Guide to Inundated Tree Planting: Practical Experience

CONSERVATION INTERNATIONAL

CRITICAL ECOSYSTEM PARTNERSHIP FUND

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All photos by Dong Tangkor unless otherwise stated.

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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 fire wood 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 working with several community fisheries (CFi) in the Tonle Sap Lake and with the Fisheries Administration (FiA) to support flooded forest restoration. With technical and financial support from CI and several lake communities we have replanted 99,741 plants, covering 160 hectares in Kampong Prak Conservation Area in Pursat province.

This guide covers all aspects of replanting a flooded forest. This includes site selection, seed collection, nursery preparation, seedling maintenance, transplanting, and caring for the replanted seedlings. The document also includes instructions to monitor and evaluate seedling survival rate.

Re-planting the flooded forest

Re-planting a flooded forest comprises four main components: site selection, the nursery, tree planting and survival rate assessment (Figure 1).

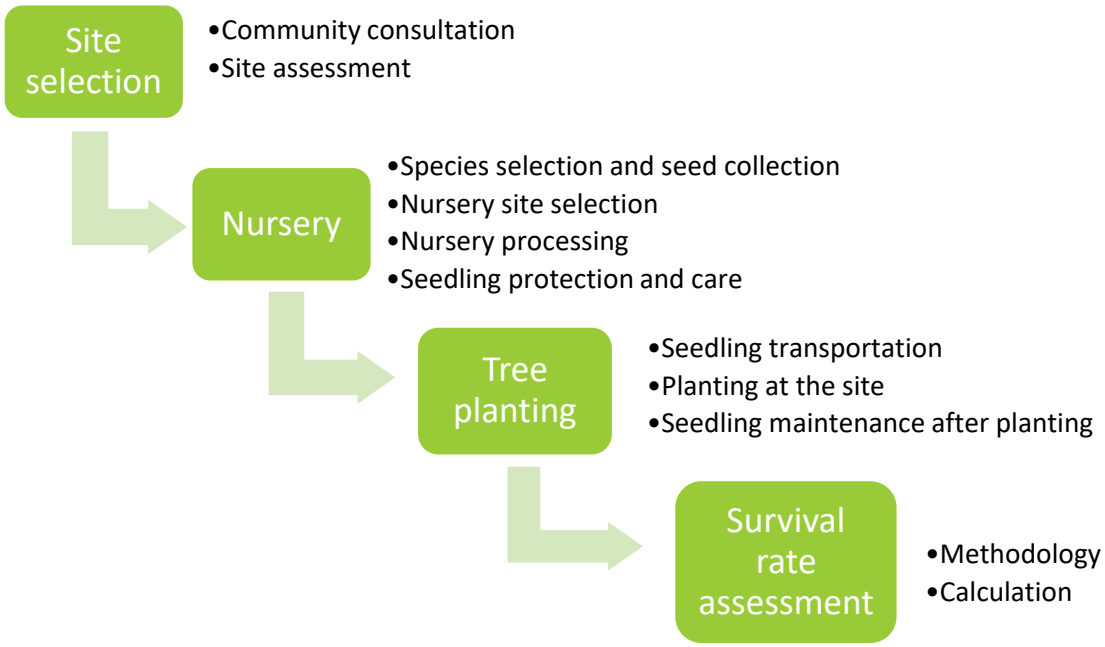


Figure 1. Steps in re-planting a flooded forest

Site selection

It is essential to consult with local communities at the beginning of the revegetation process. This will ensure that the best site is selected, and the community develops a sense of ownership over both the process of replanting and the forest that grows as a result.

The revegetation site location needs to be selected in collaboration with the local community. The following sites are recommended a suitable for revegetation:

- Former flooded forest that has been cleared for agriculture or destroyed by forest fire;
- Large areas where many trees can be planted;
- Areas that belong to the local community fishery (CFi); and
- Public land.

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.

Nursery

Plants are propagated from seeds at the nursery in four steps (Figure 2).

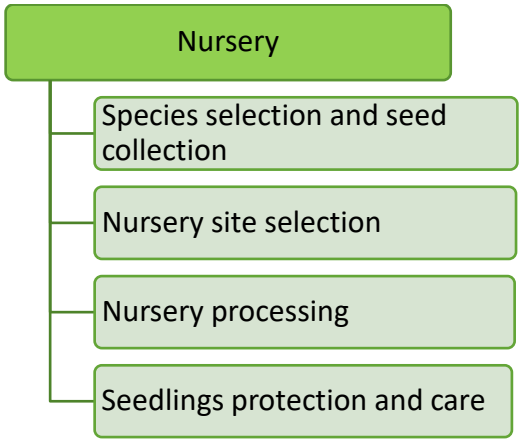


Figure 2. Four steps to propagate seeds in the nursery.

Species selection and seed collection

Species selection

A range of factors need to be considered when selecting plant species for revegetation and include site characteristics; tree height, and the benefits they provide to both the ecosystem and local communities. It is important to consult local communities when selecting tree species as they are more likely to care for trees they have chosen than for species selected for them. We recommend nine species for re-planting. They offer a range of benefits both to local peoples and the lake ecosystem (

Table 1).

Fruiting *Barringtonia actangula* on the Tonle Sap Lake

Seed collection

In the Tonle Sap Lake, flooded forest plants begin to grow new leaves in January and February after the water has receded. They then flower between July and August and bear fruits and produce seeds a few months later (Campbell et al. 2006). Different tree species produce seeds at different times (Table 1), which provides a timetable for collection.

Table 1. Recommended plant species for flooded forest revegetation

Scientific name	Local/Khmer Name	Time of seed set	Remarks
Barringtonia actangula	រាំង (Reang)	September-November	These tree species grow well, they have higher survival rates and grow faster compared to other species. They are highly recommended by the local Community Fisheries Committees.
Diospyros cambodiana	ផ្ទោល (Ptoul)	September-November	
Xanthophyllum glaucum	កន្សែង (Kanseng)	May-June	
Cynometra ramiflora	ជាំព្រីង (Chompring)	May-June	
Mallotus cochichinensis	ច្រកែង (Chrakeng)	September-October	Seeds should be collected directly from the tree, because they are not easy to find on the ground.
Terminalia cambodiana	តាអូរ (Ta Uo)	September-October	
Combretum trifoliatum	ត្រាះ (Trah)	June-August	This species provides important fish habitat. It also supports other floodplain tree species.
Garcinia loureiroi	សណ្តាន់ (Sandan)	June-August	Wild fruit trees that produce edible fruit that can be sold at the market. These species provide alternative sources of income for local communities.
Elaeocarpus lanceifolius	រំដេញទឹក (Romdenh)	June-August	

Seeds can be gathered directly from trees or from the ground or water once the fruit as fallen. Upon collection seeds need to be thoroughly dried on mats in direct sunlight. Seeds may be stored in net sacks which are completely submerged in either the lake or a pond. Or they may be stored in large jars or other containers filled with enough water to completely cover the seeds. If seeds are not completely immersed in water, they may geminate prematurely. Alternatively, seeds can be stored dry in a large jar. However, if the storage container is too humid this may affect seed quality and subsequent germination success.

Nursery site selection

Six criteria should be considered when selecting a nursery site:

1. A nursery is best located close to public infrastructure like schools, CFi office/station, community conservation ponds, or close to the replanted are;
2. It must be near a water sources like a community pond, natural lakes, wells, or streams;
3. The soil at the site must be fertile and of good condition;
4. The site must receive direct sunlight and not be shaded by trees or buildings;
5. The site must have good drainage; a gentle slope is recommended;
6. Consider areas that aren't adjacent to livestock;

We have found locating nursery's next to CFi conservation ponds is ideal as it is easy for Community Fisheries Committee members take care of the seedings.

Nursery preparation and seed processing

Timeframe

In the Tonle Sap region seedlings must be four or five months old before they are planted out at the beginning of the wet season (between May and June). To achieve this the nursery needs to be established or prepared between December and February.

Nursery design

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 6 x 10 m nursery is large enough to raise 10 000 seedlings. The nursery must be covered by a roof of blue or green mesh netting (shade cloth) to provide shade and reduce the impact of heavy rainfall. The nursery should be surrounded by a fence to prevent livestock from entering and reduce the impact of strong winds. A three-meter high wooden plank fence is recommended (Figure 3).

Figure 3. The nursery in Kampong Prak Community Fisheries.

Soil collection and preparation

Fertile and well-draining propagating soil needs to be used to ensure that the seedlings grow strong and healthy. The procedures for soil collection and mixture are:

- Ideally soil should be collected from the replanting sites or elsewhere with similar soil;
- Prior to excavation weeds, leaves and other litter should be cleared from the soil surface;
- Topsoil should be excavated to a depth of 10 cm;
- Stones, roots and other waste should be removed, ideally by sieving;
- The soil should be mixed with manure or compost at a ratio of 1-part soil to 1-part compost or manure;
- Pots or plastic bags are then filled with soil. Pots should be 15 cm deep by 10 cm wide. Black plastic bags with 10 cm width and 15 cm depth can be used if small holes are punched in the bottom to allow for drainage. These bags are available from district and provincial markets.

Seed pre-treatment

To ensure uniformity of germination, dry seeds require pre-treatment before they are sowed. Dry seeds need to be soaked in water for between 12-48 hours as they do not have strong or hard husks. Seeds that have been stored in water do not require pre-treatment. Non-viable or damaged seeds are discarded prior to sowing.

Sowing the seeds

Pre-treated seeds are sowed either into a nursery bed or directly into pots. When sowing to a nursery bed seeds are planted directly into the ground and after germination young seedlings are transferred into pots. Each nursery bed covers an area of one square meter and is 20 cm deep. A nursery bed may be constructed by excavating the ground to a depth of 20 cm or by constructing a 20 cm high wooden frame. The bottom of the bed is covered by thick plastic which stops the seedlings roots reaching the subsoil. The plastic base is covered by a 10 cm layer of manure or composted soil. Healthy seeds are then spread on the layer of manure or compost. Seeds should be placed 5 cm apart. The seeds are then covered with 5 cm layer of mixed

manure and composted soil. Rice hay or similar mulch is then spread over the nursery bed to a depth of 5 cm to stop the soil drying out.

The seeds are watered twice a day for around two weeks until the seedlings germinate and emerge. Once the seedlings are around five days old or 1.5-2 cm high, they are transferred to pots. Pots are filled with an equal parts soil / compost mixture and a hole is made in the center of each pot using a stick or your finger. Young seedlings are carefully dug from the nursery bed and planted one to a pot (Figure 4). Potted seedlings continue to be watered twice a day until they are ready to be planted out.

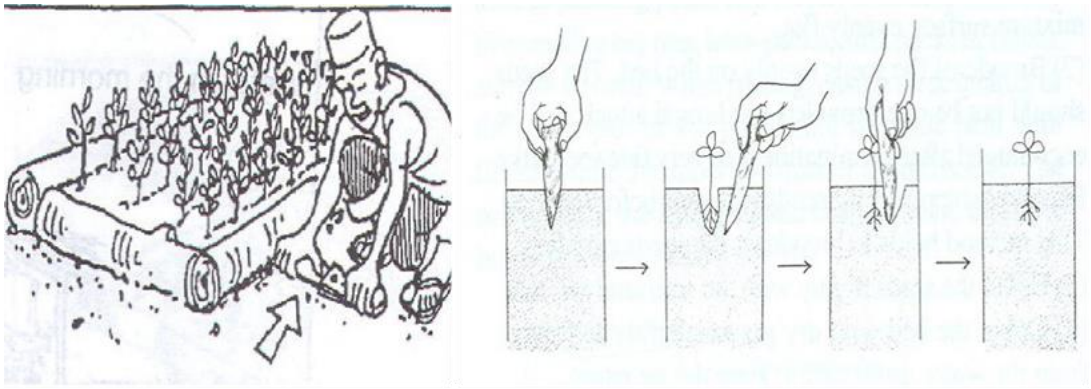


Figure 4. Transferring young seedlings from the nursery bed into individual pots (from Ruvuga et al. 2002).

Instead of using a nursery bed, healthy seeds can be sowed directly into pots (Figure 5). Make a hole in the center of each pot using a stick or your finger. The hole needs to be twice the depth of each seed. Place one seed in each hole and then cover with the soil mixture equal to the size of the seed itself. If the seed is sowed too deep it may delay germination or if too shallow, the seedling may not grow well. Water twice a day until the seeds have germinated and is ready to be planted out.

Figure 5. Sowing seeds directly into pots.

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 this would occur twice a day, in the morning and the evening. More water is required as the seedlings grow larger. A watering can, which can be purchased from local markets, or self-made watering tin should be used (Figure 6).

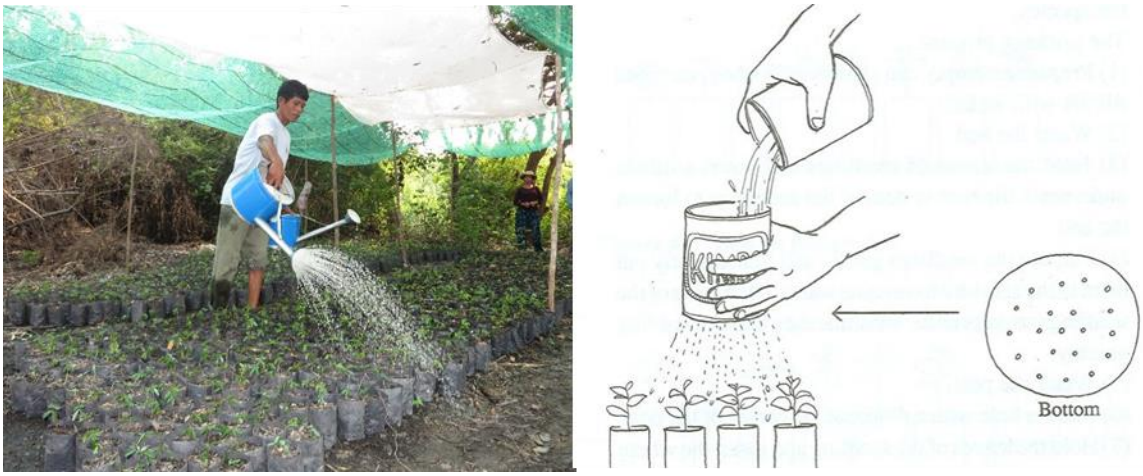


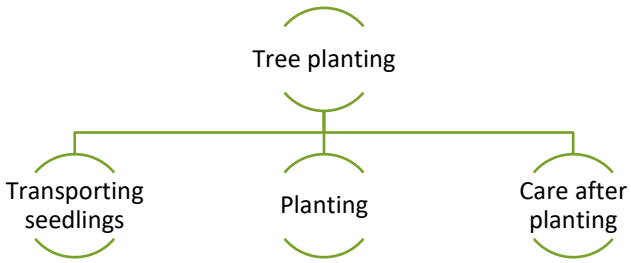
Figure 6. Watering can (left) and self-made watering tin (right, from Ruvuga et al. 2002.).

- **Weeding:** Weeds affect the growth and the survival of plants or seedlings. Weeds compete with seedlings for nutrients, moisture, light, and they may attract insects. Weeds can be pulled out gently by hand and then composted for later use.
- **Fertilizer:** Fertilizer or manure can be applied to improve seedling growth. Livestock manure is a source of organic fertilizer. However, it must be composted before being applied directly to seedlings.
- **Livestock and wild animals:** Livestock and wild animals can browse on seedlings and a strong fence around the nursery is needed to exclude them. Mice and rats frequently cause serious damage to seedlings in the nursery. Keeping the area inside and around the nursery clean and clear of rubbish can help reduce their numbers (Ruvuga *et al.,* 2002).
- **Insects:** A range of insects may eat the seedlings. Termites and tree worms may eat the roots and stems, whilst grasshoppers and crickets eat the seedlings young leaves (Ruvuga et al., 2002). Insect pests are best removed by hand.

Do	Do not
To grow healthy seedlings, you **must**: • Collect ripe seeds and store them correctly; • Establish your nursery in a convenient location close to water; • The nursery must be fenced and have a shade cloth roof to ensure seedlings are well-protected; • The soil used to propagate the seeds must be free draining and mixed with 50% compost; • Discard bad seeds and sow only healthy seeds; and • Regularly water the seedlings, remove weeds, prevent access to livestock and wild animals, add natural fertilizers, and control insects by hand.	To grow healthy seedlings, you **must not**: • Keep fresh seeds in plastic bags and store without drying; • Store seeds on the ground; • Establish your nursery in wide open or sandy areas away from water sources; • Sow seeds in heavy clay soil; • Use small plastic bags as tree pots; • Transfer naturally germinated tree seedlings (i.e. dug up from the ground) into pots as they do not grow well and are unlikely to survive when planted out again; • Apply chemical pesticides to prevent insect damage.

Tree planting

Once the seedlings are four to five months old their height should be between 40 and 80 cm. With good care some young plants can grow up to 100 cm high. These seedlings can now be transplanted to the re-vegetation area following the process outlined below:



Transporting seedlings

Seedlings need to be transported from the nursery to the planting site with care. A wide variety of vehicles can be used including trucks, ox carts (Figure 7), motorcycles, mechanical mules and boats. Seedlings should not be piled on top of one another during transport as this can damage them. Placing seedlings in boxes or baskets for transport is recommended to avoid damage. It is recommended to not water your seedlings the day before transport to keep your vehicle clean.

Figure 7. Transporting tree seedlings using an ox cart.

Planting seedlings

Seedlings should be planted at the site at the beginning of the rainy season. Generally, this occurs between May and June on the Tonle Sap floodplain. Seedlings should not be planted until enough rain has fallen to soak the soil which will give the trees a much better chance of survival. Transplanting seedlings at the start of the rainy season gives them 3 to 4 months to grow before they are flooded by the rising lake.

Seedlings need to be planted around four meters apart, a spacing recommended by both our experience and FiA officers. This gives a density of 625 plants per hectare. In preparing the soil to plant seedlings a hole of 40 cm (width) x 40 cm (length) x 40 cm (depth) should be cultivated and the soil loosened to allow the roots to penetrate the ground easily and quickly.

The following steps need to be taken when planting seedlings:

- Choose strong and healthy seedlings;
- Excavate and water 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 plastic bag from the seedlings and its soil (from the pot) by tearing;
- Put the seedling in center of the hole and cover it with the soil;
- The soil can be mixed with manure or compost which will provide the plant with more nutrients;
- Use your hands to firm the soil carefully around the seedling; and
- Water the newly planted seedling to provide additional water if there is insufficient rainfall in the next few weeks after planting.

Planting seedlings in the field

Maintaining replanted trees

Once they have been planted seedlings need to be maintained to ensure high survival rates, preferably between 50% and 70 %. To achieve this goal, the community must attend to the following activities.

Seedling replacement: It is necessary to check and monitor the replanted trees every three months (unless they are inundated). If any of them have died or do not look healthy, replace them with good, strong plants.

Invasive species: *Mimosa pigra* threatens the entire native flora and fauna of the Tonle Sap floodplain. It is very common in areas where land has been cleared for agriculture. This species grows quickly and rapidly dominates the nearby species by shading and crowding them out. Whilst *M. pigra* is difficult to kill or eliminate from a site, the best method is to clear them at a young age or cut them down before the yearly flood (Figure 8).

Figure 8. Cutting down *Mimosa pigra* from a replanting site.

Fire prevention: Most restoration sites are covered by dense grass. This presents a fire hazard in the dry season, particularly as the dry grass piles up around the tree seedlings and young trees. Remove the dry grass from around the seedlings at the beginning of the dry season is recommended to reduce the risk of fire (Figure 9).

Figure 9. Removing floodplain grass from around planted seedlings to reduce the risk of fire damage.

Monitoring and Evaluation

A survival rate assessment should be conducted the following year after planting. It should be repeated for three years, or until the seedlings grow to one meter in height. The survival rate assessment tells us how well each species survives and grows at a site and information about the challenges which impact the seedlings in each site.

The survival rate assessment is best carried out after water recedes and the site dries. March is ideal, as whilst the water has receded the weeds have not yet grown, which makes it easy to find and count seedlings. Seedling are assessed in multiple sample plots, the total number of which depends on the total replanting area. The plots should cover 10% of the total replanting area and be randomly located. Square plots of 25 × 25 m^2 are used to count the seedlings. String is used to mark the outlines of the plot with one person holding the string in each corner (Figure 10a).

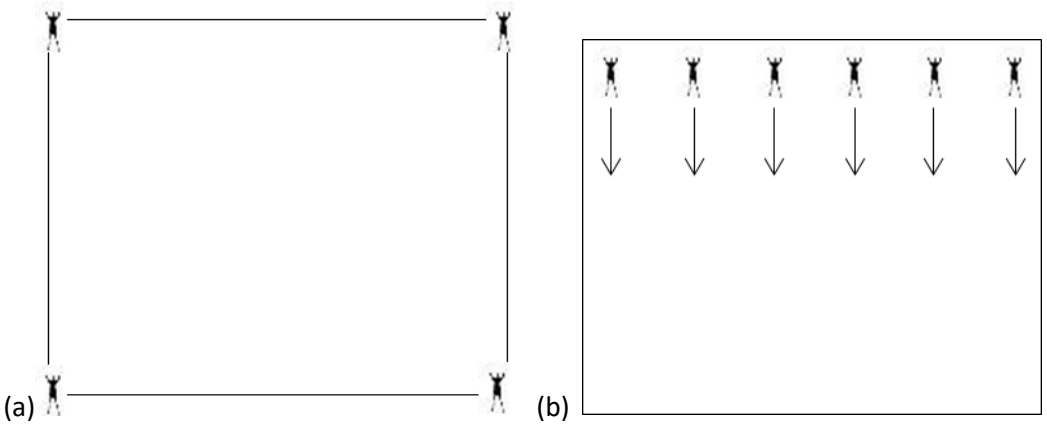


Figure 10. Square plot used in the seedling survival rate assessment. (a) setting the square, (b) counting the seedlings.

Six people then count the number of surviving seedlings in each plot by walking across the plot in straight lines (Figure 10b). One person is responsible for recording data. All seedlings are counted including both planted and natural seedlings, but they are recorded in different columns. To monitor seedling survival, the same sample plots need to be monitored over time.

To analyze the survival rate of seedlings, use the formula below:

$$Survival\ rate\ per\ plot\ (\%) = \frac{Number\ of\ surviving\ seedlings\ counted\ per\ plot}{Total\ number\ of\ seedlings\ planted\ per\ plot} * 100$$

To estimate the site survival rate, calculate the average survival rate for each of the plots:

$$Estimated\ site\ survival\ rate\ (\%) = \frac{Sum\ of\ survival\ rates\ for\ each\ plot}{Total\ number\ of\ plots}$$

You need to pay attention to the variation in survival rate between plots. Seedlings in some plots may survive better than others. If you can identify the reasons why the survival rates differ

you can use this information to guide both future site management and replanting efforts at other sites.

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Further Reading

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Appendix 1. Survival rate assessment sheet

Name of Recorder: ……

Name of counters: ……

Name of Replanting site:……

Date of Assessment: ……

ID Plot	UTM		Number of seedling count		Remark
	North	East	Replanted seedling	Natural seedling	
P1					
P2					
P3					
P4					
P5					
P6					
P7					