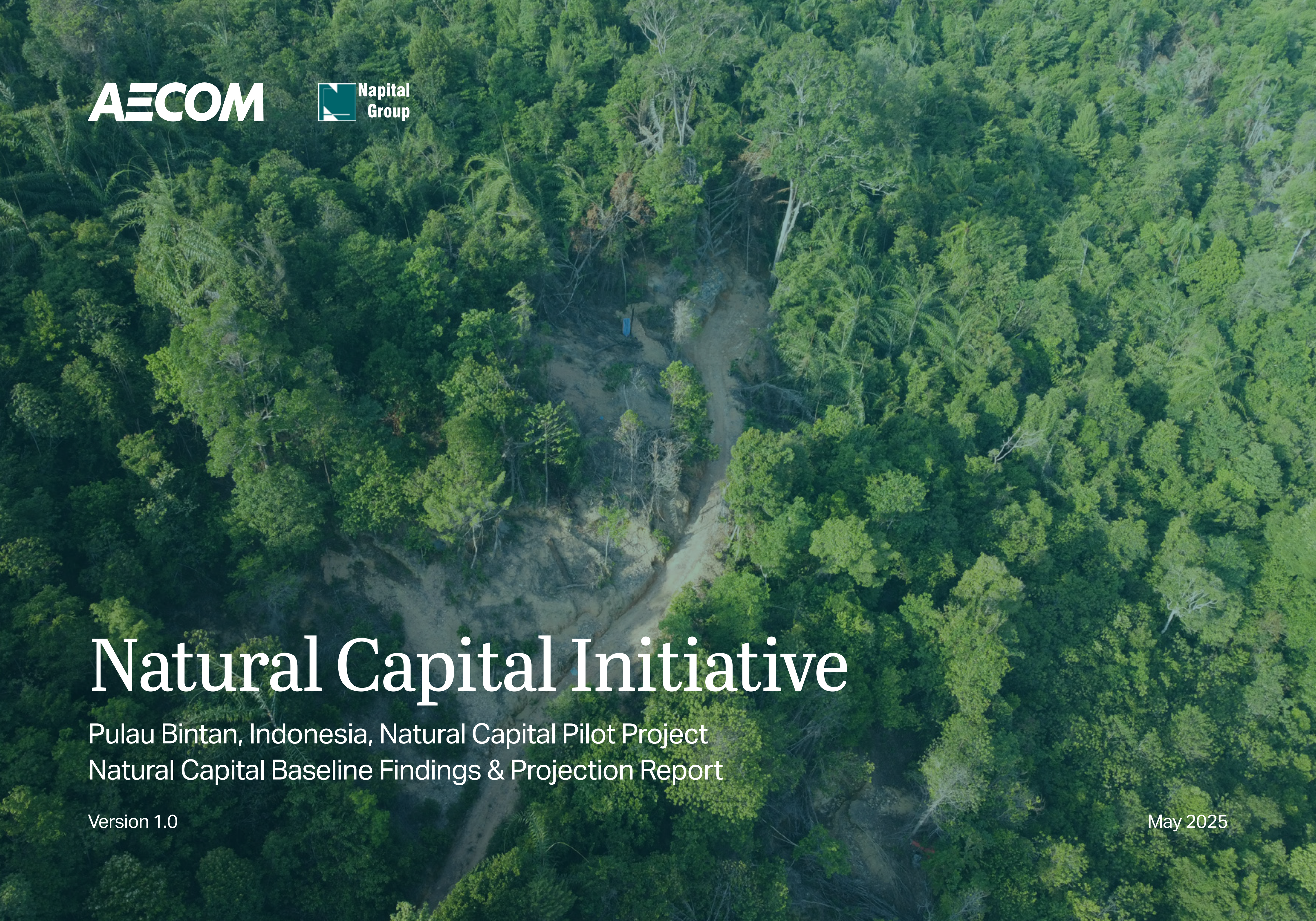


Natural Capital Initiative

Pulau Bintan, Indonesia, Natural Capital Pilot Project
Natural Capital Baseline Findings & Projection Report

Version 1.0

May 2025

Project Overview

The Natural Capital Initiative

The Natural Capital Initiative pioneers a strategy that merges conservation, technology, and financial incentives to restore ecosystems. Today, “nature positive” resonates as strongly as the call for “net zero”. However, measuring nature positivity is still in its infancy compared to the well-established metrics and market incentives for net-zero carbon emissions. The Initiative seeks to elevate the importance of nature positivity, galvanizing corporations and businesses to address the biodiversity crisis through natural capital.

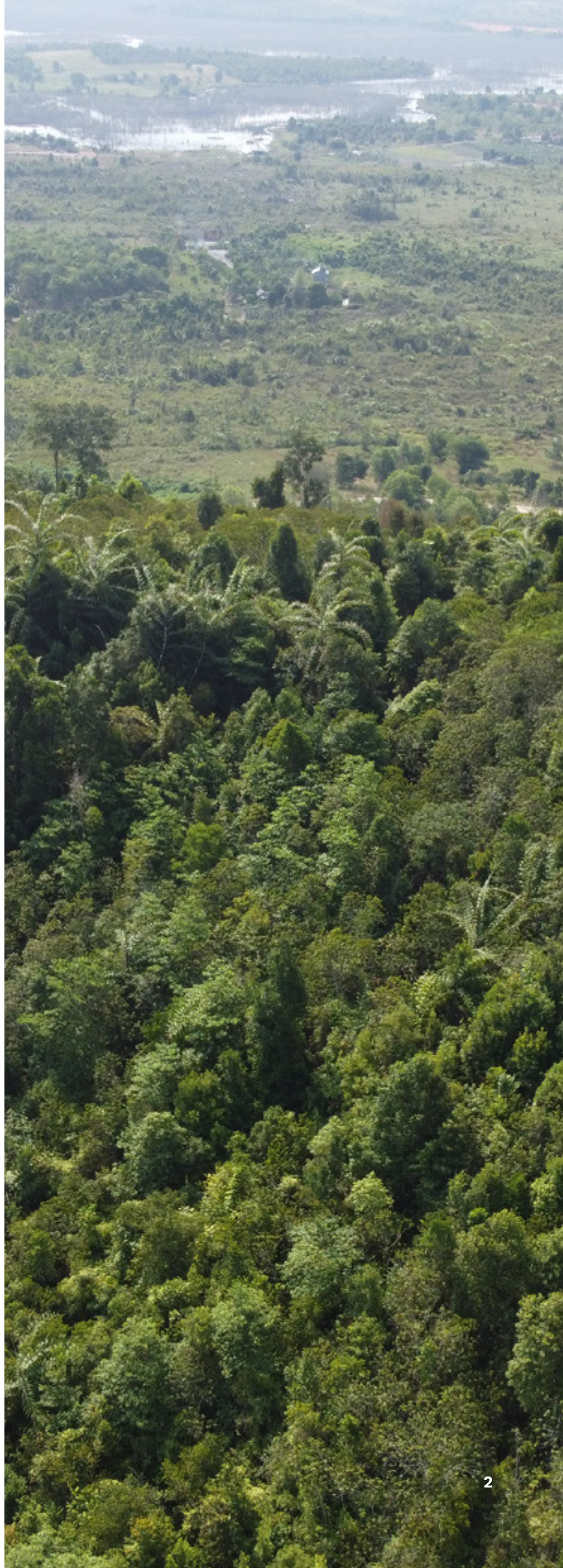
Natural capital is defined by a basket of metrics relating to air, water, soil, carbon, and biodiversity. The methodology in which natural capital is embedded is further discussed in the **Natural Capital Manifesto**. Developing natural capital begins with the design of High-Performance Ecosystems, where land is enhanced through nature-based solutions or ecosystem-based approaches that are planned, designed, and managed to optimize the delivery of ecosystem services. **The Design Principles for High-performance Ecosystems** provide guidance on achieving this.

Introduction of this report

AECOM was commissioned by the Initiative’s proponent, Napital Group, to establish a pilot project within a 760 ha study area in Bintan Island, Indonesia. This pilot project aims to localize a cutting-edge methodology for restoring degraded forest while harnessing the power of digital tools to monitor and communicate ecological gains through key natural capital data.

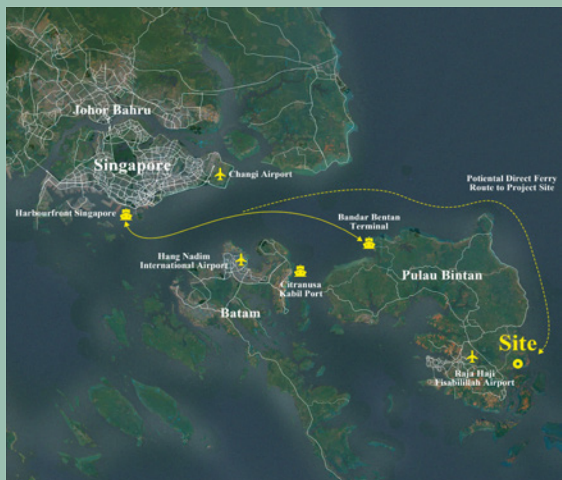
The Natural Capital Index is an approach to baselining, monitoring and evaluating the environmental performance of natural assets, such as forests, as they undergo restoration or enhancement. To understand whether true nature recovery is occurring within a site, a holistic approach is required, which not only assesses carbon or biodiversity, but which assesses and monitors uplift across multiple ecosystem services.

This index has been applied to a 100 ha forest restoration site to test the feasibility, practicality and accuracy of the assessment approach in determining and monitoring restoration success. This report contains the baseline findings drawn from the pilot project as well as the potential uplift over a 30-year period.



Pulau Bintan Natural Capital Pilot Project

Project Context



The Pilot Project is located on the southeast coast of Pulau Bintan, an island that forms part of Indonesia's Riau Archipelago. Bintan was historically covered in tropical rainforest characterised by dipterocarp trees, however, most of this has been lost due to landuse change. With the exception of Gunung Bintan and a few remaining forested patches, the rest of the island has faced significant human disturbance (Puspitaningtyas, 2019).

Citation: Puspitaningtyas, D. M., 2018. Orchid exploration in Mount Bintan Besar Protected Forest, Bintan Island, Riau Islands Province, Sumatra, Indonesia. Biodiversitas. 19 (3): 1081-1088.

Site Context

In the 1740s, Gambier and pepper plantations thrived in Bintan Island, later replaced by rubber. These large-scale monoculture plantations led to soil degradation and biodiversity loss. Abandoned plantations have since succeeded to secondary forest. By the 1990s, Bintan Island was densely vegetated. From 1990 to 2020, bare land increased by 186%, with vegetation hitting its lowest point in 2016 due to expanding mining activities. This mining has harmed soil fertility, impacting forest vegetation and biodiversity.

100 ha Site of Degraded Forest

Within the wider Project Site, a 100ha area of degraded forest has been identified as the focus of the restoration efforts for the Bintan Project Pilot. Whilst land within Gunung Kijang still contains forest, much of the 100ha area is highly degraded, comprising regrowth scrubland or young secondary forest that has been subject to human disturbance and resource extraction.

Natural Capital Index: A Comprehensive Set of Natural Capital Performance Data

To understand whether true nature recovery is occurring within a site, a holistic approach is required, which not only assesses carbon or biodiversity, but which assesses and monitors uplift across multiple ecosystem services. To quantify the results of restoration and enhancement actions, natural capital accounting will be employed, using five selected performance metrics. These were selected as being representative of core ecosystem services: soil, life, water, air and climate regulation.

Biodiversity Gain

Biodiversity Unit

Biodiversity gain involves creating, enhancing or restoring natural habitats with gains reflected by numerical change in ‘biodiversity units’. The UK has already rolled out a statutory biodiversity metric to measure losses and gains. In Asia, AECOM has developed the Singapore Biodiversity Accounting Metric and is developing similar metrics elsewhere.

By quantifying the value of habitats, biodiversity metrics calculate the potential loss or gain in biodiversity resulting from plans or projects,that can help stakeholders improve the sustainability of natural asset management.

Other Key Ecosystem Services

Air Index

Water Index

Soil Index

Natural capital projects aim to restore and protect natural ecosystems by reintroducing native species, improving habitat quality, and reducing human impacts. These projects help improve air, soil, and water quality and flood control by promoting natural processes that enhance ecosystem health.

By restoring balance and biodiversity, these projects improve environmental quality: further enhancing biodiversity as well as bringing societal benefits.

Carbon Sequestration

tCO_2e

Carbon dioxide (CO_2) is a greenhouse gas that is the main contributor to the climate crisis, being released in huge amounts through the burning of fossil fuels. Plants naturally absorb and store CO_2 during photosynthesis, a process know as sequestration.

The conservation and restoration of ecosystems with high sequestration rates (such as forests and wetlands) is therefore a major tool in the fight against global heating .

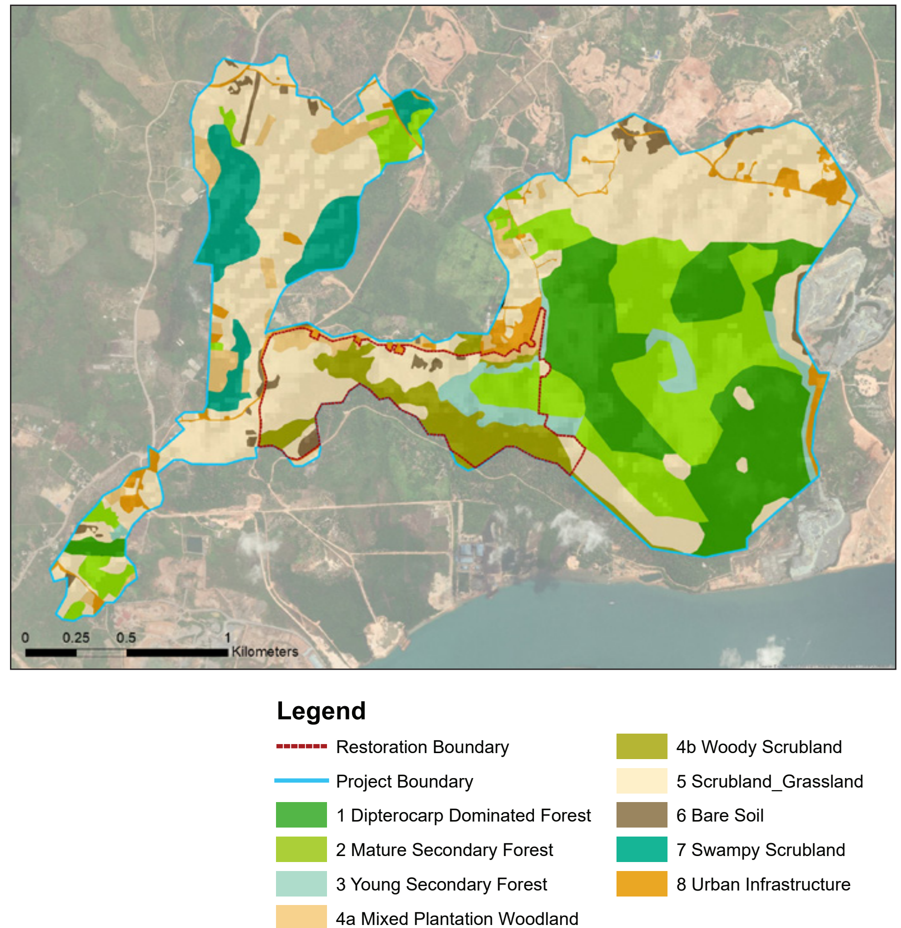
Natural History and Habitat Findings

Key findings

A preliminary assessment of the Project Site was conducted through a combination of remote sensing data analysis and scoping surveys conducted in September 2024. Key findings included:

- Remnants of a primary forest (dipterocarp-dominated forest) can be found sporadically across the 760 ha site, indicating the maximum potential for forest succession within the area, however the most accessible areas of the forest have been periodically logged and cleared for mining.
- The site was found to support low animal diversity amidst high plant diversity, which may be symptomatic of hunting pressure.
- Large areas on site are covered in scrubland and woody scrubland. The high percentage of scrub coverage likely results from logging and rock extraction. Whilst the 100ha restoration area has been highly disturbed, this leaves high potential for natural capital uplift.
- Forest restoration within disturbed areas might inhibited by low amounts of leaf litter and high topsoil compaction which indicates slower nutrient cycling and inconsistent organic matter source.

9 habitat types across 760 ha of land



Habitat Degradation

Many habitats across the 760 ha site were found to be highly disturbed by human activities, as either degraded forest or scrubland that has colonised felled forested areas.

What's preventing natural forest recovery:

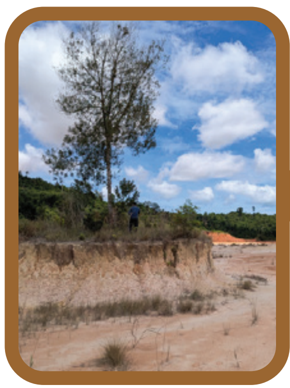
- Localised, small scale bauxite extraction has led to the complete removal of vegetation and topsoil, making vegetation reestablishment very challenging
- Local villagers extracting timber – preventing mature forest growth.

Potential of the Site

Successional Stages

From newly cleared land, plant communities can transition from grassland to forest, encouraging the growth of slow-growing woody species over fast-growing shrubs. This process is known as 'succession'. The types of habitats present indicate the development towards climax communities on of the restoration site.

Swampy scrubland and urban infrastructure do not follow similar successional stages and are omitted in this diagram.



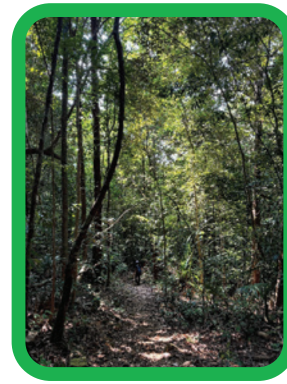
6. Bare Soil

5. Scrubland / Grassland

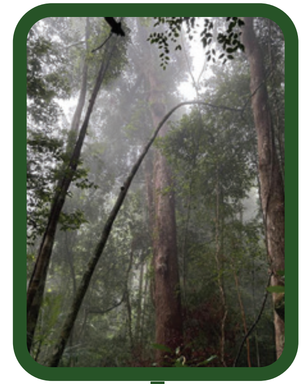
4b. Woody Scrubland

4a. Mixed Plantation Woodland

3. Young Secondary Forest



2. Mature Secondary Forest



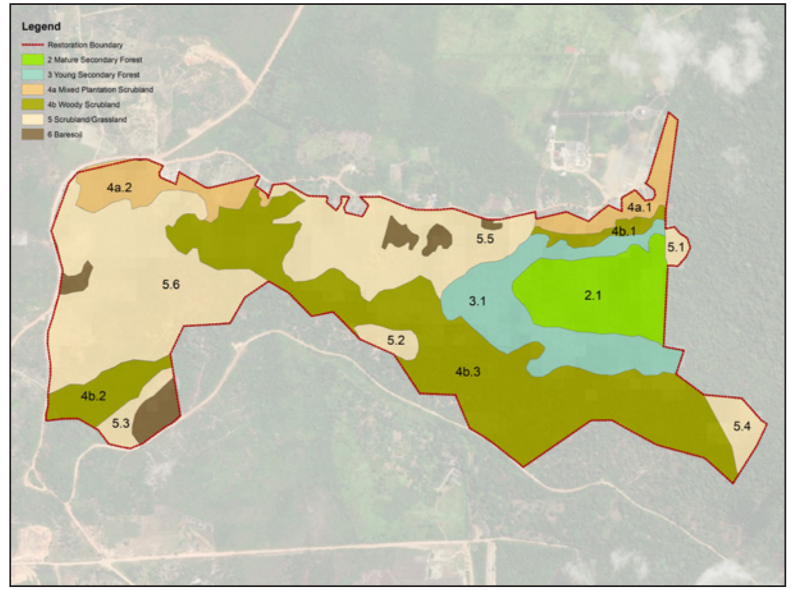
1. Dipterocarp dominated forest

Dipterocarp-dominated forest (i.e., Lowland primary rainforest) are forests characterised by the presence of mature dipterocarp trees. Whilst such forests were not found within the 100ha restoration site, remnants were identified within the 760ha site boundary; surrounded by secondary forest regrowth where the forest had been previously cleared. Within Bintan Island, Gunung Bintan is known to support dipterocarp-dominated forest at the hill's summit.

Dipterocarp-dominated forests typically have higher topsoil quality due to a higher turnover of leaf litter, which in turn encourages seedling establishment and forest regeneration. Due to the high canopy coverage, the understory experiences low light levels and high humidity, which creates a wider range of microhabitats that allows a wider range of plant growth forms, such as lianas, epiphytes, palms, herbs, shrubs, ferns and ground layer plants, which leads to greater structural diversity. A forest with greater structural complexity is likely to support higher biodiversity that improves ecosystem resilience and functioning.

100 ha Pilot (Restoration Site)

Most of the restoration site comprises a mosaic of different scrubland types, although forest habitats can also be found. The two forest habitats (mature secondary forest and young secondary forest) can be found mainly on the eastern fringes of the site, while plantation woodlands can be found on the northern fringes of the site, close to the villages. Scrublands found in the restoration site are typically evidence of past or ongoing human disturbance (logging and rock extraction) as there are often exposed, or even bare, patches of highly compacted and reddish soil high in iron. Meanwhile, the soil found in the forests are much less compact and contain higher amounts of organic matter which provides the nutrients necessary for forest species to grow.



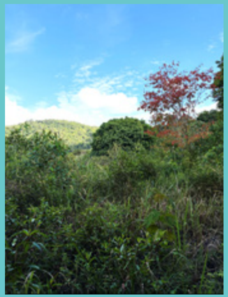
Bare Soil

Open ground with little to no vegetation cover. Typical of sites which were once mined or extracted for minerals.

Scrubland and Plantation

Scrubland / Grassland

Scrubland with little to no woody species; Mostly covered by grasses or shrubs.



Mixed Plantation Woodland

Possibly previously kampung plantations which have succeeded into a mix of woody species and grasses and/or shrubs

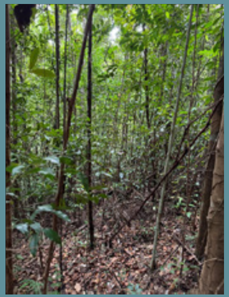
Woody Scrubland

Scrubland with occasional young woody species.

Forest

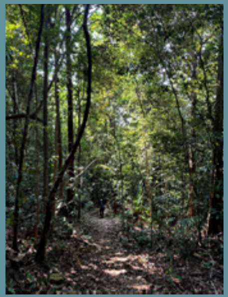
Young Secondary Forest

Young regrowth forest with smaller trees and dense undergrowth



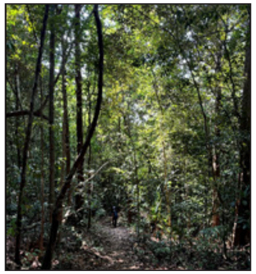
Mature Secondary Forest

Slightly more mature forest with woody species and a relatively covered canopy with some leaf litter present.



100 ha Pilot (Restoration Site)

Mature Secondary Forest


Regrowth in the site's mature secondary forests is much more apparent compared to young secondary forest. Within this habitat type, mature trees are present, however these are fewer compared with the dipterocarp-dominated forest found at Gunung Bintan. Some tall emergent trees identified within this habitat type are possibly remnants of the dipterocarp-dominated forest (primary forest) once present. Compared to dipterocarp-dominated forests, there is a higher proportion of younger trees, with a less dense canopy and higher light levels. Combined with high topsoil quality and an appropriate seed source, saplings within this habitat type mature quickly, and will transition to dipterocarp-dominated forest. Examples of species found include mousedeer tree *(Anisophyllea disticha)*, santol *(Sandoricum koetjape)* and shaggy leaved fig *(Ficus villosa).*

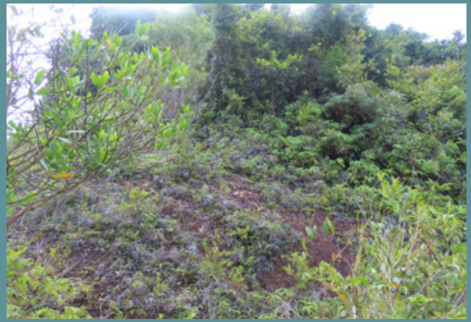
Young Secondary Forest



The young secondary forests across the site vary in their maturity, likely ranging from 10-20 years of regrowth. Most parcels of young secondary forest have a complete absence of mature trees, signifying the age. In addition, despite the relatively high topsoil quality, the forest structure is generally not complex or diverse, with a much lower canopy than mature secondary forests and denser undergrowth. As such, animal diversity and ecosystem functioning are limited. The young secondary forest has the potential to transition into a mature secondary forest within a 30-year period – however, a limiting factor in its succession to dipterocarp-dominated forest would be the lack of dipterocarp trees. These trees typically release seeds in cycles that span multiple years, meaning succession could be slow. Planting of dipterocarps within these areas would accelerate this process. Examples of species found in these forests include chemperai *(Champereia manillana),* greater grasshopper tree *(Archidendron clypearia)* and *Ficus hispida.*

Woody Scrubland

Woody scrubland habitats consist of a patchwork of shrubs and trees across scrublands. The ground frequently shows signs of disturbance such as exposed soils suggesting that this habitat had transitioned from a recently felled forest. Due to the poor quality of soil and the higher temperature and light levels from the lack of canopy coverage, only a distinct suite of woody species can thrive in these habitats. Woody scrublands will naturally transition into a young secondary forest after the early successional trees completely grow over small scrub. However, this is limited by the regeneration of topsoil and human disturbance (i.e., tree felling and rock extraction). Woody shrubs of pioneer species such as *Macaranga heynei, Phanera semibifida* var. *semibifida* and rattan palms dominate the landscapes.

100 ha Pilot (Restoration Site)

Mixed Plantation Woodland

Mixed plantation woodlands are typically found in close vicinity to kampungs (villages), where locals have cleared secondary forests and planted crop, fruit, ornamental, or medicinal species in their place. Like the woody scrubland, mixed plantation woodlands usually consist of scrubland or grassland habitat with the patches of woody tree growth. Topsoil quality is likely to have been adversely affected by the clearance and lack of canopy coverage, leading to erosion and exposed pockets of soil. Provided the habitat is located close to secondary forests, the mixed plantation woodland is likely to transition into a young secondary forest with time. Species include cempedak *(Artocarpus integer)*, banana *(Musa sp.)* durian *(Durio zibethinus)*, saga *(Adenanthera pavonina)* and corn palm *(Dracaena fragrans)*. Exposed pockets of soil can also be found in this habitat.

Scrubland / Grassland

Scrubland / grassland habitat establishes on highly degraded land with little to no topsoil following tree felling or bauxite extraction. These habitats consist primarily of dense and usually monotypic undergrowth. If woody trees and shrubs are present, they are short and scattered throughout the habitat. Due to the minimal canopy coverage, fast-growing herbaceous species quickly dominate the landscape and shade out the floor. Whilst the habitat will naturally transition into woody scrubland or young secondary forest, the disturbance to the topsoil may mean that taller woody species may find it difficult to establish until a topsoil layer has been reestablished. This may limit the speed of natural succession. The landscape is dominated by Resam *(Dicranopteris linearis)*, pitcher plants *(Nepenthes spp.)*, and woody saplings such as nettle tree *(Trema tomentosum)* and tiup-tiup *(Adinandra dumosa)*.

100 ha Pilot (Restoration Site)

Bare Soil

Bare soil, largely found around peripheries and within excavated forest paths, are a recent result of tree-felling and soil/mineral excavation, leaving an exposed soil profile which shows the characteristic red colouration associated with lateritic soils. Due to the extremely high temperature and low humidity levels of this exposed environment, flora communities are limited to scattered patches of monotypic herbaceous growth, of pioneer species such as pitcher plants and grasses. Due to the lack of vegetation and biodiversity, ecosystem functioning is near non-existent. Cessation of human disturbance within this habitat type will enable bare soil areas to transition to scrubland / grassland habitat.

Swampy Scrubland

Swampy scrubland habitats contain very waterlogged and often flooded soils and comprise only flora species tolerant of marshy conditions. Dead trees are often observed in this habitat, indicating woodlands were present before changes to site drainage caused the inundation of these areas. Swampy scrubland is unlikely to transition into any other habitat type unless the flooding is alleviated, and drier conditions are reestablished. The dead standing trees indicate that flooding was likely recent. Depending on how the hydrology changes overtime, the habitat could stabilise as a marshland, transition to a swamp forest, or if the area dries out again, see scrubland regrowth.

Natural Capital Uplift Strategy

Overview

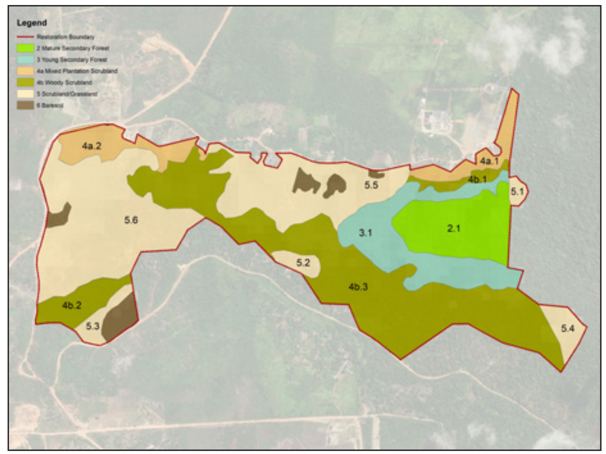
The main causes of habitat disturbance across the site includes tree felling and soil/mineral extraction. In order to restore the 100ha area, these pressures will first need to be relieved, allowing habitats to naturally transition into more mature habitat types. Plans to accelerate the succession will also be adopted and will include planting of dipterocarp trees.

For the purpose of projecting natural capital uplift, all projections will be assessed over a 30-year period. While our ambitions for our restoration site extend beyond 30 years, this timeframe represents a reasonable balance. It allows us to witness significant nature recovery while also serving as a suitable period for contracting purposes that fits within most people's lifetimes.

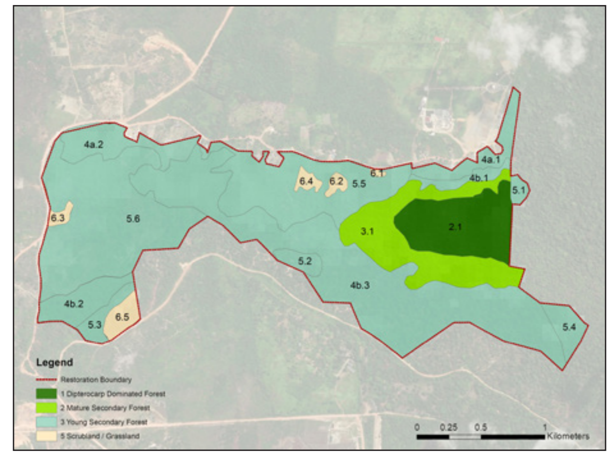
Projections are determined not only for the entire restoration site, but also the different habitat types identified within the baseline. The reasons for this are:

- Different habitat parcels will be subject to a different range of environmental conditions which may influence or restrict the potential for uplift.
- The length of time required to enhance or restore to higher successional stages will be dependent on the baseline successional stage. For example, within the Southeast Asian tropics, a grassland or scrubland can transition into a secondary forest much more quickly than it would take for a secondary forest to transition into primary forest.

Baseline Habitat Types



Target Habitat Types



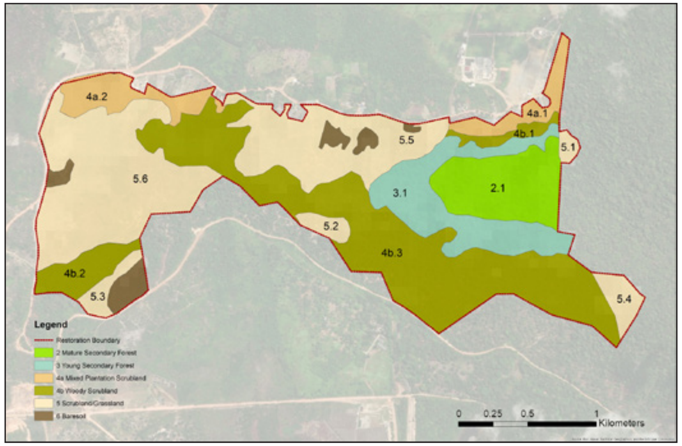
Site preparation, planting, maintenance, and management to achieve uplift for 30 years

Natural Capital Uplift Target

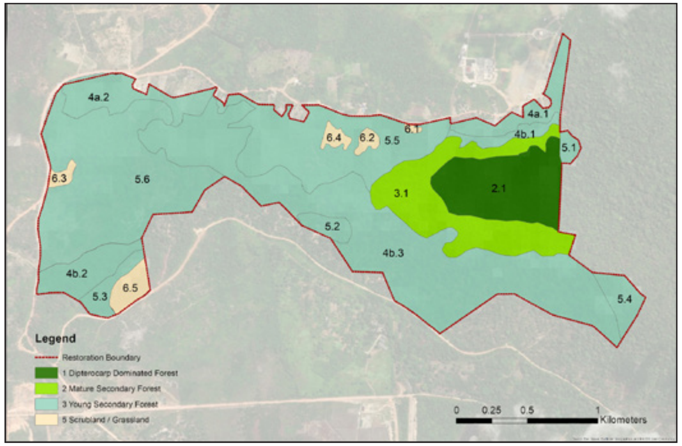
Natural capital uplift refers to the improvements in air quality, soil quality, biodiversity, carbon sequestration and water management that will occur as the forest is restored. These ecosystem services have both environmental and economic benefits, and as such are referred to as the big five data which will be monitored throughout the lifetime of the restoration to ensure natural capital uplift occurs in line with our projections. By implementing management measures such as replanting native tree species and working with local communities to safeguard the forest from resource extraction, the habitats will regenerate, improve in condition, and enhance the ecosystem performance of the site.

As grasslands turn into forests, a greater variety of flora and fauna will thrive. With the establishment of more mature forests, there will be greater carbon sequestration, cleaner air and water, as the forests become richer in biodiversity, and healthier, their ecosystem performance will improve. Mature forests are also capable of improving soil quality as their leaves decompose on the forest floor, replenishing the nutrients in the soil. Using data that can track these parameters would allow us to monitor our efforts and make adjustments when needed, ensuring the natural capital uplift of these habitats is maximised.

Current (Baseline) Habitat Types



Target (Projected) Habitat Types



Habitat Type	No. of habitat parcels	Area (ha)
1 Dipterocarp Dominated Forest	-	-
2 Mature Secondary Forest	1	8.9
3 Young Secondary Forest	1	10.7
4a Mixed Plantation Woodland	2	7.2
4b Woody Scrubland	3	33.4
5 Scrubland / Grassland	6	36.9
Bare ground	-	2.9
TOTAL		100

Habitat Type	No. of habitat parcels	Area (ha)
1 Dipterocarp Dominated Forest	1	8.9
2 Mature Secondary Forest	1	10.7
3 Young Secondary Forest	11	77.5
4a Mixed Plantation Woodland	-	-
4b Woody Scrubland	-	-
5 Scrubland / Grassland	5	2.9
Bare ground	-	-
TOTAL		100

Biodiversity Uplift

Measuring Biodiversity Uplift

Habitat Vegetation

Improves understanding of habitat distribution

Walkover surveys were used to ground-truth preliminary mapping done on Google Earth

The Singapore Biodiversity Accounting Metric (SGBA) is a tool that can be used to quantify the biodiversity value of habitat parcels within Singapore and neighbouring areas. It can be used to assess changes in biodiversity value of a site and to track compositional and structural changes to habitats. The SGBA has been modified for applicability to the pilot project, given that Bintan Island and Singapore fall within the same ecoregion and share similar habitats and ecosystems. Utilising literature and knowledge of rates of enhancement or restoration of habitat types, we have estimated the approximate number of years required to reach a target habitat condition or higher successional state. This function is used as a guide to determine what the highest possible condition each habitat parcel can be restored/enhanced to within 30 years.

Utilising this method, the total increase in biodiversity units that could be achieved within 30 years is determined and thus used as a mechanism to monitor and evaluate the restoration process.

DISTINCTIVENESS CRITERIA - TERRESTRIAL

CRITERIA	HIGH (3)	MEDIUM (2)	LOW (1)	ZERO (0)
SPECIES RICHNESS: the total number of flora (vascular plant) and fauna (bird, butterfly, odonate, amphibian, reptile, mammal) species that can be expected to occur in the habitat, excluding introduced fauna species.	High flora and fauna species richness (900 or more species)	Moderate flora and fauna species richness (600 to 899 species)	Low flora and fauna species richness (300 to 599 species)	Very low flora and fauna species richness (Less than 300 species))
IRREPLACABILITY: the difficulty of recreating, or replacing the habitat to its ecologically optimal structure and species composition via human intervention, natural or accelerated succession within 30 years. This also takes into account re-establishing of habitat or ecosystem health, and ecological (biotic and abiotic) dynamics required to establish an effectively functioning habitat.	Impossible to recreate/replace (e.g., lowland dipterocarp primary forest)	Difficult to recreate/replace (e.g., native-dominated secondary forest, coastal forest)	Easy to recreate/replace	Not ideal to recreate/replace for biodiversity
RARITY: area of a particular habitat type remaining as a percentage of all terrestrial land mass in Singapore. For intertidal and marine habitats, this is taken as the proportion of land to sea surface area that the habitat covers across Singapore's total coastal area.	Habitat is rare in Singapore (e.g., lowland dipterocarp primary forest, native-dominated secondary forest, coastal forest, casuarina-dominated forest, grassland, fern-dominated vegetation)(<5%).	Habitat is uncommon in Singapore (e.g., abandoned-land forest, waste woodland, scrubland) (5% to 30%)	Habitat is common Singapore (e.g.,vertical greenery, streetscape, urban park/garden, community farm, commercial farm, golf course, turf, skyrise greenery). (>30%). Habitat types which support <300 species, are asumed to be lowest priority for biodiversity and therefore automatically fall under this	Habitat is ubiquitous in Singapore (e.g., buildings).
UNIQUE SPECIES: the total number of unique flora (vascular plant) and fauna (bird, butterfly, odonate, amphibian, reptile, mammal) species that can be expected to occur in the habitat. Unique species are those that are not typically found in other habitats.	Supports a high number of unique flora and fauna species (15 or more unique species)	Supports some unique flora and fauna species (10 to 14 unique species)	Supports few unique flora and fauna species (Less than 10 species)	Does not support any unique flora and fauna species

Biodiversity Accounting Assessment (Biodiversity Unit Calculation)

A - Baseline Habitat Calculation

1 . HABITAT PARCEL (HA) X 2. DISTINCTIVENESS X 3. HABITAT CONDITION

B - Post-Development Habitat Calculation

1 . HABITAT PARCEL (HA) X 2. DISTINCTIVENESS X 3. HABITAT CONDITION X 4. PERFORMANCE AND CONTROL

C - Calculating Change in Bio Units

B - A = NET CHANGE IN UNITS

B - A / A = UNIT CHANGE (%)

The SGBA uses the ecological value of the habitats to estimate overall biodiversity value, transforming complex data into quantifiable units.

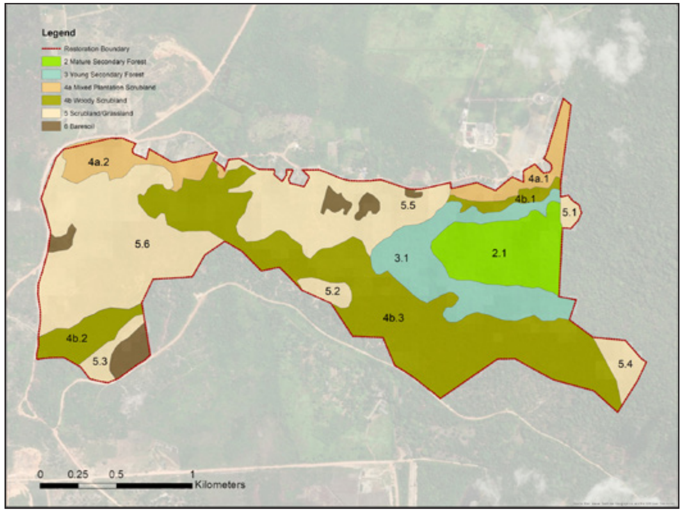
Each habitat type has been split into several habitat parcels, for which specific restoration actions are recommended based on the type and intensity of the disturbance.

Habitats with the highest potential restoration value are

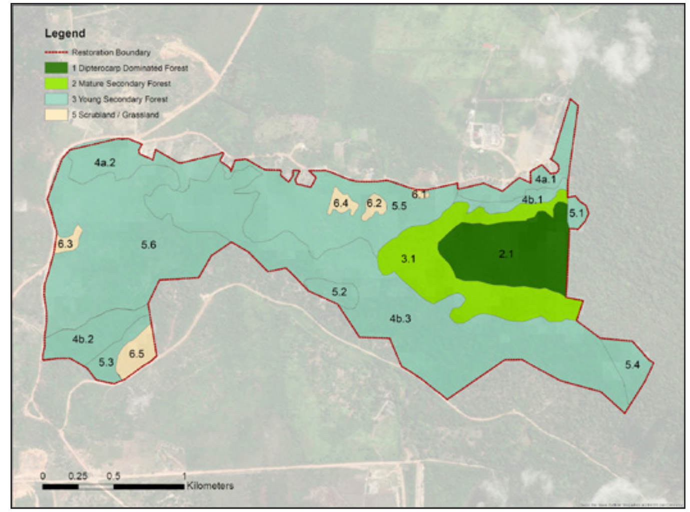
- Bare soil (0 units/ha)
- Scrubland / Grassland (2 units/ha)

Biodiversity Units - Habitats & Vegetation

Current (Baseline) Habitat Types



Target (Projected) Habitat Types



Habitat Types	No. of habitat parcels	Area (ha)	Biodiversity Units
1 Dipterocarp Dominated Forest	-	-	-
2 Mature Secondary Forest	1	8.9	106.80
3 Young Secondary Forest	1	10.7	64.20
4a Mixed Plantation Woodland	2	7.2	43.20
4b Woody Scrubland	3	33.4	133.60
5 Scrubland / Grassland	6	36.9	73.80
Bare ground	-	2.9	-
TOTAL		100	421.60

The restoration of the site can more than double the biodiversity value.

Habitat Types	No. of habitat parcels	Area (ha)	Biodiversity Units
1 Dipterocarp Dominated Forest	1	8.9	195.44
2 Mature Secondary Forest	1	10.7	149.59
3 Young Secondary Forest	11	77.5	547.70
4a Mixed Plantation Woodland	-	-	-
4b Woody Scrubland	-	-	-
5 Scrubland / Grassland	5	2.9	5.80
Bare ground	-	-	-
TOTAL		100	898.53

Measuring Biodiversity: Additional Pilot Indicators

Whilst the natural capital projection approach assesses the upper limit of enhancement or restoration over 30 years in terms of biodiversity units, utilising SGBA alone is not sufficient to accurately determine if a true uplift in biodiversity is occurring. This is due to the habitat condition assessments that were designed for Singapore being built around traditional survey methods which cannot be fully undertaken on Natural Capital Initiative projects due to:

- The sheer comprehensive extent of surveys required which would require extensive time and expense; and,
- Paucity of biodiversity reference data for locations like Bintan Island to establish accurate condition criteria for fauna (note that the condition criteria for Bintan were modified to focus on vegetation, structural diversity and degradation only and do not consider fauna).

With this in mind, a combination of camera traps, environmental DNA (eDNA), and bioacoustics are used to complement the biodiversity accounting metric, considering that the SGBA has been modified to assess habitat value and structural diversity only, meaning there is a need to factor in above and below ground fauna to effectively track and monitor uplift in biodiversity against the habitat enhancement projections across a 30-year period.

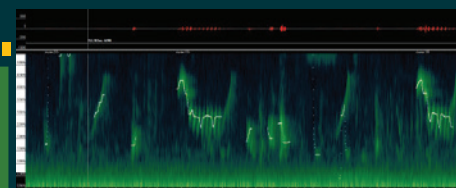
Soil Biota Community Composition

Provides insight into soil health

Soil and aquatic samples were taken and analysed for

- Metazoans
- Bacteria and fungi
- Vertebrates

Fauna Species Diversity

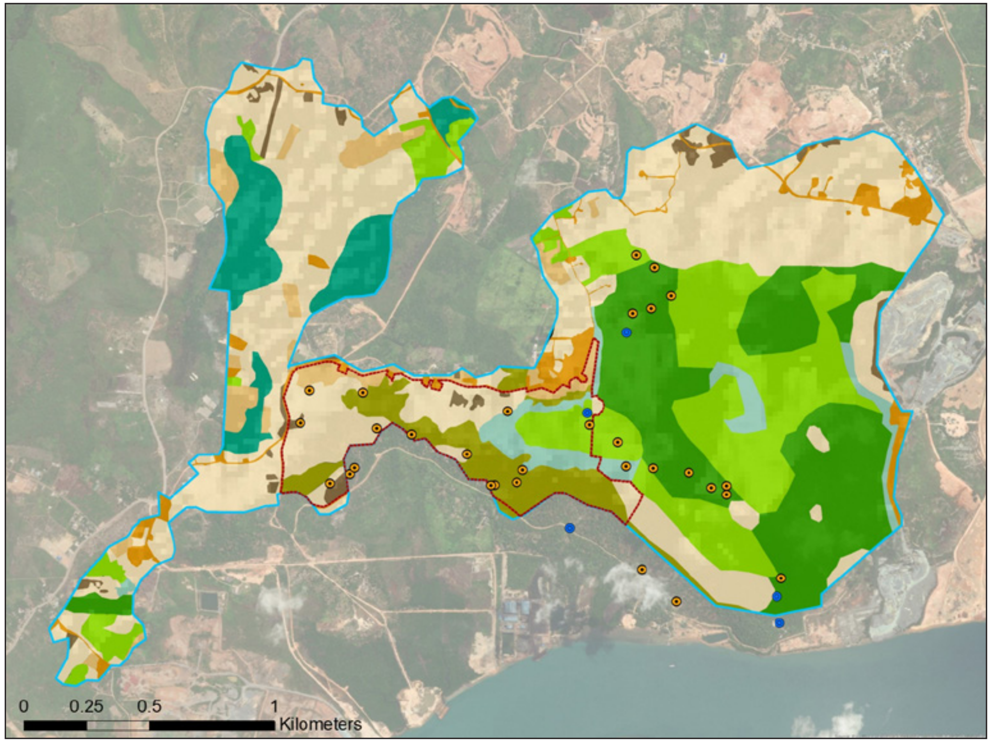


Measures soundscape to estimate species diversity

Bioacoustic Composite Metric $= \frac{1}{6}\sum_{i=1}^{6} Index_i$

Individual bioacoustics indices were computed, normalized and weighted to form a composite metric which estimates species diversity

Soil Biota - eDNA



Legend

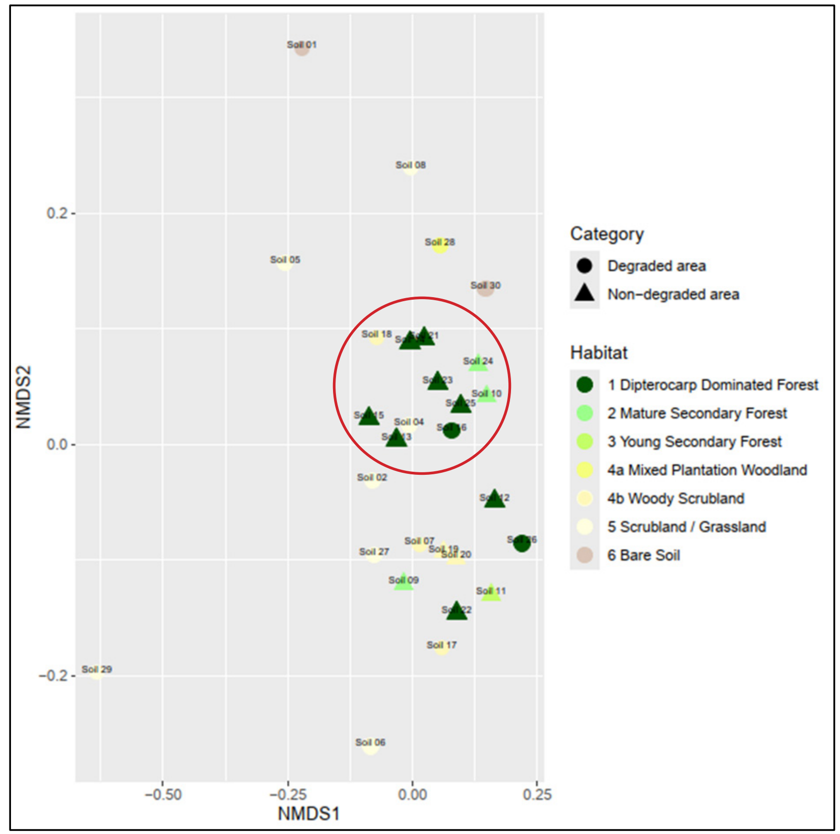
Sample Type

- Aquatic eDNA sample point
- Soil eDNA sample point
- Project Boundary
- Restoration Boundary
- 1 Dipterocarp Dominated Forest
- 2 Mature Secondary Forest
- 3 Young Secondary Forest
- 4a Mixed Plantation Woodland
- 4b Woody Scrubland
- 5 Scrubland_Grassland
- 6 Bare Soil
- 7 Swampy Scrubland
- 8 Urban Infrastructure

Environmental DNA

By amplifying DNA fragments sampled from different habitats, the soil microbial communities from different habitats can be quantified and visualized based on composition in a plot. The healthier the soil community, the closer they will be to the dark green points (representing high value dipterocarp dominated forests) on the plot below.

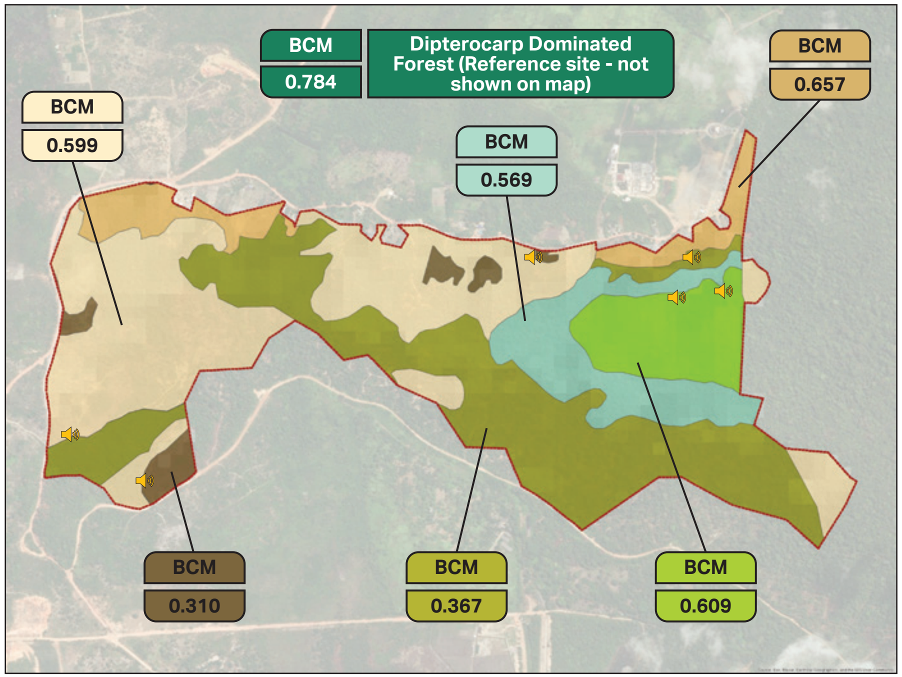
Strong clustering of Dipterocarp Dominated Forests (DDF) below indicate high similarity in community composition. As habitats mature, they should migrate towards the cluster of DDF points.



Fauna Species Diversity - Bioacoustics

Bioacoustics recorders were deployed and set to record at dawn, dusk and night to capture calls from various vocalising fauna. The recordings captured were processed and scored based on several metrics that captured elements of evenness, intensity and diversity.

The biodiversity indices produced were normalised and combined to form a Bioacoustics Composite Metric (BCM) which serves as a proxy for species diversity on site. The higher the BCM value, the higher the estimated species diversity.

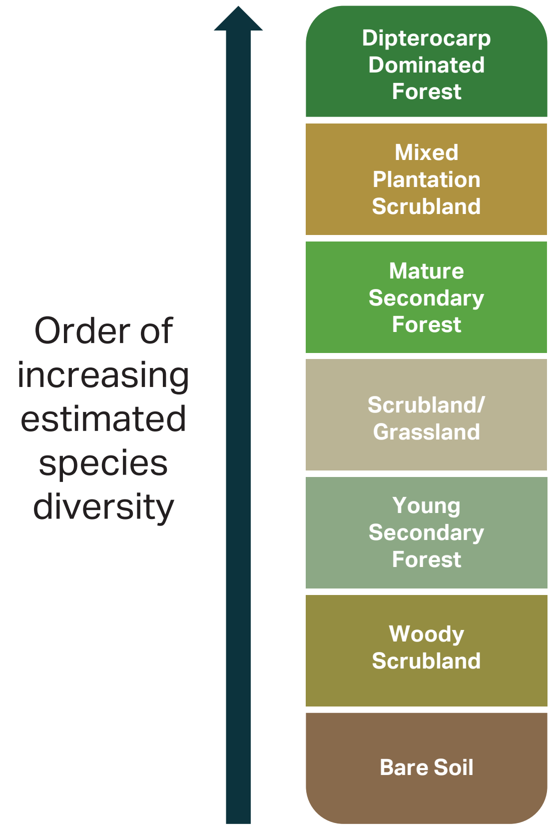


Legend

Restoration Boundary

Baseline Map

- 2 Mature Secondary Forest
- 3 Young Secondary Forest
- 4a Mixed Plantation Woodland
- 4b Woody Scrubland
- 5 Scrubland_Grassland
- 6 Bare Soil
- Soundmeter Locations



As habitat quality increases, we expect the score of the composite metric to increase.

Currently, the Dipterocarp Dominated Forest (reference site) has the highest estimated diversity while the bare soil has the lowest.

Faunal Species Richness and Species of Conservation Significance

Using data from camera traps, walkover surveys and bioacoustics recordings, a repository of fauna species found on site was created.

Total fauna species richness	Total endangered species	Total species found in CITES Appendices
34	**2**	**6**

2 IUCN Red List (Endangered) species

Spiny Terrapin
Heosemys spinosa
*also in the CITES appendices

Long-tailed Macaque
Macaca fascicularis

6 species found in the CITES Appendices

Brilliant rasbora
Rasbora einthovenii

Brahminy Kite
Haliastur indus

White-bellied Sea Eagle
Haliaeetus leucogaster

Common treeshrew
Tupaia glis

Lesser mousedeer
Tragulus kanchil

Soil Index

Baseline & Projection Findings

Healthy soils are essential for resilient forest ecosystems and underpin the services they provide. The clearance of vegetation and/or conversion of forest to other land uses has multiple impacts on soils, including erosion, loss of litter influx after canopy removal and enhanced decomposition and nutrient mineralization rates.

Higher Soil Organic Matter (SOM) is generally an indicator of better-quality soils. 30 SOM samples were taken from 7 different habitat types across the Project Site, with measurements varying from 1.65% SOM in areas of bare soil to 7.27% SOM in dipterocarp dominated forests, indicating a range of soil quality conditions.

Based on existing habitat conditions, the current average SOM across the 100ha restoration site is 4.31%. Based on 30-year projected habitat restoration conditions, the average SOM across this area would be 5.40%, an increase of 25.3%.

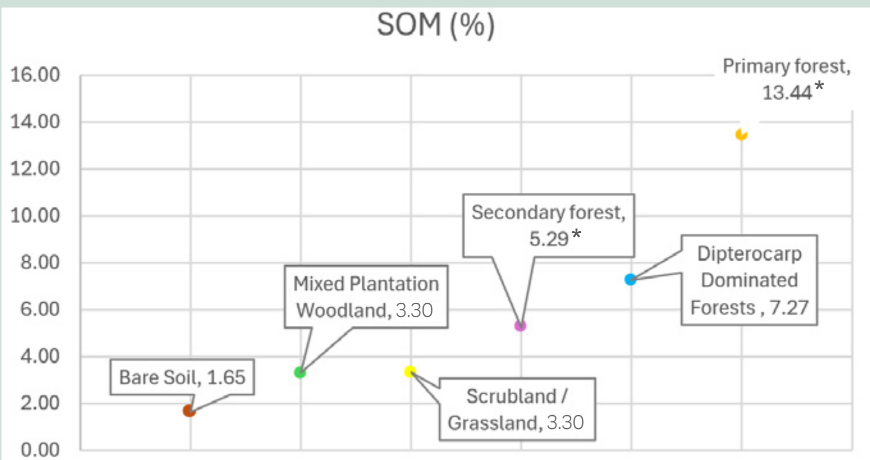
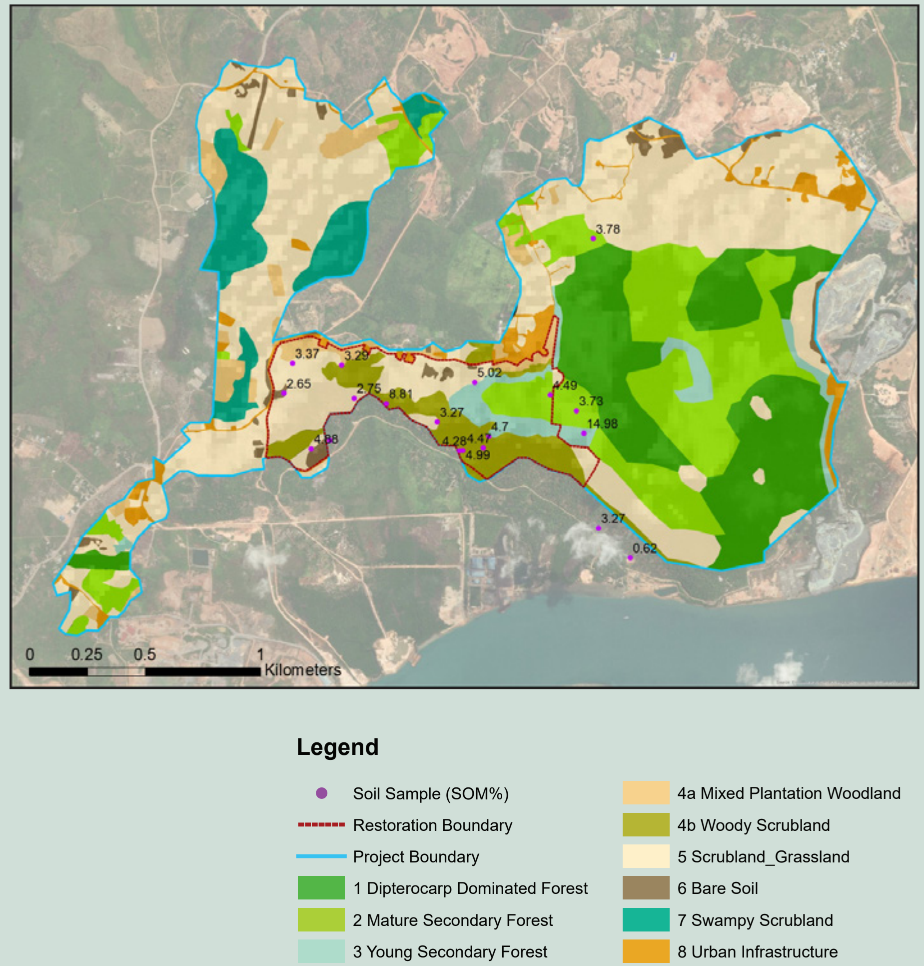


Table. Soil carbon matter across all soil samples based on Walkey & Black method

* data sourced from Helmi & Sufardi (2024)



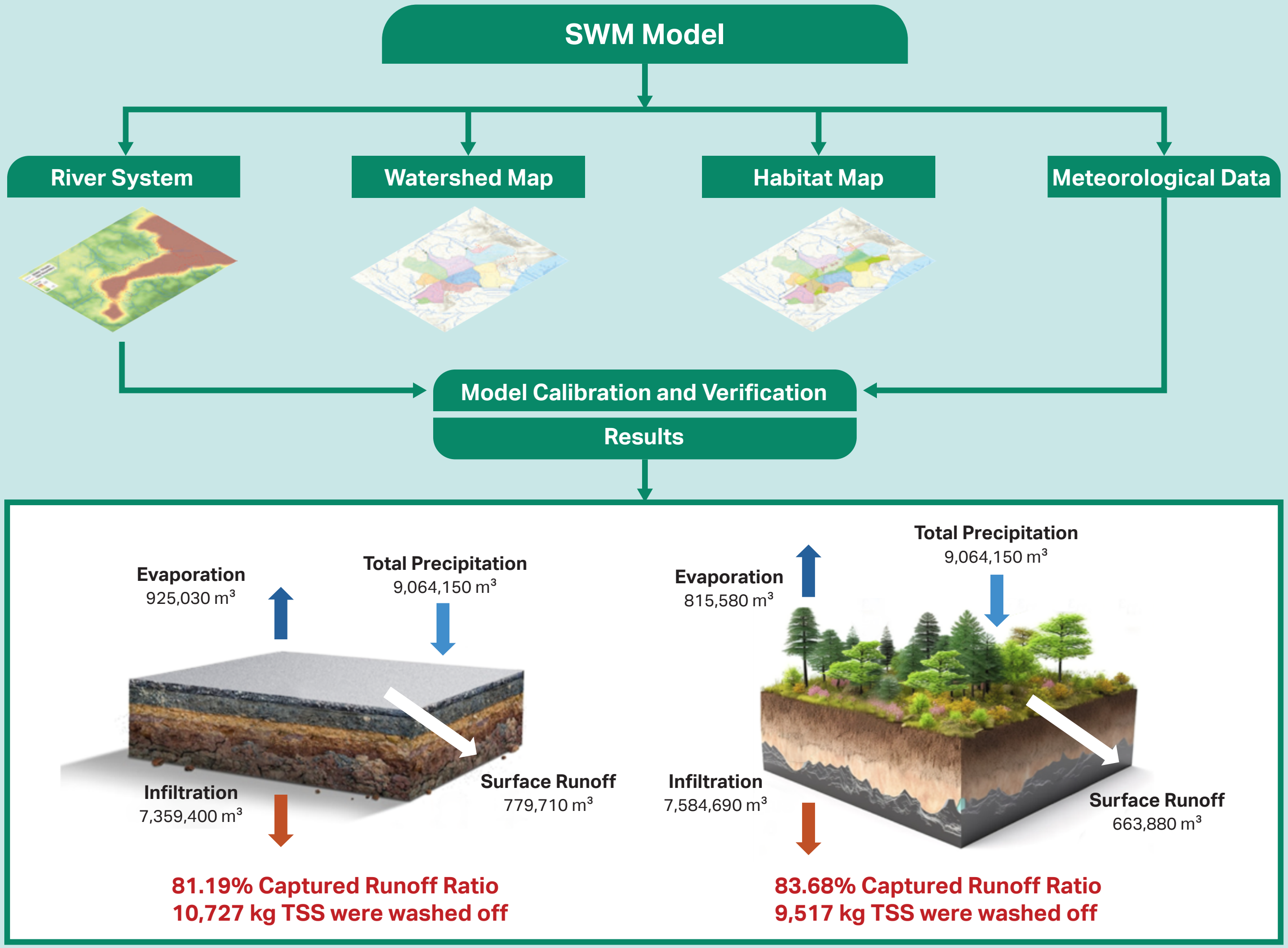
Water Index

Baseline & Projection Findings

Healthy ecosystems play an essential role in regulating the water cycle, moderating climate through evapo-transpiration, attenuating stormwater run-off during rain and reducing water pollution. These functions are less effective in degraded habitats. Converting degraded habitats areas into forest can reduce sedimentation and control nutrient runoff.

The SWM Model was used to estimate improvements in flood control functions and reduced sediment erosion and run-off. The projected habitat enhancement works would increase rainwater infiltration, resulting in an overall surface runoff reduction of 12.1%. TSS (Total Suspended Solids) washoff would be reduced by 7.58%.

A Normalized Composite Index was applied to assess runoff control and TSS washoff capacity, incorporating a weighted allocation (60% for runoff control and 40% for TSS washoff). The baseline composite water index was 0.201, which is projected to increase to 0.223 following 30-year projected habitat restoration, demonstrating an improvement of 0.022.



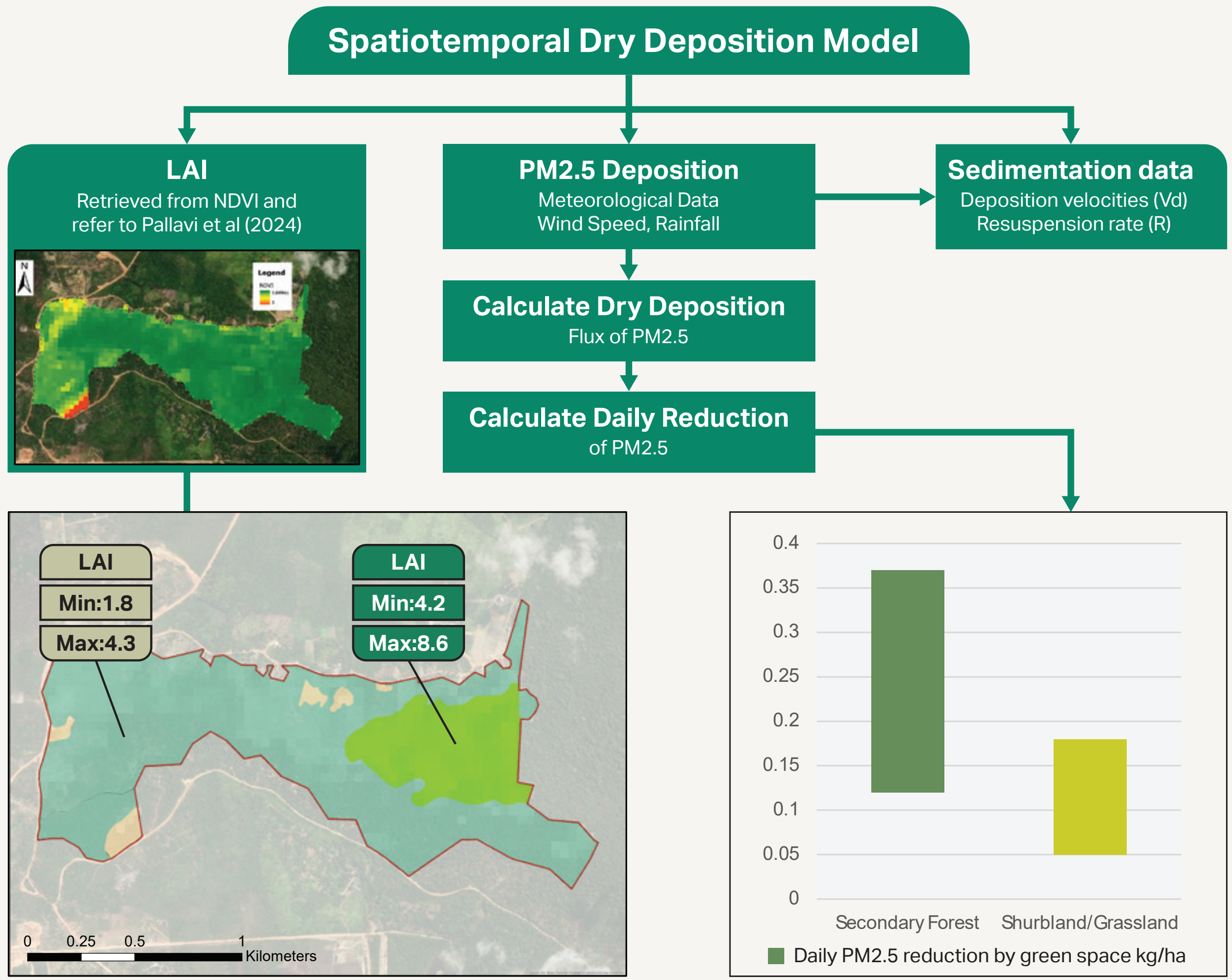
Air Index

Baseline & Projection Findings

Air pollution is the greatest environmental threat to public health globally. Air pollution and climate change are closely linked as all major pollutants have an impact on the climate and most share common resources with greenhouse gases. Improving our air quality will bring health, development, and environment benefits.

Spatiotemporal Dry Deposition Model that take factors such as climate, biogeography, deposition velocity and concentration of PM2.5, and Leaf area index (LAI) (i.e. , Normalized Difference Vegetation Index (NDVI)) were used to estimate air pollutant removal potential of the habitats. The daily PM2.5 reduction of forest is 0.12-0.25kg/ha, as the high LAI (ranging between 4 to 9), provides a larger surface area for PM2.5 settle on leaves and branches. In contrast, grassland typically have a lower LAI (less than 4) which would remove 0.05-0.13kg/ha daily.

The current estimated PM2.5 removal provided by the 100ha restoration site is approximately 2.12 tonne/yr. Based on 30-year projected habitat restoration conditions, the PM2.5 removal is expected to increase to approximately 3.64 tonne/yr, an increase of 71%.



Carbon Sequestration

Baseline & Projection Findings

The ability of ecosystems to absorb carbon from the atmosphere and store it is a key service that helps regulate the climate and fight the worst impacts of the climate crisis. This process is known as carbon sequestration and refers to the total amount of carbon stored in ecosystem booth in living (i.e. biomass) as well as non-living (i.e. soils) material. Carbon sequestration can be measured as the sum weight of carbon contained in a particular ecosystem, or the amount of carbon absorbed by the ecosystem per unit of time.

Mature forests typically have greater carbon sequestration capability in above-ground biomass (AGB) and soil carbon than other habitats such as grassland and shrubland.

With reference to published literature, the current estimated carbon stock of the 100ha restoration site is approximately 15,207 tonne C. Based on 30-year projected habitat restoration conditions, the carbon stock across this area would be 22,129 tonne C, an increase of 45.5%.

Demonstration for Baseline and Target Habitat Types

Baseline Habitat Types[1]	Area (ha)	Baseline Average Carbon Stock in Vegetation and Soil (tonne C)[2]	Baseline Carbon Stock (tonne C)	Target Habitat Type	Target Average Carbon Stock in Vegetation and Soil (tonne C)	Projected Carbon Stock (tonne C)	Projected Increase in Carbon Stock (tonne C)
Mature Secondary Forest	8.9	194-253.6 Mean: 223.8	1991.82	Dipterocarp Dominated Forest	223.8	1991.82	0
Young Secondary Forest	10.7		2394.66	Mature Secondary Forest		2394.66	0
Mixed Plantation Woodland	7.2	111.5-162.8 Mean: 137.1	987.12	Young Secondary Forest		17344.50	6719.25
Woody Scrubland	33.4		4579.14				
Scrubland / Grassland	36.9		5058.99				
Bare ground	2.9	67.5	195.75	Scrubland / Grassland	137.1	397.59	201.84
	-	-	**15207**	-	-	**22129**	**6921**

Notes:

[1]"For the baseline assessment, the various habitats recorded on the site were consolidated into three categories to align with the data obtained from our literature review."

[2] The range of carbon stock is sourced from Publication from FAO; IPCC (2019); Krisnawati et al., (2024)

tCO_2e per unit time = **Scientific Literature** Sequestration rate multiplier X **Field Data** Measured quantity of habitat

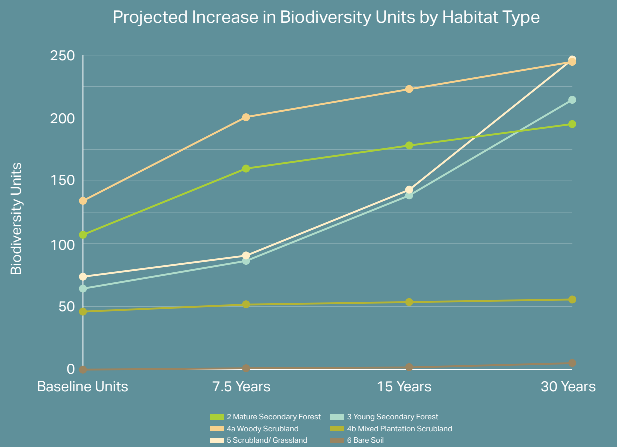
Bintan 100ha Forest Pilot Project Natural Capital Index

	Biodiversity Unit	Air Index (ton PM2.5)	Water Index	Soil Index (%SOM)	Carbon (tCO_2e)
Baseline data	421.60	2.12	0.201	4.31	15,207
Projection data	898.53	3.64	0.223	5.40	22,129
	Biodiversity Gain	Other Key Ecosystem Services			Carbon Sequestration

Note: the data and methodologies used to calculate these indices were derived from various sources including scoping surveys and available literature. They represent a reasonable estimate of potential natural capital uplift on the site based on these data sources. Detailed site investigations would yield more accurate and verifiable results.

Natural Capital Index Projection

Biodiversity Gain Projection



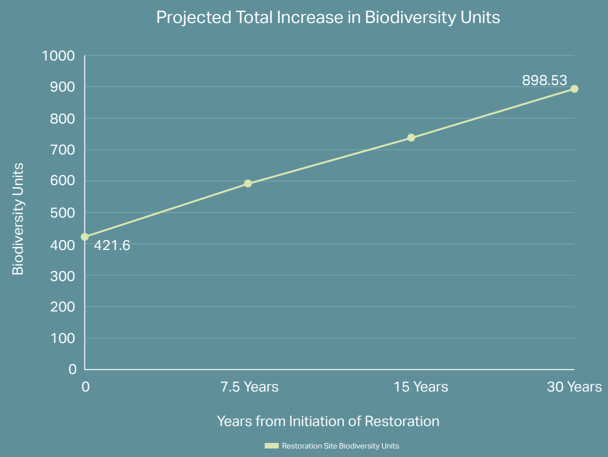
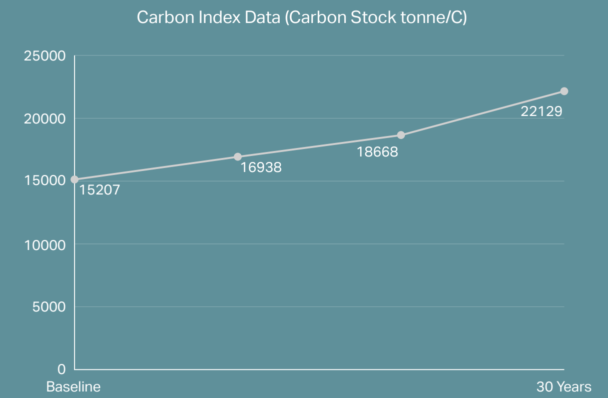
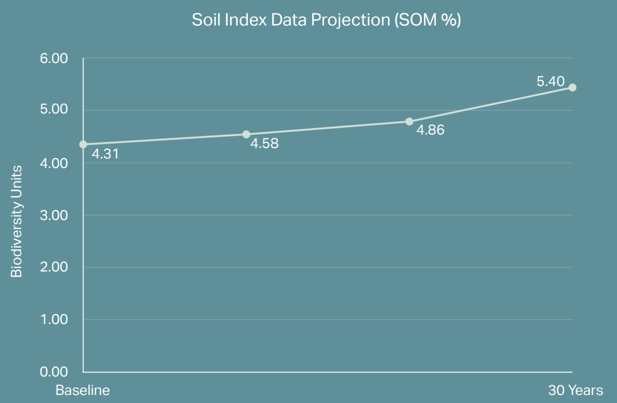
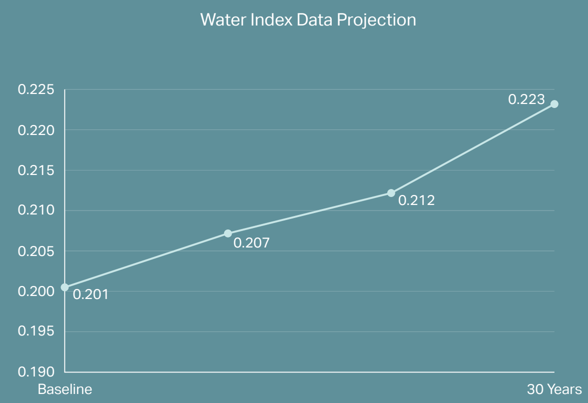
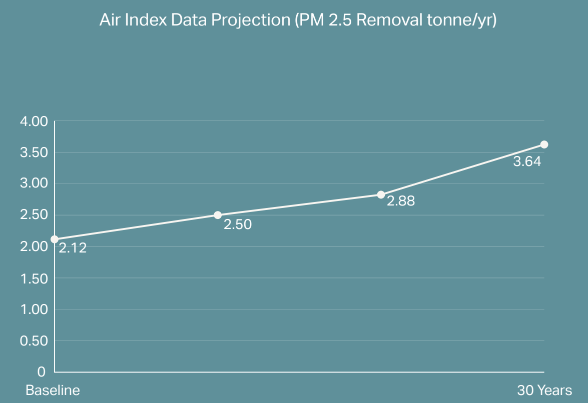


Figure 0-2 Visualised projection of the project uplift in biodiversity units over a 30-year period









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