FINAL REPORT ON BAN MEH MEH SITE TO CDSC MAY 2023

FOREST RESTORATION FOR CARBON OFFSET FOR CDSC: 1,000 AND 370-TREES PROJECT AT BAN MEH MEH

Projects:	Forest Restoration for Carbon Offset for CDSC – 1000-trees project (2020) and Plot Extension—370 trees (2021)
Donors:	Christliche Deutsche Schule Chiang Mai (CDSC)
Grant requested:	**151,704** and **47,979 THB**
Project Duration:	1/5/20 – 31/01/22 and 1/07/21-31/01/23
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Checked by:	Steve Elliott

Introduction

FORRU-CMU received a request from CDSC in 2019 for technical assistance with tree-planting, to offset the school's carbon footprint and provide education opportunities for pupils. The project plan evolved during the last quarter of 2019 and several preliminary activities were implemented, including participation of pupils in seed collection around FORRU-CMU's nursery on Doi Suthep (7-10/10/19), establishment of a school tree nursery, promotion of the project during the school fair and tuition in tree care and tree nursery management (17/10/19). A site near Ban Meh Meh (Mae Rim District) was selected for the first planting, during a trip to view several potential sites with watershed officers, on 16/1/20 and an initial map of the area made by drone on 31/1/20. Although, restrictions during the COVID pandemic obstructed involvement of CDSC pupils in site preparation in 2020, site preparation was carried on by Mae Ram Sub-district officers, villagers and FORRU staff. Fortunately, by planting week, restrictions had been lifted and CDSC pupils participated in the first tree-planting event 16th June 2020.

After good results in the 2020 plot, CDSC opted to continue forest restoration work and asked FORRU-CMU to arrange to plant more in 2021. The 2021 restoration plot was a small forest gap adjacent to the 2020 plot. The project plan evolved during online meetings in May 2021. The budget was reduced from 2020, since fewer trees were planted and we tried to combine activities across the two plots to save money on transport and FORRU staff costs. In 2022, CDSC join in FORRU-CMU's Young Forest Restorers project we were therefore able to provide nursery support and various related activities free of charge to support the schools continued forest restoration program, under that project.

Objectives: -

- to plant up to 1,000 and 300 trees of species (in 2020 and 2021 respectively) that are indigenous to bamboo-deciduous forest for ecosystem restoration.
- to offset the school's carbon footprint (estimated[1] at about 97 tC or 355 tCO_2) over 14 years, as the trees grow.
- to provide environmental education opportunities for the school's pupils.

[1] Jantawong, K.; Kavinchan, N.; Wangpakapattanawong, P.; Elliott, S. Financial Analysis of Potential Carbon Value over 14 Years of Forest Restoration by the Framework Species Method. *Forests* **2022**, *13*, 144. https://doi.org/10.3390/f13020144

Planting-site description and map

Both plots are located within Doi Suthep-Pui National Park, on the north side of highway 1096 at Ban Meh Meh. The site entrance is at N 18.901472° E 98.882392° at 527 m. above sea level. A family, housed next to the entrance point, had practiced agriculture on the site for about 3-4 years previously. Consequently, this family were stakeholders in the project and involved in project planning. They also contributed to maintenance of the plot and, most importantly, fire prevention and assisting staff with the smooth implementation of the project.

Both the 2020 and 2021 sites were originally densely covered in tall grasses (*Phragmites, Imperata, Thysanolaena* etc.) with scattered tall trees and a few shrubs. Bamboos dominated the mid-slopes. Remnant forest, adjacent to the site, is degraded bamboo-deciduous forest (formerly teak forest) (*sensu* Maxwell and Elliott, 2001).

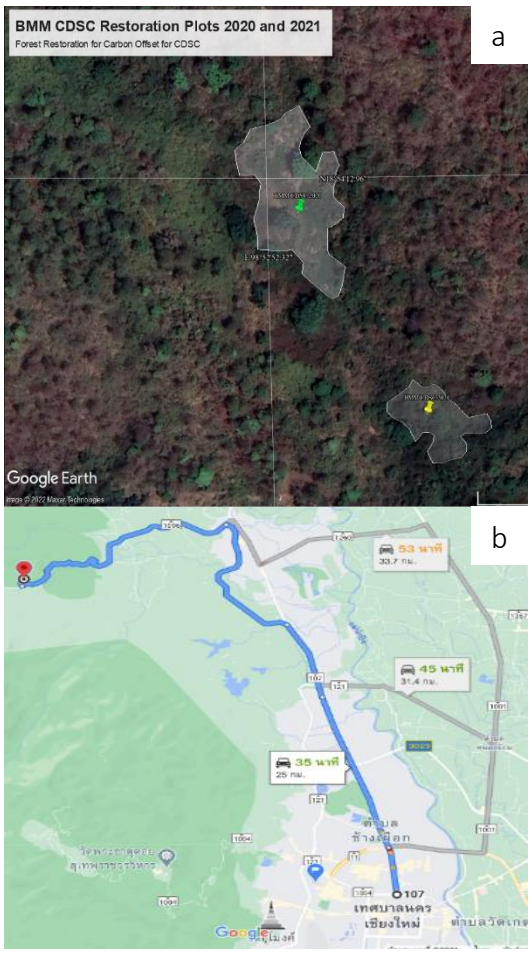

Figure 1: (a) The 2020 (green pin) and 2021 (yellow pin) plot maps. (b) The route to the site.

Figure 2: Orthomosaic overview of the sites of pre-planting, using Pix4D mapper demo combine 387 images, taken by DJI Phantom 4 Professional Drone did flight planning at altitude 80 metres above ground

Rapid Site Assessment

Usually, a ground survey is performed, to determine i) initial density of natural regenerants (seedlings/saplings/adult trees and live tree stumps) and ii) identify tree species already present on the restoration site. However, the COVID situation in early 2020, prevented such an assessment at that time (therefore only a drone survey to produce the map was included in the budget). Furthermore, since the aim was to plant 1,000 trees and the area was more than large enough, the strategy was to start planting trees from the lower site edge, working upwards until all 1,000 trees had been planted 1.8 m apart or 1.8 m away from any natural regenerants found on planting day. This would achieve optimum stocking density without a regular pre-planting ground assessment. The same procedure was followed in 2021 but this time, planting 300+ trees, evenly spaced across the site at least 1.8 m away from any pre-existing natural regenerants.

Site preparation

Metal poles were placed to mark the 2020 plot boundary on 10/6/20. Seedlings were transported to plot entrance and natural regenerants were marked with bamboo poles on 14/6/20, before slashing weeds on 15/6/20, over approximately 3 rai. Paths were cut for easy access onto the site. Bamboo poles were place, to mark tree-planting points 1.8 m apart (or the same distance from natural regenerants). Holes were dug approximately 30 x 30 cm. Site preparation was done by FORRU-CMU staff, with help from Mae Ram Subdistrict officers and local villagers on 15/6/20.

In 2021, due to requested budget cuts, more site preparation was performed on planting day. Weed slashing was performed 5 days before planting, but staking with bamboo poles was performed early on planting day by FORRU staff, who also did hole-digging, in advance of the arrival of the CDSC group, with some help from rangers from Mae Sa Waterfall Unit and BMM villagers.

FORRU staff staking and hole digging early in the morning in advance of arrival of CDSC on planting day at the 2021 plot

Planting

In 2020, tree planting was carried out on 16th June, in collaboration with CDSC pupils and teachers, national park officers, Mae Ram Subdistrict Municipality and the local community of Ban Meh Meh, with additional support from Christliche Deutsche Schule Chiang Mai (CDSC) (in terms of food transport etc.). After planting, 100 gm of fertilizer was applied in a ring about 20-30 cm away from each tree stem.

Similarly for the 2021 plot, planting day was 11st June. Saplings were transported to the entrance spot 3 days before, with help from the Pong Khrai Watershed Unit crew.

The following planting equipment and materials for both years planting events were organized in advance by FORRU-CMU, the lists showed down below

- Baskets to distribute saplings
- Hoes for hole-digging
- Knives – for cutting plastic bags
- Gloves
- Fertilizer + buckets and cups
- Bamboo poles
- First aid kit

Figure 3: Planting Day 2020 ceremony, head of Maesa waterfall unit gave speech to planters

Ceremonies and speeches for both events were organized by CDSC (Figs. 3 and 4). The exact area planted was assessed, after all the trees had been planted: 1,016 trees on the 2020 plot across almost 3 rai and 376 trees on the 2021 plot across 1 rai.

Figure 4: Planting Day 2021 ceremony, CDSC director gave speech to planters

Tree species provisional planting list

For the 2020 project, five tree species came from the CDSC school nursery, grown from seeds collected during school trips to FORRU's nursery on Doi Suthep. The aim was to produce up to 400 seedlings for this planting at the CDSC school nursery. Unfortunately, half of them had not grown tall enough (30-50 cm tall) by planting date, so totally, 216 trees were transferred to the site from the school nursery. The rest—21 species, totaling 800 trees—were produced in a community tree nursery at the nearby Hmong village of Ban Mae Sa. So, the total number of trees planted was 1,016 trees. Seedlings were prepared for the hot, dry, sunny conditions of the planting site, by hardening off (reducing shade and watering frequency for 1 month before planting day). Before planting day, all trees were labelled with aluminium tags, engraved with identification numbers (on 11/6/20). Label

numbers included species (S.no.), and tree number, example the 1st tree of *Protium serratum*, label is 131-1.

For the 2021 project, most trees were supplied from Pong Khrai Watershed Unit (PKWU): 16 species. Ban Mae Sa Mai tree nursery, supplied 66 trees of 8 different species (see tables 1 & 2)

Table 1 – Species and numbers planted of 2020 project

No	S.no	Species	Family	Thai name	CDSC nursery
1	131	*Protium serratum*	Burseraceae	มะแฟน	8
2	162	*Mesua ferrea*	Guttiferae	บุนนาค	20
3	41	*Cassia bakeriana*	Leguminosae(C)	กัลปพฤกษ์	23
4	66	*Choerospondias axillaris*	Anacardiaceae	มะกอกห้ารู	45
5	183	*Terminalia chebula*	Combretaceae	สมอไทย	120
				Total CDSC	216
No	S.no	Species	Family	Thai name	BMSM nursery
1	26	*Dalbergia cultrata*	Leguminosae (P)	กระพี้เขาควาย	20
2	22	*Ficus capillipes*	Moraceae	กะเหรี่ยง	25
3	36	*Phyllanthus emblica*	Euphorbiaceae	มะขามป้อม	25
4	65	*Xylia xylocarpa*	Leguminosae(M)	แดง	25
5	91	*Gluta usitata*	Anacardiaceae	รัก	25
6	131	*Protium serratum*	Burseraceae	มะแฟน	25
7	133	*Afzelia xylocarpa*	Leguminosae(C)	มะค่าโมง	25
8	216	*Eriobotrya bengalensis*	Rosaceae	ตะเกราน้ำ	25
9	241	*Eugenia fruticosa*	Myrtaceae	หว้าขี้กวาง	25
10	255	*Trewia nudiflora*	Euphorbiaceae	มะฝ่อ	25
11	5	*Melia toosendan*	Meliaceae	เลี่ยน	50
12	118	*Adenanthera microsperma*	Leguminosae(M)	มะกล่ำตาไก่	50
13	121	*Careya arborea*	Lecythidaceae	กระโดน	50
14	129	*Artocarpus lakoocha*	Moraceae	หาด	50
15	161	*Alangium kurzii*	Alangiaceae	ฝาละมี	50
16	195	*Terminalia bellirica*	Combretaceae	สมอพิเภก	50
17	323	*Erythrina stricta*	Leguminosae(P)	ทองเหลือง	50
18	425	*Spondias lakonensis*	Anacardiaceae	มะห้อ	50
19	449	*Bauhinia variegata Linn.*	Leguminosae (c)	เสี้ยวดอกขาว	50
20	450	*Polyalthia viridis*	Annonaceae	ยางโอน ยางพาย	50
21	13	*Sapindus rarak*	Sapindaceae	มะซัก	55
				Total FORRU	800
				TOTAL ALL	1,016

Table 2 – Species and numbers planted of 2021 project

No	S.no	Species	Family	Thai name	PKWU nursery
1	3	*Garcinia xanthochymus*	Guttiferae	มะดะหลวง	20
2	4	*Bischofia javanica*	Euphorbiaceae	ประดู่ส้ม หรือ เติม	20
3	31	*Acrocarpus fraxinifolius*	Leguminosae(C)	สะเดาช้าง	20
4	36	*Phyllanthus emblica*	Euphorbiaceae	มะขามป้อม	20
5	41	*Cassia bakeriana*	Leguminosae(C)	กัลปพฤกษ์	30
6	120	*Garcinia cowa* Roxb.	Guttiferae	ชะมวง	20
7	129	*Artocarpus lacucha*	Moraceae	มะหาด	20
8	170	*Canarium subulatum*	Burseraceae	มะกอกเกลื้อน	20
9	195	*Terminalia bellirica*	Combretaceae	สมอพิเภก	20
10	232	*Dipterocarpus turbinatus*	Dipterocarpaceae	ยางแดง	20
11	233	*Baccaurea ramiflora*	Euphorbiaceae	มะไฟ	20
12	277	*Paranephelium xestophylum*	Sapindaceae	ลำไยป่า	20
13	415	*Hopea odorata*	Dipterocarpaceae	ตะเคียนทอง	20
14	448	*Syzygium odorata*	Myrtaceae	หว้า	20
15	449	*Bauhinia variegata*	Leguminosae(C)	เสี้ยวดอกขาว	20
16	500	*Magnolia rajaniana*	Meliaceae	จำปาป่า	20
				Total: Pong Khrai Watershed Unit	310
No	**S.no**	**Species**	**Family**	**Thai name**	**BMSM nursery**
1	3	*Garcinia xanthochymus*	Guttiferae	มะดะหลวง	1
2	41	*Cassia bakeriana*	Leguminosae(C)	กัลปพฤกษ์	26
3	120	*Garcinia cowa*	Guttiferae	ชะมวง	2
4	195	*Terminalia bellirica*	Combretaceae	สมอพิเภก	1
5	233	*Baccaurea ramiflora*	Euphorbiaceae	มะไฟ	1
6	415	*Hopea odorata*	Dipterocarpaceae	ตะเคียนทอง	33
7	449	*Bauhinia variegate*	Leguminosae(C)	เสี้ยวดอกขาว	6
8	500	*Magnolia rajaniana*	Meliaceae	จำปาป่า	1
				Total FORRU-CMU	66
				TOTAL ALL	**376**

Figure 5: Drone maps pre- and post-planting of BMM CDSC 2020 plot

Figure 6: Drone map post-planting of BMM CDSC 2021 plot

Maintenance

FORRU staff organized maintenance of the trees at both plots – weeding and fertilizer application – 3 times in the first rainy season and 3 times follow up during second rainy season (total 6 times for each plot by the end of 2nd rainy season). This work was mostly done by local villagers with CDSC pupils joining in the 3rd operation 19/10/20) (Fig.7). Some pictures of maintenance in the 2021 plot are shown below (Fig 8). FORRU staff also joined all maintenance activities, to ensure quality control (for dates see Appendix III). To reduced transport/staff costs, maintenance events at both plots were combined (for Y2 or 2020 and Y1 or 2021) (see in Appendix IV).

Figure 7: Students hands-on activity in the 2020 plot - applying fertilizer around seedlings (October 2020).

Figure 8: The students took care seedlings on the 2021 plot - applying fertilizer and remove weed around seedlings.

Monitoring

Post-planting baseline monitoring

FORRU staff organized baseline monitoring 2 weeks after planting, 8/7/2020 (Fig. 9) for 2020 plot and 25/6/2021 for 2021 plot (Fig. 10). In both plots, tree height was measured with 1.5-m tape measures on plastic poles, from the base of the trunk to the highest living meristem. Root collar diameter was measured with Vernier calipers at the widest point. A tape measure was used to measure the width of the crown's widest point. A simple health score of 0-3 each tree was applied (3=perfect or nearly perfect health; 2= some signs of damage but retaining healthy foliage over half or more of their crowns; 1= trees have few leaves, leaves discoloured or severe insect damage; 0 if the tree appears to be dead). A weed-cover score was applied to circles of about 1-m diameter around the base of the tree (3= weed cover dense across entire circle; 2= weed cover moderate; 1= only a few weeds and 0= no weeds). Initial size measurements provided a baseline against which for growth during the 1st rainy would be assessed.

Immediate post-planting mortality assessed during baseline monitoring and confirmed in subsequent monitoring (for any sapling not found during baseline monitoring) was 6 (0.6%) for the 2020 plots and none for the 2021 plot (trees not found during the baseline were subsequently confirmed alive during the subsequent R1 survey).

Figure 9: Height, RCD, crown width, health score, shade score and weed score were recorded of 2020

Figure 10: Monitoring of height, RCD, crown width, health score etc. of 2021 plot

The monitoring of the 2020 plot

End-of-1st-rainy-season monitoring (R1) – 2020 plot

After 3 times plot maintenance, over the 1st rainy season, monitoring was repeated on 9th November 2020, measuring the same variables, and using the same methods as described above for baseline monitoring.

Over the whole 3-rai, 87 had died (8.6% mortality) - this is a low R1 mortality rate, compared with FORRU-CMU's other trial plots. Figure 11 shows differential mean % survival among species. The top 5 for survival were: 1) *A. xylocarpa*, 2) *B. variegata*, 3) *M. toosendan*, 4) *E. fruticosa* and 5) *S. rarak.* Species with lowest survival were 1) *C. bakeriana*, 2) *C. axillaris* 3) *E. stricta*, 4) *M. ferrea* and 5) *A. kurzii*.

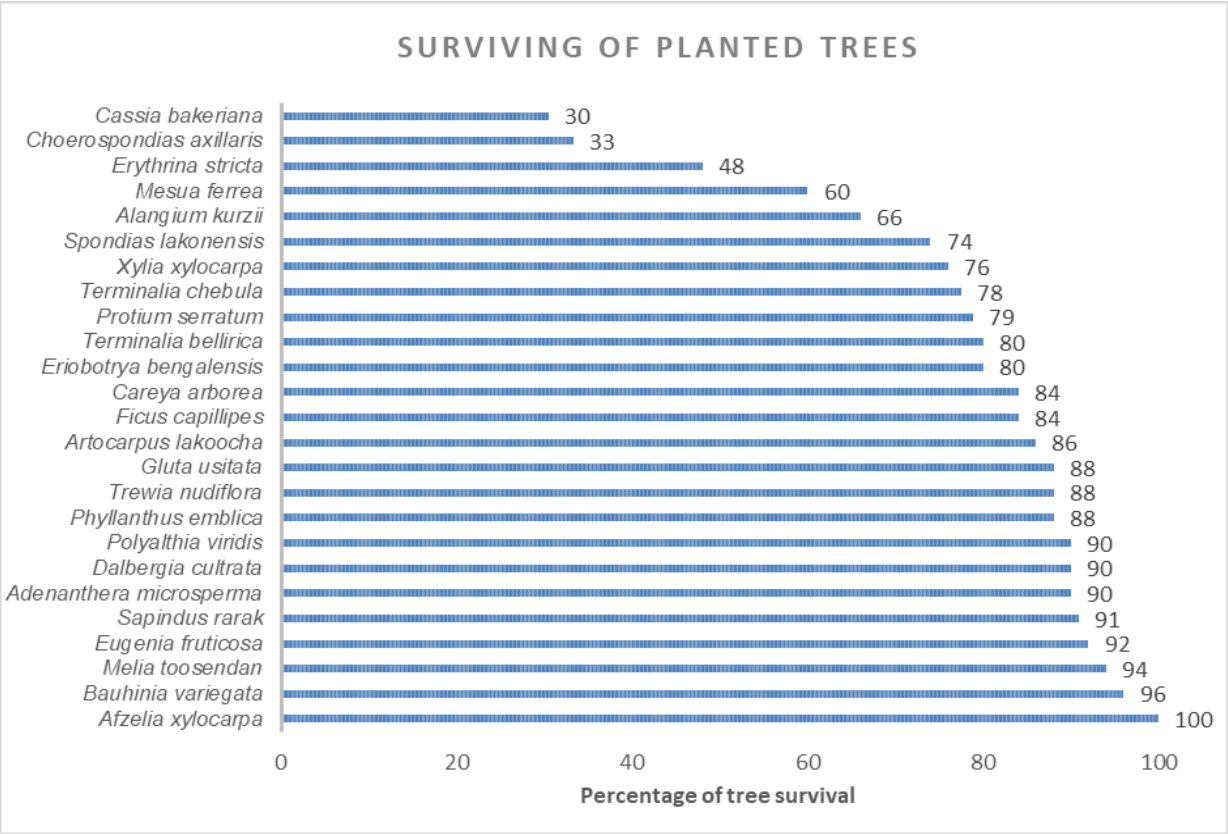

Figure 11: Tree survival R1 of 2020 plot

Relative growth rate of root collar diameter (RGR-RCD) is a measure that allows standardized comparison of growth rates among species of different initial sizes. It expresses annual size increase as a percentage of the average size of the plant throughout the measurement period (mm growth/mm size/year, as a per cent). Changes in size from baseline monitoring to R1 monitoring (5 months) were extrapolated to arrive at a standardized annual rate.

Almost all species exceeded 100% RGR-RCD (Fig. 12) i.e., indicating a potential doubling in size each year (until competition limits growth of the larger trees). For 9 species, RGR-RCD exceeded 200% i.e., those species could be expected to more than triple in size each year e.g., *B. variegata*, *T. chebula, F. capillipes, C. axillaris* and *E. stricta* and especially *M. toosendan*

(466% RGR-RCD) (Fig. 12). Furthermore, species that had lowest RGR-RCD, were still classed as "acceptable" at this site (acceptable limit is arbitrarily 50%, derived from previous plots). This is exceptionally high growth, compared with FORRU's previous plots and may have been due to the high fertility of this previously cultivated agricultural plot.

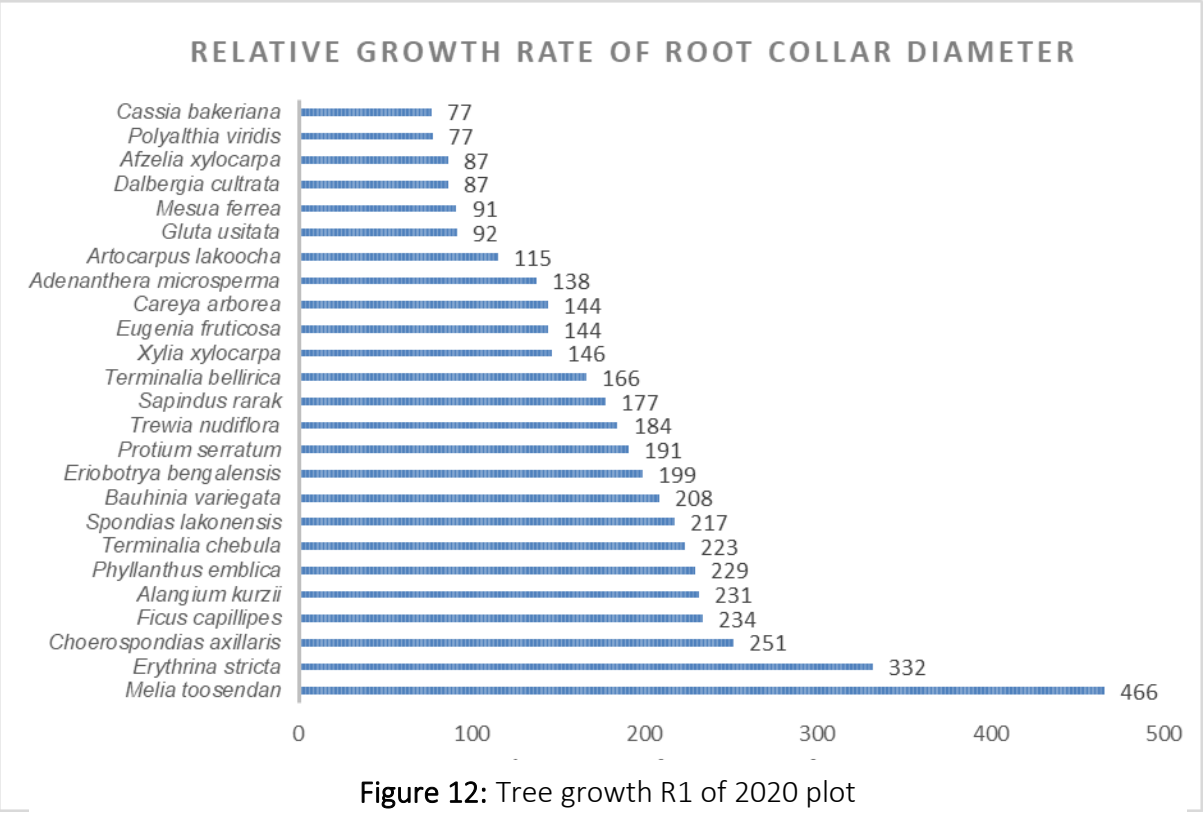

Figure 12: Tree growth R1 of 2020 plot

Figure 13: Extraordinary rapid growth of *Melia toosendan* at this site (2020 plot) end of 1st rainy season.

Relative species performance index combines survival and growth, as being equally important (equal weight) (%survival x %RGR-RCD). Scores are expressed as a percent of that of the top-most performing tree species (in this case *M. toosendan*) and the species are ranked thereby. So, the score is a "relative" performance index.

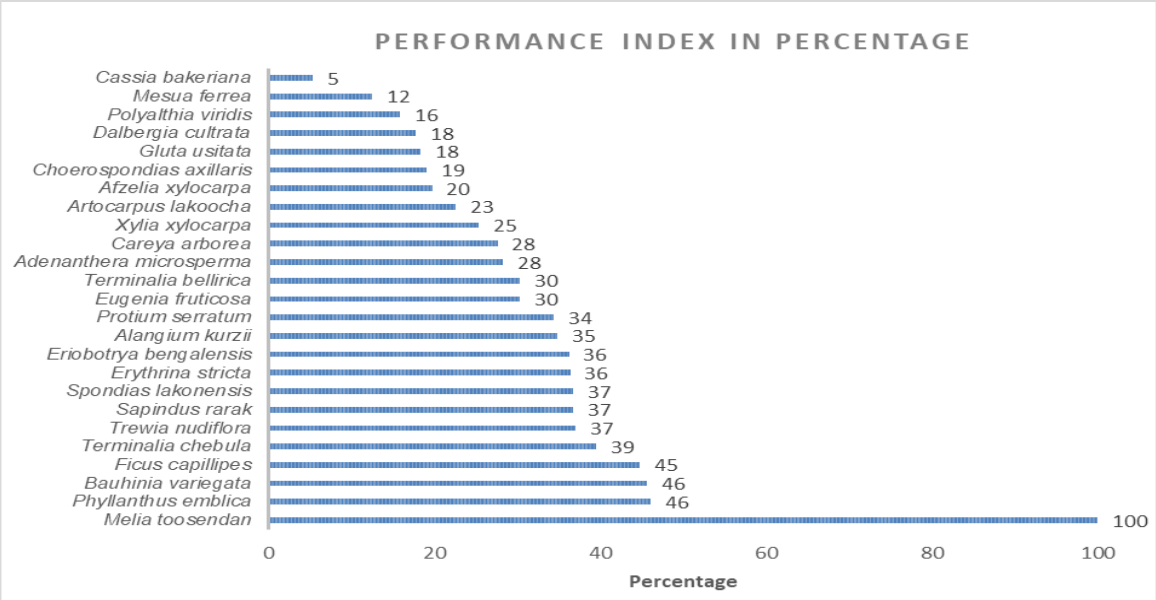

Figure 14: Relative species performance index R1 of 2020 plot

M. toosendan was an exceptionally high-performing species which severely skewed the relative performance chart (other species all less than 50% of the value for *Melia*). So, if the second-best species is used as comparison (*Phyllanthus*, 46), then any species scoring 23 or higher is considered "acceptable" and those scoring 34 or higher would be considered "excellent"[2].

End-of-2nd-rainy-season monitoring (R2) – 2020 plot

FORRU-CMU staff and volunteer group performed monitoring during the weekend of 27th November 2021, applying the same measuring methods and variables as for baseline and R1 monitoring. A total of 174 trees were confirmed dead or probably dead (not found but with very low health score recorded during R1 monitoring). This amounts to 17% mortality, again lower than is usually recorded in FORRU's previous plots.

Species showing excellent survival rates (>75%) were: *M. toosendan*, *P. emblica*, *A. microsperma*, *S. rarak*, *C. arborea*, *E. bengalensis* and *B. variegata*. Those species with unacceptably low survival, which would be excluded from further planting in this habitat were *M. ferrea*, and *C. bakeriana*, with just 5 and 12% survival, respectively. Comparing R1 and R2 survival, *A. xylocarpa* showed the most substantial drop in survival in the second year (with 100% in R1, dropping to 72% in R2). *G. usitata* (survival 88% falling to 66%) also experienced unusually high mortality in the second year.

[2] Elliott, S., P. Navakitbumrung, C. Kuarak, S. Zangkum, V. Anusarnsunthorn & D. Blakesley, 2003. Selecting framework tree species for restoring seasonally dry tropical forests in northern Thailand based on field performance. Forest Ecology & Management 184: 177-191

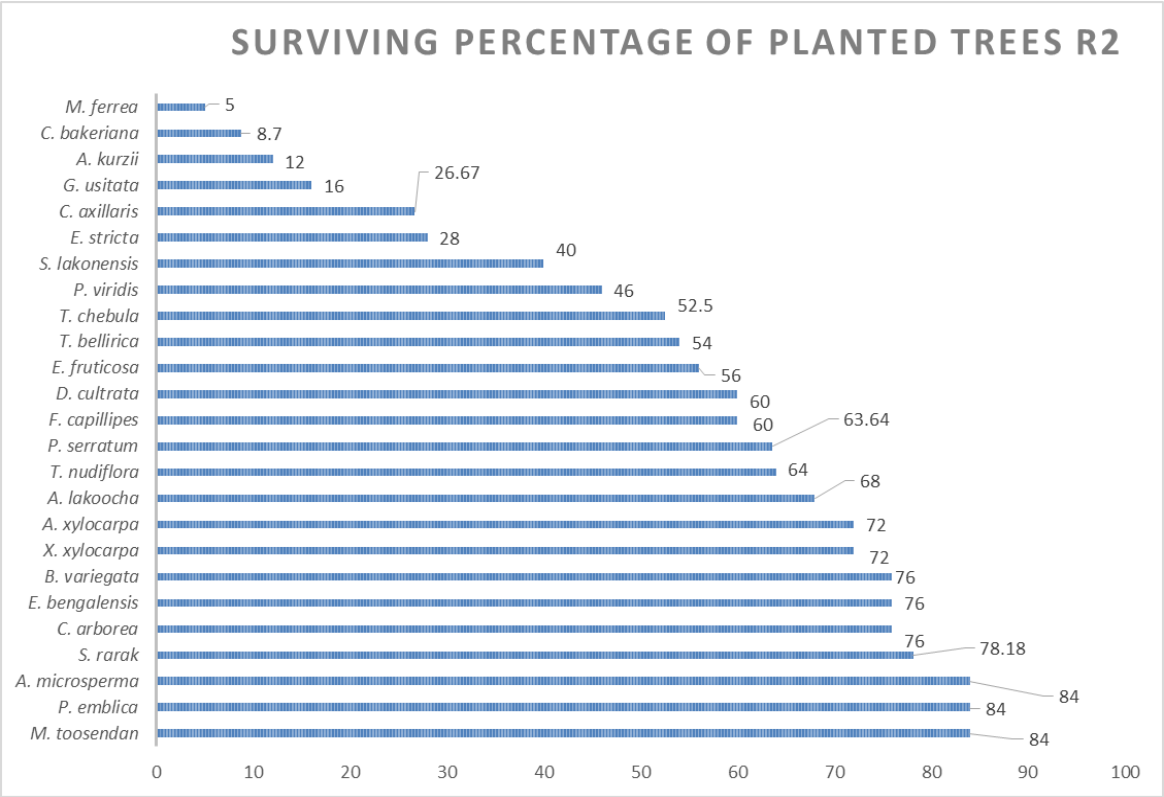

Figure 15: Tree survival R2 of 2020 plot

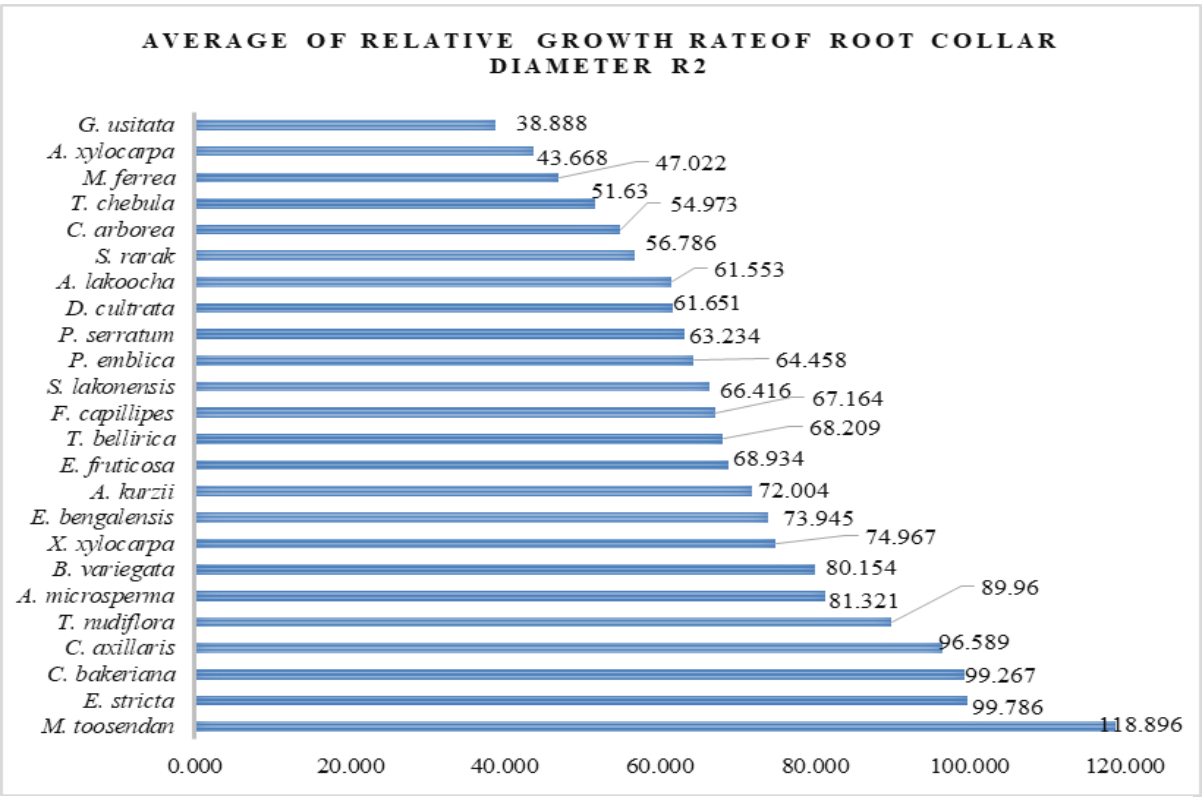

Figure 16: Relative growth rates by species R2 monitoring of the 2020 plot

As expected, RGR values in the second year were lower than in the first year (since growth is logistic). *M. toosendan* retained is position as the fastest growing species (annual doubling in size) with *E. stricta*, *C. bakeriana* and *C. axillaris* not far behind, also achieving a near annual doubling of size in the 2nd year. Only 3 species failed to achieve the acceptable standard of 50% RGR2 by R2: *G. usitata*, *A. xylocarpa* and *M. ferrea*.

In terms of overall performance *M toosendan* emerges again as clearly the highest performing species. But again, it skews the bar chart. So, if the second top-most performing species is taken as the max standard (*A. microsperma*, 68) we see that 10 species fall short of the 50% "acceptable" value (i.e., 34).

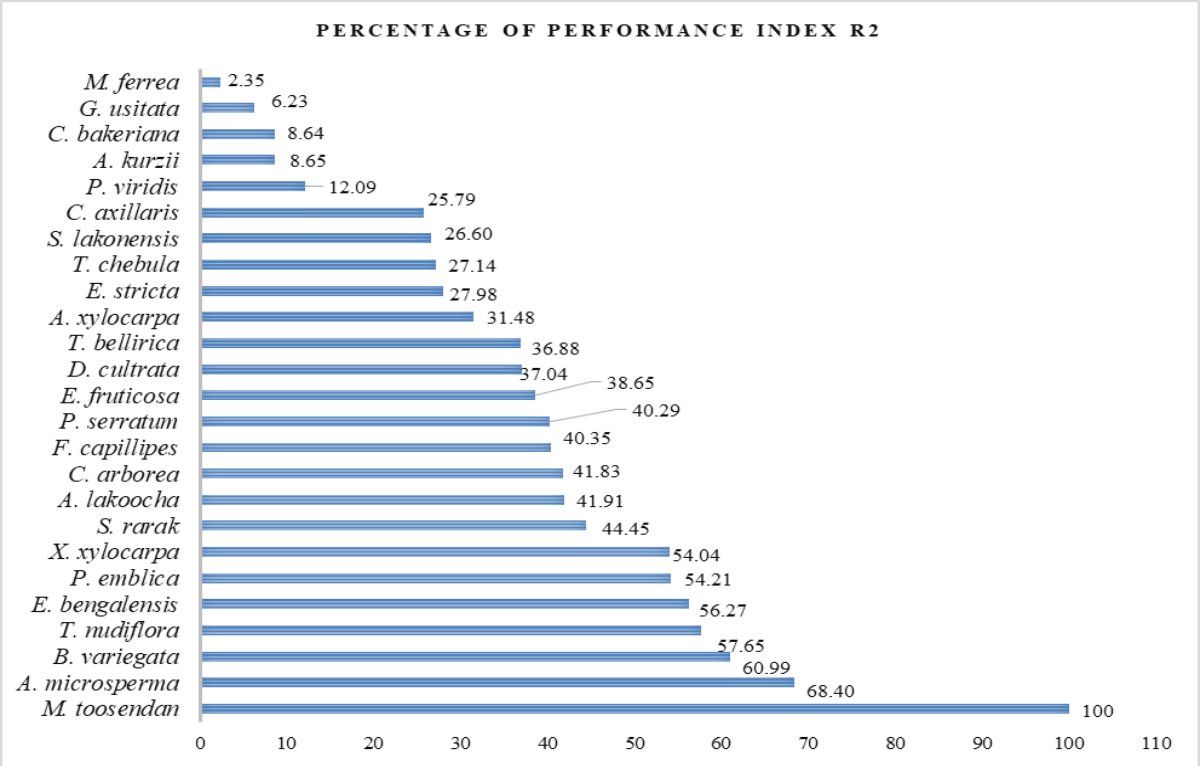

Figure 17: Relative species performance index R2 of 2020 plot

Monitoring of the 2021 plot

End-of-1st-rainy-season monitoring (R1) – plot 2021

The end-1st-rainy-season monitoring was performed on 17th November 2021. During planting in 2021, some trees were moved to the 2020 plot (due to small plot size) leaving 337 trees to be included in R1 monitoring on the 2021 plot. During R1 monitoring, 37 dead or probably dead trees were reported (the latter, not-found trees with low health scores recorded during baseline monitoring) i.e., an overall %mortality of 11%. The top highest surviving species were *T. bellirica* (100%), *M. rajaniana* and *B. ramiflora* (90%), *G. xanthochymus* and *B. variegata* (80%). The lowest surviving species were *B. javanica* (45%), *A. fraxinifolius* (50%) and *P. xestophylum* (55%) (Figure 18.).

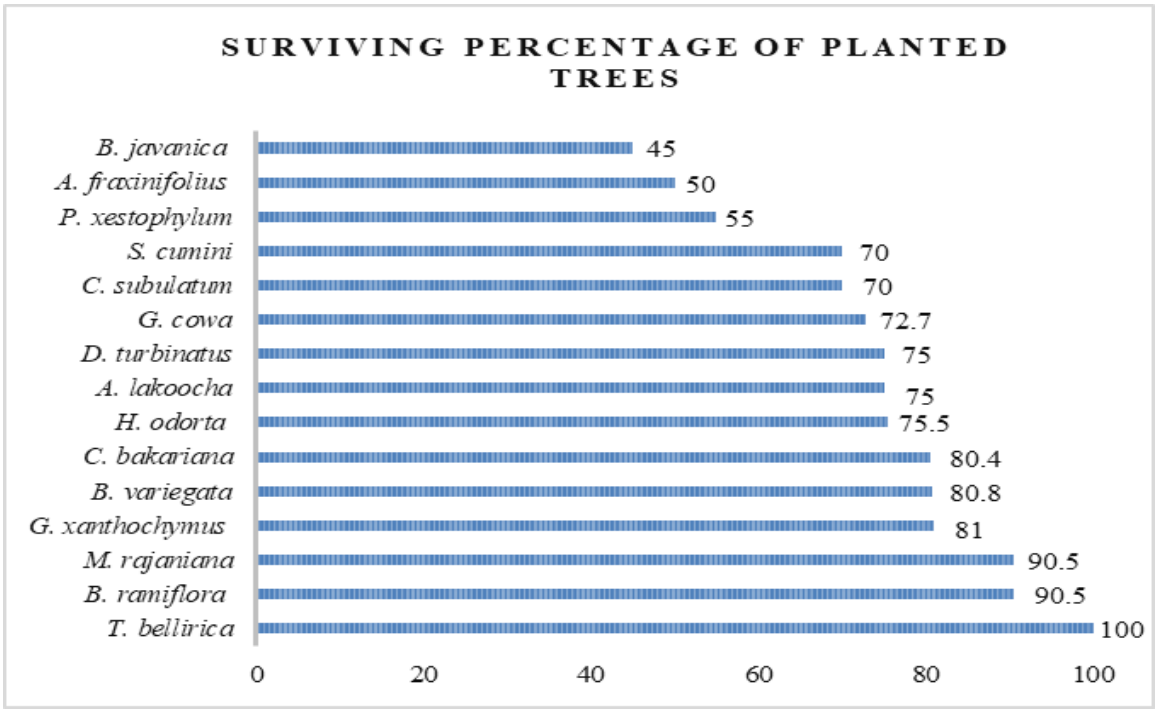

Figure 18: Tree survival R1 in the 2021 plot

All species exceeded acceptable RGR-RCD rates (>50%/y) with *C. bakeriana* attaining an astonishing 390% per year. It is interesting to note that two species among those with the highest survival rates had the lowest growth rates: *G. xanthochymus* (61%) and *T. bellirica* (60%). This lends credence to the widely accepted ecological theory of a trade off between survival and growth for tropical forest trees.

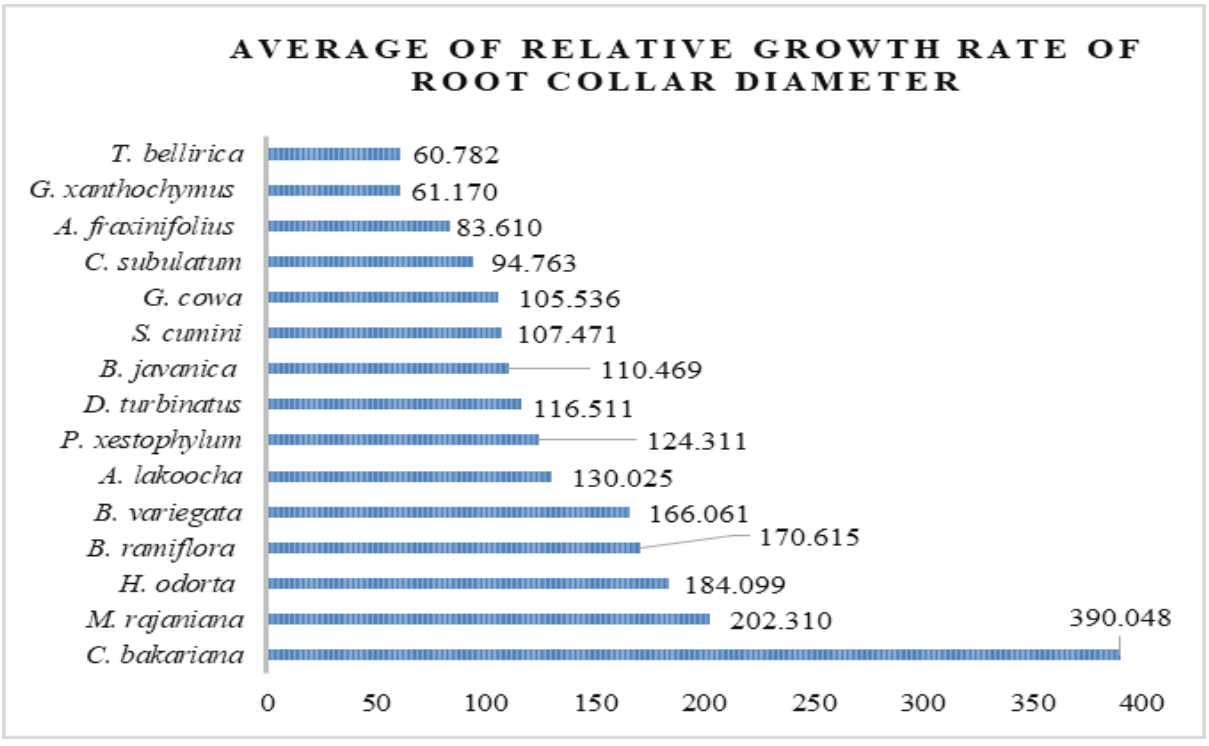

Figure 19: Trees growth R1 in the 2021 plot

In terms of combined overall performance *C. bakeriana* was the outlying highest ranked species. Therefore, if we compare to the second highest ranked species (*M. rajaniana*, 58), we see most species in this plot are rather lower-performing (less than half the value of *M. rajaniana*, i.e., <29): *D. turbinatus, G. cowa, S. cumini, P. xestophylum, C. subulatum, T. bellirica, B. javanica, G. xanthochymus and A. fraxinifolius.* It is astonishing that C. bakeriana was the highest performing species in the 2021 plot and the lowest performing one in the R1 survey at the 2020 plot. It demonstrates the need for replication of experiments and the potential sensitivity of species to small changes in environmental conditions.

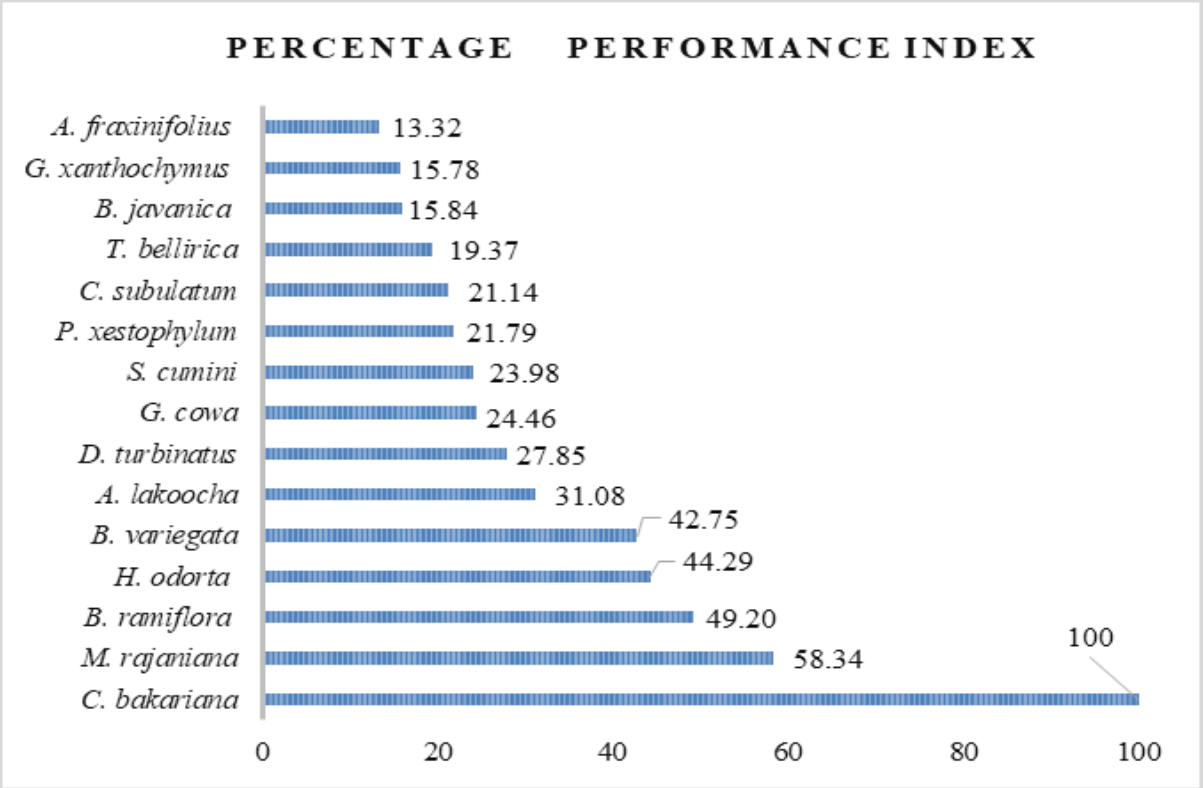

Figure 20: Relative species performance index in percentage R1 at 2021 plot

End-of-2nd-rainy-season monitoring (R2)

FORRU-CMU staff monitored planted trees on 27th November 2022, applying the same measuring methods and variables as for baseline and R1 monitoring. A total of 210 trees were found alive, equivalent to 56.6% of survival (43.4 % mortality – higher than at the 2020 site).

Species showing excellent survival rates (>70%) were: *T. bellirica* and *M. rajaniana*, with *81* and *76.2%.* Species with survival rate of 50-69.9%, considered acceptable were: *B. variegate*, *C. bakeriana*, *S. cumini*, *B. ramiflora*, *G. xanthochymus*, *A. lakoocha*, *H. odorata*, *D. turbinatus* and *C. subulatum*. *G. cowa,* with a survival rate of 45-49.9% was classed as marginally acceptable. Species with unacceptably low survival, which should be considered from exclusion from further planting in this habitat were *B. javanica, A. fraxinifolius* and *P. xestophylum* (figure 21) (Elliot et al., 2003).

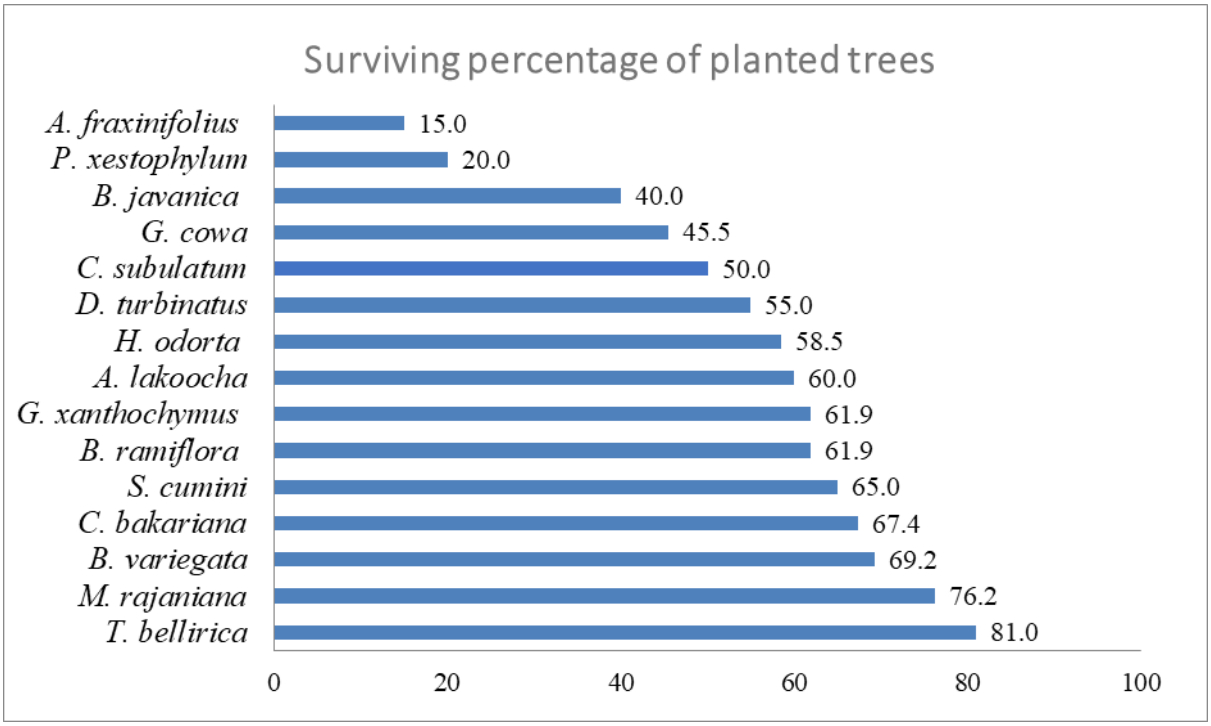

Figure 21: The tree survival at the end of rainy season (R2) of 2021 plot

Considering growth, we see again the slowdown in growth in the second year as competition kicks in and the growth transitions from exponential to logistic. Nonetheless, several species retained RGR-RCD values above 100% (annual doubling): *C. bakeriana*, *M. rajaniana*, *H. odorata and B. variegata*. Ten species exhibited RGR-RCD values exceeding 70%: *D. turbinatus*, *B. javanica*, *B. ramiflora*, *A. lakoocha*, *P. xestophylum*, *C. subulatum*, *A. fraxinifolius*, *S. cumini*, *G. cowa* and *T. bellirica*. Even, the species with low RGR-RCD, *G. xanthochymus* was only 1% below the acceptable level of 50% (Figure 22). (Elliott et al., 2003). These growth rates were very similar to the R2 values of the 2020 plot and to those recorded at FORRU's other plot beside Ban Meh Meh village planted in 2016.

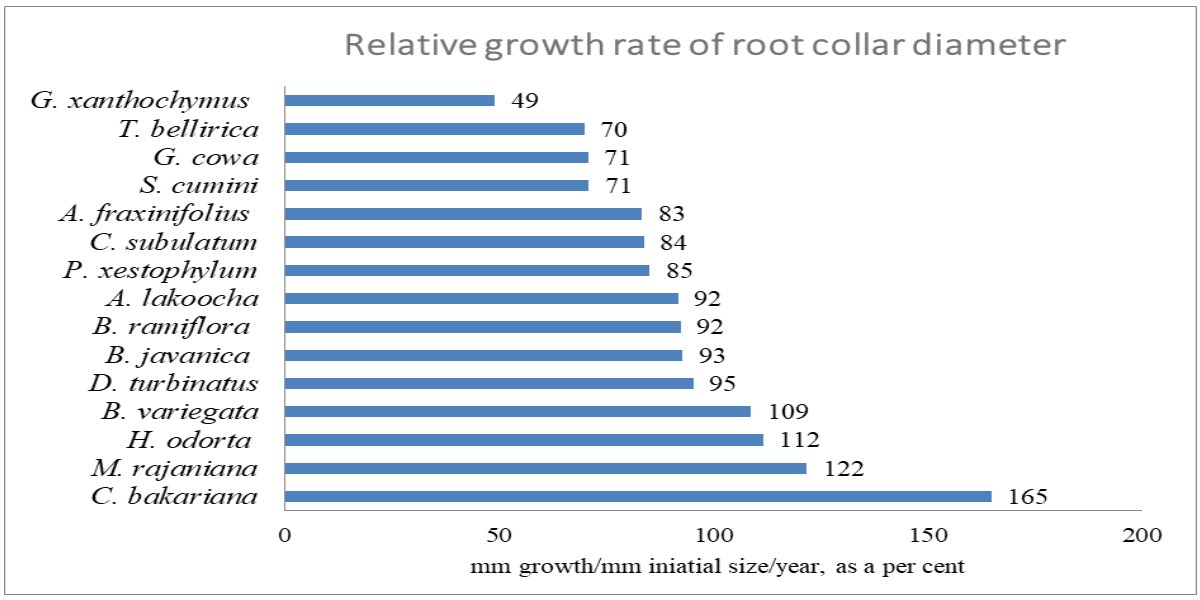

Figure 22: Relative growth rate of root collar diameter (R2) of 2021 plot

Performance indices were calculated relative to the top performer in this case *C. bakeriana*. Species achieving performance indices exceeding 50% were: *M. rajaniana*, *B. variegata*, *H. odorata*, *B. ramiflora*, *T. bellirica* and *A. lakoocha*. Unacceptably low performing species were: *A. fraxinifolius*, *P. xestophylum*, *G. xanthochymus* and *B. javanica*.

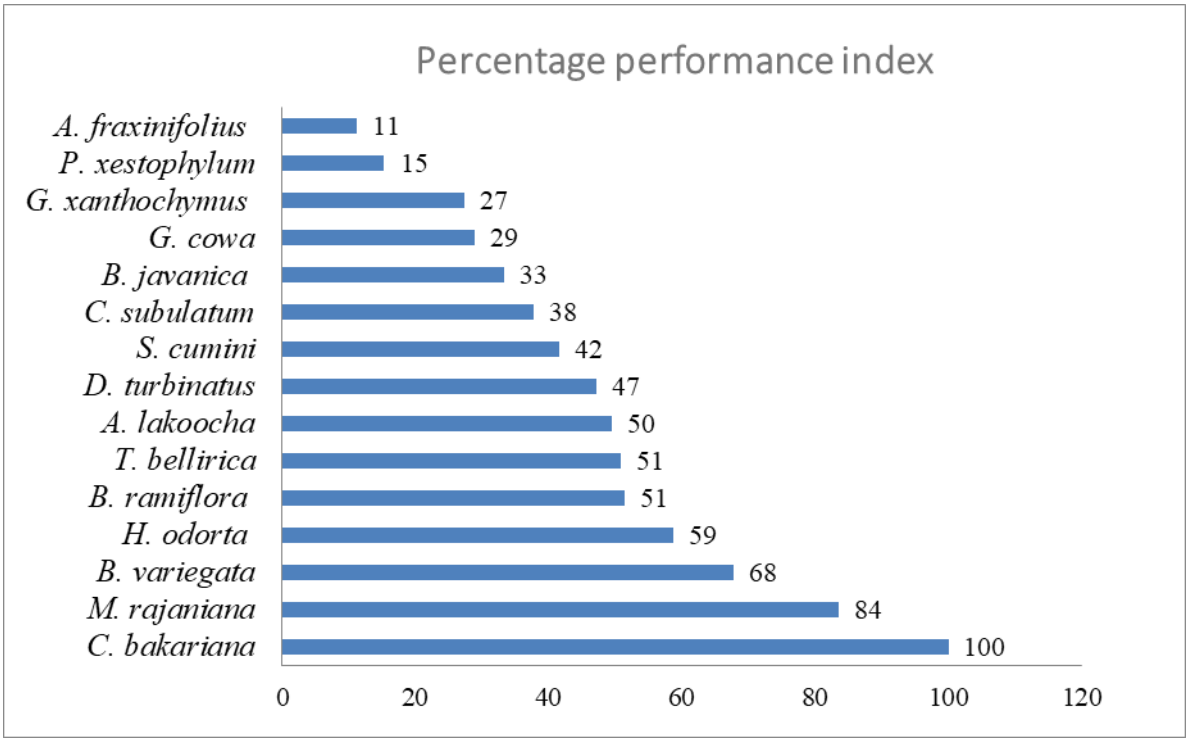

Figure 23: Relative species performance index in percentage of 2021 plot

Conclusions

The project has had three kinds of outputs: i) offset part of the school's carbon footprint; ii) educational awareness of environmental issues and plant biology; iii) building team spririt and iv) scientific results.

Carbon:

Although the trees are still too young and small for carbon assessment, all signs indicate that the CDSC Ban Meh Meh plots are performing comparably, or better, than most of FORRU's previous plots. The trees have grown up to escape competition from weeds and have nearly achieved canopy closure – the first milestone of restoration. Consequently, we are confident that the trees will continue to grow, without further intervention, and accumulate carbon at or above the rates recorded in FORRU's previously plots–about 143 tC/ha in trees and 8.5 tC/ha in soil—over the first 14 years (Jantawong, 2022). The total area planted (2020 and 2021) was 0.64 ha. So, the expected carbon uptake over 14 years is projected to be about 97 tC. The school's annual carbon footprint was originally calculated to be 70.4 tC (=258 tCO_2). So 97 tC represents offset of 1.4 years of CDSC emissions.

Education

Students learnt about global climate change, their involvement in the problem and how they can take direct action to mitigate their impact. Furthermore, FORRU staff have helped to teach students about the mechanics of forest restoration: seed collection/banking, nursery techniques and field skills such as planting, maintenance and monitoring—skills and knowledge that aree widely applicable to other fields such as horticulture and agriculture. The site was also used for teaching restoration to visit Lao PDR forestry officials on 10/11/23.

Figure 24 - Lao PDR Foresters learning in the CDSC plots November 2022

Team spirit

Forest restoration involves many atsks ans skills to come together for success. Close collabroation among many people drawing on their individual knowledge, skills and strengths. During the project students have collaborated enthusiastically with FORRU staff and with each other—thus building team spirit. The ability to work as part of a team is a valuable social skill particualry for build future employment opportunities.

Scientific results

The charts above show that the project has generated an enormous amount of scientific data and interesting observations that will be used to improved forest restoration techniques in bamboo-deciduous forest for many years to come. FORRU staff will continue to analayses these data and they may be prepared for publication in a scientific journal.

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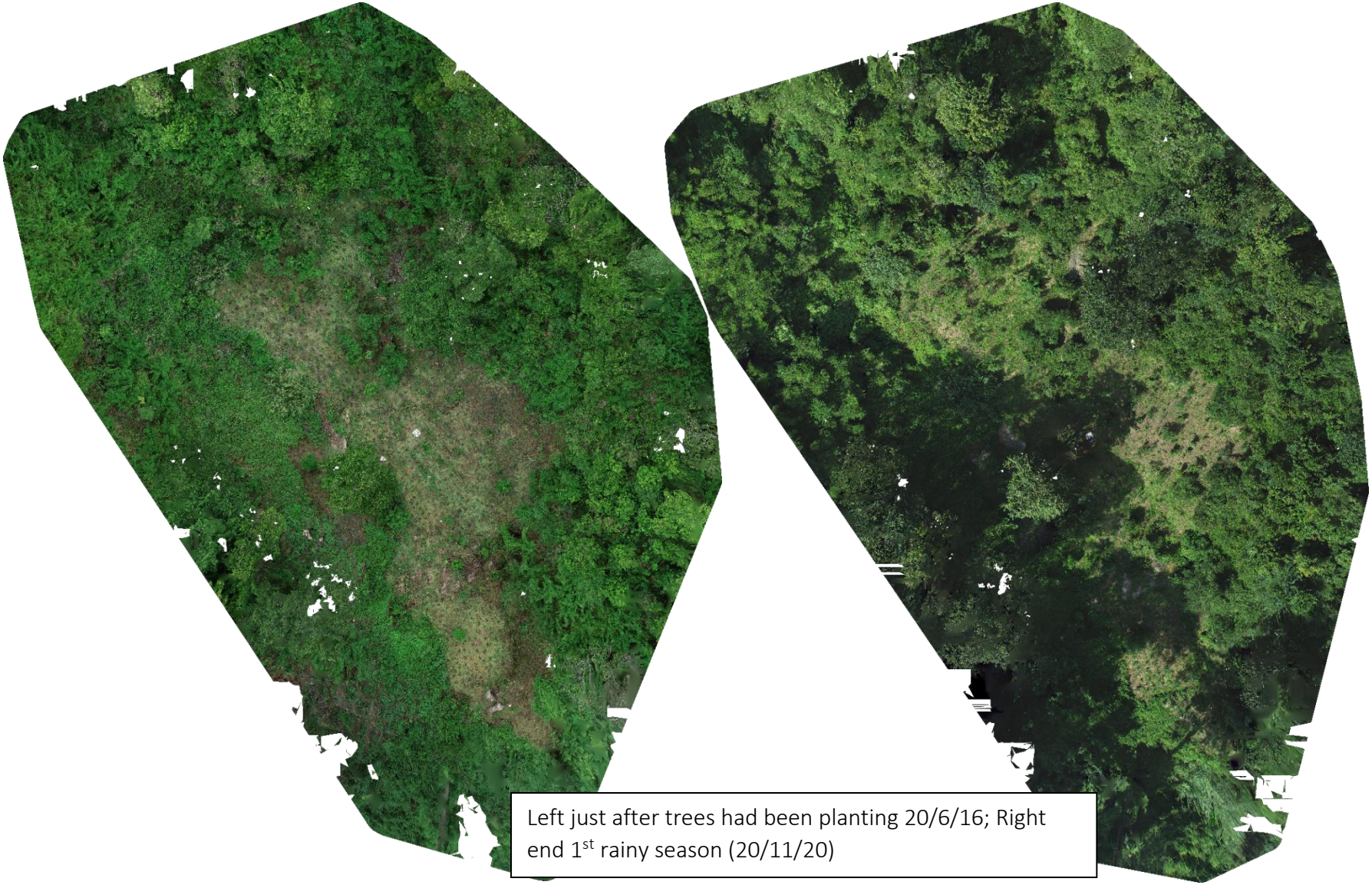
Appendix I



Left just after trees had been planting 20/6/16; Right end 1st rainy season (20/11/20)

Appendix II

Tree’s location of BMM CDSC 2021 restoration plot

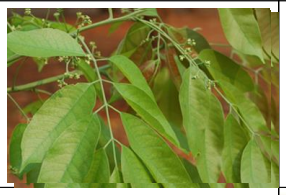
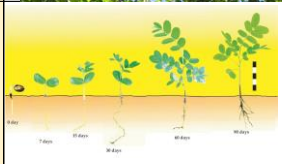
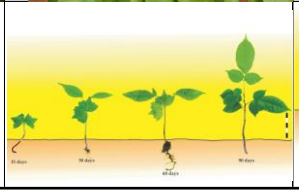
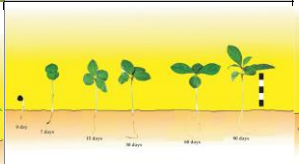
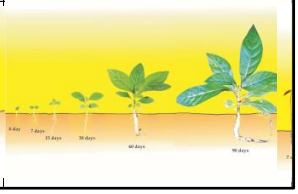
Appendix III -Project Task Schedule of 2020

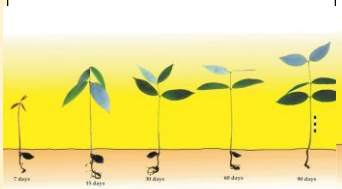
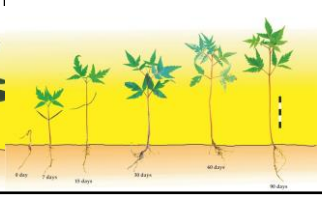
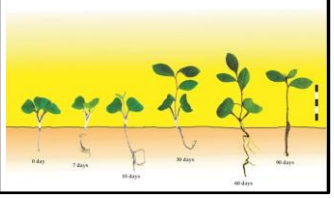
Date	Task
January 2020	Site selection
January 2020	Site map prepared from drone imagery
April 2020	Project plan produced
May 2020	Permission requested from park HQ
June 11st 2020	600 Trees were labelled at BMSM nursery
June 13rd 2020	Planting preparation: plot boundary, mark natural regenerants with bamboo poles and weeding cutting
June 14th 2020	Planting preparation: transport seedlings and fertilizer to the sites, bamboo poles staking.
June 16th 2020	Planting day, holes digging.
July 8th 2020	Baseline monitoring of planted trees (BL)
August 1st 2020	1st weeding and fertilizer application (100 g organic per tree)
September 7th 2020	2nd weeding and fertiliser application (100 g organic per tree)
October 19th 2020	3rd weeding and fertiliser application (100 g organic per tree)
November 9th 2020	The end of 1st rainy season trees monitoring: R1
January 2021	Report of the end of 1st rainy season
Jan-May 2021	Fire prevention (organize through Watershed Office)
Rainy season 2021	4th weeding and fertiliser application (100 g organic per tree)
Rainy season 2021	5th weeding and fertiliser application (100 g organic per tree)
Rainy season 2021	6th weeding and fertiliser application (100 g organic per tree)
December 2021	The end of 2nd rainy season monitoring (R2)
January 2022	Final Report

Appendix IV -Project Task Schedule of 2021

Date	Task
May 18th 2021	Financial and planning online meeting with CDSC
May 19th 2021	Sending letter to DS HQ
May 19th 2021	Contract signing
May 30th 2021	Planting preparation: • Weeding
Jun 9th 2021	Planting preparation: • Bamboo poles staking • 50% of holes digging • Transport fertilizer to the sites
Jun 11st 2021	Planting day • 50 % of holes digging • transport seedlings to the site by CDSC school
Jun 26th 2021	Baseline monitoring of planted trees (BL)
Jul 26th 2021	1st weeding and fertilizer application (100 g organic per tree)
Sep 27th 2021	2nd weeding and fertiliser application (100 g organic per tree)
Oct 25th 2021	3rd weeding and fertiliser application (100 g organic per tree)
Nov 17th 2021	The end of 1st rainy season trees monitoring (R1)
Jan 2022	Report of the end of 1st rainy season
Jan-May 2022	Fire prevention (organize through Watershed Office)
May 16th 2022	4th weeding and fertiliser application (100 g organic per tree)
July 26th 2022	5th weeding and fertiliser application (100 g organic per tree)
Sep 27th 2022	6th weeding and fertiliser application (100 g organic per tree)
Nov 27th 2022	The end of 2nd rainy season monitoring (R2)
Jan 2023	Final Report

Appendix V -Trees at the CDSC nursery

Scientific Name	*Cassia bakeriana* Craib	*Protium serratum* (Wall. ex Colebr.)	*Rothmannia sootepensis* (Craib) Bremek.	*Hymenodictyon orixense* (Roxb.) Mabb.
Family	**Leguminosae**	**Burseraceae**	**Rubiaceae**	**Rubiaceae**
Common Name (English)	Wishing Tree, Pink Shower	Indian Red Pear		
Common Name (Thai)	Gan-la-pa-pruek (กัลปพฤกษ์) Ga-la-pruek (กาลพฤกษ์)	Ma Phan (มะแฟน)	Salaeng Hom Kai (สะแล่งหอมไก่)	U Lok (อุโลก)
Common Name (German)				
Height	6-12 meters	10-25 meters	up to 10 meters	up to 25 meters
Habitat	Bamboo forest, mixed forest, evergreen forest	Bamboo forest, deciduous forest, evergreen forest, disturbed forest	Deciduous forest, evergreen forest	Deciduous forest
Altitude Range	800-1350	200-1500	450-1250	100-1500
Flowering Season	Feb - Apr	Feb - Oct	Jan - May	May - Jun
Fruiting Season	Sep - Apr	Jun - Oct	Jul - Jun	May - Dec
Uses	Pods - laxative	The fruits are used in the treatment of mouth ulcers.		The bitter bark is used in local medicine as an antiperiodic, astringent and febrifuge. It contains scopoletin and a very bitter glycoside.
Seeds				
Seedlings				
Blossom/Fruit				
Tree				
Greuk's seedling growth stage photos				

Scientific Name	*Mesua ferrea* L.	*Choerospondias axillaris* (Roxb.) B.L.Burtt & A.W.Hill	*Terminalia chebula* Retz.
Family	**Calophyllaceae**	**Anacardiaceae**	**Combretaceae**
Common Name (English)	Ironwood	Himalayan Ambarella	Black Myrobalan
Common Name (Thai)	Boon Nak (บุนนาค)	Ma Kak (มะกัก)	Sa Mor Thai (สมอไทย)
Common Name (German)			
Height	30-45 meters	10-40 meters	up to 25 meters
Habitat	Evergreen forest, evergreen forrst with bamboo	Mixed, evergreen forest, evergreen with pine and bamboo	Deciduous forest, bamboo forest, mixed evergreen forest
Altitude Range	60-1500	460-1600	60-850
Flowering Season	May - Jun	Jan - Mar	Mar - Jul
Fruiting Season	Jun - Jul	Mar - Aug	Aug - Feb
Uses	Medicine use, edible nut	Edible fruit	Traditional medicine
Seeds			
Seedlings			
Blossom/Fruit			
Tree			
Greuk's seedling growth stage photos			

Appendix VI -End-of-1st-rainy-season monitoring data by species in declining order of RSPI of 2020 plot

S.no.	Species	Height (cm.)	RCD (mm.)	Crown Width (cm.)	Number of alive trees	Definitely Alive (%)	Indeterminate (%)	Appear Dead (%)	Average RGR RCD	Relative Species Performance index (RSPI) (%)
5	*Melia toosendan*	199	25.26	132	47	94	4	2	466	100.00
36	*Phyllanthus emblica*	84	13.51	101	22	88	8	4	229	46.09
449	*Bauhinia variegata*	92	14.52	72	48	96	4	0	208	45.64
22	*Ficus capillipes*	66	11.13	54	21	84	12	4	234	44.83
183	*Terminalia chebula*	58	7.41	33	93	78	18	4	223	39.49
255	*Trewia nudiflora*	106	24.04	76	22	88	12	0	184	37.06
13	*Sapindus rarak*	96	12.69	70	50	91	9	0	177	36.81
425	*Spondias lakonensis*	91	15.66	84	37	74	24	2	217	36.70
323	*Erythrina stricta*	85	21.50	72	24	48	38	14	332	36.38
216	*Eriobotrya bengalensis*	105	20.92	148	20	80	20	0	199	36.26
161	*Alangium kurzii*	81	12.13	49	33	66	22	12	231	34.86
131	*Protium serratum*	82	16.17	53	26	79	21	0	191	34.37
241	*Eugenia fruticosa*	90	13.84	55	23	92	8	0	144	30.34
195	*Terminalia bellirica*	60	12.21	45	40	80	18	2	166	30.33
118	*Adenanthera microsperma*	69	15.59	69	45	90	8	2	138	28.27
121	*Careya arborea*	38	9.48	45	42	84	16	0	144	27.64
65	*Xylia xylocarpa*	48	10.11	55	19	76	24	0	146	25.36
129	*Artocarpus lakoocha*	89	11.40	53	43	86	14	0	115	22.62
133	*Afzelia xylocarpa*	62	14.39	33	25	100	0	0	87	19.75
66	*Choerospondias axillaris*	65	7.52	57	15	33	22	44	251	19.12
91	*Gluta usitata*	60	12.31	37	22	88	4	8	92	18.39
26	*Dalbergia cultrata*	38	6.97	25	18	90	10	0	87	17.79
450	*Polyalthia viridis*	72	12.62	46	45	90	8	2	77	15.92
162	*Mesua ferrea*	35	4.06	23	12	60	40	0	91	12.49
41	*Cassia bakeriana*	23	2.71	11	7	30	52	17	77	5.33

Appendix VII -End-of-2st-rainy-season monitoring data by species in declining order of RSPI of 2020 plot

S.no.	Species	Height (cm.)	RCD (mm.)	Crown Width (cm.)	Number of alive trees	Definitely Alive (%)	Indeterminate (%)	Appear Dead (%)	Average RGR RCD	Relative Species Performance index (RSPI) (%)
5	*M. toosendan*	360.88	465.996	410.06	42	84	16		118.896	100
118	*A. microsperma*	131.59	137.610	178.08	42	84	14	2	81.321	68
449	*B. variegata*	163.19	208.747	256.05	38	76	24		80.154	61
255	*T. nudiflora*	224.95	184.475	274.03	16	64	32	4	89.96	58
216	*E. bengalensis*	171.08	198.544	319.42	19	76	24		73.945	56
36	*P. emblica*	116.03	229.429	348.37	21	84	16		64.458	54
65	*X. xylocarpa*	136.66	146.178	135.95	18	72	28		74.967	54
13	*S. rarak*	204.22	177.367	217.7	43	78.18	20	1.82	56.786	44
121	*C. arborea*	148.15	144.117	169.91	38	76	24		54.973	42
129	*A. lakoocha*	98.57	115.205	226.61	34	68	28	4	61.553	42
22	*F. capillipes*	184.29	233.752	297.48	15	60	40		67.164	40
131	*P. serratum*	137.78	175.113	132.71	21	63.64	36.36		63.234	40
241	*E. fruticosa*	93.68	144.467	204.66	14	56	40	4	68.934	39
26	*D. cultrata*	-10.79	86.586	-6.46	12	60	25	15	61.651	37
195	*T. bellirica*	106.28	166.059	209.49	27	54	46		68.209	37
133	*A. xylocarpa*	54.68	86.533	137.53	18	72	28		43.668	31
323	*E. stricta*	171.56	331.992	336.82	14	28	66	6	99.786	28
183	*T. chebula*	133.59	223.189	155.93	63	52.5	45.83	1.67	51.63	27
425	*S. lakonensis*	199.53	217.267	299.72	20	40	58	2	66.416	27
66	*C. axillaris*	168.28	251.313	346.07	12	26.67	51.11		96.589	26
450	*P. viridis*	18.11	77.493	157.39	23	46	52	2	26.256	12
41	*C. bakeriana*	-58.08	76.784	-155.92	2	8.7	91.30		99.267	9
161	*A. kurzii*	83.03	231.376	242.76	6	12	80	8	72.004	9
91	*G. usitata*	31.52	91.562	82.31	4	16	80	4	38.888	6
162	*M. ferrea*	70.17	91.169	66.17	1	5	85	10	47.022	2

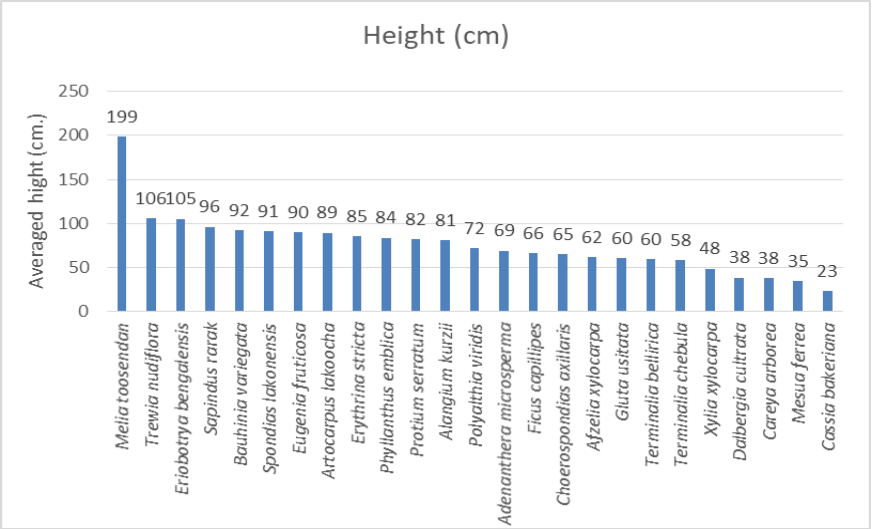
Appendix VIII -End-of-1st-rainy-season monitoring data by species in declining order of RSPI of 2021 plot

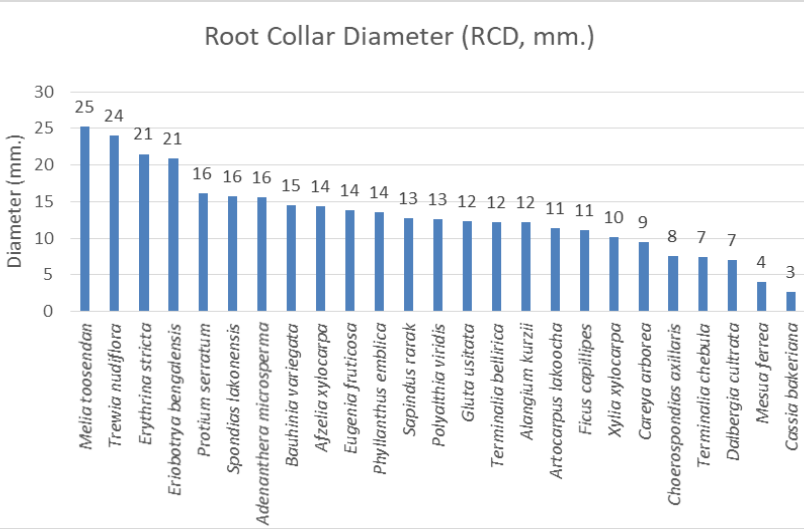
S.no.	Species	Height (cm.)	RCD (mm.)	Crown Width (cm.)	Number of alive trees	Definitely Alive (%)	Indeterminate (%)	Appear Dead (%)	Average RGR RCD	Relative Species Performance index (RSPI) (%)
41	*C. bakariana*	123.92	15.633	106.71	37	80.4	17.4	2.2	390.048	100.00
500	*M. rajaniana*	87.37	16.064	68.21	19	90.5	9.5		202.310	58.34
233	*B. ramiflora*	60.34	9.951	39.76	19	90.5	9.5		170.615	49.20
415	*H. odorta*	73.94	9.478	63.40	40	75.5	24.5		184.099	44.29
449	*B. variegata*	60.09	9.654	66.45	21	80.8	15.4	3.8	166.061	42.75
129	*A. lakoocha*	68.00	8.363	33.80	15	75	25		130.025	31.08
232	*D. turbinatus*	57.73	8.281	47.73	15	75	25		116.511	27.85
120	*G. cowa*	31.78	5.793	21.67	16	72.7	22.7	4.5	105.536	24.46
448	*S. cumini*	96.14	13.316	59.21	14	70	30		107.471	23.98
277	*P. xestophylum*	23.15	4.381	20.38	11	55	35	10	124.311	21.79
170	*C. subulatum*	100.87	12.047	64.07	14	70	25	5	94.763	21.14
195	*T. bellirica*	85.67	18.072	56.19	21	100			60.782	19.37
4	*B. javanica*	68.33	12.488	61.44	9	45	55		110.469	15.84
3	*G. xanthochymus*	56.11	10.964	49.65	17	81	19		61.170	15.78
31	*A. fraxinifolius*	68.50	8.069	45.00	10	50	45	5	83.610	13.32

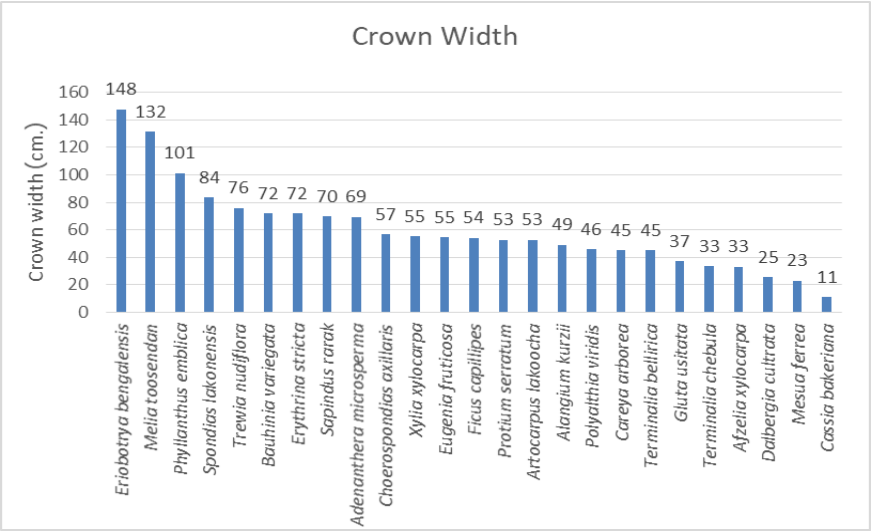
Appendix IX-End-of-2st-rainy-season monitoring data by species in declining order of RSPI of 2021 plot

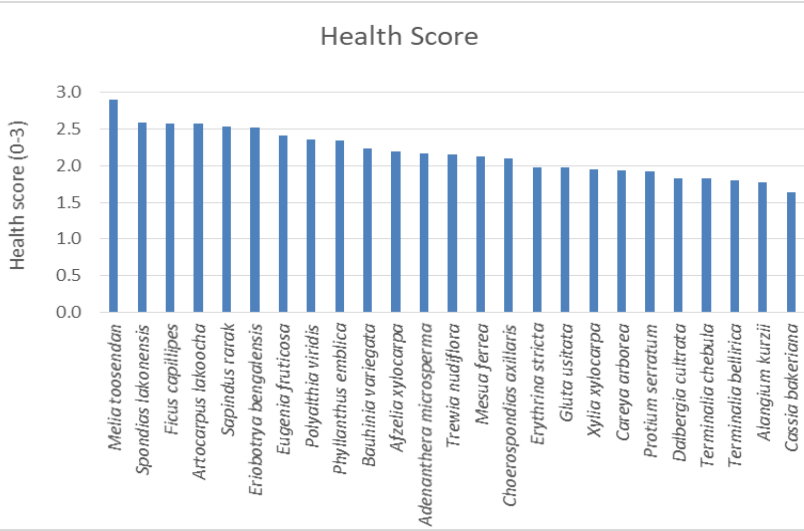
S.no.	Species	Height (cm.)	RCD (mm.)	Crown Width (cm.)	Number of planted trees	Definitely Alive (%Survival)	Appear Dead (% Mortality)	Average of RGR RCD	Relative Species Performance index (RSPI) (%)
41	*C. bakariana*	277	48.44	345	46	67.4	32.6	165.06	100.00
500	*M. rajaniana*	207	40.78	158	21	76.2	23.8	121.96	83.54
449	*B. variegata*	162	21.60	124	26	69.2	30.8	108.92	67.79
415	*H. odorta*	176	20.42	119	53	58.5	41.5	111.76	58.77
233	*B. ramiflora*	104	16.18	84	21	61.9	38.1	92.40	51.42
195	*T. bellirica*	133	56.91	108	21	81.0	19.0	69.92	50.88
129	*A. lakoocha*	150	17.55	63	20	60.0	40.0	91.82	49.53
232	*D. turbinatus*	137	19.32	96	20	55.0	45.0	95.42	47.18
448	*S. cumini*	124	21.08	67	20	65.0	35.0	71.06	41.53
170	*C. subulatum*	210	29.24	125	20	50.0	50.0	83.83	37.68
4	*B. javanica*	189	30.23	108	20	40.0	60.0	92.82	33.38
120	*G. cowa*	60	10.78	45	22	45.5	54.5	70.81	28.93
3	*G. xanthochymus*	93	15.87	69	21	61.9	38.1	49.06	27.30
277	*P. xestophylum*	67	9.39	52	20	20.0	80.0	85.18	15.32
31	*A. fraxinifolius*	355	32.46	119	20	15.0	85.0	83.29	11.23

Appendix X – Species graphed results of BMM CDSC 2020 end 1st rainy season

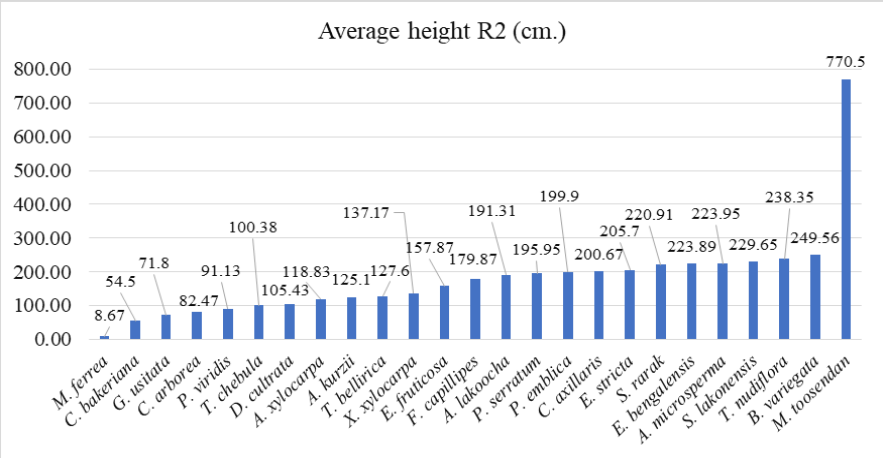


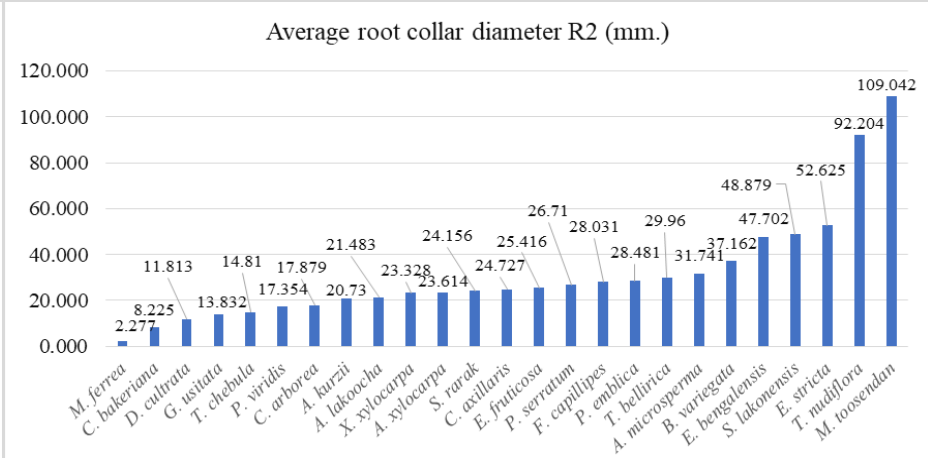


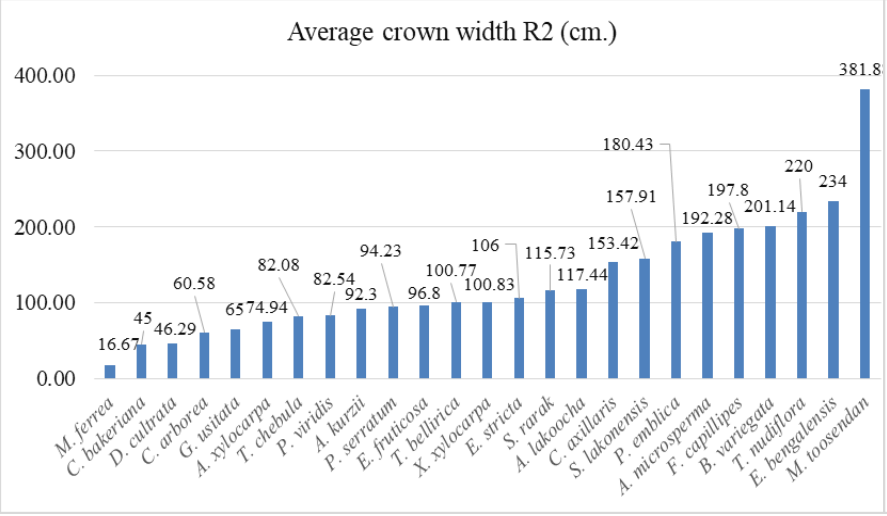


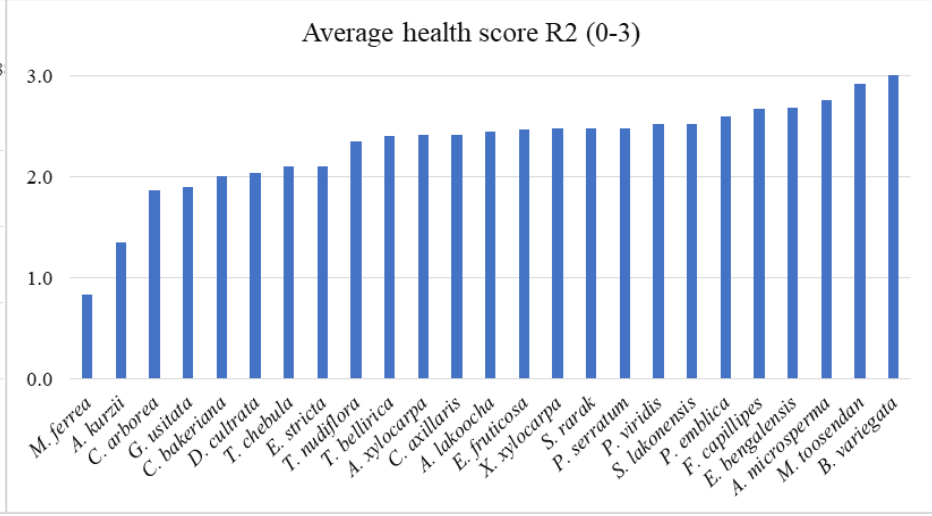


Appendix XI – Species graphed results of BMM CDSC 2020 end 2nd rainy season

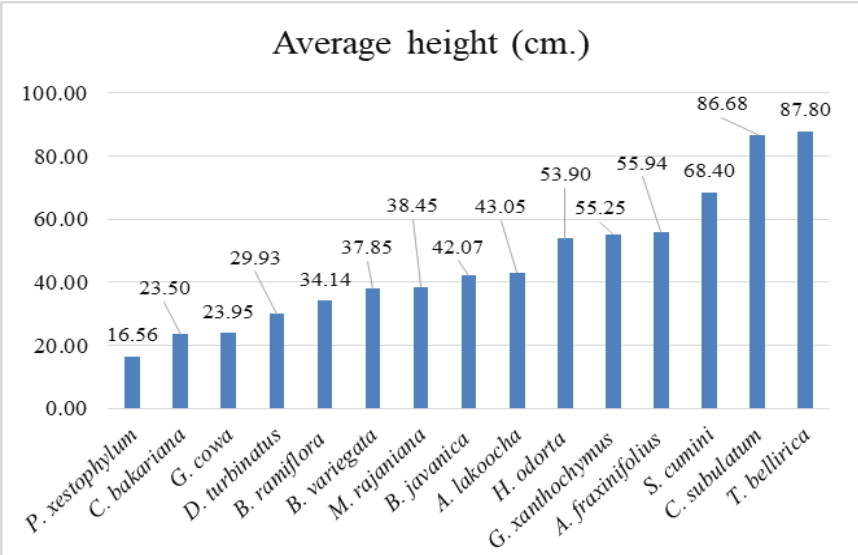


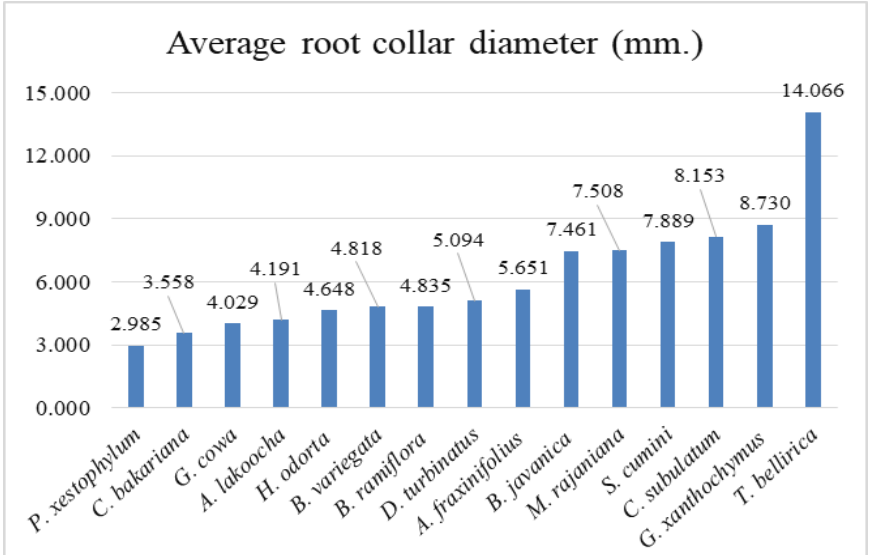


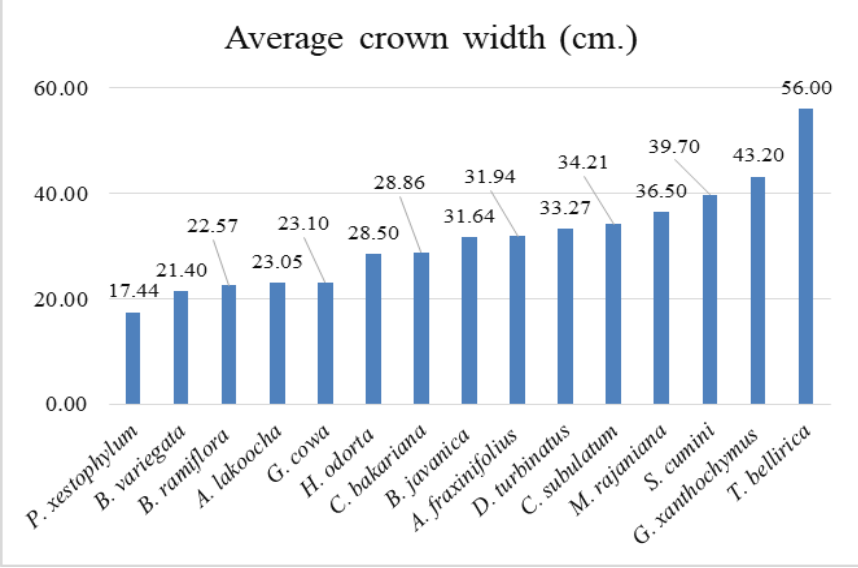


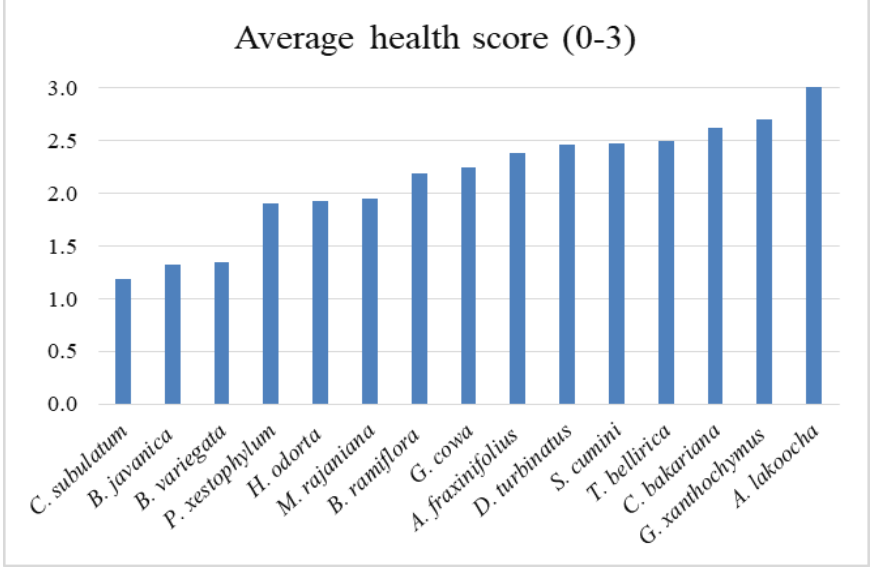


Appendix XII – Species graphed results of 2021 plot end 1st rainy season

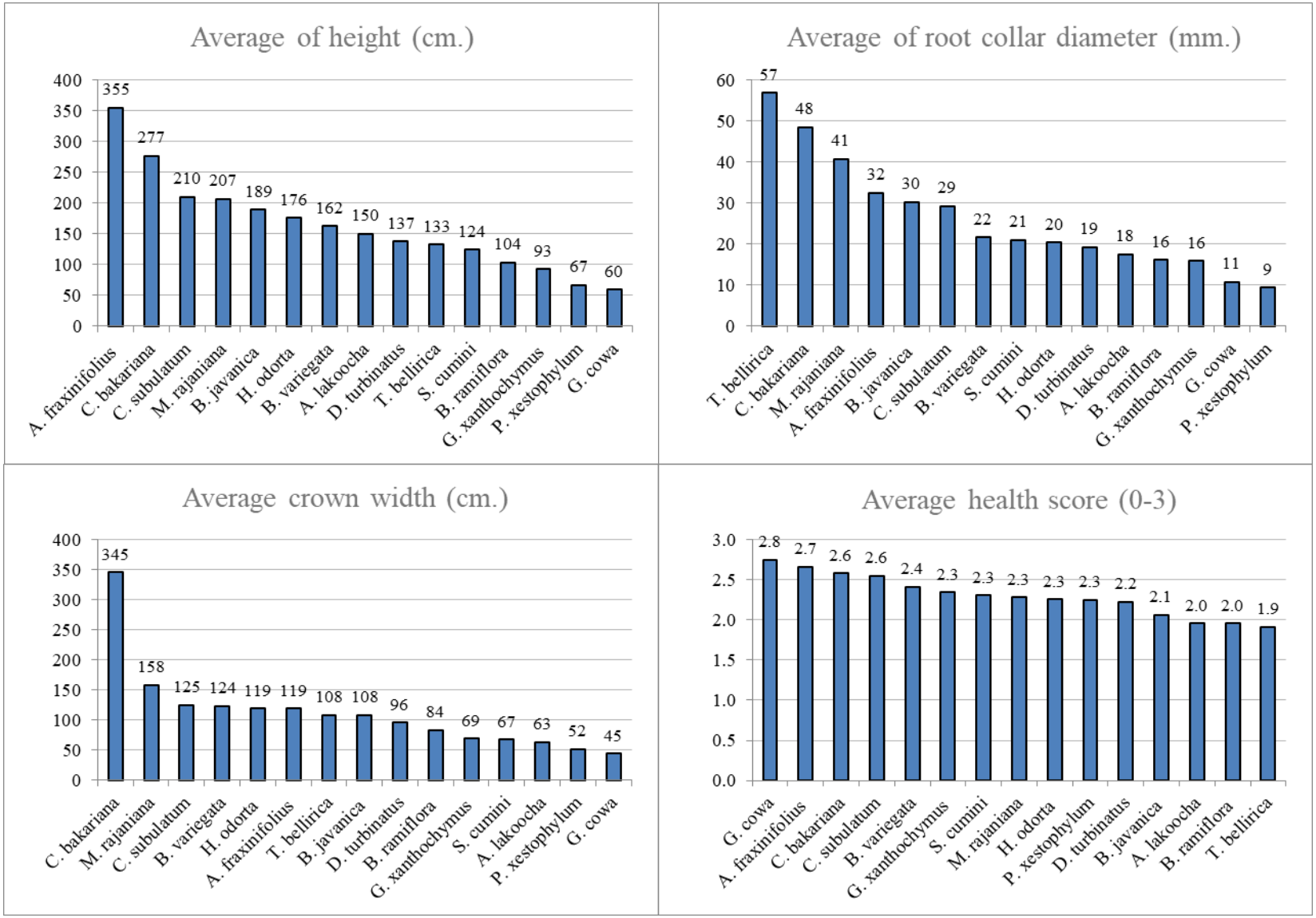




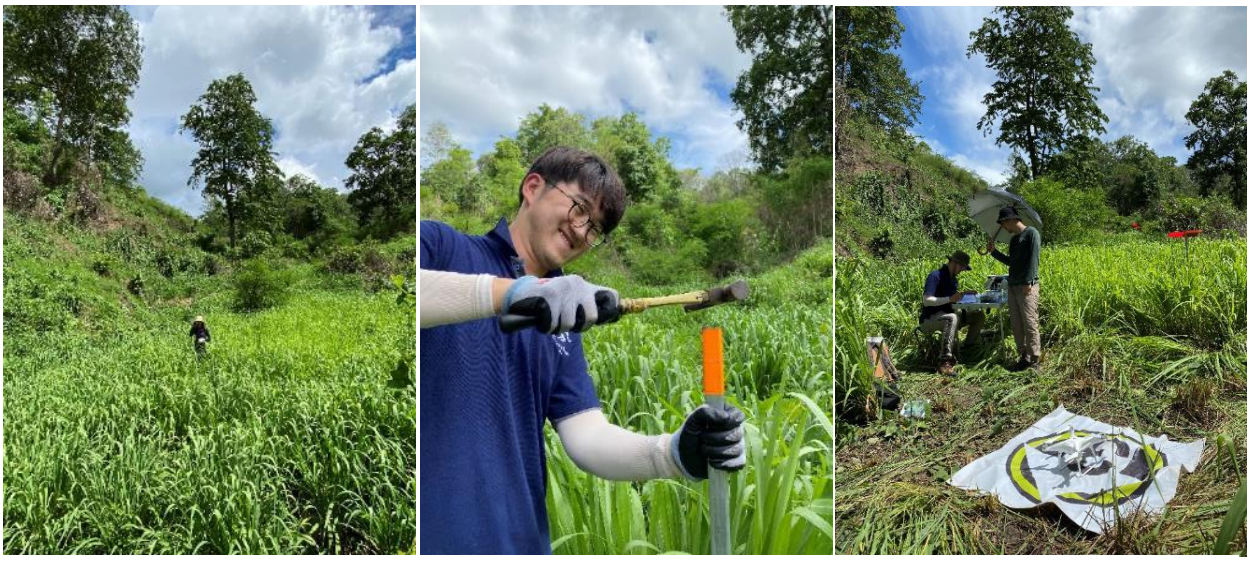




Appendix XIII – Species graphed results of 2021 plot end 2rd rainy season



Appendix XIV – Photo album



Site preparation of BMM CDSC 2020 plot

Planting day of 2020 plot

CDSC pupils, FORRU staff and volunteers are involved 2020 plot during 1st and 2nd year maintenance

The end of 1st and 2nd rainy season monitoring of 2020 plot

FORRU-CMU staff did photo monitoring of BMM CDSC 2020 plot

Site preparation of BMM CDSC 2021 restoration

Planting activity of BMM CDSC 2021 restoration plot

Photo monitoring of BMM CDSC 2021 restoration plot in November 2021 (5 months)

Photo monitoring of BMM CDSC 2021 restoration plot in May 2022 (1 year old)