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A Technical Report for

# PROJECT PALMS

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An Assessment of Transplantation of Six Threatened Palm Species

August - 2024

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## 1. Summary

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Project Palms seeks to improve the conservation status of six threatened palm species in the Sainte Luce littoral forest through increasing understanding of the distribution, population, phenology, and natural history of each species. A major outcome of the project is large scale *in-situ* planting efforts in three protected forest fragments in Sainte Luce, an area of fragmented littoral forest in southeast Madagascar. Informed by the project's initial research into nursery trials and microhabitat assessments, this report details the progress of *in-situ* planting efforts thus far in Sainte Luce. As of July 2024, 1,075 palm seedlings have been planted in the three areas of protected forest (IUCN Category V) with a survival rate of 96.5%.

Extensive research efforts were conducted to optimise nursery management and sowing as well as understand the six study species habitat preferences and local distribution. Securing the target number of seedlings for planting was difficult for some species due to limited accessible donor trees to source seeds from in addition to low germination rates amongst seeds sown in the nursery. The process of site selection for *in-situ* planting in protected areas of littoral forest included consultation with local experts followed by rigorous microhabitat assessments.

## 2. Introduction

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### 2.1. Background

Madagascar is one of the world's highest conservation priorities (Myers et al., 2000). With 98% of its palm species endemic to the island, the country has one of the most unique and diverse palm collections in the world (Méndez et al., 2022). Forest ecosystems across Madagascar, however, are in decline, with 4.62 million hectares of Madagascar's forest cover lost to deforestation between 2001 and 2021 (Global Forest Watch, 2024). More specifically, littoral forests are one of the rarest and most threatened ecosystems in Madagascar and are considered a national conservation priority (Ganzhorn et al., 2001) with an estimated 90% of original littoral forest cover lost (Krishnan et al., 2012).

The southeast region of Anosy contains some of the few remaining viable littoral forests in Madagascar (Bollen & Donati, 2006). The Sainte Luce littoral forest (SLLF) is comprised of 17 fragments and is one of three larger littoral forest areas remaining in the region. Sainte Luce, with approximately 2,800 inhabitants (Berina, Chef de Fokontany, pers. comm., 2023), is just one of the local communities supported by the SLLF which provides natural resources for firewood, construction materials, and local livelihood generation (Bollen & Donati, 2006; Hyde Roberts et al., 2020; SEED Madagascar, 2021).

A total of 13 species of palm are supported by the SLLF (Hogg et al., 2013) and although they are a critically important natural resource for communities bordering the SLLF, six are threatened<sup>1</sup> with extinction (Bennet, 2011; Couvreur & Baker, 2013; Hogg et al., 2013). Extant populations in the SLLF are threatened by habitat fragmentation and degradation, drought, fire, and proposed mining activities by QIT Madagascar Minerals (QMM) (Bollen & Donati, 2006; Vincelette et al., 2007; Krishnan et al., 2012; Ashraf et al., 2021). With 83% of endemic palm species threatened with extinction in Madagascar (Rakotoarinivo et al., 2014), it is crucial to understand the local pressures on palms, and map viable pathways for their conservation and continued availability. A previous study by SEED Madagascar (SEED) identified rapidly declining populations of *B. madagascariensis* and *C. saintelucei* in Sainte Luce (Hyde Roberts et al., 2020). While limited information exists on the current demography and distribution of the other four target species, it is believed that the local populations of these species are also in decline.

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<sup>1</sup> Threatened is an umbrella term consisting of Vulnerable (VU), Endangered (EN) and Critically Endangered (CR) species (IUCN Standards and Petitions Committee, 2022).

## 2.2. An Overview of Project Palms

Project Palms aims to improve the conservation status of six threatened palm species: *Beccariophoenix madagascariensis* (VU), *Chrysalidocarpus prestonianus* (VU), *Chrysalidocarpus psammophilus* (EN), *Chrysalidocarpus saintelupei* (EN), *Dypsis brevicaulis* (CR), and *Dypsis scottiana* (VU) (Hyde Roberts et al., 2020; Rakotoarinivo & Dransfield, 2012a; 2012b; 2012c; 2012d; 2012e; 2012f). Increasing understanding of the distribution, population, phenology, and natural history of each species has informed the project's primary outcome, *in-situ* planting efforts. The project aims to improve understanding of the preferred microhabitat conditions of each species, through the completion of focussed assessments on their environment (e.g. environmental, topographic, and soil characteristics), the learnings from which, inform local restoration efforts and contribute to the sustainable growth and survival of each species. These restoration efforts taken place in three different forest fragments in areas with legally protected status, known as S8, S9 and S17 (see maps in section 1.1.2).

Transplantation can be a successful method to increase populations of certain species, helping to increase numbers of juvenile palms that may not have germinated naturally in suitable habitats. The S8 and S9 forest fragments are designated conservation zones (IUCN Category V), and this classification helps to protect threatened palm populations within the SLLF (Temple et al., 2012). The fragment S17 is partly designated as a conservation zone and partly privately owned and managed. This results in multiple available forest fragments that provide different specialised habitats for transplanting the target palm species. This transplantation effort aims to help bolster populations of Project Palms' six target species within protected fragments, to ensure the survival of these species in the future, both for conservation and livelihood purposes.

## 3. *In-Situ* Planting Methodology

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### 3.1 *In-Situ* Trial Planting 2023

In October 2021, *C. saintelupei* seedlings were sown in the SEED nursery, grown for 17 months ahead of transplantation into the protected fragment of S9 in February 2023 (Annex 1). S9 was chosen as pilot planting location due to its classification as a conservation zone, suitability of habitat for *C. saintelupei*, and proximity to the SEED Research camp.

Prior to planting, palms were watered and labelled by fragment, designated planting site, species, and plant number. Sites had equal numbers of seedlings planted ( $n = 16$ ), except Site TRIAL1 where 18 seedlings were planted. Once planted, the height of each palm was recorded in cm, using a ruler to measure from the soil surface to the highest point of the seedling (stretching the leaves upwards to find the highest point) (Figure 1). Condition was recorded on a scale from 'dead' to 'good' (Table 1). Fixed-point photographs were also taken of all seedlings at Site TRIAL4 for monitoring purposes. See section 2.3.6 for details.



Figure 1 – Left: Measuring to the tip of the longest leaf to record height of seedling, Right: Labelling of palms for monitoring.

Table 1: Descriptions of palm quality to aid in scoring of the Condition.

Condition	Description
1 - Dead	Palm has wilted, lost all its leaves, and turned brown
2 - Poor	Severe signs of either, damage, pest infestation, discolouration, fungi, or abnormal growth
3 - Fair	Signs of either, damage, pest infestation, discolouration, fungi, or abnormal growth
4 - Good	Healthy palm, with green leaves showing no evidence of pests/disease, or human disturbance such as leaf removal or axe marks on trunk

## 3.2 In-Situ Mass Planting 2024

### 3.2.1 Microhabitat Assessments

SEED's Conservation Research Programme (SCRIP) consulted with local experts and identified 34 sites which were considered for the 2024 mass planting. Microhabitat assessments were conducted at 30 of these sites that would be feasibly accessible for palms planting.

Sites were assessed against several ecological characteristics. The density and species of trees of two size categories, small (6.5cm-12cm circumference) and large (> 12.5cm circumference), were recorded to determine habitat density and local arboreal diversity. Canopy cover and canopy height were recorded as proxies for light penetration. Each site's slope angle, aspect, and elevation were assessed. Soil suitability was determined by pH and qualitative measures of leaf litter cover and soil texture (relative sand content). Full descriptions of the habitat characteristics are in Annex 4.

### 3.2.2 Site Selection

Microhabitat data was analysed and compared to data previously collected by Project Palms on the microhabitat preferences on the six target species of palms. Sites were determined by microhabitat compatibility, feasibility of planting, and accessibility. Planting numbers for sites were determined during microhabitat assessments, where the number of palms a site could feasibly host was assessed, considering palms should be planted at a 3m distance from large trees (DBH ~25cm), other target palms within the forest, and other palm seedlings being

planted. A total of 16 sites (Figures 2.1-2.4) were deemed suitable and selected for planting, descriptions of the planting sites can be found in Annex 3.

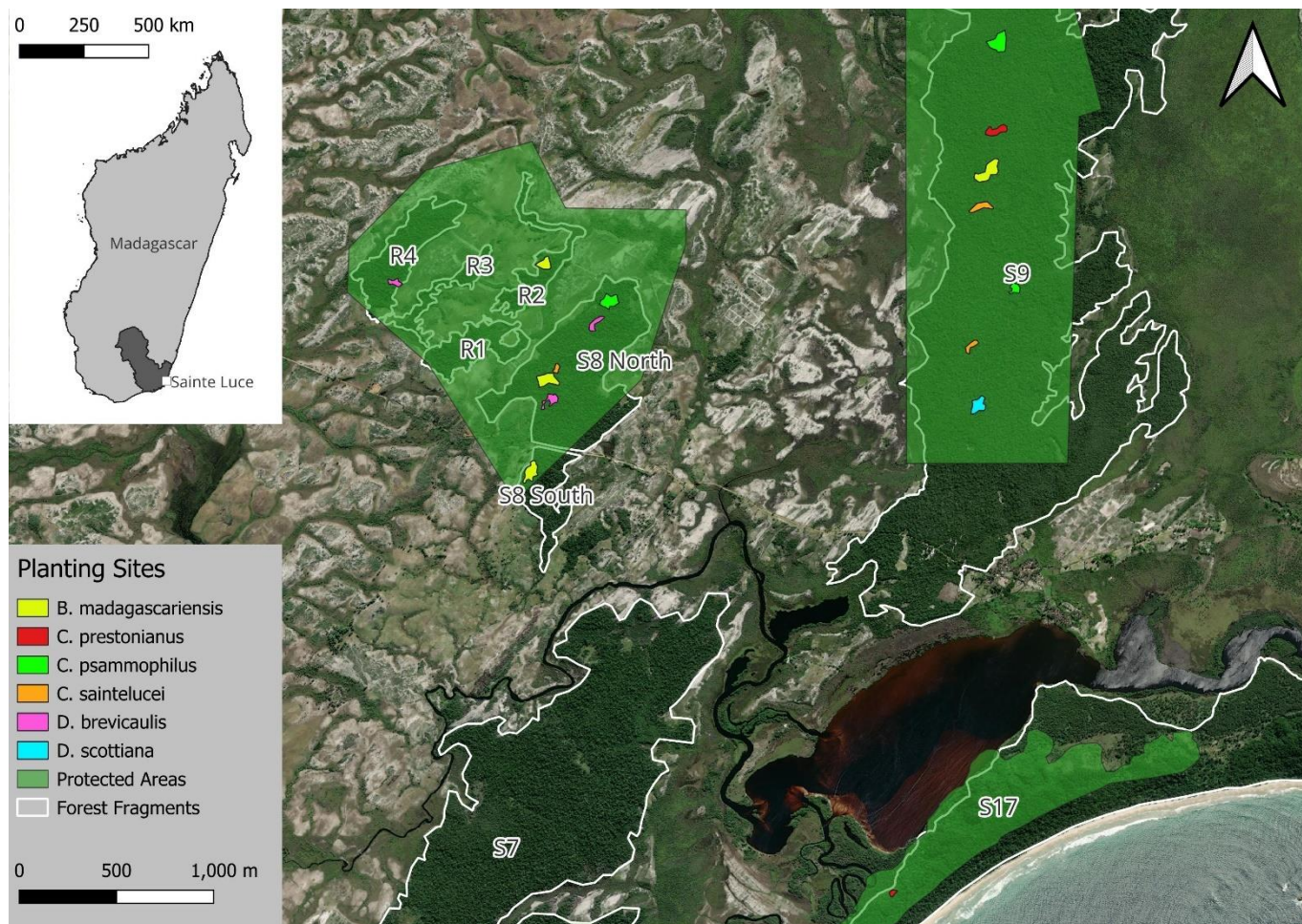


Figure 2.1. Map of Sainte Luce planting sites - all sites.

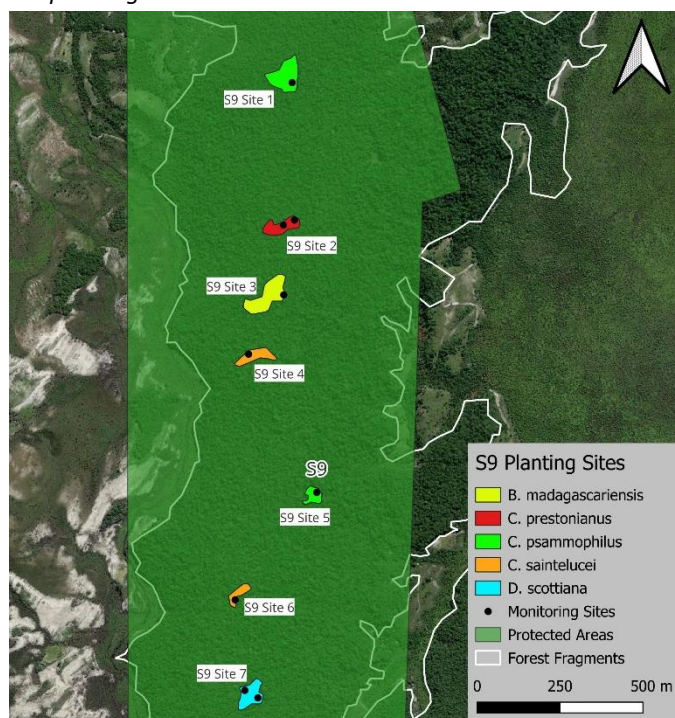


Figure 2.2. Map of Sainte Luce planting sites – S17 Fragment. Figure 2.3. Map of Sainte Luce planting sites – S9 Fragment.

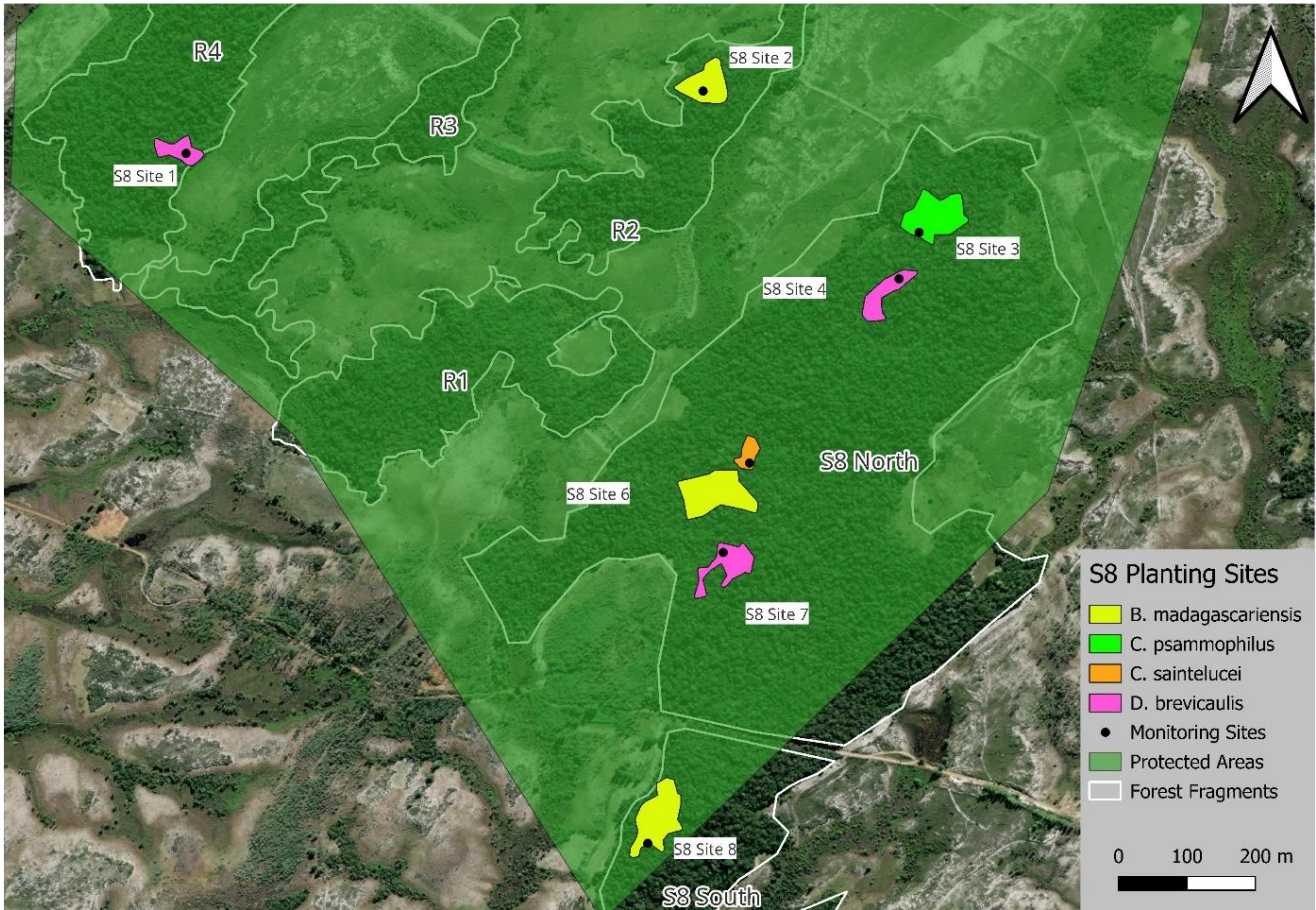


Figure 2.4. Map of Sainte Luce planting sites – S8 Fragment.

### 3.2.3 Seedling Selection

To mitigate seedling mortality after planting, only seedlings in SEED’s nursery that were above a species-specific height threshold (Table 2) were planted. This requirement determined the total number of palms planted in February and April 2024. Height thresholds were measured by experienced local staff, considering relative growth speeds, seedling age, and relative robustness to size ratio. Only plants which had been sown in the nursery in 2022 were selected to be planted in 2024, for all species except *B. madagascariensis*. This species displayed a faster rate of growth and high plant vigour, as such, around 60 palms sown in 2023 were selected for planting.

Table 2: Species-specific height thresholds. This measurement determined if a seedling was ready for in-situ planting.

Species	Height thresholds for planting (cm)
<i>B. madagascariensis</i>	15
<i>C. prestonianus</i>	10
<i>C. psammophilus</i>	15
<i>C. saintelupei</i>	20
<i>D. brevicaulis</i>	10
<i>D. scottiana</i>	11

### 3.2.4 Transplanting

Transplantation of the six endangered palms was carried out in February and April 2024, by members of SCRIP, the Palms Implementation Team and members of the Sainte Luce community. In total, 1,009 palms were planted in the three protected forest fragments.

All palm species were planted in holes with dimensions of 40cm x 40cm x 20cm as recommended by Missouri Botanical Gardens. Precise planting locations were chosen so that every hole was  $\geq 3\text{m}$  away from any other

transplanted seedling,  $\geq 3\text{m}$  from any existing adult palm of a study species, and  $\geq 3\text{m}$  from any large tree (DBH  $\sim 25\text{cm}$ ). This aimed to reduce competition among transplanted seedlings, from existing palms, and large trees. When large tree roots ( $>5\text{cm}$ ) were found in the holes prior to planting seedlings, they were left in place and the hole excavated underneath the large tree root.

In each prepared hole, three handfuls of compost were placed in the centre and the seedling's roots set directly above. The seedling was held in place in the centre so that the lowest leaves were level or higher than the surrounding forest floor. The topsoil and remaining soil which has been carefully piled next to each hole during digging, was placed back in the hole around the roots and base of the seedling. The hole was filled up to 2-3 cm below the surrounding forest floor, leaving a small edge around the sides of the hole to retain rainwater. Care was taken to not leave any seedling leaves covered in soil.

Table 3: Number of palms planted and sites in each forest fragment per species in 2024

Species	S8		S9		S17		Total	
	Number planted	Number of sites	Number planted	Number of sites	Number planted	Number of sites	Number planted	Number of sites
<i>B. madagascariensis</i>	209	3	120	1	0	0	<b>329</b>	<b>4</b>
<i>C. prestonianus</i>	0	0	67	1	40	1	<b>107</b>	<b>2</b>
<i>C. psammophilus</i>	50	1	165	2	0	0	<b>215</b>	<b>3</b>
<i>C. saintelupei</i>	42	1	84	2	0	0	<b>126</b>	<b>3</b>
<i>D. brevicaulis</i>	132	3	0	0	0	0	<b>132</b>	<b>3</b>
<i>D. scottiana</i>	0	0	100	1	0	0	<b>100</b>	<b>1</b>

### 3.2.5 Monitoring

Monitoring of the palms planted *in-situ* began at the time of planting for each of the six species to establish a baseline. Subsequent monitoring took place at one, three, six and 12 months after planting, thereafter, annual monitoring is conducted for a period of five years. Monitoring involves recording the height (cm) and condition (1-4) of 45 individual seedlings per species (Table 4). Height is measured by stretching the longest leaf and measuring the distance from soil level to the leaf apex.

A total of 15 individuals of each species were monitored at three sites however, *C. prestonianus* were only planted in two sites due to limited availability of seedlings and insufficient habitat to support *C. prestonianus* in S17. As such, 30 *C. prestonianus* individuals were monitored in one site (S9 Site 2), 15 individuals were monitored in the second site (S17 Site 1), with 45 monitored in total (Table 4). *D. scottiana* was the only species with fewer than 45 individuals monitored. For this species, 30 were monitored (S9 Site 7) and were grouped into two sets of 15 seedlings that were segregated and planted in different locations within the one large site. Only 30 have been monitored as this sufficiently monitors the planting effort which only comprises 100 individuals in total. *B. madagascariensis* was the only species that was planted at four sites, of which, Site 6 will not be monitored due to its proximity to other planting sites and other sites within the same fragment being monitored for that species.

As per SEED's monitoring guidelines, if 20% of the monitored palms (nine individuals) from one species or site are classified as 'dead' or 'poor', this condition will be reported. This will determine whether an evaluation of all palms planted of that species may need to be conducted to assess if aftercare is necessary.

Table 4: Number and sites of palms monitored for height, condition, and fixed-point photography. A total of 15 individuals are monitored at each site mentioned, unless a different number is specified (S9 Site 2 and S9 Site 7).

Species	Total monitored palms	Total sites monitored	Sites monitored (height and condition)	FPP sites
<i>B. madagascariensis</i>	45	3	S8 Site 2 & 8 S9 Site 3	S8 Site 2
<i>C. prestonianus</i>	45	2	S9 Site 2 (30 individuals) S17 Site 1	S9 Site 2
<i>C. psammophilus</i>	45	3	S8 Site 3 S9 Site 1 & 5	S9 Site 5
<i>C. saintelupei</i>	45	3	S8 Site 5 S9 Site 4 & 6	S9 Site 4
<i>D. brevicaulis</i>	45	3	S8 Site 1, 4, & 7	S8 Site 1
<i>D. scottiana</i>	30	1	S9 Site 7 (30 individuals)	S9 Site 7

### 1.1.6. Fixed-Point Photography

As part of Project Palms, fixed-point photographs were taken to provide change-over-time images of the transplanted palms. One monitoring site per species was randomly selected for photography equating to 15 palms per species or 9% of the total number of palms transplanted to date (n=90). The same palms were photographed at each pre-established monitoring interval. To take the fixed-point photograph, the camera was positioned 30cm above the ground on a bucket, 100cm away, facing south towards the palm. A measuring tape was held next to the palm during the photo for scale (Figure 3). Any leaves, twigs, or branches impeding the view of the palm were moved. If there was a large tree or too much foliage in front of the camera, the bucket was repositioned slightly to obtain a clearer image. A photo was also taken of the palm label to ensure data was correctly recorded.



Figure 3 – Fixed-point photograph method for palm monitoring. Left: The setup with camera resting on a bucket. Right: Example of the fixed-point photograph.

## 4. Results

### 4.1 In-Situ Planting Trials 2023

The *C. saintelupei* seedlings reached a mean height of 38.9cm 12 months after planting *in-situ* in S9, showing a 104% height increase (from 19.1cm) since planting in February 2023. They exhibited a 97% survival rate 12 months after planting (out of the 66 seedlings planted, 64 were still alive).

The *C. saintelupei* planted *in-situ* at planting Sites TRIAL1 and TRIAL4 show an initial increase in mean height between month zero and month one, before a decrease in mean height between month one and month three. Seedlings at Site TRIAL5 displayed an initial decrease in mean height between month zero and month one, before increasing between months one and three. Whereas Site TRIAL3 showed a continuous increase in mean height over time (Table 5). At every site, between months three and 12, the mean seedling height increased (Figure 4). Overall, the mean growth rate at all sites was measured at 0.42mm/day for the 12 months after *in-situ* planting.

The mean condition of seedlings after planting reduced in all sites after 12 months (Table 6). In Site TRIAL4, one seedling died between months three and six, and a second seedling died at Site TRIAL5 between months six and 12.

Table 5: Mean height of seedlings at each trial planting site at months one, three, six, and twelve after planting.

Planting Site	Day of planting: 20/2/2023	Month One: 19/03/2023	Month Three: 11/06/2023	Month Six: 13/09/2023	Month Twelve: 13/02/2024
<b>Trial Site 1</b>	19.16	20.15	19.55	21.67	39.17
<b>Trial Site 3</b>	17.36	19.96	22.02	24.25	38.70
<b>Trial Site 4</b>	17.72	18.95	17.80	20.03	35.34
<b>Trial Site 5</b>	22.03	20.64	23.60	26.13	42.49
<b>Total Mean</b>	19.07	19.93	20.74	23.02	38.93

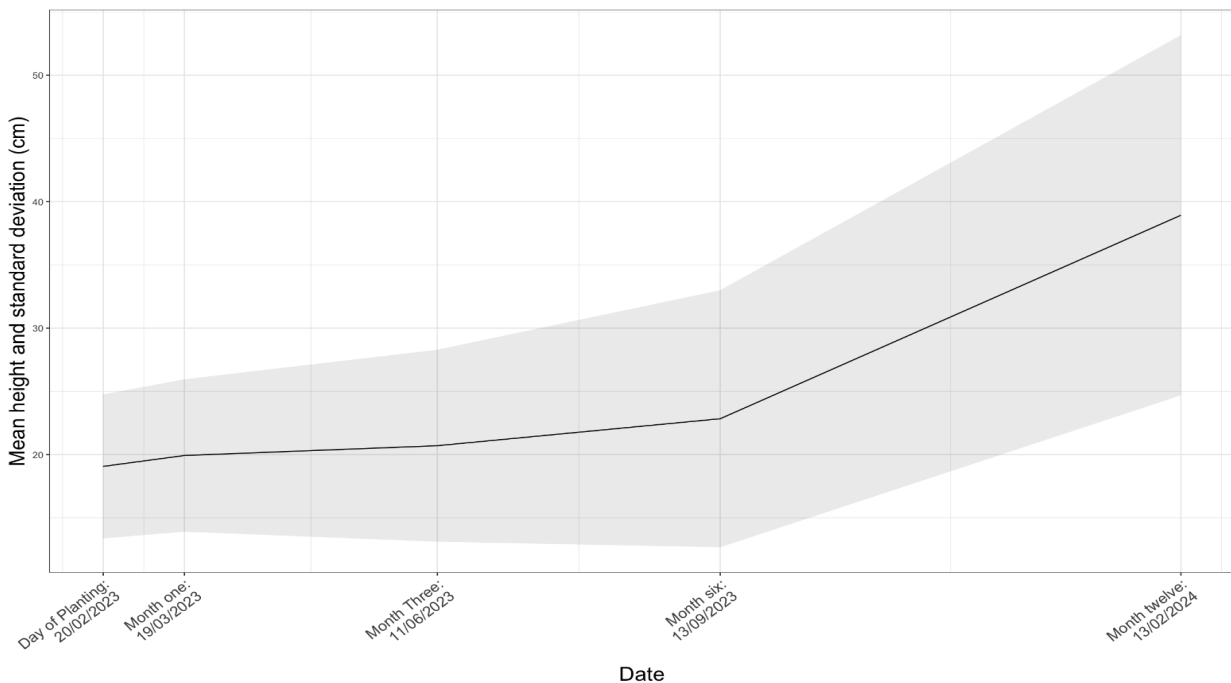


Figure 4: Mean height of *C. saintelupei* seedlings from all trial planting sites, over time. Shaded region indicates standard deviation.

Table 6: Mean and mode condition of seedlings at each trial planting site at months one, three, six, and twelve after planting.

Planting Site	Day of Planting: 20/02/2023		Month One: 19/03/2023		Month Three: 11/06/2023		Month Six: 13/09/2023		Month Twelve: 13/02/2024	
	Mean	Mode	Mean	Mode	Mean	Mode	Mean	Mode	Mean	Mode
Site 1	3.61	4	3.83	4	3.94	4	3.06	3	3.28	4
Site 3	3.63	4	3.81	4	3.88	4	3.25	3	3.31	4
Site 4	3.50	4	3.69	4	3.81	4	3.00	3	3.06	3
Site 5	3.56	4	3.88	4	4.00	4	3.06	3	3.25	3
Total	3.58	4	3.80	4	3.91	4	3.09	3	3.23	3.5

### 3.3 In-Situ Mass Planting 2024

To date, the *in-situ* mass planting has demonstrated a high level of palm survival across all six species of palms (Table 7). For *D. scottiana*, all planted individuals survived (100 %) by month 3. For three species of palm, *B. madagascariensis*, *C. saintelupei*, and *C. prestonianus*, one individual had died by month 3, leaving a relative species survival rate of 97.7% three months after planting. Three *D. brevicaulis* individuals were dead by month 3, resulting in a relative survival rate of 92.6%. *C. psammophilus* had the lowest survival rate, with four individuals that died by month 3, resulting in a relative survival rate of 90.3%. *C. psammophilus* was the only species which showed a statistically significant decrease in condition over time (3.1 to 2.8, a decrease of 9.7%,  $p = 0.0081$ ) (Figure 5). All other species' conditions did not differ significantly over time. For all transplanted palms (the six species combined), the overall change in mean condition after three months was not significant (condition score 3.27 to 3.2,  $p = 0.29$ ).

For all transplanted palms (the six species combined), the mean height increased during the initial three-month period ( $p = 0.0096$ ) (Figure 6). Individually, there were three species which changed in mean height over time, *C. prestonianus* (18.6 to 21.6cm, an increase of 13.8%,  $p = 0.031$ ), *C. saintelupei* (39.5 to 45.7cm, an increase of 13.6%,  $p = 0.0041$ ), and *D. brevicaulis* (13 to 14.7cm, an increase of 11.6%,  $p = 0.023$ ). The other three species did not have a statistically significant change in mean height over time.

Table 7: Number of plants alive at time of planting, one month after planting, and three months after planting, with the relative survival percentage at each interval for six endangered species on Palms.

Species	Month 0		Month 1		Month 3	
	Number of Palms monitored	Percentage of alive palms	Number of alive palms	Percentage of alive palms	Number of alive palms	Percentage of alive palms
<i>B. madagascariensis</i>	45	100	45	100	44	97.7
<i>C. prestonianus</i>	45	100	44	97.7	44	97.7
<i>C. psammophilus</i>	45	100	45	100	41	90.3
<i>C. saintelupei</i>	45	100	45	100	44	97.7
<i>D. brevicaulis</i>	45	100	45	100	42	92.6
<i>D. scottiana</i>	30	100	30	100	30	100

## The change in average condition for six endangered palm species

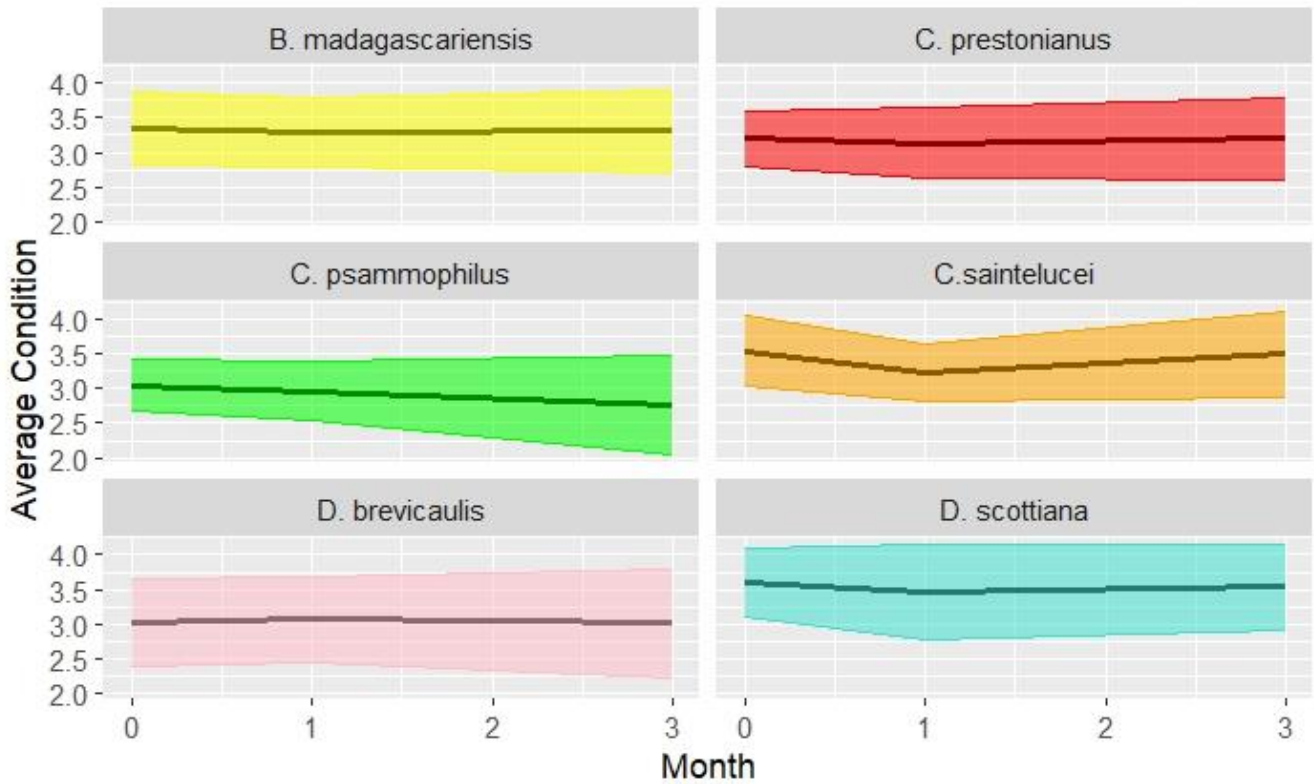


Figure 5: The mean condition of six species of palms from planting to three months after planting. The conditions were 1 (dead), 2 (poor), 3 (fair), and 4 (good). Species-specific condition did not change over time, except for *C. psammophilus*. The ribbon was calculated using standard deviations of the mean.

## The change in average height for six endangered palm species

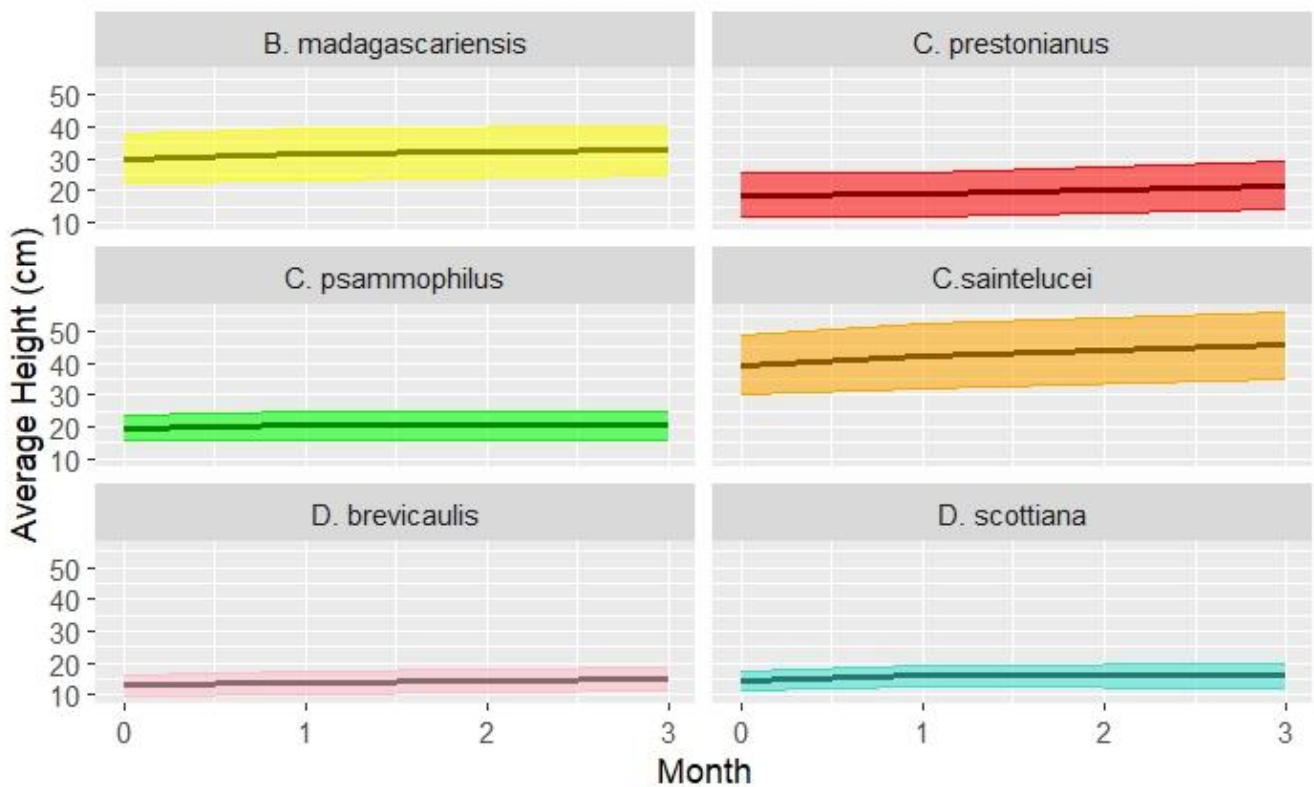


Figure 6: The mean height in centimetres of six species of palms, from planting to three months after planting. Three species, *C. prestonianus*, *C. saintelupei*, and *D. brevicaulis* showed a statistically significant increase in height over time, the other species' heights did not change over time. The coloured ribbon shows the standard deviation of the mean.

## 5. Discussion

Within global academia, there are few examples of *in-situ* transplantation of plants taking place within an existing forest ecosystem in southeast Madagascar. Thus, findings from this project significantly contribute to the closing of this knowledge gap. There are examples of studies that have assessed the success of reforesting areas completely absent of trees or creating corridors between remaining forest fragments through open habitat, however, these studies were not palms focused. This gap in literature reveals the necessity of trialling and recording the novel *in-situ* mass planting that Project Palms completed in 2024.

A study by Manjaribe et al. (2013) recorded survival rates of 42.4% and 67.5% one year after planting of *Dypsis fibrosa* and *Dypsis mananjarensis* respectively within a corridor habitat within the low elevation humid evergreen forests of Kianjavato, southeastern Madagascar. *C. mananjarensis* (formerly *D. mananjarensis*) is in the same genus as three of Project Palms' study species. Similarly to *C. prestonianus* and *C. saintelupei*, they are solitary palms and have inflorescences that are found below the leaves (Palmpedia, n.d. a; Palmpedia, n.d. b; Palmpedia, n.d. c). These species had a monthly growth rate of 1.02cm and 0.20cm, respectively. This growth rate was slower than the average growth rate of *C. saintelupei* in the Project Palms planting trial at 1.26cm per month. Factoring in the potential for different survival rates, which is dependent on many substantial stochastic abiotic and biotic differences, achieving a 97% survival for the *in-situ* *C. saintelupei* trial is a major success for Project Palms.

The survival rate for all seedlings planted *in-situ* in 2024 was high at 96.5% after three months. The high survival rate, particularly in the first month strongly suggests that the seedling selection process and the transplanting protocol used in this study were well adapted to the palm species. Palma and Laurence (2015) found that planting locally sourced seedlings, yielded a higher survival rate than sowing seeds *in-situ*. As the failure-prone stages of germination and initial growth are completed prior to the *in-situ* planting, this could be a factor contributing to the success of mass *in-situ* planting.

Three species of palm have seen a statistically significant increase in height three months after planting: *C. prestonianus*, *C. saintelupei* and *D. brevicaulis*, all of which increased by more than 10% from month 0 to 3. The other three species of palm did not show a statistically significant difference in height. Despite this, half of the palm species transplanted displayed a significant difference in height, resulting in an overall significant increase in height for the mass planting event.

According to Fahselt (2007), transplantation needs to be coupled with ecosystem functions such as productivity, seed dispersal, pollination, biochemical interactions, and food-chain relationships, to fulfil comparisons to natural areas and be considered a success. Considering the microhabitat requirements of the target species of palms and only transplanting into fragments in which they naturally occur, this project ensures that these natural processes can still take place, and that natural regeneration can occur following successful transplantation.

Despite consideration of the microhabitat requirements of each target species and comparing these with the microhabitat of each potential planting site, local microhabitats may not be optimal for every individual seedling planted. This is due to the large number of seedlings planted and the planting protocol that was followed, whereby every seedling planted was required to be  $\geq 3\text{m}$  from any large tree, already-present target palm species, or other seedling planted in the forest. The final planting sites were sprawling, and it is possible the site did not contain precisely the same microhabitat conditions across the whole location. Sites did not, however, sprawl into open habitat, swamp, inundated soil, clearings, areas dominated by specific vegetation (e.g. ferns, *Pandanus* spp.), or other deviating habitat.

Data collectors were trained to standardise condition scores. Despite this, inconsistencies may have arisen due to different data collectors recording condition scores when monitoring the planting. Within the trial planting all palms were planted with a condition of 'fair' or above. Following this, the mean condition of seedlings improved until month six, after which, it fell in all sites back to a mean of 'fair' at month 12. An initial decline in condition scores is to be expected after *in-situ* planting, as the seedlings are moved out of the controlled and pest monitored environment of the nursery to the forest. Stochastic events of plant death are inevitable within *in-situ* environments, due to many factors such as environmental stress, herbivory, pests, and diseases (Grossnickle, 2012). The overall condition of the trial palms planted in 2023 demonstrates viable growth potential for the palms in all sites planted in 2024. Of which, the mean condition score of palms at all planting sites is 'fair' or better, therefore, all transplanted palms are currently considered healthy.

## 6. Conclusion

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SEED Madagascar's Project Palms has increased the number of juvenile palms of six different endemic and endangered palm species by 1,063 at the time of reporting. Ongoing monitoring is continuing to assess the health of the transplanted palms. Following the 2024 mass planting, the first 3 months have shown a survival rate of over 96%. The greatest mortality of transplanted seedlings is to be expected in the first few months immediately after planting, but this high survival rate is promising. This is mainly attributed to three factors, the first of which is limiting the palms considered suitable to plant using pre-determined, species-specific planting thresholds. The second contributing factor has been attributed to the thorough assessment of the habitat suitability of potential planting sites using known, species-specific habitat preferences and lastly by following strict planting protocols.

Madagascar is a global biodiversity hotspot with levels of species endemism almost unparalleled elsewhere in the world. Yet the country is experiencing rates of deforestation and destruction that are threatening nearly all native species, including these six endangered species of palms. Project Palms has demonstrated the possibility of a local increase in the population of juvenile palms through *in-situ* transplantation.

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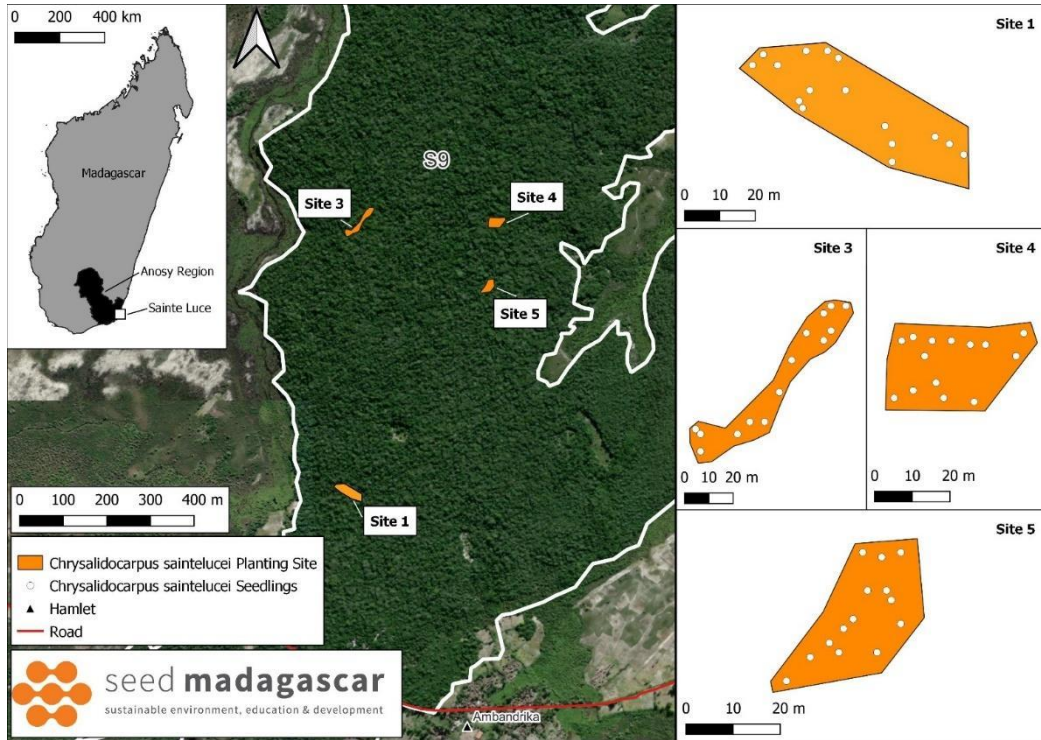
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# Annexes

## Annex 1 - *In-situ* planting trial sites



## Annex 2 – Planting site descriptions for *in-situ* planting trial (2023).

Potential Site	Description
Site 1	Many juveniles present. Wetland. Shaded but partially open canopy.
Site 3	Few juveniles present. Stream running through site. Partially closed canopy at roughly 75% cover, and around 15m tall. Many Pandanus spp. and Bamboo spp. ( <i>voliandroky</i> ) within the vicinity. Close to bridge over stream and pathway, ensuring easier accessibility for monitoring and local forest users.
Site 4	Few juveniles present, few adults have grown here in the past. Stream runs through the site with steep slopes alongside each side of the site. Close to bridge over stream and pathway, ensuring easier accessibility for monitoring and local forest users. Open canopy, with canopy height around 10m tall.
Site 5	Very few juveniles present. Area is swampy, with soil consisting mainly of organic matter and little to no sand. Steep sides on either side of the site. Close to pathway, ensuring easier accessibility for monitoring and local forest users.

## Annex 3 – 2024 Site descriptions

### Forest Fragment S8 Site Descriptions

Site Number	Species	No. palms	Description
1	<i>D. brevicaulis</i>	44	This site lies on the southeast edge of Remnant 4. The forest is dense (mean distance to a large tree is 2.55m), with intermediate canopy cover (64%) and a mean canopy height of 8.25m. There are <i>D. scottiana</i> , <i>C. psammophilus</i> , and <i>D. brevicaulis</i> palms within the area, along with tree species such as <i>hazomainty</i> , <i>ampoly</i> , and dominated by <i>fotsiavaliky</i> . The land slopes mildly north-west towards a lower lying inundated area with many <i>Pandanus sp.</i> The soil is composed of equal amounts of sand and organic matter.
2	<i>B. madagascariensis</i>	50	This site is west of the centre in Remnant 2. Canopy height of large trees is 9.5m and canopy cover is intermediate at 62%, although there are a few small clearings present with open canopy. Prevalent tree species include <i>falinandro</i> , <i>votsila</i> , and <i>mangavao</i> . Target palm species are present in the area, including juvenile <i>B. madagascariensis</i> , <i>D. brevicaulis</i> , and <i>C. psammophilus</i> with mainly <i>D. scottiana</i> in the immediate site location. The site slopes very slightly towards the east. The soil is composed of equal amounts of sand and organic matter, but the soil is more acidic than most other sites within S8 at pH 3.73.
3	<i>C. psammophilus</i>	50	This site lies in the north of fragment S8 North. This site and its surroundings are dense with small trees, but there are more clearings in the northeast. There is an intermediate to high canopy cover (73.3%). Mean canopy height of large trees is 6.38m, and prevalent species include <i>mapay</i> , <i>fotsiavaliky</i> and <i>beronono</i> . There are also substantial numbers of <i>C. psammophilus</i> and <i>C. saintelupei</i> juvenile and adult palms here. The soil is composed of 75% organic matter and 25% sand, which is covered by a large amount of leaf litter.
4	<i>D. brevicaulis</i>	45	This site lies in the north of fragment S8 North. This site is reasonably dense with trees and target palm species, and average distances to small and large trees is 1.59m and 3.35m, respectively. Mean canopy height of large trees is 7.13m tall and there is a high canopy coverage of 75%. Surrounding trees include species <i>makaragna</i> , <i>zoramena</i> , <i>kalavelo</i> , along with palm species <i>C. saintelupei</i> , <i>C. psammophilus</i> , <i>D. scottiana</i> , and adult <i>D. brevicaulis</i> . The soil here has the highest pH (5.9) relative to other sites within S8 although is still acidic. The soil is composed of 25% sand with 75% organic matter and covered with a thick leaf litter.
5	<i>C. saintelupei</i>	42	This site lies west of centre of fragment S8 North. The canopy is composed of large trees with a height of 10.75m, and an intermediate canopy cover of 65%. Species at this site include <i>sagnira</i> , <i>zamba</i> , <i>falinandro</i> , and <i>bamby</i> , with prevalence of <i>D. scottiana</i> adults and juvenile <i>C. saintelupei</i> s, <i>D. brevicaulis</i> , <i>C. prestonianus</i> and <i>C. psammophilus</i> . The palms here show a very clustered spatial distribution. The site slopes slightly to the NE toward a tree dense swampy area in the NW, and therefore, planting was planned further SE for <i>C. saintelupei</i> s as this is less dense. The soil is composed of 25% sand and 75% organic matter, with high leaf litter cover.

6	<i>B. madagascariensis</i>	50	This site that lies west of centre of the fragment S8 North, south of site 5. The large tree canopy height is tall (10m), and there is an intermediate canopy cover of 61%. Surrounding trees include <i>kalavelo</i> , <i>nato</i> , and <i>sagnira</i> along with juveniles of target palm species <i>D. scottiana</i> , <i>B. madagascariensis</i> , <i>D. brevicaulis</i> and <i>C. sainteluceis</i> in clusters at this site. Overall, there is a high density of palm species present here. If necessary, this site scan be expanded over a larger area further south if difficult to find a distance of 3m away from neighbouring palms. Due to the relatively high density of existing palms, the planted palms were placed sprawling southwards in order to adhere to 3m distance requirements to any other palms. The soil has the lowest mean pH of all the S8 sites (pH 3.39) and is composed of 25% sand with 75% organic matter.
7	<i>D. brevicaulis</i>	45	This site lies in the west of fragment S8 North. The mean canopy height is 6.75m with some clearings and intermediate canopy cover of 66%. This is a small site but has lower tree density than other sites, and only target palm <i>D. scottiana</i> present in the area. Other surrounding trees include <i>kalavelo</i> , <i>sarikafe</i> , and <i>Pandanus sp.</i> . The soil is composed of 75% sand with 25% organic matter. Clusters of bamboo and palms mean this site is not evenly spread and planted palms are unevenly dispersed.
8	<i>B. madagascariensis</i>	111	This site lies on the western edge of the fragment of S8 South, spanning mainly north but also southwest, bordering the edge of the designated protected area. Mean canopy height is 6.75m, and canopy cover is high at 83%. The NW area of the site is less dense and better for planting as there is a slope ending in a stream in the south of the site. Tree species include <i>fonto</i> , <i>kangy</i> , <i>votsila</i> along with target palm species <i>C. saintelucej</i> , <i>D. scottiana</i> , <i>D. brevicaulis</i> which are also present at the site. There is limited presence of <i>B. madagascariensis</i> in the SE of the site. The soil is composed of 75% organic matter and 25% sand and covered with substantially thick leaf litter.

### Forest Fragment S9 Site Descriptions

Site number	Species	No. palms	Description
1	<i>C. psammophilus</i>	100	This site lies in the far north of fragment S9. Mean canopy height is 9.75m, with a high mean canopy cover of 77%. The site is dominated by small tree species including <i>voralahy</i> , <i>haramboango</i> , and <i>harandrato</i> as well as palm species <i>C. psammophilus</i> , <i>D. scottiana</i> and juvenile <i>C. prestonianus</i> . The soil is composed of 25% sand and 75% organic matter.
2	<i>C. prestonianus</i>	67	The site lies in the north of fragment S9, west of the main path, and not far from Site 3. Mean canopy height is 9m, with some small open clearings and an intermediate mean canopy cover of 64%. Surrounding tree species include <i>hazomainty</i> , <i>ambora</i> , and <i>falinandro</i> as well as target palms, <i>D. scottiana</i> , <i>C. psammophilus</i> and juvenile and adult <i>C. prestonianus</i> . Soil is composed of 50% soil and 50% organic matter.
3	<i>B. madagascariensis</i>	120	The site lies in the north of fragment S9, between T3 and T5, south of Site 2 and west of the main path. The forest is reasonably dense

			with small trees. There is an intermediate mean canopy cover (68%) and relatively low canopy height (6.7m). Topography is mainly flat, with a very minor N facing slope. There are no juvenile <i>B. madagascariensis</i> present in this exact location, but adult <i>B. madagascariensis</i> are located within the vicinity of this fragment. The ground is constituted of 75% sand and 25% organic matter.
4	<i>C. saintelupei</i>	42	This site lies in the centre of fragment S9. This site is dense with limited light penetration due to a closed canopy and high canopy cover of 78%. There is a taller than average canopy height of 8.25m. Surrounding trees include <i>hazondrofotsy</i> , <i>sarivontaky</i> and <i>varolahy</i> . There are also <i>Dypsis fibrosa</i> palms here, and target species <i>D. scottiana</i> , and <i>C. saintelupei</i> . Soil is composed of 75% organic matter and 25% sand.
5	<i>C. psammophilus</i>	65	This site lies in the centre of fragment S9. This site has the lowest density with the lowest distances between small and large trees recorded when surveying candidate sites in S9. There is a high mean canopy cover of 76% and canopy height of 8.5m. Surrounding trees include <i>ambora</i> , <i>vahabahatry</i> , and <i>hazomainty</i> , along with target palms <i>C. prestonianus</i> and <i>D. scottiana</i> . This site has the lowest pH soil in this fragment of pH3.9. The soil is composed of 75% organic matter and 25% sand and has high leaf litter coverage.
6	<i>C. saintelupei</i>	42	This site lies in the south of fragment S9. This site has small areas of open canopy, although a recorded mean of 72% canopy cover, and canopy height of 7.25m. Surrounding tree species include <i>ambora</i> , <i>sarikafe</i> , <i>sisikandrongo</i> along with target palm species <i>C. prestonianus</i> , <i>D. scottiana</i> , and high relative density of juvenile <i>C. saintelupei</i> . Presence of <i>Dypsis fibrosa</i> here indicate more water saturated soil. Soil is composed of 75% organic matter and 25% sand.
7	<i>D. scottiana</i>	100	This site lies in the south of fragment S9. There is a high mean canopy cover of 76%, and the lowest mean canopy height within forest fragment S9 is 5.75m. Other tree species include <i>falinandro</i> , <i>fantsikahtsy</i> , and <i>saridobakoho</i> along with target palms <i>D. scottiana</i> and <i>C. prestonianus</i> of all age categories. Soil is composed of 25% sand and 75% organic matter.

### Forest Fragment S17 Site Description

<u>Site number</u>	<u>Species</u>	<u>No. palms</u>	<u>Description</u>
<u>1</u>	<i>C. prestonianus</i>	40	This site lies to the west of the transect in S17. The area is less dense than surrounding forest with a lower distance to nearest small and large trees (recorded as 4.6m and 4.0m respectively), although there are many small ferns covering the ground. Despite low tree density there is a high average canopy cover (76%). Canopy height is 7.25m. There are no palm species within the site area, although <i>C. prestonianus</i> is prevalent in this fragment. The area is dominated by <i>beronono</i> and <i>fantsinakoho</i> trees. Soil pH is higher (pH6.7) in the S17 fragment, due to the proximity of the ocean, and the soil is composed of equal amounts of sand (50%) and organic matter (50%).

## Annex 4 – Microhabitat characteristics

### 1.1.1.1 *Habitat Density*

Tree density was measured using a point-centred-quarter (PCQ) methodology. Density was inferred by measuring the distance from the palm to the nearest small (6.5cm-12cm circumference) and large (> 12.5cm circumference) tree in each cardinal direction. Tree species was identified by a local expert guide and recorded to assess the local arboreal diversity.

### 1.1.1.2 *Canopy Cover and Height*

Canopy coverage measurements were taken five meters from the base of the palm in each cardinal direction using transparent plastic with 25 black dots in a square grid. At each point, the plastic case was held vertically above the observers head towards the sky, recording the number of points that were obscured by the canopy and converted to a percentage<sup>2</sup>. Canopy height (tree base to canopy apex) (m) was recorded for each large tree identified during the PCQ. Due to the dense nature of the SLLF, it was necessary for experienced staff to visually estimate height of individual trees.

### 1.1.1.1 *Topographic Characteristics*

Slope angle, aspect, and elevation were recorded. Slope angle was measured using a digital level application installed onto a smartphone. Aspect was measured by assessing the direction of slope in the habitat and measuring the degrees from north using a compass when facing down the slope. Elevation measurements were made using a Garmin 62S Global Positioning System (GPS).

### 1.1.1.3 *Soil Composition*

A detailed description of the physical properties of the soil at each palm site were recorded, including soil texture and leaf litter coverage. Soil texture information was visually estimated and defined into distinct categories that could be applied to each palm site. Categories included pure sand (100% sand), sand with low organic matter (~75% sand), sand with medium organic matter (~50% sand), sand with high organic matter (~25% sand), organic matter with little sand (<25% sand), and organic matter with no sand (0% sand).

### 1.1.1.4 *Soil pH*

Soil pH was measured to determine the physicochemical properties of the soil. Measurements were taken by inserting a Hanna Halo 2 Soil pH probe into the soil and recording the pH reading once stabilised. The probe was rinsed with de-mineralised water between samples and was fully calibrated and cleaned with an electrode cleaning solution for microhabitat assessments completed on different days.

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<sup>2</sup> Percentage canopy cover was calculated by counting the number of points that were obscured by the canopy in the four cardinal directions. This value was divided by 20 to find the average proportion of points and then multiplied by 100 to obtain the average percentage of points obscured.