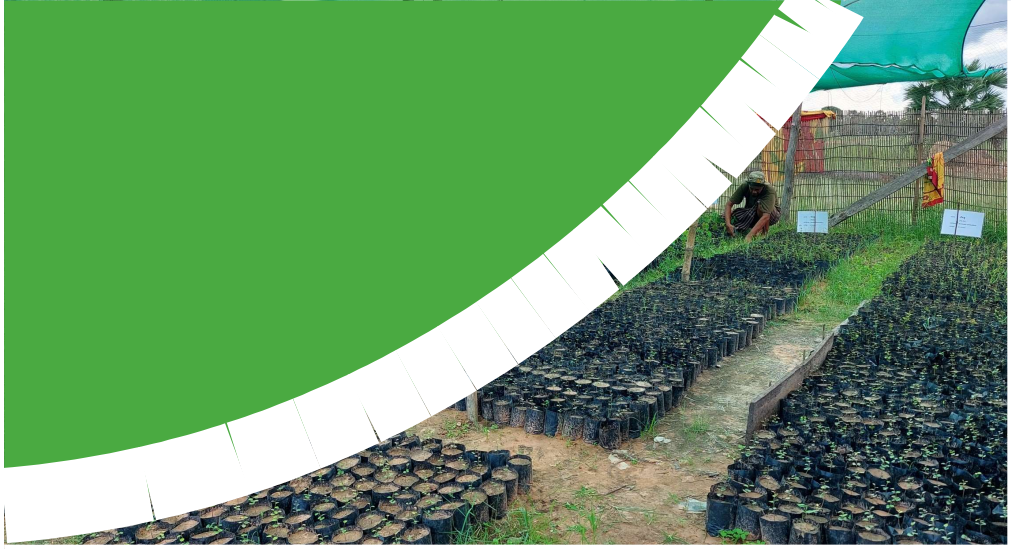

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