CDSC FOREST 2022

Project Title:	CDSC Forest 2022
Grant Amount:	78,111 THB
Donors:	CHRISTLICHE DEUTSCHE SCHULE CHIANG MAI (CDSC)
Project Duration:	1/06/2022 and 31/01/2024
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Checked by:	Steve Elliott

Introduction

This project arose from an initial request from CDSC in 2019 for scientific advice and technical assistance with a tree-planting project, aimed at offsetting the school's carbon footprint and providing environmental education opportunities for pupils. The project planted trees twice at Ban Meh Meh in June 2020 and 2021. The project reported continues the school's efforts to offset carbon emissions and by planting 600 trees at Mon Cham view point, in collaboration with the Royal Project (who exercises responsibility for the site), the Ban Pong Khrai Watershed Unit and the nearby Hmong community of Ban Nong Hoi. The planting complements efforts to restore forest cover to the site ongoing since 2012-13 originally supported by Rajapruek Institute Foundation and Plant a Tree Today Foundation. Two rai of the restoration site was allocated to CDSC for planting 600 trees, according to the rapid site assessment, performed on 21/4/22, and the site map made from droning on 25/4/22.

Objectives: -

- to plant 600 trees of species that are indigenous to evergreen forest for ecosystem restoration (complementing natural regeneration),
- to offset about 180 tonnes of CO_2 emissions over 14 years, as the trees grow and
- to provide environmental education opportunities for the school's pupils.

Planting site description and map

The plot is degraded agricultural land, with a patchy history of tree planting with limited results. adjacent to a patch of upland evergreen forest. The plot was dominated by herbaceous weeds and grasses, beneath which tree seedling/saplings occurred sparsely. There were very few tall trees. This constitutes Stage 3 degradation, with recommended action of complementing ANR (assisted natural regeneration by weeding around natural regenerants) with planting framework tree species, to raise the initial stocking density above 3,000/ha). The Mon Cham site is also being used for educational events, such as tree planting maintenenance and monitoring including return of forest animals via camera trapping.

Rapid Site Assessment (RSA)

An RSA was performed on 21st April 2022, to determine the density of natural regenerants across the site, and to identify that tree species that are present as seedlings, saplings or live tree stumps. Hand-held GPS was used to map the plot boundaries and calculate the total area. Four circular sample units (5 m radius) were placed across the site, within which the numbers of regenerants, signs of factors likely to hinder forest restoration (fire, cattle etc.) and weed cover were recorded. The average number of natural regenerants recorded was 178 per rai (extrapolated from the circle data). Variability on this site was exceptionally high 95% c.l. ±236 14/rai. Consequently, planting of 322 trees/rai was recommended, to raise initial tree stocking density to 500/rai (approx. 3000/ha). This is the optimal density, which FORRU-CMU has found initiates canopy closure in evergreen forest and starts to shade out weeds by the end of the 2nd rainy season after tree planting. Therefore, the total number of trees required for 2 rai was 644. However, this was rounded down to 600 for this project. The full results of the RSA are presented in Appendix 1. Fourteen species of natural regenerants were recorded during the RSA. Signs of cattle were not present, and evidence of previous fire was recorded in only one circle. Weed cover was high. Average height of weed canopy was 1-1.5 m. Effective fire prevention measures may still be necessary to protect the planted trees (according to Royal Project) and weeding will be necessary (and was included in the budget) (Table 1). Figure 1 shows the entire 12 rai site. The 2-rai outlined in red at the top is the area allocated to CDSC this year.

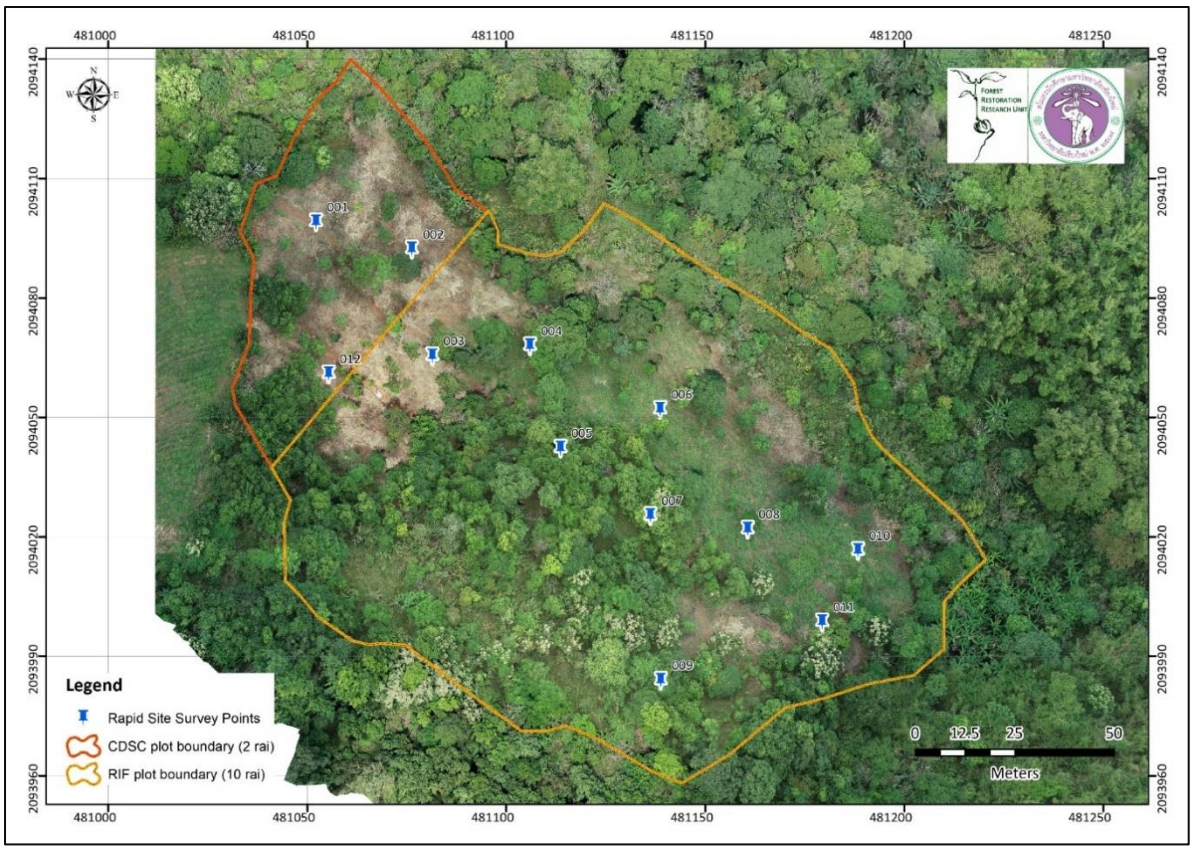


Figure 1 Orthomosaic from droning on 2022 April 25th showing the restoration site boundary. CDSC site is at the top outlined in red.

Table 1- Species of natural regenerants recorded during the rapid site assessment

No.	Thai name	Species
1	ตีนเป็ด (สัตตบรรณ)	*Alstonia scholaris*
2	เดื่อชัน	*Ficus Subulata*
3	จำปีป่า	*Michelia baillonii*
4	แคบิด	*Markhamia stipulata*
5	เสี้ยวป่า	*Bauhinia variegata*
6	กางหลวง	*Albizia chinensis*
7	หม่อนหลวง	*Morus macroura*
8	นางพญาเสือโคร่ง	*Prunus Cerasoides*
9	ซ้อ	*Gmelina Arborea*
10	หมีเหม็น	*Litsea Glutinosa*
11	ก่อ	*Lithocarpus sp.*
12	ทองหลาง	*Erythrina subumbrans*
13	มณฑาแดง	*Manglietia garrettii*
14	ประดู่ขาว	*Pterocarpus sp.*

Tree species planting list

Trees were provided from both the FORRU-CMU nursery at Ban Mae Sa Mai (210 trees of 7 species; Table 2) and from the Pong Khrai Watershed Nursery (390 trees of 13 species; Table 3). Thirty trees of each species were labelled for monitoring.

Table 2 Species donated from FORRU

S.no	Thai Name	Name	Recommended number of seedlings	LABELING
15	สลีนก	*Balakata baccata*	30	15_1-30
34	กางขี้มอด	*Albizia odoratissima*	30	34_1-30
41	กัลปพฤกษ์	*Cassia bakeriana*	30	41_1-30
72	กร่าง	*Ficus altissima*	30	72_1-30
78	ซ้อ	*Gmelina arborea*	30	78_1-30
115	ยมหอม	*Toona ciliata*	30	115_1-30
348	ไทรย้อยใบทู่	*Ficus microcarpa*	30	348_1-30
		TOTAL	210	

Table 3 Species donated from Pong Khrai Nursery

S.no	Thai Name	Name	Recommended number of seedlings	LABELING
190	ก่อแป้น	*Castanopsis diversifolia*	30	190_1-30
270	ก่อเดือย	*Castanopsis acuminatissima*	30	270_1-30
217	เก็ดขาว หรือกำพี้	*Dalbergia glomeriflora*	30	217_1-30
355	หว้า	*Syzygium cumini*	30	355_1-30
170	มะกอกเกลื้อน	*Canarium subulatum*	30	170_1-30
13	มะซัก	*Sapindus rarak*	30	13_1-30
195	สมอพิเภก	*Terminalia bellirica*	30	195_1-30
387	มะดะหลวง	*Garcinia xanthochymus*	30	387_1-30
118	มะกล่ำต้น	*Adenanthera pavonina*	30	118_1-30
294	มะขามป้อม	*Phyllanthus emblica*	30	294_1-30
138	จำปีป่า	*Magnolia baillonii*	30	138_1-30
415	ตะเคียนทอง	*Hopea odorata*	30	415_1-30
120	พะวา หรือชะมวง	*Garcinia cowa*	30	120_1-30
		TOTAL	**390**	

Site preparation

The site was initially cleared of weeds using hand tools in mid-April 2022, shortly before the rapid site assessment, when natural regenerants were marked with bamboo poles. A path was cut for easy access.

Planting Day

CDSC agreed to take care of moving planting stock to the site, staking and hole digging on planting day, scheduled on 9th June 2022. The program for planting day, provided by CDSC is presented in Table 4.

Figure 2 Planting day

Table 4 CDSC Planting Day Program

Time	Activities	Person in Charge
07:45 - 09:00	Driving to Pong Khrai Unit	David Hester
09:00 - 09:30	Bringing seedlings and tools to the planting plot	Calvin Ji
09:30 - 10:00	**1. Speeches** - Vice principal of CDSC (Markus Stüber) => Thank you and welcome speech - Director of the Watershed Management (Mr.Chatchai Naktippawan) - FORRU Co-Founder & Research Director (Dr. Stephen Elliott) **2. Planting demonstration by FORRU** **3. Group Photo**	David Hester FORRU Staff Calvin Ji
10:00 - 11:30	Planting trees	Watershed Management
11:30 - 12:00	Camera trap workshop	FORRU Staff (Aom)
12:00 - 13:00	Lunch Break	David Hester
13:00 - 13:30	Clean-up & class group photo	Calvin Ji
13:30 - 14:30	Driving back to CDSC	David Hester

Bamboo poles were used to mark the tree planting points 1.6-1.8 meters (m) apart (or equal distance from natural regenerants). Holes were dug approximately 30 x 30 centimeters (cm). After planting, approx. 100 grams (g) of fertilizer was applied around each sapling in a ring about 20-30 centimeters (cm) away from the tree stem.

The following planting equipment and materials FORRU were organized in advance:

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

Maintenance

Weeding and fertilizer application were performed 3 times over the first rainy season and are being implemented 3 times over the 2023 rainy season. This work was done jointly with Nong Hoy Royal project (NH-RDF) staff, local villagers CDSC pupils and volunteers. NH-RDF staff and villagers took care of fire prevention measures during the 2023 fire season. None of the plot system burnt this year.

Monitoring

Monitoring of tree survival and growth were performed with CDSC pupils, supervised FORRU-CMU staff, shortly after planting (baseline data) and at the end of the first rainy season (R1 monitoring). FORRU-CMU staff analyzed the data and results are presented below. Measurements included tree height and root collar diameter (RCD) to assess tee growth. For the small trees, Vernier calipers were used to measure RCD at the widest point. Tape measures were used to measure tree height from the root collar to the highest shoot tip and to measure crown width at the widest point. A simple health score was assigned to each tree and a descriptive note about any health problems observed recorded. A simple scale of 0 to 3 will be used to indicate overall health. The same scoring system was applied to weed cover (within 1 m of the tree stem) and for shade over the planted trees.

Post-planting baseline monitoring (BL)

Although the plan was to plant 600 labeled trees of 20 species across the site, (Tables 2 & 3) 2), only 591 were found during the BL survey. The rest may have been missed during the survey, or planted outside the CDSC area, or not labelled and were therefore assigned as "not planted". Therefore, the starting cohort size of trees for subsequent survival monitoring was established as 591. Of these, only 7 (1.2%) were recorded as dead, probably as a result of rough handing during the planting process. Species-specific averages for tree height are presented in Figure 3. All except 1 species were taller than the recommended 30 cm minimum, but several were oversized (>50 cm tall, mostly from the BPK nursery).

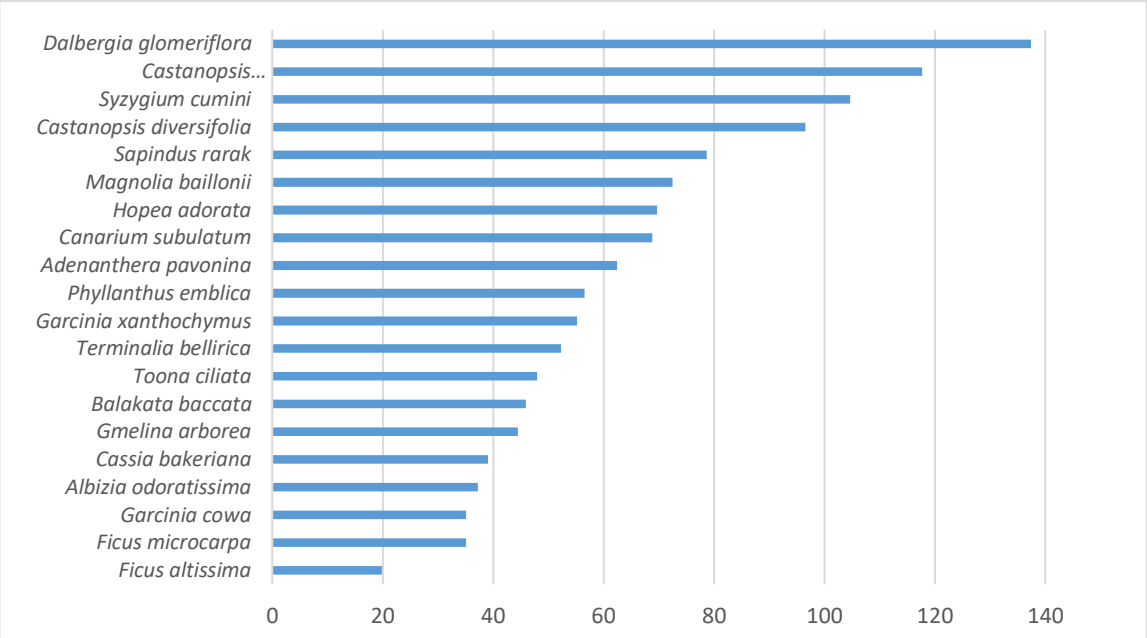


Figure 3: Average sapling height (cm) during the baseline survey for each of the 20 species planted

End of 1st rainy season monitoring (R1)

During R1 monitoring, 553 trees were recorded as alive and 38 were recorded as dead. A small number of "not found" trees were considered "probably alive" if the previous BL health score was high or "probably dead" if the previous BL health score was low. If such trees are found in subsequent surveys, their status will be back-dated accordingly. Therefore, overall survival was estimated to be about 94%, which is considered "excellent" survival. This was almost the same rate as recorded in the adjacent plot (96%), planted by Rajapruek Institute Foundation (RIF). Species specific survival is shown in Figure 4. All species maintained 70% survival or higher and 7 maintained 100% survival which is considered an excellent result.

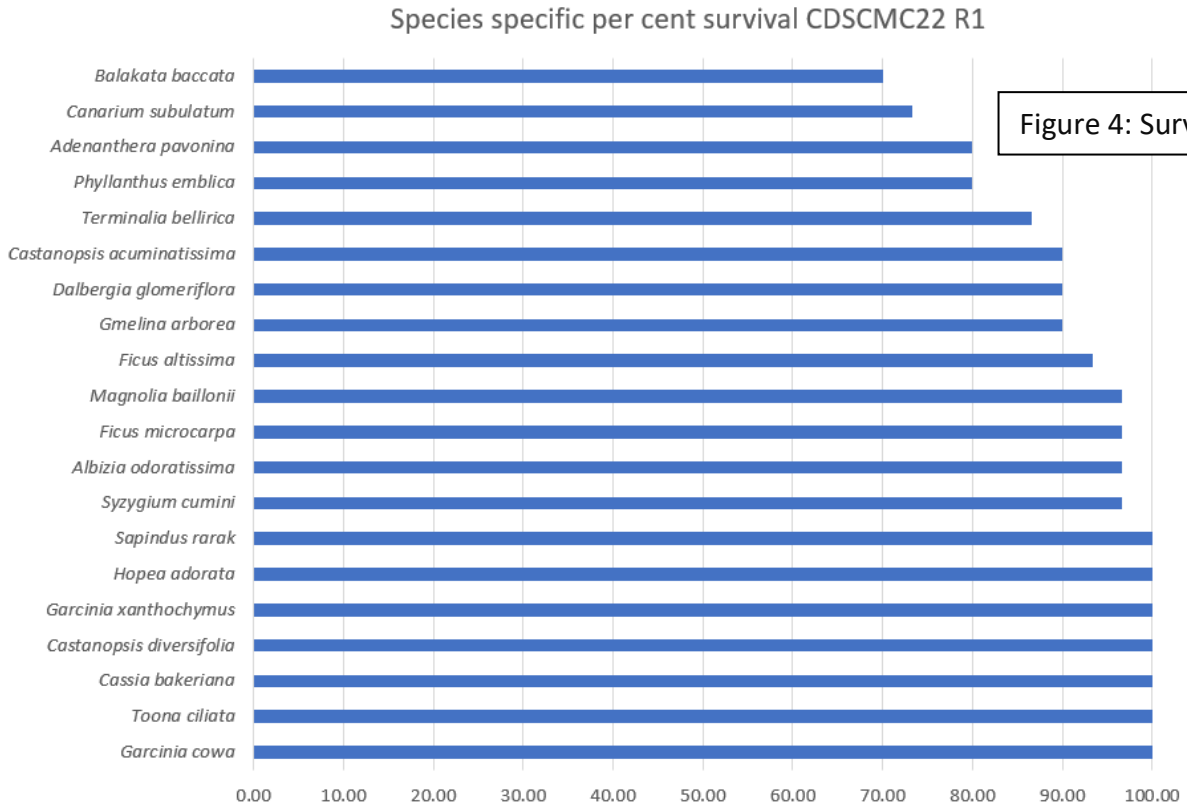


Figure 4: Survival R1

However, relative growth rate of root collar diameter (RGR-RCD) was considered low for this plot. Only 6 of the 20 species exceeded the acceptable standard of 50%/y (Figure 5) and several species had negative growth rates indicating die-back: *Adenanthera pavonina, Sapindus rarak, Ficus altissima* and *Hopea odorata.* This is in contrast to the adjacent RIF plot where 15 out of 22 species exceeded mean RGR-RCD values of 50%/y and none were negative, although even there, growth rates were lower than we usually record in other FORRU plots. Two differences in planting conditions may account for the difference in RGR values between the CDSC and RIF plots:

1) During site preparation, weeds in the CDSC were slashed (but not uprooted), whereas glyphosate herbicide was applied to clear the weeds in the RIF plot
2) All seedlings in the RIF came from the BMSM nursery, whereas most of those in the CDSC plot came from the BPK Watershed unit nursery.

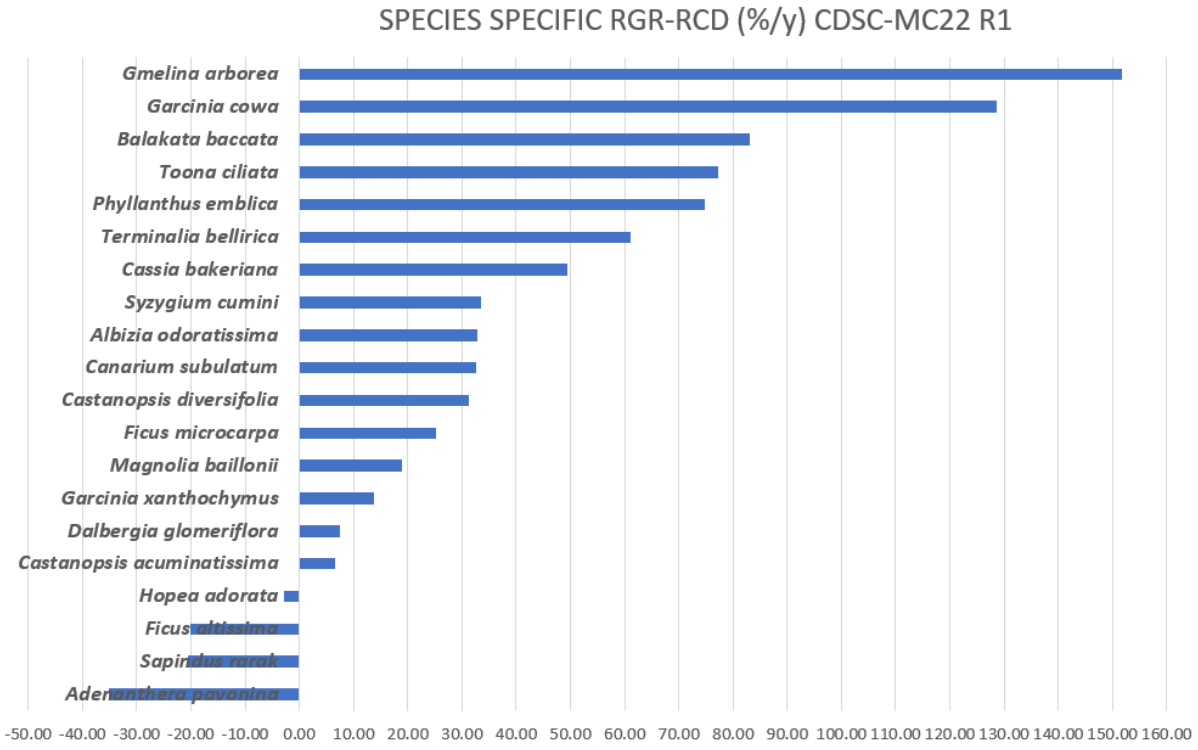


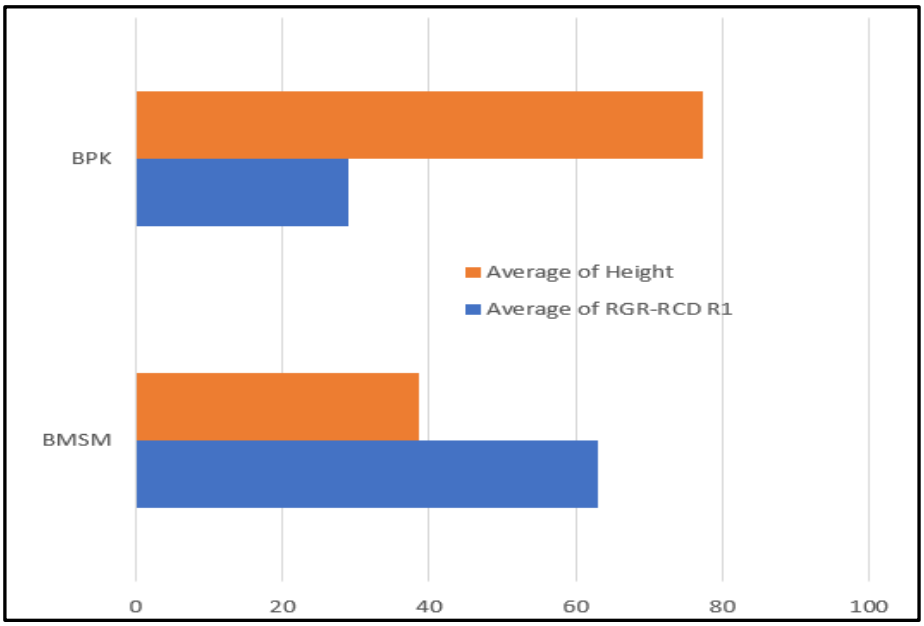
Figure 5: Species-specific growth rates at the end of the first rainy season.

The difference between the two weeding methods is evident in Figure 6.

Figure 6: The difference between the weed treatments of the CDSC plot (left) and the RIF plot (right)

Figure 6 shows that for the saplings from the BMSM nursery, the mean RGR-RCD across all 7 species was 63.0 %/y (with one negative value), whereas the mean RGR-RCD across all 13 species obtained from the BPK Watershed nursery 29.1% (including 3 negative values. As mentioned above, many of the saplings from BPK were oversized, which may have resulted in transplantation shock. This occurs when loss of root connectivity during planting results in failure to deliver enough water to large sapling crowns, resulting in wilting. Figure 6 shows that the mean heights of saplings from the BPK nursery was almost 80 cm (30 cm taller than the recommended maximum to avoid transplantation shock), which may have been responsible for the low RGR-RCD. In contrast, the saplings from FORRU's BMSM nursery averaged 38 cm tall (within the 30-50 cm recommended range), resulting in a healthier RGR-RCD, almost double that of the BPK saplings (Figure 6).

Figure 6: Size at planting time and RGR-RCD compared between planting stock from the Ban Mae Sa and Ban Pong Khrai nurseries.
and the RIF plot.



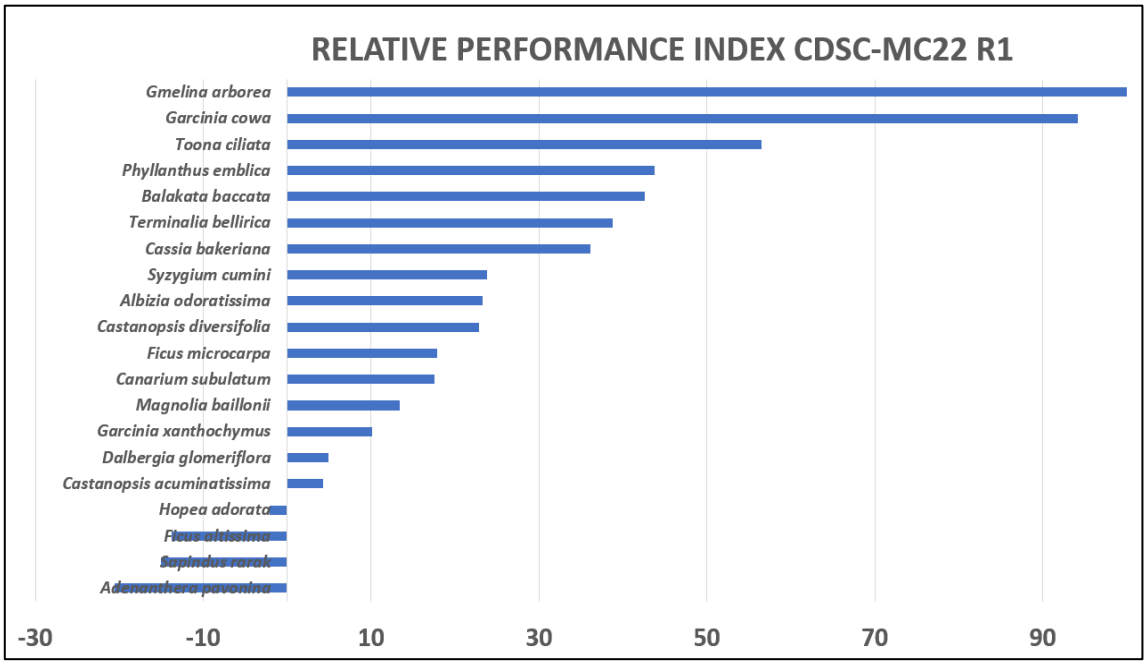


Figure 7: Relative species performance index

Standardized survival and growth data were multiplied to produce an overall performance index, which was converted into a relative performance index (RPI) by expressing each species' performance score as a percentage of the highest performing species (*Gmelina arborea*) (Figure 7). *Toona ciliata* and *Garcinia cowa,* achieved excellent relative performance, whilst *Phyllanthus emblica, Balakata baccata, Terminalia bellirica, Cassia bakeriana,* attained good relative performance.

Carbon Monitoring

RIF are kindly supporting carbon monitoring of this site compared with the reference forest (on the ridge above the planting site), a control site (where no trees were planted) and a former 10-year older restoration plot.

Initial results highlighted once again the effectiveness of the FSM in sequestering carbon (Figure 8). The carbon density in reference forest at Mon Cham was 177.85 tC/ha. In the 10-year-old restoration plot carbon levels had already reached 138.86 tC/ha, i.e. 78% of the reference forest value. Due to the absence of trees at the control plot, carbon levels were low there 25.70 tC/ha almost entirely in the soil, whereas in the plots planted on 2022, carbon levels were slightly higher mostly due to some sparse pre-existing tree cover. The potential for further carbon sequestration in the CDSC plot is therefore in the order of about 100 tC/ha over the next 10 years or so, which is equivalent to 33 tC over the 2-rai area planted.

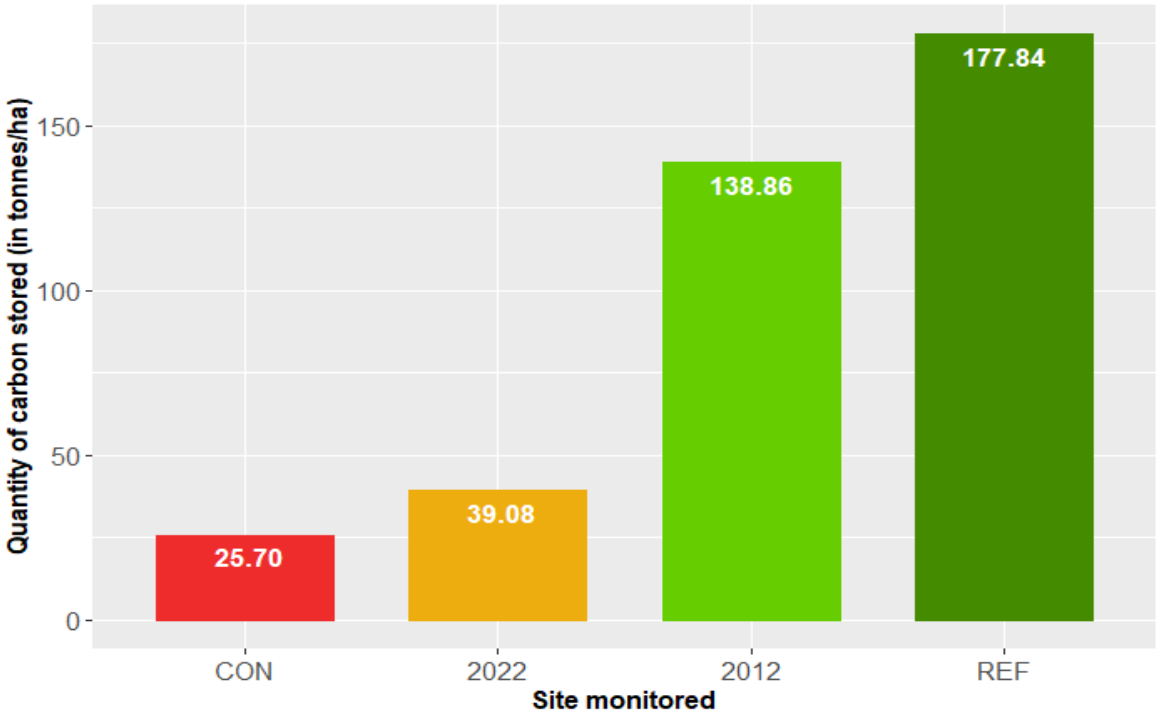


Figure 8 - Average quantity of carbon stored in each of the site surveyed in tonnes/ha for CO_2 multiply by 44/12.

Conclusions

- Survival of most species is good or excellent
- Some of the larger saplings may have been affected by transplantation shock, resulting in lower than ideal growth over the first rainy season.
- Relative performance was lower than expected for many of the species planted, probably because of lower growth rates of oversized saplings.
- Comparing with the adjacent site, evidence from the study supports effectiveness of using glyphosate to initially clear weeds prior to planting.
- Sequestration of 30 tonnes of carbon (=110 tons CO_2) is likely over the 2-rai planted over the next ten years contributing substantially towards offsetting the school's carbon footprint.

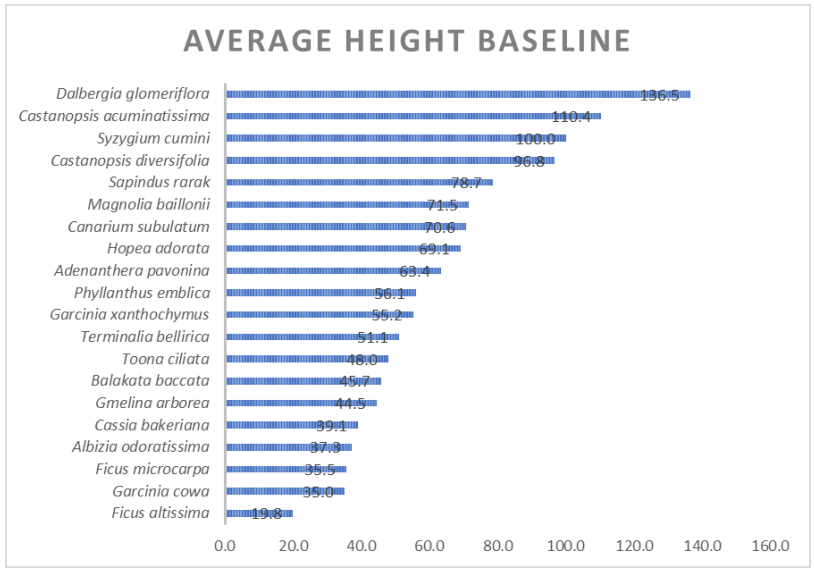
Appendix I- rapid site assessment detailed results

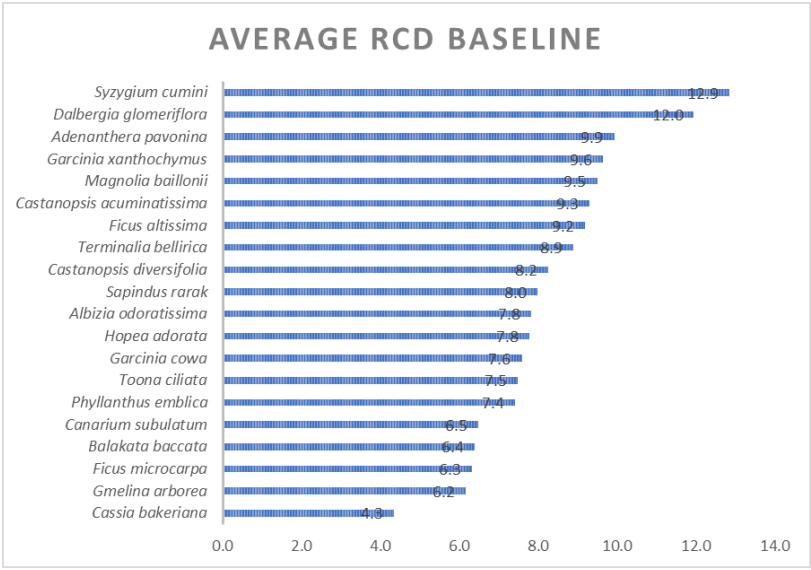
RAPID SITE ASSESSMENT									
Site: CDSC MC 2022						**Recorder: Worayut (Nan)**		**Date: 2022 April, 21st**	
Circle	**Latitude (N)**	**Longtitude (E)**	**Livestock signs**	**Fire signs**	**Weeds - %cover/mean height/ ± tree seedlings**	**No. trees >50 cm tall (<30 cm gbh)**	**No. live tree stumps**	**No. trees>30 cm gbh**	**Total No. regenerants**
1	18.939103	98.820039	Not Found	Not Found	100% cover / 2-4 m.	**7**	**1**	**0**	**8**
2	18.939041	98.820268	Not found	Not found	100% cover / 2 m.	**0**	**0**	**2**	**2**
3	18.938799	98.820317	Not Found	Not Found	90% cover / 1-2 m.	**0**	**6**	**0**	**6**
12	18.938758	98.820070	Not found	Found	90% cover / 1-2 m.	**8**	**10**	**1**	**19**
					TOTALS	**15**	**17**	**3**	**35**
Site description							**(= total/12)**	**Mean**	**8.8**
							(= mean x 1,600/78.5)	**Average /Rai**	**178.3**
							95% c.l.		**235.9**
							Recommended planting density per rai		**322**

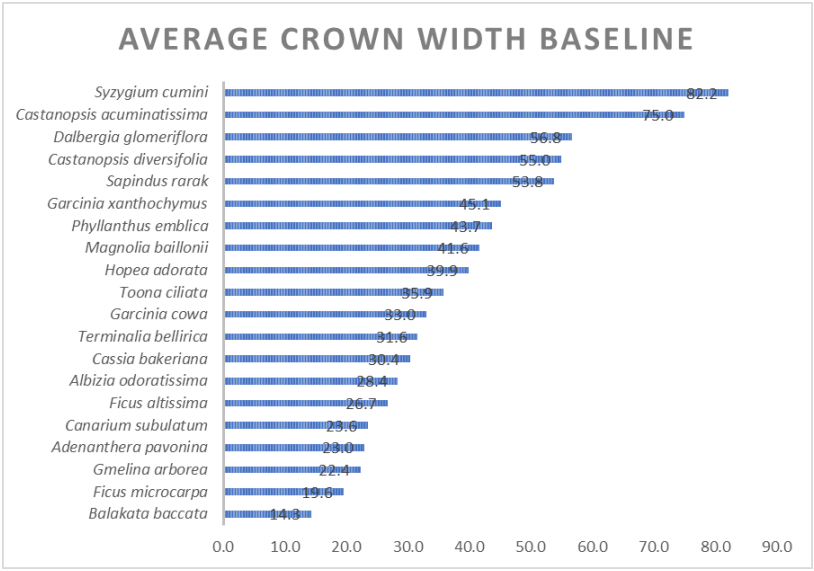
Appendix II - Provisional Project Task Schedule (greyed rows are completed tasks)

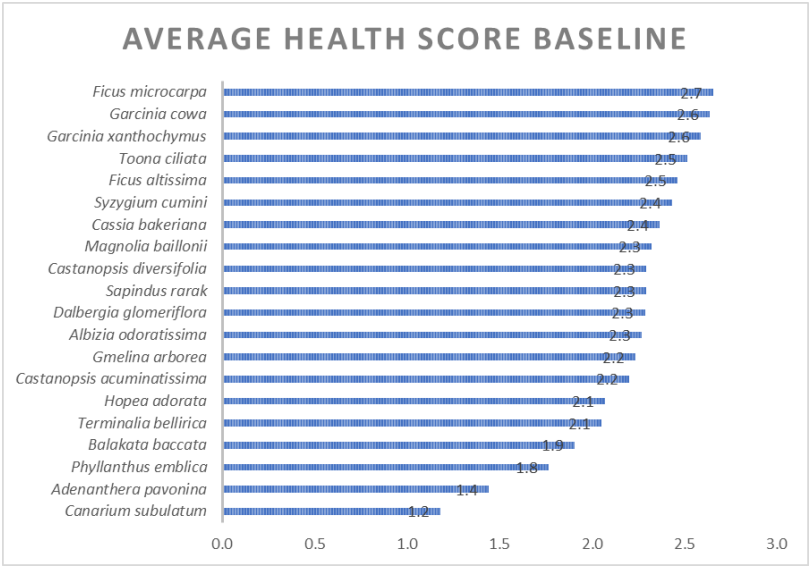
Date	Activity
Nov 2021 to Apr 2022	Site selection
April 2022	Site map prepared from drone imagery
Mid May	Project plan produced
Late May 2022	Site preparation: mark natural regenerants with bamboo poles and weeding cutting.
Early June 2022	Labelling seedlings ready for monitoring
9th June 2022	Transport seedling from watershed unit to entrance plot. Planting preparation transport seedlings, bamboo poles and fertilizer to the sites, hole digging. Planting trees – with CDSC pupils
16th August 2022	1st weeding and fertilizer application (100 g organic per tree) Baseline report
26th August 2022	Baseline monitoring of planted trees (BL)
5th October 2022	2nd weeding and fertiliser application (100 g organic per tree)
3rd November 2022	3rd weeding and fertiliser application (100 g organic per tree)
26th November 2022	The end of 1st rainy season trees monitoring (R1) – with CDSC pupils
February 2022	Fire prevention (Nong Hoy Royal Project)
June 2023	Report of the end of 1st rainy season
Late June 2023	4th weeding and fertiliser application (100 g organic per tree)
Mid-August 2023	5th weeding and fertiliser application (100 g organic per tree)
Early October 2023	6th weeding and fertiliser application (100 g organic per tree)
Late October 2023	The end of 2nd rainy season monitoring (R2)
December 2023	Final Report

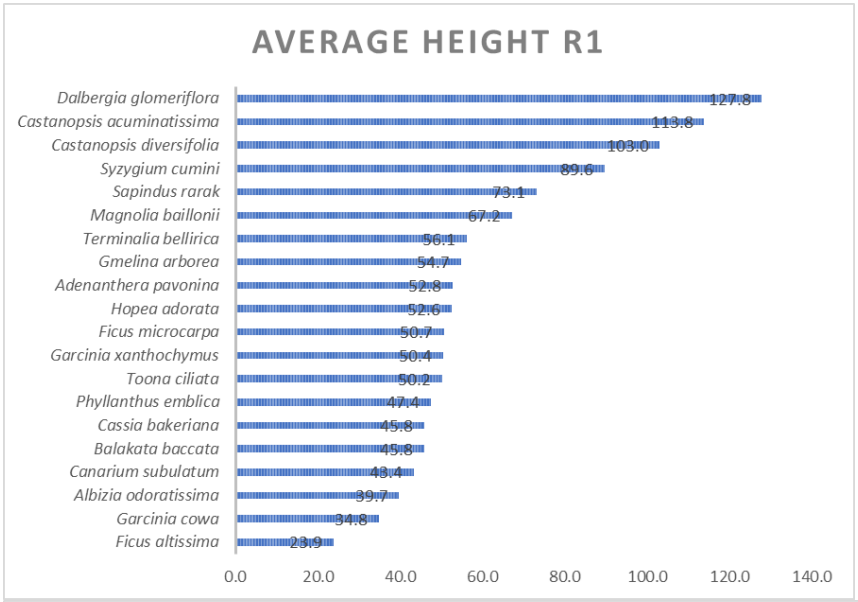
Appendix III - species specific results for BL (this page) and R1 (next page) surveys

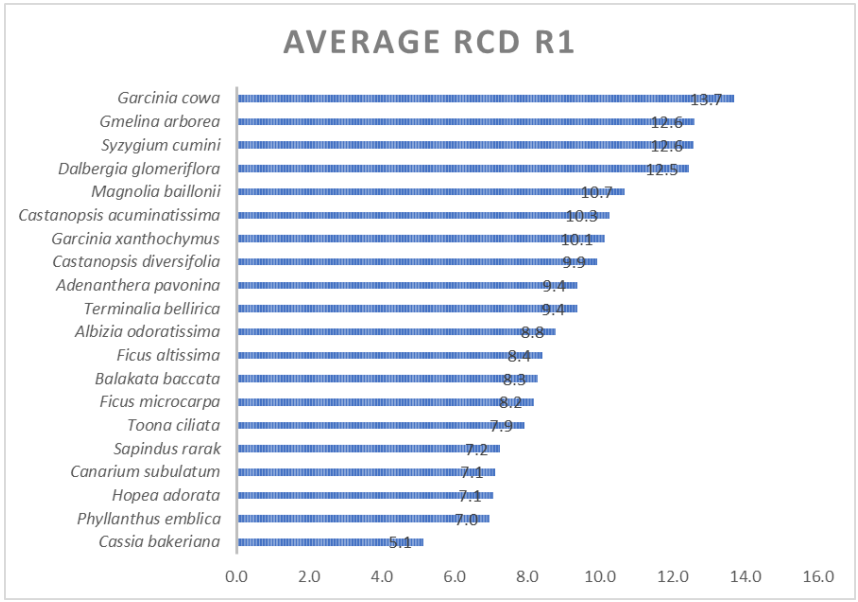


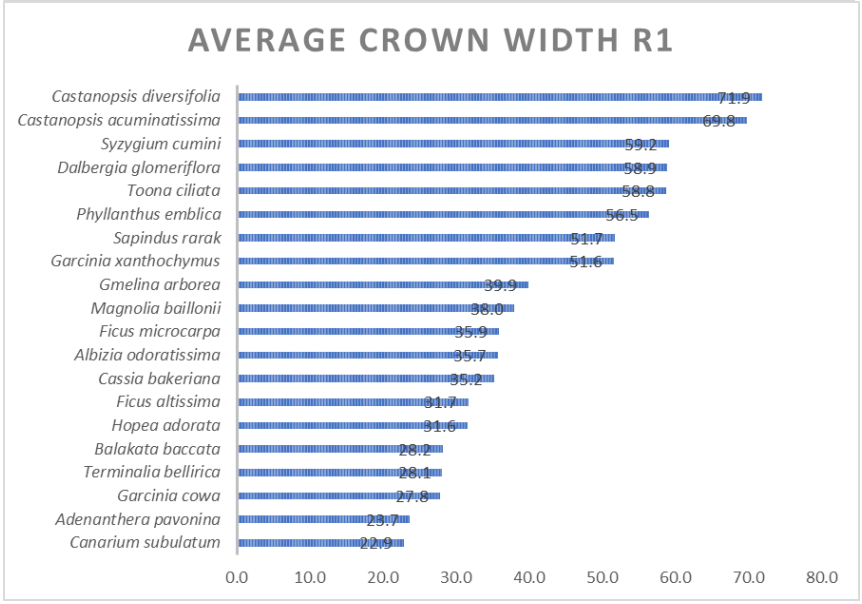


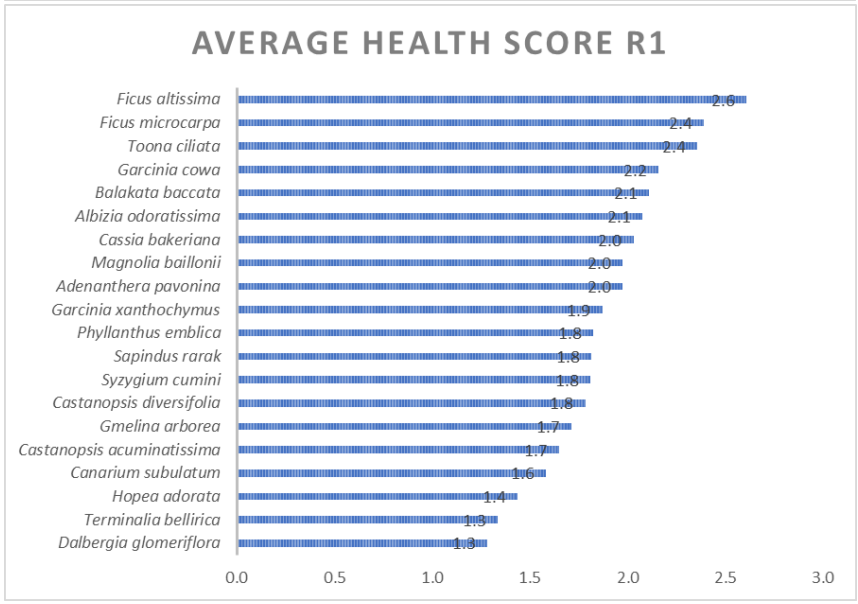





AVERAGE HEIGHT R1
Dalbergia glomeriflora 127.8
Castanopsis acuminatissima 113.8
Castanopsis diversifolia 103.0
Syzygium cumini 89.6
Sapindus rarak 73.1
Magnolia baillonii 67.2
Terminalia bellirica 56.1
Gmelina arborea 54.7
Adenanthera pavonina 52.8
Hopea adorata 52.6
Ficus microcarpa 50.7
Garcinia xanthochymus 50.4
Toona ciliata 50.2
Phyllanthus emblica 47.4
Cassia bakeriana 45.8
Balakata baccata 45.8
Canarium subulatum 43.4
Albizia odoratissima 39.7
Garcinia cowa 34.8
Ficus altissima 23.9
0.0 20.0 40.0 60.0 80.0 100.0 120.0 140.0


AVERAGE RCD R1
Garcinia cowa 13.7
Gmelina arborea 12.6
Syzygium cumini 12.6
Dalbergia glomeriflora 12.5
Magnolia baillonii 10.7
Castanopsis acuminatissima 10.3
Garcinia xanthochymus 10.1
Castanopsis diversifolia 9.9
Adenanthera pavonina 9.4
Terminalia bellirica 9.4
Albizia odoratissima 8.8
Ficus altissima 8.4
Balakata baccata 8.3
Ficus microcarpa 8.2
Toona ciliata 7.9
Sapindus rarak 7.2
Canarium subulatum 7.1
Hopea adorata 7.1
Phyllanthus emblica 7.0
Cassia bakeriana 5.1
0.0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0


AVERAGE CROWN WIDTH R1
Castanopsis diversifolia 71.9
Castanopsis acuminatissima 69.8
Syzygium cumini 59.2
Dalbergia glomeriflora 58.9
Toona ciliata 58.8
Phyllanthus emblica 56.5
Sapindus rarak 51.7
Garcinia xanthochymus 51.6
Gmelina arborea 39.9
Magnolia baillonii 38.0
Ficus microcarpa 35.9
Albizia odoratissima 35.7
Cassia bakeriana 35.2
Ficus altissima 31.7
Hopea adorata 31.6
Balakata baccata 28.2
Terminalia bellirica 28.1
Garcinia cowa 27.8
Adenanthera pavonina 23.7
Canarium subulatum 22.9
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0


AVERAGE HEALTH SCORE R1
Ficus altissima 2.6
Ficus microcarpa 2.4
Toona ciliata 2.4
Garcinia cowa 2.2
Balakata baccata 2.1
Albizia odoratissima 2.1
Cassia bakeriana 2.0
Magnolia baillonii 2.0
Adenanthera pavonina 2.0
Garcinia xanthochymus 1.9
Phyllanthus emblica 1.8
Sapindus rarak 1.8
Syzygium cumini 1.8
Castanopsis diversifolia 1.8
Gmelina arborea 1.7
Castanopsis acuminatissima 1.7
Canarium subulatum 1.6
Hopea adorata 1.4
Terminalia bellirica 1.3
Dalbergia glomeriflora 1.3
0.0 0.5 1.0 1.5 2.0 2.5 3.0

Appendix IV – CDSC pupils joined events (planting day and R1 monitoring)

Planting event

R1 monitoring

Appendix V –Orthomosaic after R1