Before and After One Growth Season

Planting Day 13TH August 2021

NOVEMBER 2021 (END OF THE FIRST RAINY SEASON)

BAN PONG YAENG NAI RESTORATION 2021 PLOT

PROGRESS REPORT – END 1ST RAINY SEASON

Project Title:	Testing the Effects of Biochar on Forest Restoration: Pong Yaeng Trail Project #4—restoring forest to 4 rai at Pong Yaeng (FORRU project, 2021)
Sponsors:	Pong Yaeng Trail (PYT) via Doi Suthep-Pui Nature Centre (DSNC)
Project Duration:	01/06/2021 - 31/01/2023
Reporting Period:	01/06/2021 – 31/01/2022
Prepared by:	Worayut Takaew, Benjapan Manohan & Steve Elliott

Background and introduction

This project arose out of discussions with Doi Suthep National Park authority (DSPNP) in 2020-21, during which the Doi Suthep-Pui Nature Centre (DSNC) and FORRU-CMU were requested to advise and assist with the restoration of various forest areas, severely impacted by forest fires during the dry season in 2020. DSPNP assigned FORRU-CMU to work on a site near Mae Taeng. A rapid site assessment was performed on June 8th 2022. Lists of suitable species and planting stock available were compiled and a budget was drafted. On June 30th, the site was mapped in high-resolution detail by drone photogrammetry surveying and processing. That afternoon, however, the park authority abruptly changed its mind about the target site at a meeting with the DSPNP and the sponsor, the Pong Yaeng Trail (PYT) running group. It requested that FORRU-CMU instead work on an alternative plot near Pong Yaeng, where research on the planted trees would be more "bureaucratically acceptable". The area covers 4 rai near Ban Pong Yang Nai, Pong Yang sub district, within Doi Suthep-Pui National Park. Spontaneous natural regeneration has failed to restore forest cover. Hence the need to accelerate forest recovery with tree planting. DSNC accepted responsibility for project implementation and PYT agreed to fund it. DSNC subcontracted technical arrangements for the project to FORRU-CMU via a service agreement (from June 1st). This report covers the rapid site assessment and drone mapping of the initial conditions at the Pong Yaeng plot (PY21), the planting plan (including experimental design for testing the effects of biochar on planted tree performance), the planting event, baseline survey of the planted trees and end-1st-rainy-season (R1) data.

The **broad aim** of the project is to restore forest cover and recover biodiversity in line with the aims of the national park. The plot will also contribute towards climate-change mitigation by acting as a carbon sink.

Specific Objectives: -

- To restore biomass, structural complexity, biodiversity, and ecological functioning to the indigenous forest ecosystem near Ban Pong Yaeng Nai.
- To compare field performance among 20 tree species.
- To determine the effects of biochar on the performance of 12 planted tree species.

Planting site description and map

The planting plot is located near Ban Pong Yaeng Nai, under the local authority of Pong Yaeng Sub-district in Mae Rim District of Chiang Mai Province. It is an irregular area, covering about 4 rai, within Doi Suthep-Pui National Park (DSPNP). The plot had been cultivated since illegal forest clearance many years ago and had been reclaimed by the park authority about 10 years ago. Since the area was surrounded by forest, the park authority relied on spontaneous natural regeneration to restore the natural forest ecosystem. However, after 10 years, canopy closure had not been achieved – possibly due to invasion of the area by aggressive weeds, changes in soil condition due to previous cultivation, or the continued presence of cows. The area was classified as stage-3 degradation (*sensu* Elliott et al., 2013).

Figure 1.*-The plot was an open area, which supported very little natural regeneration, despite being surrounded by forest*

Elevation ranged from 1,007 to 1,026 metres above sea level. The indigenous forest ecosystem is evergreen forest "EGF" (*sensu* Maxwell & Elliott, 2001), dominated by species of the family Fagaceae. Grasses grew very densely across the site, in places mixed with other herbaceous weeds, with a few remaining scattered trees creating sparse crown cover. Figure 1. shows initial site conditions, following weeding, whereas Figure 2 provides a broad aerial overview using satellite imagery (Google Earth).

Rapid Site Assessment

FORRU-CMU and DSNC staff, with DNP officers and villagers performed a routine rapid site assessment on August 2nd (3.2 in Elliott et al, 2013). The density of natural regenerants[1] was calculated from 10 circular sample plots (5-m radius, area 78.6 m^2 each), spaced evenly across the site to capture its variability (especially with respect to slope). Obstacles to restoration, such as weeds, signs of fire and cattle, were recorded. Handheld GPS and the Google base map were used to digitize the plot boundary and calculate its total area.

[1] a) trees larger than 30 cm girth at breast height (gbh) (i.e., 1.3 m from the ground), b) saplings taller than 50 cm (but smaller than 30 cm gbh) and c) live tree stumps (with green shoots).

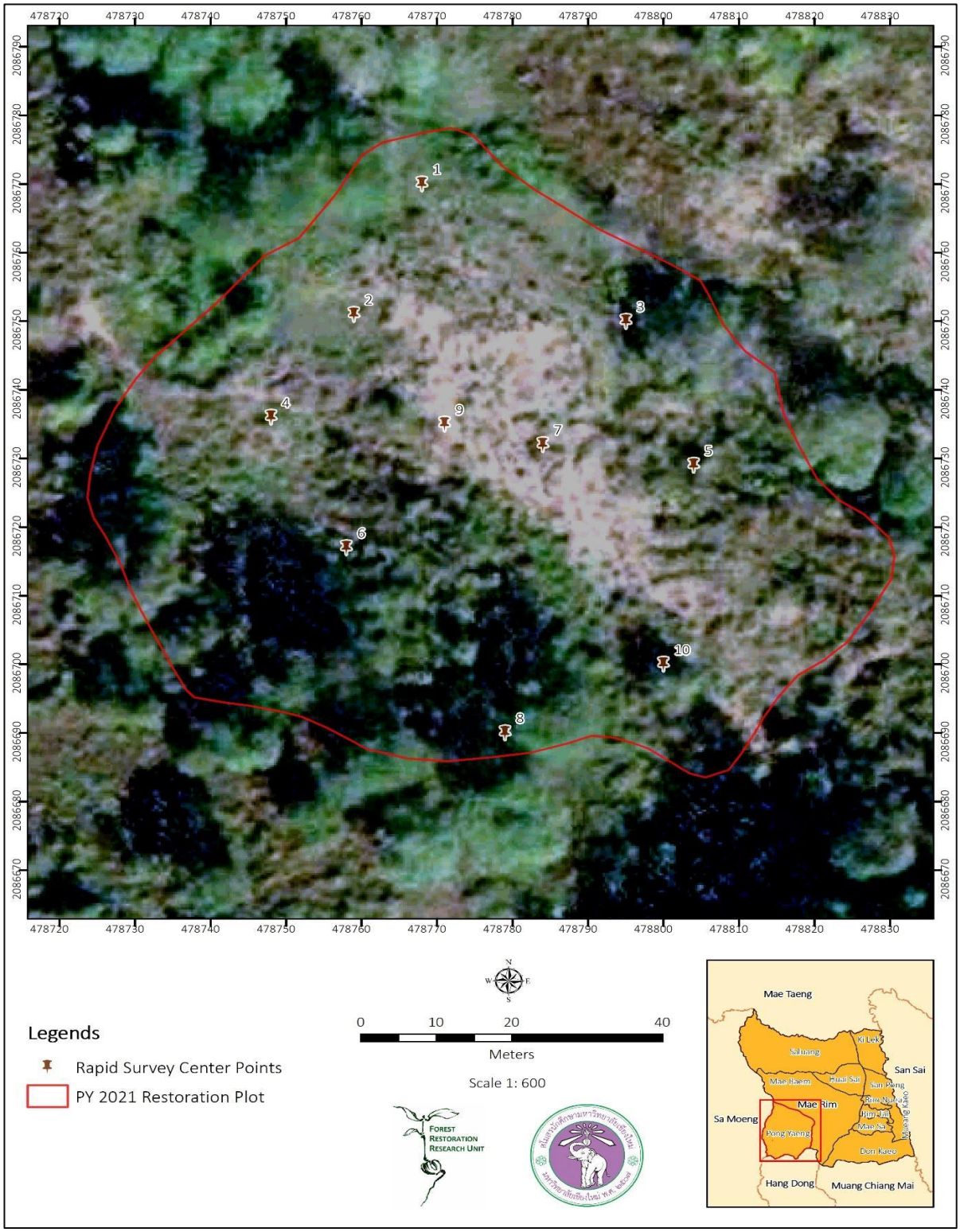

Figure 2.- *the google base map of 2021 planting site boundary and coordinates of center points of the rapid survey at Ban Pong Yaeng Nai*

The average number of regenerants per circle was 8.7 (±2.5 95% c.l.), extrapolating to a density of 177.3/rai (±50.5, 95% c.l.). From FORRU-CMU's previous experience of restoring EGF, an average stocking density of 500/rai is required to initiate canopy closure by the end of the 2nd rainy season and complete it before the end of the 3rd rainy season. Therefore, the recommended number of trees to plant at this site was 323/rai (1,292 totally). Circle #5 had the highest number of regenerants (15), whilst circle #3 had the lowest (just 3). Detailed results are in Appendix 2. Both pioneer and climax tree species were represented in the sample plots. The list of species found in presented in Table 1.

Twenty-five species of regenerants were identified in total. *Litsea glutinosa* was the most abundant (23 individuals). Most species were rare, for example, *Morus macroura, Dillenia pentagyna, Albizia chinensis, Fernandoa adenophylla, Catunaregam tomentosa, Magnolia baillonii, Casearia grewiifolia, Bischofia javanica,* and *Prunus persica* were all represented by a single individual.

Signs of cattle were found more than 50% of the sample circles, but signs of fire were absent. The average density of weed cover exceeded 90%, with the weed canopy level varying between 80 cm and 3 m. Fire-prevention measures might not be necessary at this site, but cattle exclusion and intensive weeding were recommended.

In addition, the original condition of the vegetation at each circular plot was recorded by photo-monitoring – pointing the camera at each of the four cardinal compass points at the central pole in each circular sample plot (Figure 3). The full photoset is here.

Figure 3.- *The example photo-monitoring pole at the center pole of rapid-site-surveying*

Table 1 Natural regenerant species and their abundance from the rapid site assessment of the PY21 plot

Species Name	Family	Thai Name/ Local Name	Number in 10 circles
Alangium kurzii	Alangiaceae	ฝาละมี	2
Albizia chinensis	Leguminosae (M)	กางหลวง	1
Bauhinia variegata	Leguminosae (C)	เสี้ยว	9
Bischofia javanica	Euphorbiaceae	เติม	1
Broussonetia papyrifera	Moraceae	ปอสา	3
Casearia grewiifolia	Flacourtiaceae	กรายป่า	1
Catunaregam tomentosa	Rubiaceae	หนามแท่ง	1
Dalbergia ovata	Leguminosae (P)	กำพี้	3
Dillenia parviflora	Dilleniaceae	ส้านหิ่ง	4
Dillenia pentagyna	Dilleniaceae	ส้านช้าง	1
Engelhardia spicata	Juglandaceae	คำหด	2
Fernandoa adenophylla	Bignoniaceae	แคบิด	1
Glochidion sphaerogynum	Euphorbiaceae	มันปลา	7
Heynea trijuga	Meliaceae	ตาเสือทุ่ง	2
Litsea glutinosa	Lauraceae	หมีเหม็น	23
Magnolia baillonii	Magnoliacae	จำปีป่า	1
Mallotus philippensis	Euphorbiaceae	คำแสด	2
Markhamia stipulata	Bignoniaceae	แคหางค่าง	3
Morus macroura	Moraceae	หม่อนหลวง	1
Oroxylum indicum	Bignoniaceae	เพกา	4
Prunus persica	Rosaceae	ท้อ	1
Sapindus rarak	Sapindaceae	มะซัก	3
Schima wallichii	Theaceae	ทะโล้	2
Senna siamea	Fabaceae	ขี้เหล็ก	3
Toona ciliata	Meliaceae	ยมหอม	4
Total number in 10 circles			87

Tree species planted

Based on the experience of restoring EGF and availability of planting stock at FORRU-CMU's two nurseries the twenty tree species, listed in Table 2, were selected for planting to increase stocking density (including NR) to 500/rai. This added 18 species to the species richness recorded during the rapid site assessment (since *M. philippensis* and *B. javanica* were already present) bringing total species richness to 43.

Tree seedling production costs at Ban Mae Sa Mai (BMSM) and Doi Suthep (DS) nursery averaged about 20 THB/plant, but FORRU provided the trees for free for this project. A total of 1,370 saplings were planted (slightly above the recommended number and bringing final stocking density up to 518/rai i.e., mean spacing 1.76 m). *Hovenia dulcis* was the most abundant (saplings from BMSM nursery): 100 trees, whilst *Cinnamomum iners* was the rarest 25 trees.

Table 2 Number of trees and species planted at Pong Yaeng Nai

S. No	Scientific name	Thai name	No. of trees	Sources of saplings
4	*Bischofia javanica*	เติม	35	BMSM Nursery
5	*Melia toosendan*	เลี่ยน	100	BMSM Nursery
15	*Balakata baccata*	สลีนก	35	BMSM Nursery
18	*Hovenia dulcis*	หมอนหิน	120	BMSM Nursery
31	*Acrocarpus fraxinifolius*	สะเดาช้าง	35	BMSM Nursery
55	*Mallotus philippensis*	คำแสด	35	BMSM Nursery
62	*Quercus semiserrata*	ก่อตาหมูหลวง	35	BMSM Nursery
66	*Choerospondias axillaris*	มะกัก	100	BMSM Nursery
71	*Prunus cerasoides*	นางพญาเสือโคร่ง	100	BMSM Nursery
89	*Micromelum hirsutum*	หัสคุณ	35	BMSM Nursery
101	*Alseodaphine andersonii*	ทังใบช่อ	100	BMSM Nursery
105	*Sarcosperma arboreum*	มะยาง	100	BMSM Nursery
129	*Artocarpus lakoocha*	หาด	35	BMSM Nursery
146	*Nyssa javanica*	คางคาก	100	BMSM Nursery
157	*Heynea trijuga*	ตาเสือทุ่ง	100	DS Nursery
161	*Alangium kurzii*	ฝาละมี	100	DS Nursery
218	*Cinnamomum iners*	อบเชย	25	BMSM Nursery
268	*Cryptocarya amygdalina*	หมากขี้อ้าย	45	DS Nursery
317	*Erythrina subumbrans*	ทองหลางป่า	100	DS Nursery
476	*Madhuca thorelii*	ละมุดป่า	35	DS Nursery
Total quantity			**1,370**	
Total species			**20**	

Site preparation

Site preparation was carried out on 3rd-10th August (Figure 4). Villagers from Ban Pong Yaeng Nai cleared the site of herbaceous weeds and marked locations of natural regenerants with bamboo poles. Usually, glyphosate would have been sprayed on sprouting weeds, but in this area, the chemical treatment was not allowed.

***Figure 4.**- Site preparation, grass slashed by villagers from Ban Pong Yaeng Nai*

Preparing trees

All selected trees were hardened off by reducing shade and watering frequency for about 1 month prior to planting. The trees were also labeled with aluminum tags, stamped with a unique code, consisting of species number (Table 2) and tree number on 11th August, and immediately transferred to the trailhead leading to the planting site.

***Figure 5.**- Seedlings transferred preparing at the entrance of the plantation plot*

Planting Day

***Figure 6.**- PYT running group transported seedlings and essential equipment from the entrance to the planting plot*

Tree planting was carried out on 13th-14th August 2021 (in the middle period of the rainy season) by Pong Yaeng Trail running group (PYT), DSNC, DSNPN officers, Ban Pong Yaeng Nai villagers, and general volunteers around Chiang Mai and supervised by FORRU-CMU staff.

The following equipment and materials were organized in advance:

- Baskets to transfer and distribute seedlings
- Buckets and cups for put in fertilizer
- Hoes for hole-digging
- Knives for cutting plastic bags
- Gloves
- Bamboo stake
- First aid kit

***Figure 7**.- Ben demonstrated how to plant trees properly*

Standard Planting Method and Experimental Design

Standard planting methods, following Elliott et al. (2013, Chapter 7) were applied, following the framework species method. Bamboo stakes were inserted 1.8 m apart. Planting holes were dug by the stakes approximately 15 x 15 x 25 (deep) cm. Polybags, containing the saplings, were cut with a box cutter and the saplings were placed into the holes. Loose soil filled the holes and was then firmed down. Lastly, 100 grams (g) of organic fertilizer was applied in a ring about 20-30 cm away from the tree stems. Plastic bags were removed from the site.

Since the area had been cultivated, soil deterioration might have been the main factor that had prevented natural regeneration. Reports suggest that biochar improves soil structure and moisture retention. Therefore, it was decided to test the effects of biochar on planted saplings. Biochar was kindly provided by the Warm Heart Foundation.

Saplings receiving the biochar treatment were planted into 5 square replicate subplots (20 x 20 m), placed across the total area planted, to capture intra-site variation in conditions. Fifty individuals of each of 10 species were planted-10 per subplot. two hundred grams of biochar was put into the planting holes. The species tested were: *Melia toosendan, Hovenia dulcis, Choerospondias axillaris, Prunus cerasoides, Alseodaphine andersonii, Sarcosperma arboreum, Nyssa javanica, Heynea trijuga, Alangium kurzii*, and *Erythrina subumbrans*. Further details of the experiment are here. Planted saplings of the same species planted outside the demarcated subplots served as controls.

On both planting days, FORRU-CMU staff managed and checked the plant quality and biochar treatment application. PYT took a leading role in transferring saplings from the road to the planting site and distributing them to planting holes. DNP, villagers, and volunteers helped put the bamboo stakes in place, digging holes and planting the trees in both control and biochar experiments.

Figure 8.- *DNP, DSNC, PYT, teenager volunteers, and FORRU-CMU nursery staff planted trees in both planting days*

Figure 9. *– PYN Villagers, DSNC, PYT, DNP, and FORRU-CMU on planting day.*

Maintenance

Tree maintenance was performed three times during the first rainy season on: September 11th, October 9th, and November 13th, 2021, co-ordinated mostly by the DSNC crew. Weeds were pulled from around the bases of planted trees and vines gently removed from their crowns. Then 100 g organic fertilizer was applied a circle 20-40 cm away from the tree stem. A fire break around the whole plot was created by co-working with main 3 organizations (volunteers from science program in computer science CMU, DSNC officers and FORRU staff), March 18th 2022. The fire break was 3-5 m wide around the outside of the plot. Machetes were used to clear tall grass and dry branches, followed by raking to drag the potential fire fuel into the middle of the firebreak for burning off.

Figure 10*. Volunteers created fire break round restoring plot*

Baseline Monitoring

Baseline monitoring was completed on 28th August 2021, 2 weeks after planting. A group of bachelor's degree students from the Economic Faculty of Mae Jo University joined with FORRU CMU staff to record baseline data, as part of their co-learning course with FORRU education team). Equipment used was: Vernier calipers, scale tape poles, recording datasheets, planting species lists, and drone orthomosaic base maps. 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.

Figure 11. *- MJU students measured trees for baseline monitoring*

Results are presented in Tables 3-5.

The average seedling height was 64.2 cm (±95% c.l. = 1.35), exceeding the minimum recommended height for planting. RCD ranged from 4 to 10 mm across species, with an overall mean of 6.76 mm (±95% c.l. = 0.125), whilst crown widths were mostly in the range of 30-40 cm.

In the biochar plots, one *B. javanica* and one *M. philippensis* were mistakenly planted inside the plots. In most plots, 2-3 individuals of the target species had been planted outside the plot boundaries (two of the mistake had been removed from advance analysis) or were not found in the survey. T-tests showed that on average, by chance, control seedlings were slightly but significantly taller than those planted in the biochar plots (74.8 vs 67.2 cm tall, P <0.001). However, differences in RCD and crown diameter between the control and biochar treated seedlings were insignificant (P=0.15 and 0.74 respectively).

The whole site was also surveyed by drone to get an overall image of the original condition on 11/9. The resulting map is presented in Figure 13)

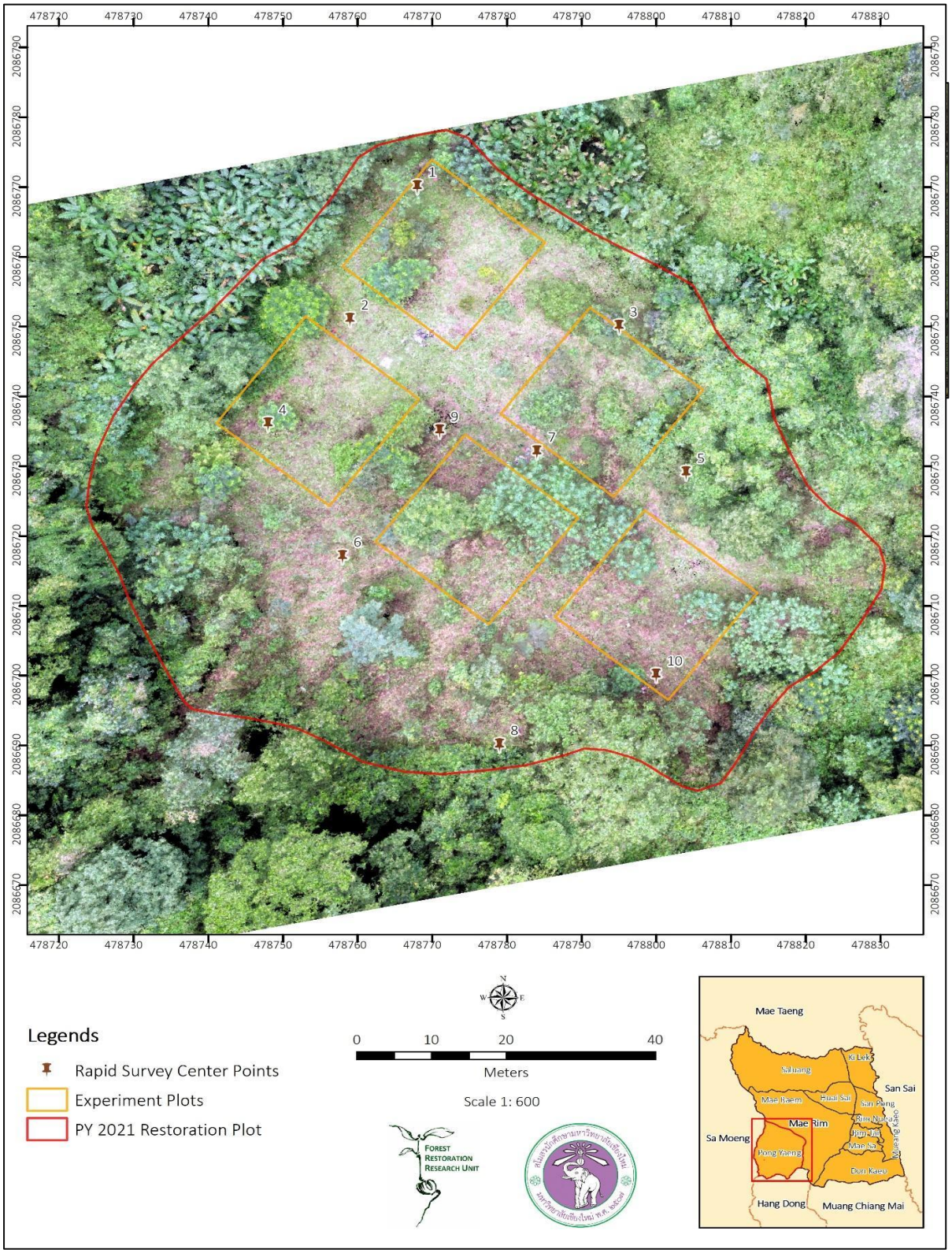

Figure 13: The location of circular plots and experiment boundaries base on drone orthomosaic (11/9/21)

Table 3 Baseline results all trees - numbers of individuals, average sizes, and scores for health (HS), weed cover (WS), and shading (SS) – values are means for all individuals found of each species

S. No	Tree Species	Thai Name/ Local Name	Total planned	Counted BL	Avg. Height (cm)	Avg. RCD (mm)	Avg. CW (cm)	Avg. HS (0-3)	Avg. WS (0-3)	Avg. SS (0-3)
4	*Bischofia javanica*	เติม	35	31	41.73	5.307	32.29	2.5	0.9	0.5
5	*Melia toosendan*	เลี่ยน	100	95	84.57	5.872	28.94	2.6	1.2	0.5
15	*Balakata baccata*	สลีนก	35	34	37.69	5.125	22.56	2.8	1.1	0.6
18	*Hovenia dulcis*	หมอนหิน	120	113	77.31	7.038	23.89	2	1.2	0.7
31	*Acrocarpus fraxinifolius*	สะเดาช้าง	35	33	53.35	6.447	33.17	2.4	0.9	0.7
55	*Mallotus philippensis*	คำแสด	35	34	47.34	4.907	27.43	2.3	0.9	0.5
62	*Quercus semiserrata*	ก่อตาหมูหลวง	35	35	47.27	7.327	33.1	2.4	0.9	0.5
66	*Choerospondias axillaris*	มะกัก	100	97	63.18	6.759	31.39	2.1	1.1	0.5
71	*Prunus cerasoides*	นางพญาเสือโคร่ง	100	99	98.79	8.066	27.97	1.9	1.2	0.7
89	*Micromelum hirsutum*	หัสคุณ	35	35	35.54	4.444	31.29	1.8	1.2	0.9
101	*Alseodaphine andersonii*	ทังใบช่อ	100	94	83.19	10.04	44.44	2.4	1.1	0.6
105	*Sarcosperma arboreum*	มะยาง	100	97	51.79	6.861	32.16	2.5	1.3	0.5
129	*Artocarpus lakoocha*	หาด	35	34	52.69	6.466	23.93	1.8	0.8	0.6
146	*Nyssa javanica*	คางคาก	100	93	63.39	5.918	29.27	2.4	1.1	0.6
157	*Heynea trijuga*	ตาเสือทุ่ง	100	95	52.18	7.684	37.89	2.4	1.1	0.9
161	*Alangium kurzii*	ฝาละมี	100	96	83.29	6.826	34.39	2.3	1.0	0.7
218	*Cinnamomum iners*	อบเชย	25	23	55.89	5.295	32.74	2.4	1.6	1
268	*Cryptocarya amygdalina*	หมากขี้อ้าย	45	43	35.01	4.412	25.23	2.3	1.5	0.7
317	*Erythrina subumbrans*	ทองหลางป่า	100	96	51.46	7.028	26.76	2.3	1.2	0.8
476	*Madhuca thorelii*	ละมุดป่า	35	32	42.44	5.096	34.25	2.5	1	0.9
		Total	**1,370**	**1,309**	**64.24**	**6.762**	**30.98**	**2.3**	**1.1**	**0.7**

Table 4 Baseline results for control trees - numbers of individuals, average sizes, and scores for health (HS), weed cover (WS), and shading (SS) – values are means for all individuals found of each species

S. No	Tree Species	Thai Name/ Local Name	Total planned	Count BL	Avg. Height (cm)	Avg. RCD (mm)	Avg. CW (cm)	Avg. HS (0-3)	Avg. WS (0-3)	Avg. SS (0-3)
4	*B. javanica*	เติม	35	31	41.73	5.307	32.29	2.5	0.9	0.5
5	*M. toosendan*	เลี่ยน	50	49	91.05	6.315	28.90	2.5	1.3	0.8
15	*B. baccata*	สลีนก	35	34	37.69	5.125	22.56	2.8	1.1	0.6
18	*H. dulcis*	หมอนหิน	70	63	66.62	5.874	21.83	1.8	1.3	0.9
31	*A. fraxinifolius*	สะเดาช้าง	35	33	53.35	6.447	33.17	2.4	0.9	0.7
55	*M. philippensis*	คำแสด	35	34	47.34	4.907	27.43	2.3	0.9	0.5
62	*Q. semiserrata*	ก่อตาหมูหลวง	35	35	47.27	7.327	33.10	2.4	0.9	0.5
66	*C. axillaris*	มะกัก	50	48	77.14	8.776	32.09	2.1	1.3	0.6
71	*P. cerasoides*	นางพญาเสือโคร่ง	50	50	99.01	7.849	29.76	2.0	1.4	0.8
89	*M. hirsutum*	หัสคุณ	35	35	35.54	4.444	31.29	1.8	1.2	0.9
101	*A. andersonii*	ทังใบช่อ	50	46	88.59	10.220	44.99	2.5	1.2	0.8
105	*S. arboreum*	มะยาง	50	48	49.99	6.820	31.41	2.4	1.5	0.8
129	*A. lakoocha*	หาด	35	34	52.69	6.466	23.93	1.8	0.8	0.6
146	*N. javanica*	คางคาก	50	46	71.24	6.207	30.97	2.3	1.1	0.6
157	*H. trijuga*	ตาเสือทุ่ง	50	46	57.53	6.826	37.64	2.5	1.1	1.1
161	*A. kurzii*	ฝาละมี	50	47	99.36	7.746	36.29	2.3	1.1	0.8
218	*C. iners*	อบเชย	25	23	55.89	5.295	32.74	2.4	1.6	1
268	*C. amygdalina*	หมากขี้อ้าย	45	43	35.01	4.412	25.23	2.3	1.5	0.7
317	*E. subumbrans*	ทองหลางป่า	50	50	54.21	7.292	26.88	2.4	1.3	1.2
476	*M. thorelii*	ละมุดป่า	35	32	42.44	5.096	34.25	2.5	1	0.9
		Total	**870**	**827**	**62.7**	**6.582**	**30.71**	**2.3**	**1.2**	**0.8**

Table 5 Baseline results for biochar-treated trees - numbers of individuals, average sizes and scores for health (HS), weed cover (WS), and shading (SS) – values are means for all individuals found

S. No	Tree Species	Thai Name/ Local Name	Total planning	Count. BL	Avg. Height (cm)	Avg. RCD (mm)	Avg. CW (cm)	Avg. HS (0-3)	Avg. WS (0-3)	Avg. SS (0-3)
5	*M. toosendan*	เลี่ยน	50	46	77.66	5.399	28.98	2.7	1.1	0.3
18	*H. dulcis*	หมอนหิน	50	50	90.77	8.504	26.49	2.2	1.1	0.5
66	*C. axillaris*	มะกัก	50	49	49.51	4.782	30.7	2.2	1	0.4
71	*P. cerasoides*	นางพญาเสือโคร่ง	50	49	98.57	8.288	26.15	1.8	1.1	0.6
101	*A. andersonii*	ทังใบช่อ	50	48	78.02	9.868	43.91	2.3	1.1	0.5
105	*S. arboreum*	มะยาง	50	49	53.56	6.900	32.91	2.5	1.1	0.3
146	*N. javanica*	คางคาก	50	47	55.71	5.636	27.62	2.5	1.2	0.5
157	*H. trijuga*	ตาเสือทุ่ง	50	49	47.16	8.489	38.12	2.3	1.1	0.6
161	*A. kurzii*	ฝาละมี	50	49	67.88	5.944	32.57	2.3	1	0.5
317	*E. subumbrans*	ทองหลางป่า	50	46	48.47	6.740	26.63	2.2	1.1	0.5
		Total	**500**	**482**	**66.8**	**7.070**	**31.4**	**2.3**	**1.1**	**0.5**

End of first rainy season monitoring (R1)

R1 monitoring was performed after of 3 months (11th November 2021), using the same methods as for baseline monitoring.

A total of 1,225 trees (89.4%) of those recorded in the baseline survey were confirmed alive and 33 (2.4%) confirmed dead. The others, 122 trees (8.18 %) were not found or of indeterminate status. This overall R1 survival rate is considered excellent, compared with FORRU's former restoration plots.

The top 5 highest-ranking survival species included *A. fraxinifolius, Q. semiserrata, P. cerasoides, A. andersonii,* and *N. javanica* which are percentage survival rates of 100%, 97%, 95%, 94, and 93% respectively. On the other hand, the lowest 5 species surviving rate including *C. iners, C. axillaris, C. amygdalina, M. hirsutum*, and *M. thorelii* which are percentage 76%, 82, and 83% respectively

Figure 13: Volunteers, DSNC crew and FORRU staff on R1 monitoring

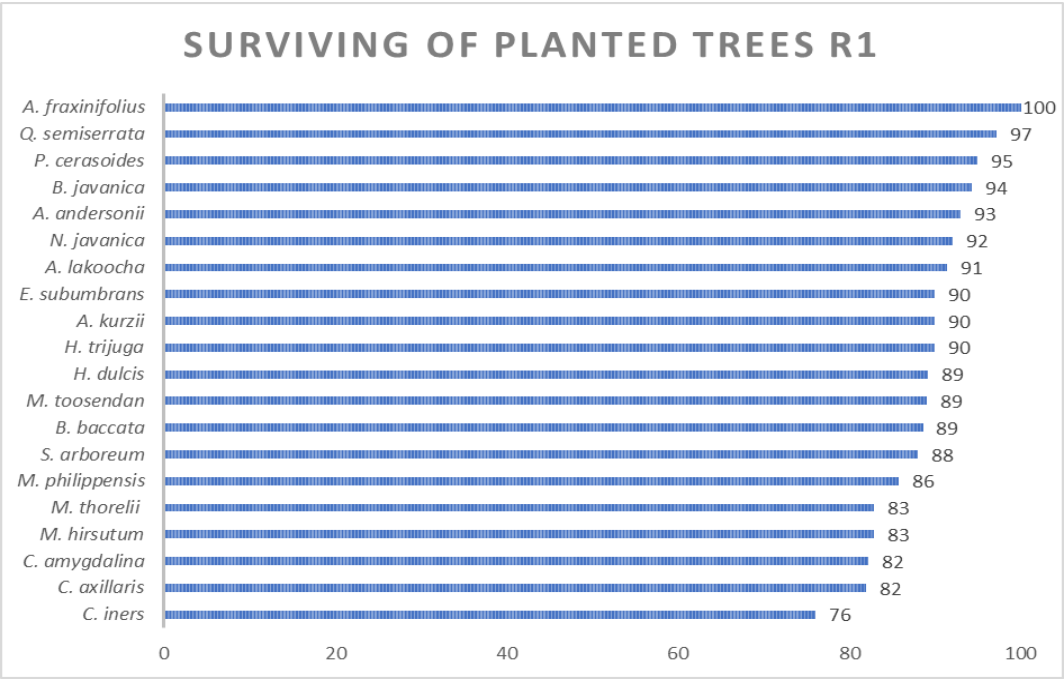

Figure 14 Tree survival by the end of 1st rainy season of total plot

Moreover, the relative growth rate of root collar diameter (RGR-RCD) is a standardized measurement enabling the growth rates to be compared among species of different initial sizes. It is size increase as a per cent of the average size of the plant during the measuring period. An RGR of 100 indicates annual doubling in size.

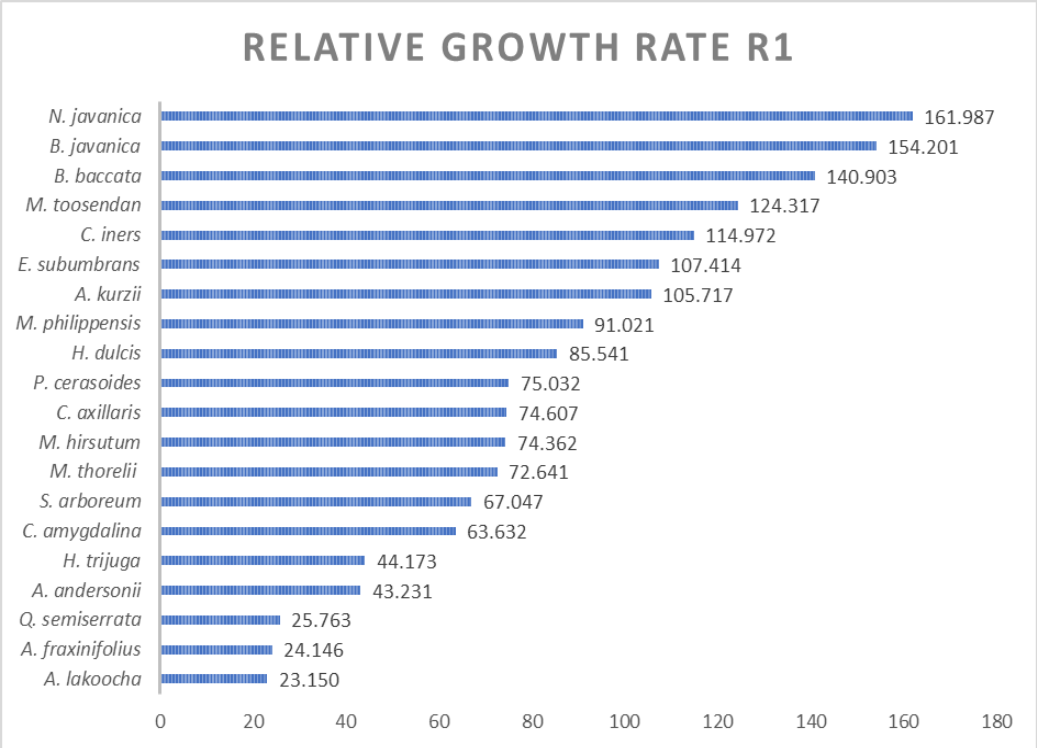

Figure 15 Tree growth by the end of 1st rainy season of total plot

Seven species exceeded 100% RGR-RCD considered excellent (Fig 15): N. javanica, B. javanica, B. baccata, etc. A further 8 exceeded 50% - considered good. Those with unacceptably low growth at this site included A. lakoocha, A. fraxinifolius, Q. semiserrata, etc.

The 3rd main part indicator is the species performance index which key results combine between survival and growth as equal weight (calculated from % survival x % RGR-RCD). The average total scores are displayed in a percent of the top-most performing tree species (in this time *N. javanica*), and the species performance of the whole plot is ranked and expressed comparing follow candle graph down below (Fig. 16)

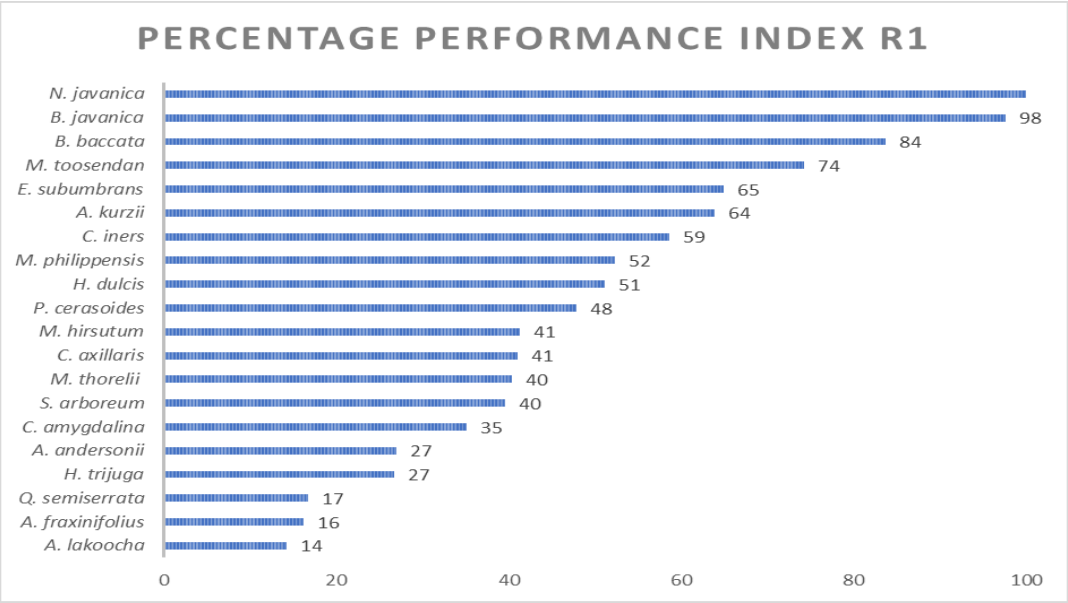

Figure 16 Relative species performance index R1 of total plot

Totally 4 rai restoration plot of Pong Yaeng project 4, *N. javanica* was the extreme high-performance species of total planted trees than the rest, because of the survival and high growth rate. Next on down *B. javanica* (97.5%), *B. baccata* (83.7%), and *M. toosendan* (74.2%). For the middle-performance index, the average percentage between 50%-80%, such as *H. dulcis, M. philippensis, C. iners, A. kurzii*, and *E. subumbrans* by the value of 51.1%, 52.4%, 58.6%, 63.8%, and 64.9% respectively.

Comparing biochar and control results

The survival rate of the experiment, using biochar testing within 10 native trees species over 5 sub-plots and total numerous experiment 500 trees. The resulting difference when compared with the total whole plot or control, 6 species from biochar testing have higher survival rate, highest 3 ranks surviving are *H. dulcis* survive 100% on experiment test after 1st rainy season ended, inferior to *A. andersoniii* (98%), and S*. arboreum* (96%). On the other hand, the result from regular zone has 4 species appeared higher survival than biochar testing plot including *P. cerasoides* (95%), *A. kurzii, E. subumbrans* (90%), and *C. axillaris* (82%) showing (Fig. 17)

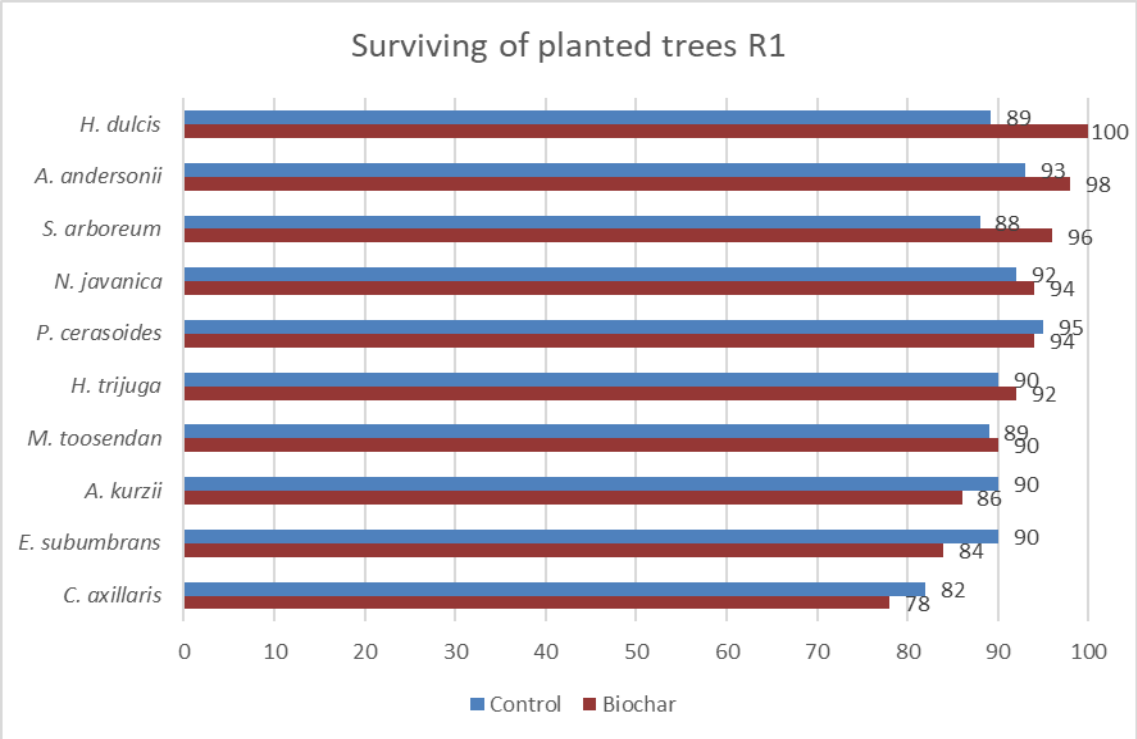

Figure 17 Trees survival by the end of 1st rainy season of biochar and control plot

Comparison of the surviving graph of biochar treatment 5 plots have been expressed a differential percent mean among species,). In addition to the top 3 highest surviving from the previous paragraph, the bottom 3 lowest-ranking survival species included *C. axillaris* (78%), *E. subumbrans* (84%), and *A. kurzii* (86%). For the control plot, the bottom 3 lowest included *C. axillaris* (82%), *S. arboreum* (88%), and *H. dulcis, M. toosendan* (89%)

The next major resultant is the relative growth rate of root collar diameter or the short abbreviation “RGR-RCD”, which normally is a standardized measurement that compared the growth rates among species of different initial sizes in diverse times. It is displayed average

percent of annual size increasingly after planted trees and during the measuring period. The consequence of RGR-RCD of biochar experiment and control were analyzed and represented in the comparison candle chart down below on the next page (Fig. 18)

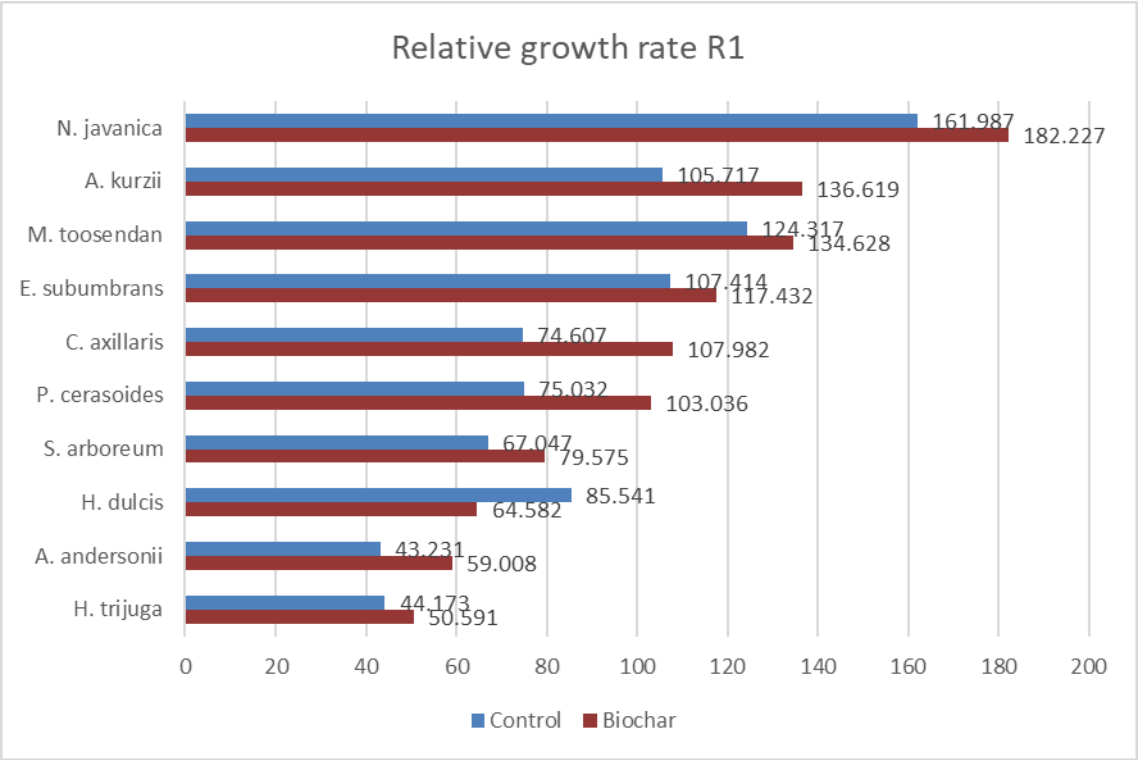

Figure 18 Trees growth by the end of 1st rainy season of biochar and control plot

The relative growth rate of biochar plots found that *N. javanica* has the annual average highest growth (182.23%mm/year), inferior to *A. kurzii* and *M. toosendan* with the close number (136.62% and 134.62% respectively). And the bottom 3 lowest mean RGR-RCD are *H. dulcis* (64.58%), *A. andersonii* (59%), and *H. trijuga* (50.59%). Almost the relative growth rate of root collar diameter result of 9 species from total 10 species were tested having same direction that figure out biochar treatment displayed higher growth rate than control except only one specie, *H. dulcis* has result from control plot better than biochar plot

For the percentage of performance index from biochar experiment comparing with control, all of results of performance index value r in the end of 1st rainy season represented performance of biochar testing higher value performance than tree species on control plot, evinced pattern candle graph similar as an annual average percentage RGR-RCD, top 3 highest performance index with the value at least 100% remained *N .javanica, M. toosendan*, and *A. kurzii* with percent of value as 146%, 103%, and 100% mm/year respectively. *N. javanica* is only tree species of control plot that has value of performance index in R1 in the level 100% mm/year, other species have values lower than 805 mm/year. All performance index resultant of trees species were applied to biochar research test and compared with control plot (planting and taking care with the regular approach) in this restoration project, have been appeared and compared following chart down below (Fig. 19)

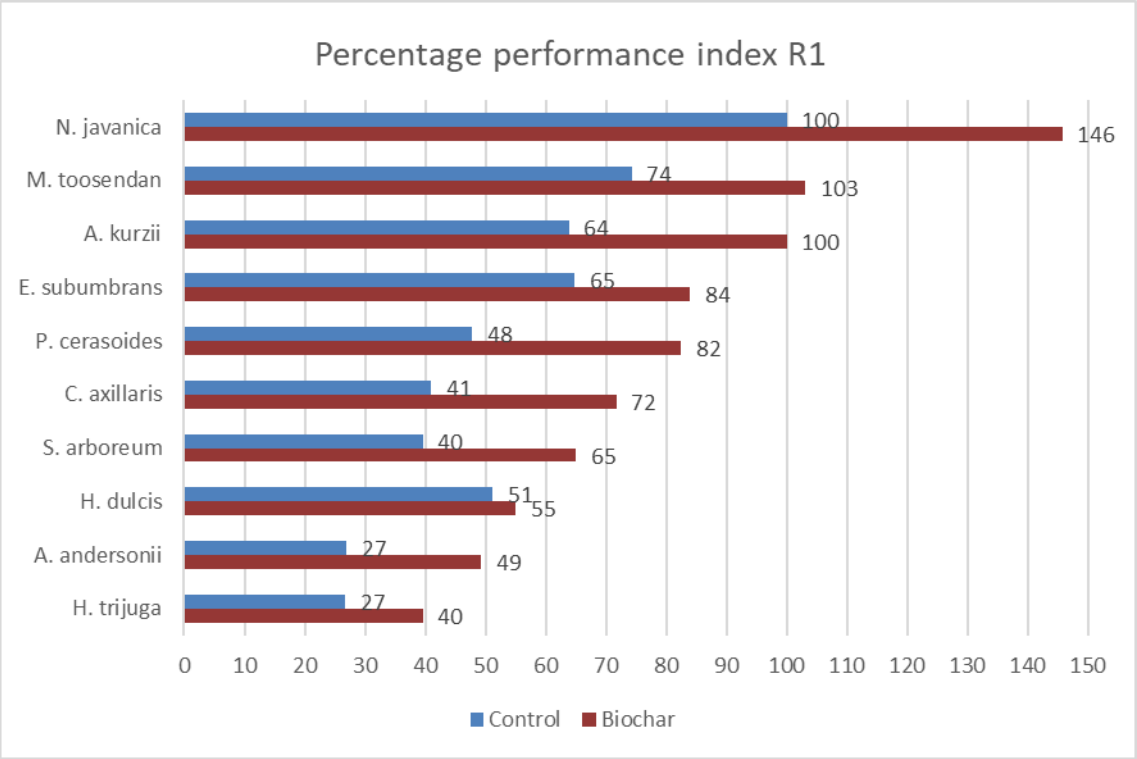

Figure 19 Relative species performance index R1 of biochar and control plot

Conclusions

Overall important results showed that both biochar and control experiments quite impressed resultant, the survival rate of R1 totally average 89%, average growth rate of seven trees species higher more than 100% mm/year and the performance index has three trees' species showed value over than 80%. For the resultant comparing separately between biochar testing and control found that the survival rate results having closely value, biochar slightly higher a bit surviving rate, some species from control plot represented higher surviving rate than biochar. The results of tree growth and performance index were appeared clearly gap between the results between control and biochar, totally restoration plot compared between control and biochar *N. javanica* has been found highest values both growth rate and performance. Almost comparison basically in R1 biochar slightly efficiency than control but remain to keep tracking and monitoring in anyways as researching team can, everything maybe changes when ended 2nd rainy season comes.

Future work

Maintenance will be repeated before the onset of the dry season, the 1st rainy season applied maintenance 3 times. Second monitoring or R1 monitoring will be performed before the end of December 2021 and an R1 report (end 1st rainy season) submitted by December 31st following the schedule plan, but because of errors and unexpected situations made repeat filtering and cleaning data several times. However, after starting analysis middle of February 2022 the final report progress of project R1 will be submitted by the end of March 2022. Fire prevention such as fire break will be placed cover the whole plot in 2022 March 18th.

Publicity for Sponsors

A project page has been published on forru.org. Project activities have been widely reported on FaceBook and have attracted a wide range of participants: students from both MJU and CMU, volunteers, park officers, and PYT members.

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APPENDIX I-Activity schedule (green shading text indicates completed tasks)

Date	Task	Note
June - July 2021	Financial and planting plan	
30th June 2021	Collaborative and cost meeting with DS-DNP, DSNC, FORRU, and villagers	
June - August 2021	Sending a letter to DS Park and Contract signing	
2nd August 2021	Rapid Site Assessment	
1st July – 10th August 2021	Planting preparation: - Species selection - Experiment designing - Seedlings hardening	FORRU
3rd – 4th August 2021	Planting preparation: Weed slashing	DS-DNP
11th August 2021	Planting preparation: - Seedlings labelling at BMSM and DS nurseries - Seedlings, bamboo stakes, and fertilizers transportation to the entrance of the plot	FORRU
13rd – 14th August 2021	Planting day - Seedlings, bamboo stakes, and fertilizers transportation from the entrance to the plot - Bamboo poles staking - Holes digging - Distribution seedlings to the holes. - Tree planting	30 Volunteers Pick up at DSNC
28th August 2021	Baseline monitoring of planted trees (BL)	FORRU
11th September 2021	1st weeding and fertilizer application (100 g organic per tree)	FORRU + 10 volunteers
9th October 2021	2nd weeding and fertilizer application (100 g organic per tree)	FORRU + 10 volunteers
13th November 2021	3rd weeding and fertilizer application (100 g organic per tree)	FORRU + 10 volunteers
20th November 2021	At the end of 1st rainy season trees monitoring (R1)	FORRU
31st December 2021	Report of the end of 1st rainy season	FORRU
January 2022	Summary meeting and project progress	
January – April 2022	Fire prevention	FORRU + 30 volunteers
4th June 2022	4th weeding and fertilizer application (100 g organic per tree)	FORRU + 10 volunteers
20th August 2022	5th weeding and fertilizer application (100 g organic per tree)	FORRU + 10 volunteers
15th October 2022	6th weeding and fertilizer application (100 g organic per tree)	FORRU + 10 volunteers
29th October 2022	The end of 2nd rainy season monitoring (R2)	FORRU
15th December 2022	Final Report	FORRU
Late of December 2022	Summary project meeting	FORRU DSNC

Appendix II – Results of rapid site assessment

RAPID SITE ASSESSMENT									
Site: BPYN 2021						Recorder: Worayut (Nan)		Date: 2021 June, 8	
Circle	Latitude (N)	Longitude (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	18.87284311	98.79842353	Found	Not Found	100% cover, 1.5 0m.	6	0	3	9
2	18.8726713	98.79833829	Found	Not found	90% cover, 1.20 m.	7	1	0	8
3	18.87266263	98.79868008	Found	Not found	100% cover, 1.70 m.	2	0	1	3
4	18.87253562	98.79823402	Found	Not found	100% cover, 1.5 m.	5	0	1	6
5	18.87247293	98.79876575	Found	Not found	90% cover, 1.80 m.	14	0	1	15
6	18.872364	98.79832916	Not found	Not found	100% cover, 1.20 m.	6	0	0	6
7	18.87249984	98.79857584	Found	Not found	100% cover, 1.60 m.	11	0	1	12
8	18.8721202	98.79852883	Not found	Not found	100% cover, 1.85 m.	9	0	1	10
9	18.87252682	98.79845239	Found	Not found	100% cover, 0.80 m.	10	0	1	11
10	18.87221079	98.79872809	Found	Not found	100% cover, 1.50 m.	6	0	1	7
11	18.87286174	98.79893618	Found	Not found	100% cover, 3 m.	6	0	0	6
12	18.87294279	98.79867025	Not found	Not found	100% cover, 1.50 m.	5	1	0	6
Site description: Deforested then reclaimed by the national park around 10 years ago. Flat central area flanked by steep slopes, mostly covered by tall grass, a few standing trees (mostly introduced exotics). Surrounded by disturbed EGF. Used by cattle							Total		87
							(=Total/10)	Mean	8.7
							(= Mean x 1,600/78)	Average/Rai	178
							Amount needs planted/ Rai (500-Average/Rai)		322

Appendix XIII: Photo album

Planting Day 13th -14th August 2021

Planting day 1

Planting day 2