001-OxC: Global Mangrove Trust Restoration & Conservation project in North Sumatra

Project Title	001-OxC: Global Mangrove Trust Restoration & Conservation project in North Sumatra
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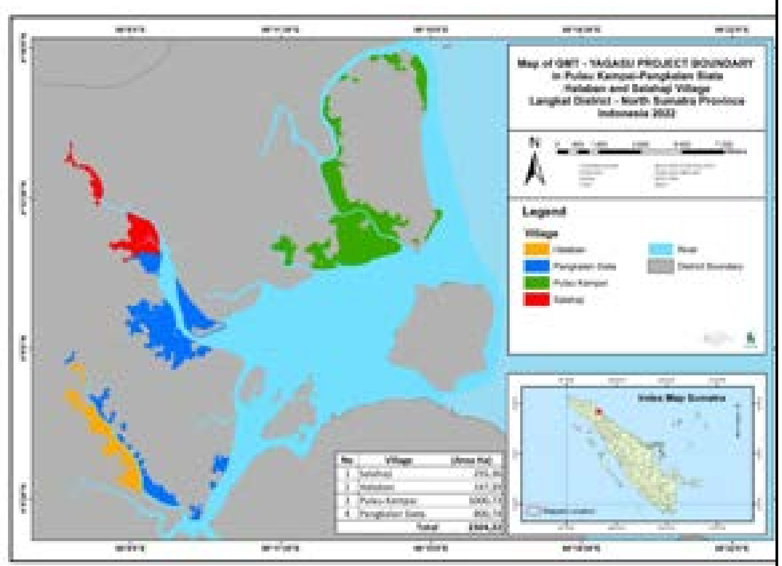
Location: **North Sumatera, Indonesia**	
Validation Standard	OxCarbon Principles - OxCarbon Ltd, United Kingdom
Project Start Date	14th September 2021
Project Lifetime & Monitoring Period	**30 Years;** **5 Year Windows, Repeating**
Local Implementation Partner and Key Benefits	**Yayasan Gajah Sumatera (YAGASU)** **Community Benefits:** Employment in forest patrols, nursery works, and restoration; artisanal women's groups, silvofishery groups, eco-tourism programs. **Biodiversity Benefits:** Tropical Mangrove Forest Conservation and Polyculture Restoration
Expected Verification Schedule	**Baseline initiation**: November 2021

Expected First Vintage of credit Issuance	2022

Executive Summary

Today, Indonesia's mangrove's carbon stocks stand among the highest of any tropical forest type in the world. Yet deforestation rates in Indonesian mangroves have remained high. A comprehensive survey of emissions due to mangrove losses has found that over 260,000 ha of mangroves suffered significant losses from 2009 to 2019, with 182,000 ha (~70%) fully deforested and the remaining 30% suffering major degradation[1]. Conversions of mangroves to production forests (e.g. palm oil) and to shrimp ponds have further decreased total carbon stocks within the national ecosystem by as much as 29%. As a result, restoration of degraded mangrove forests in Indonesia could generate emission reductions equivalent to 8% of Indonesia's 2030 NDC targets from the forestry sector. This data underscores the government's robust support for a nascent mangrove conservation and restoration sector.

The Global Mangrove Trust (GMT), in collaboration with Yayasan Gajah Sumatera (YAGASU), initiates the Global Mangrove Trust Restoration & Conservation project in North Sumatra (001-OxC). 001-OxC protects virgin and degraded mangrove areas with four villages implementing pre-defined Avoided Deforestation Activities. These have a direct positive impact on the environment, biodiversity, climate, and livelihoods. The project has potential to contribute reduced emissions of 2,594,027 tonnes CO2 equivalent over its lifetime to support the Nationally Defined Contributions (NDCs) of Indonesia.

The project period for 001-OxC will span thirty years with partners committed to providing services throughout the project's lifetime. At registration, GMT and YAGASU have secured relevant permissions to complete baselining forest carbon research from the relevant authorities in North Sumatra in a rigorous effort to protect, regenerate, and monitor 2,305.6 hectares of mangrove forest. The Kumi Analytics Carbon Sequestration Assessment Tool (KACSAT) Space-Based Innovative Monitoring Engine will be used as the monitoring tool for quantifying reduced deforestation and carbon capture rates.

Section One of this dossier presents the profile, stakeholders, and objectives of 001-OxC. Section Two focused on the applied methodology for the identified project restoration area. Section Three details the current state of research, including the OxCarbon Leakage Belt Protocol, ground observations of tree measurements, soil samples, and data findings from KACSAT's space-based monitoring tool.

[1] Arifanti, V. B., Kauffman, J. B., Ilman, M., Tosiani, A., & Novita, N. (2022). Contributions of mangrove conservation and restoration to climate change mitigation in Indonesia. *Global change biology*, *28*(15), 4523-4538.

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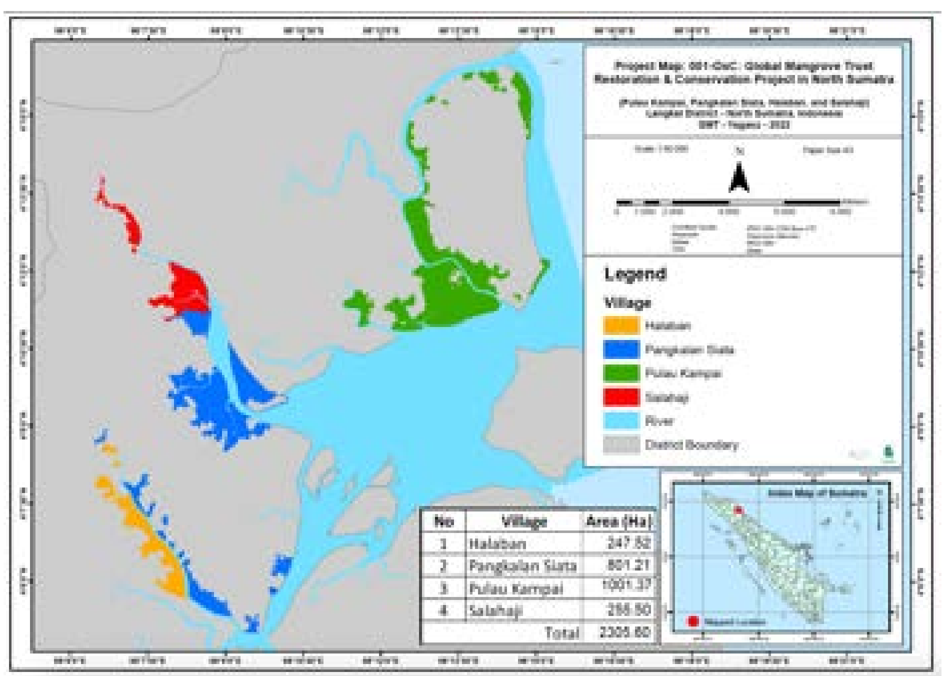
Part I: Project Profile

001-OxC is the inaugural blue carbon conservation project launched under the OxCarbon Standard. Situated in North Sumatra, 001-OxC aims to conserve and regenerate coastal ecosystems such as mangrove forests and marine coastal areas. The project actively supports nature-based solutions to the climate crisis and fortifies sustainable long-term livelihoods for coastal communities.

The total project area is 2,305.6 hectares using KACSAT's 1-metre scale, located between coordinates 04°04'30" - 04°16'30"N and 98°06'30" - 98°14'30"E on the Southwest coast of the Malacca Strait in four registered villages: Salahaji, Pulau Kampai, Halaban, and Pangkalan Siata in Langkat district, Medan, North Sumatra Province, Indonesia *(Figure 1)*.

Global Mangrove Trust (GMT), in collaboration with Yayasan Gajah Sumatera (YAGASU), organises field activities with the four communities using the space-based machine learning Kumi Analytics Carbon Sequestration Assessment Tool (KACSAT). GMT and YAGASU plan to scale up similar conservation and Restoration efforts across 25,000ha of coastal mangroves over the next 3-5 years, deploying 30-year conservation agreements with local communities.

Figure 01. Project Boundaries and Registered Areas



1.1 Objectives and Impacts

Mangroves are a vital environmental solution in fighting coastal erosion and land loss, underpinning economic development of coastal areas, sequestering and storing atmospheric carbon while reducing carbon emissions due to deforestation, providing a rich habitat for vulnerable biodiversity, and supporting local communities' livelihoods.

001-OxC baseline procedures commenced in June 2021 with the signing of MOUs with village and forest department representatives in Medan to kickstart forest research campaigns. During the project lifetime, the proponents aim to **generate a total quantum of avoided emissions and new carbon sequestration equivalent to 2,594,027 tCO2e to be contributed towards the Indonesian NDC.**

Avoided emissions and new sequestration will result from the implementation of activities in four strategic lines: 1) strengthening governance, 2) active conservation via mangrove patrols, 3) active restoration of degraded mangroves in the registered areas, and 4) responsive financial support to community social programs.

A primary objective of the project is to decrease emissions and increase carbon capture under a space-based monitoring regime (KACSAT). Providing an affordable, reliable, and fast carbon monitoring solution is key to boosting investor confidence toward financing Southeast Asian reforestation projects in the forest carbon credit market. More reliable verification and pre-financing for blue carbon have the following benefits for stakeholders:

Communities: These ecosystem projects support long-term job growth and skill-building in coastal communities while mitigating the impact of climate change with the active participation of marginalised community members such as low-income households and women, empowering them to be drivers of change toward their own sustainable livelihoods. Expanding blue carbon financing also creates new jobs in applying remote sensing data analysis and managing financing solutions for sustainable land use of high-value ecosystems.

NGOs and Society: Local NGOs will be able to more effectively engage international organisations, global investors, carbon registries, and regional networks. Engagement with an efficient crediting system is tied directly to land use outcomes bolstered by highly efficient remote sensing science. Space-based monitoring and assessment will tighten learning loops between stakeholders and align incentives with effective conservation.

Governments: Increasing issuances and slashing the cost of credit-worthy projects will make it easier for state actors to fulfil Nationally Determined Commitments (NDCs) under the Paris Accord. Innovative tools for fast, reliable verification and financing will grow skilled local labour pools for tracking parameters, organising benefit contracts, and interfacing with investors. Most importantly, increased blue carbon project volume will integrate livelihood security (e.g. fisheries) with ecological security, especially for coastal communities.

Impact and Activist Investors: Investors gain access to a novel and expanding class of premium assets - blue carbon credits - proven to capture price premiums in voluntary markets. A growing pool of fungible, blue carbon assets enables investors to diversify long and short-term portfolios, build awareness and expertise among stakeholders on climate issues and provide additional options for managing risks related to rising carbon taxes.

Underwriters and Fund Managers: Space-based verification and crediting will also unlock investable product variations at various levels of risk/reward (e.g., Annuity Note, Offtake, Spot & Debt). An impact standard that leverages readily available data for verification reduces the time lag between assessment and valorization enabling higher frequency verification events. Advances in scalability and transparency around impact will enrich the growing market for impact investing and unlock new options for realising the much-lauded potential of green bonds and other product structures to fight global warming.

Financial Institutions: Banks and other financial institutions will benefit from a more accessible nature-based solution asset class. Financing natural capital development has huge business potential in local finance and knowledge hubs, particularly Singapore. The opportunities for banks to underwrite project portfolios comprised of green bonds, carbon annuities, and offtake agreements manifest not only for blue carbon mangrove projects but also for scale-ups and scale-outs of the space-based crediting solution toward peat-lands and upland rainforest, both critical natural capital endowments Southeast Asia. A novel, more scalable verification solution and crediting standard unlocks investable Southeast Asian projects and assists carbon for brokerage and market-making in Singapore. This can further catalyse synergistic investments in related service ecosystems across Southeast Asia.

1.2 Standardised Impact Metrics

The project delivers on a range of key environmental and social metrics organised around quantified climate action, restoration and conservation results, and social impacts *(Table 1)*.

Table 01: Activities and Impact Metrics

No	Category	Description of Quantified Activities
1	**Conservation, Restoration, and Biomass Sequestration**	The project is managed in a collaboration with the local partner YAGASU to conserve and restore 2305.6 hectares of intact and partially degraded mangrove forest. The present average AGB (tree biomass) in the villages was 41.37 Mg/ha.
2	**Baselining and Measurement**	Total estimated emission reductions & removals, measured against the without-project scenario, are 2,594,027 tCO2e. Climate Impact is a function of forest and soil inventories in the four villages, carbon measurements assessments, and leakage belt designation and expert's opinions.
2	**Training, Employment, and Education**	The project provides training to communities by skilled forest instructors and biologists. The YAGASU team provides education workshops to safely and accurately collect ground data, construct and operate mangrove nurseries, and implement conservation activities. Periodic ground-truthing generates machine learning data inputs for allometric formulas used by KACSAT to estimate below-ground carbon stocks. The local communities will execute nurseries as a part of the project activities with the help of the project partner YAGASU. Degraded areas will be selected based on the space-based monitoring.
4	**Artisanal Women's Groups**	Surveys and workshops with the local communities can help understand local needs and set up plans to improve their livelihoods by implementing the project activities designed in the community sharing benefits.
5	**SilvoFishery**	Local communities will learn new fishery skills, including how to raise fish, shrimps, and crab farms that can be set up in mangrove water as a part of the project activities included in the community sharing benefits.

These metrics organise the following institutions and activities:

1. Active conservation and restoration activities to avoid increasing deforestation;
2. Community Conservation Agreements specifying conservation targets and rewards;
3. Social programs to maximise direct positive impacts on the mangrove forest;
4. Periodic field and space-based monitoring reports from YAGASU and KACSAT.

In addition, the project targets outcome measures as presented below in Table 2.

Table 02: 001-OxC Estimated project benefits for the locals in the first 5 years

Activities	Year 1	Year 2	Year 3	Year 4	Year 5
Number of trees planted (100% survival rate)	125,000 trees	125,000 trees	125,000 trees	125,000 trees	125,000 trees
Jobs - Patrols - Nurseries and Plantation workers - Management & reporting Staff	35 - 65 pax	35 - 65 pax	35 - 65 pax	35 - 65 pax	35 - 65 pax
Silvofishery trainess	(25-50)	(50-150)	(50-150)	(50-150)	(25-50)
Women artisan trainees	(30-60)	(70-150)	(70-150)	(70-150)	(50-100)
Mangrove Ecotourism Programs / village	(1-3)	(1-5)	(1-5)	(1-5)	(1-5)

1.3 Project Strategy and Scope.

001-OxC conserves and restores coastal mangrove forests on the East coast of Sumatra Island in Indonesia. Two types of forest designations predominate in the project area, 1) **Protected Forest** and 2) **Production Forest**. These land designations are defined within the Decree of the Minister of Forestry of the Republic of Indonesia number (*sk.579/menhut-ii/2014*) concerning the forest area of North Sumatra Province: *(Figure 02).*

Figure 02. Forest Classification in the project area.

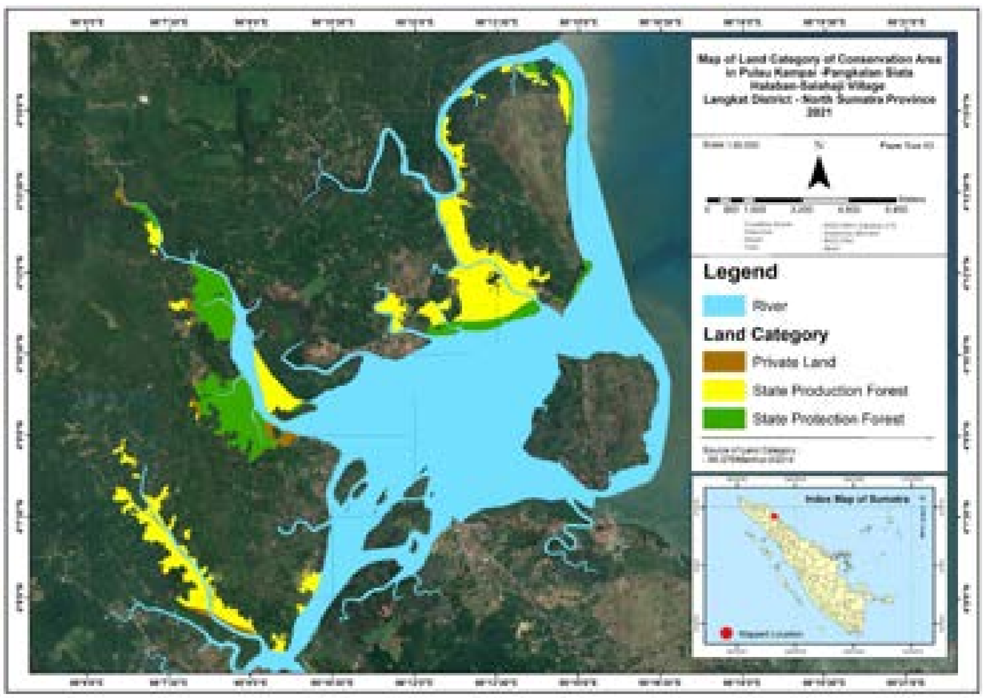


Table 03 details the key activities objectives and target impacts of the project over time. Related trainings focus on recognizing the value of and techniques for the following core activities linked to protection of marine and forest environments and empowerment of local communities to self-manage the forests for local benefit over the long run:

- Increasing the population of the mangrove and animals species;
- Conserving the ecological solidity;
- Enhancing the productivity and ecosystem associated services;
- Providing sustainable incomes for the local communities.

Table 03: Project Activities, Objectives, and Impacts

Activities	Community and Biodiversity Impacts		Project objectives
	Near-term Impacts	Long-term Impacts	
1.Local Impacts - Provide communities with the knowledge to conserve and monitor the project areas.	Schedule sustainability and forest management workshops for monitoring and implementing the designed activities.	- Strengthen technical and monitoring activities - Self-management and reporting of impacts in implementing designed activities.	- Reducing deforestation and biodiversity loss. - Educate communities on environmental and financial benefits of mangrove husbandry.
- Provide economic and material resources to implement designed project activities.	Set strategies for locals to capture benefits from sustainable natural resources management.	- Locals can harness the potential of sustainable mangrove-based economic activities for income.	- Increase environmental impact and protection above and beyond using resources for income.
2. Mangrove Impact - Restoration, Plantation, and conservation of the mangrove forest in the project area.	- Provide plantation and restoration materials and coordinates of selected areas for restoration. - Establish nurseries, select mangrove species, conduct training sessions with communities on planting and nurseryworks.	- Increase the carbon sequestration in the project area. - Provide skilled staff to nursery and planting work. - Regenerating ecosystems and enhancing positive environmental impacts of conservation work.	- Decrease deforested areas in the project area. - Increase AGB and BGB carbon sequestration. - Locals benefit from new skills and income. - Building resilience to future shocks like fire and coastal floods.
- Biodiversity impacts	- Working to replant degraded mangrove areas. - Select the best mangrove species to be planted to enhance the return of natural life.	- A significant improvement in restored mangrove areas. - Significant increase in fauna and flora in restored areas.	- Implementing the project activities and protecting biodiversity gains.

3. **<u>Monitoring and Reporting</u>** - Space-based Monitoring of the project area and the leakage belt	- Train and hire local rangers and foresters to monitor changes in project areas - Determine the current situation of the project forest and its leakage belt. - KACSAT performs space-based monitoring to report carbon sequestration and deforestation rates. - Initial monitoring reports submitted to GMT project stakeholders.	- Reports to GMT and project stakeholders every two months. - Actual observed changes during the project period to guide rewards for local communities depending on the calculated carbon sequestrations.	- Sequestration and the deforestation rates during the project lifetime will be the base for selecting scale-ups to nearby villages.

1.4 Project Participants

Table 04: Project Participants and Operational Roles

Stakeholder	Role in the project
GMT	- Project coordination, management, scoping, and scale-up; - Legal support for long-term agreements with local communities; - NGO management, coordination of ground-truthing; - Community activities management and supporting training events; - Periodic reporting and capacity building.
Local communities	- Conserving the project area and reporting to YAGASU; - Implementing ADAs; - Conducting forest research with YAGASU teams.
Government (Forest, Fishery, Tourism)	- Issuing permissions for project activities.
YAGASU	- Ground truthing, lab results, managing forest Inventory teams; - MOUs with heads of villages; permitting with relevant authorities; - Implementing designed activities and managing benefits; - Ensuring periodic reporting to GMT and stakeholders.
KUMI Analytics	- Carbon sequestration measurements; - Remote sensing, monitoring, and machine learning modelling; - Deforestation analysis and monitoring reporting.
OxCarbon	- Verification and validation of applied methodologies; - Consulting academic support; - Evaluating project outcomes; - Publishing datasets and project documentation.

1.5 Project Advisory

<u>**Legal Sector**</u> **1. Hogan Lovells (HGL)** ***(Dewi Negara Fachri & Partners)***	1. Collaboration with HGL Hong Kong and HGL Jakarta to draft long-term management and community benefit agreements. 2. Retention of HGL Jakarta for project registration with the Ministry of Environment and Forestry (MOEF) of Indonesia.

1.6 Long-term Goals and Impact Estimates

Over the course of the 30-year project life, GMT and YAGASU will implement avoiding deforestation activities *in addition to* providing financial incentives for not cutting mangrove trees. KACSAT's monitoring team will track canopy densities and carbon fluctuations.

Table 05: Carbon impact targets for the first Five Year Assessment Period

Carbon target	**Estimated by the End of Project Lifetime**
Designated Area (Ha)	2,305.6
Estimated Average Stocks per Ha (tCO2-e)	1,464
Total Carbon Stocks protected by the project(tCO2-e)	3,371,690
Avoided Deforestation (Historical) Rate	7.18%
Total OxCCs per annum (first 5 years)	116,437
Total OxCC Issuance: First 5yr period (tCO2-e)	579,117
Total NDC Contributions: First 5yr period (tCO2-e)	985,344

KACSAT engine utilises several satellite sources to improve accuracy assessments including Worldview 2, Landsat, Sentinel 1, Sentinel 2, Radarsat-2, and SRTM data with the in-site forest inventories and laboratory-measured data. Based on optimal mangrove land cover classification and carbon estimation methods use multiple sensors to ascertain not only forest area but also canopy height and structure (*Lucas et al., 2020*).

1.7 The Villages

This section reports social parameters on locals' activities in the mangrove forest, incomes and livelihoods, employment, and information on tourism, education, and healthcare for the two biggest villages, Pulau Kampai and Pangkalan Siata, being the largest, representative villages in this project. This information is intended to help in understanding communities' daily needs and livelihood obstacles and serve as a base for designing project activities.

Pulau Kampai

Pulau Kampai is administratively located in Pangkalan Susu district, Langkat regency, North Sumatera province, with coordinates 04° 13’ 45’’ North latitude and 98° 13’ 48’’ East Longitude. The total area of Pulau Kampai is 30,015 km^2. Most of the Pulau Kampai land areas are used for agriculture, such as rice fields and oil palm and coconut plantations.The population number 3,960 people, 2,507 men and 1,903 women based on 2021 survey done by the Ministry of the Homes Affairs of the Republic of Indonesia[2] .

Considered a populated village, Pulau Kampai boasts coral and white sand beaches with vegetation dominated by coconut, mangrove, and coastal plants, and is considered a tourist village in Langkat Regency and a source of local shrimp production. Besides being well known for Berawe Beach, a stretch of unspoiled white sandy beach, the village has many historical sites like the Long Sacred Tomb, the Tomb of the Violinist, and the Red Mass Grave. Pulau Kampai can be reached by land from Medan to Pangkalan Susu with a travel time of about 4 hours, after which one needs to use water transportation (speedboat or motorised boat) across the waterway to Pulau Kampai.

Coastal forests serve as a primary source of income for local communities. According to the head of the village *Mr. Amir Husain* in June 2022, the government tightened regulations on the country's forests and village authorities were mandated to prioritise protecting the forests over villagers’ daily needs. Many locals have recently switched to the fishery and use cutting wood as a secondary income source.

Pangkalan Siata

Pangkalan Siata Village is a coastal village in Pangkalan Susu, with a village area of 17.12 km^2. The village is located at the point coordinates 04° 08' 57.8" North Latitude and 98° 06' 55.1" East Longitude. Based on data from the 2021 Pangkalan Siata Village Profile, the Pangkalan

[2]Source : Ministry of Home Affairs (Kementerian Dalam Negeri Republik Indonesia), https://drive.google.com/file/d/1sL6iuzdZ0H1E3QgAVjXMX7jgqMnw36Fk/view?usp=sharing

Siata village population is 4,510 people,2,478 females and 2,032 males. Of 950 households, the average population per household is four [3].

As described in the 2016 Village Profile (*Herawati, 2016)*, the population of working adults in Pangkalan Siata village totalled 1577. Forest resources provide various sources of livelihood for the surrounding community, including mangrove charcoal makers, crab and shrimp gatherers,, as well as grouper fish cage business makers. Sources of livelihood for non-mangrove farmers include rice farming, garden farming (with commodities), oil palm and cocoa, and fisheries. Detailed data on local livelihoods by sector describe:

I. **In Agriculture**: 371 farmers, 180 farmworkers, 191 farm owners;
II. **In Plantation Forestry:** 297 plantation companies employees, 231 Plantation workers, and 66 Plantation business owners;
III. **In Fishery:** 184 fishermen;
IV. **In Trade:** 57 Agricultural trade employees.

Salahaji

Salahaji is a village in Langkat district, North Sumatera, Indonesia located between 4°10'38.1"North Latitude and 98°07'14.2" East Longitude. Based on the 2021 census survey[4], total population was 3,070 people, 1,537 men and 1,533 women . There are no tourist attractions or large infrastructures in this village, and the majority of the population are farmers and fishermen.

Salahaji is a small village. Based on 15 experts interviewed by Yagasu in June 2022, the forests - and especially the mangrove forests - are important sources of local livelihoods. The village secretary, Mr. Edie Sutrisno reports that some locals in Salahaji rely on the mangrove forests as their sole source of income. Many villages are selling wood for making charcoal, obtaining incomes of around 3,000 IDR/kilo = 0.20 USD/kilo). Mr. Sutrisno also confirmed that residents are very worried that if a private sector actor moves to take over the land and destroy and convert the mangrove forests for other businesses, they will lose their only available option to secure a basic income and cover daily expenses.

To maintain the existence of the mangrove forests in Salahaji for future decades, the head of the village and the secretaries have deployed a selective system based on a designed schedule for

[3] Source : Ministry of Home Affairs (Kementerian Dalam Negeri Republik Indonesia), https://drive.google.com/file/d/1DW44E701n5arsfJ1fvY0ikEPG1iTmW9E/view?usp=sharing
[4] Source : Ministry of Home Affairs (Kementerian Dalam Negeri Republik Indonesia), https://drive.google.com/file/d/10g_Tqid1JKZFEmmQlwwcFk2ieheO6oA9/view?usp=sharing

locals who have historically drawn wood from the forest. Local leadership seeks a fair system for villagers that also serves to limit the amounts of monthly cut wood. They advise villagers to harvest dead and fallen branches and avoid cutting stems.

Halaban

Halaban Village is located in Besitang sub-district, Langkat district, North Sumatra, between 4°07'14.6" North and 98°05'06.0" East. It is a small village with no tourist attractions or large infrastructures. The majority of the population is farmers and fishermen. Based on the 2021 census survey[5], the total population was 10,250 people, 5,100 men and 5,150 women

Based on expert interviews collected in June 2022, the village secretary Mr. Prihatin Suharyanto confirms that mangroves are very beneficial for the Halaban community. Many rural households depend on the mangrove ecosystem. Mr. Jhonson Malau is the head of a Sustainable Forest Farmers Group in Halaban. He reports that Hababan officials have established a selective logging system by which community members harvest some mangroves as in Salahaji village. To maintain the forest and limit monthly cutting, they ask farmers to take dead trees for their daily needs. He added that the village does receive nominal financial assistance from the government or other agencies to help Halaban communities in terms of socio-economic growth. The locals know if they cut mangroves for wood, fish stocks will fall, but households lack alternative solutions to secure income for daily needs and rely on mangrove harvests for essential income.

1.8 Plantation and Restoration activities

In Southeast Asia, mangroves are deforested at 4 times the global average, leading to high carbon leakage from degraded forestscapes and significant losses to habitats, to the integrity of protective coastal bands, and to the health of local fisheries. Against this backdrop, 001-OxC enables long-term rewards to flow to local community members for both conservation and reforestation of coastal mangrove forests. These rewards are designed to be superior to the perceived marginal benefits of additional deforestation activities.

[5] Source : Ministry of Home Affairs (Kementerian Dalam Negeri Republik Indonesia), https://drive.google.com/file/d/1h4cxJpesJ4QNTCSvV5A4Lqsf6yYfd7sj/view?usp=sharing

Table 06: Planting Targets for Mangrove Restoration at 001-OxC

Planting Plan Parameter	**Target Value**
Annual planting target (saplings and propagules)	125,000
Target steady state survival rate (%)	75%
Time to steady state survival rate (years)	10 years

To counterbalance short-term financial returns of land conversion and cutting, 001-OxC couples its core conservation work with a robust restoration component. Restoration produces sustained local employment benefits in nursery works, planting, and patching, while accelerating direct emissions removals. Starting with a target planting quantum of seedlings and propagules prepared in the local nursery, 001-OxC will plant 125,000 juvenile mangroves each year for 20 years to restore an estimated 1.875 million healthy, mature trees.

Figure 03. Planting Plan and Survival Projections

Restoration Impacts

Restoration activities will generate an array of positive impacts on the local ecosystem and upon the individual households and individuals comprising the local communities:

- Generating direct emissions reductions via new removals of atmospheric carbon.
- Contributing to global climate change adaptation and mitigation.
- Increasing biodiversity and the planted mangrove areas.
- Improving local communities' livelihood and providing jobs.
- Mitigating natural disaster risks from coastal flooding and fire.
- Increase the local communities' awareness to maintain and plant mangroves, in addition to knowing the environment and livelihood benefits of healthy forests.

Restoration Processes

Site selection

For the implementation of restoration work at the four villages, GMT and YAGASU survey the project area using remote sensing analysis and local ground surveys to determine possible planting sites in the registered villages each planting season. Surveys inform proposals to project stakeholders about target planting zones to be confirmed with the village authorities. Factors influencing site selection include elevation (allowing seawater tides flow), absence of waste and seagrass, and tidal / wind direction. On approval, Yagasu prepares the required maps and site preparations and proceeds with planting operations.

Nurseryworks

Nursery sites are selected initially and iteratively as the project expands. The first nursery was established in August of 2022 in Pangkalan Siata near locals' homes so as to be easily monitored. Local villagers are employed in collecting seeds and preparing seedlings in the nurseries, with consideration of collecting +10% extra seeds above the number of the agreed trees for replacing the future dead trees pre-planting. Saplings and propagules are raised in the nursery for a minimum of 3 months.

Figure 04: GMT Nurseries - Pangkalan Siata, August 2022.

Future Planting Ambition

Imminent scale-up of the solution will enable active regenerative conservation of 25,000ha of mangrove forest in Aceh and North Sumatra over the next 3-5 years. GMT and YAGASU have completed scoping with communities in this area to procure immediate co-operations for restoring and converting as much as 25,000 ha of identified mangrove forest under this solution. The project proponents hope to provide this effort with a high scaling assessment solution to support long term sustainable financing.

1.9 Project Climate Impacts

The OxCarbon solution is tailor-made for the policy goals of the host country's leadership. All credits generated under 001-OxC will count solely toward Indonesia's NDCs. (in compliance with Article 6) Table 07 describes the target total and average climate impact outcomes for the project, while Table 08 details the year-on-year breakdown for the avoidance, removal, and reserve OxCCs, as well as annual and total NDC contributions up to 2050.

Table 07: Climate Impacts - Target Outcomes at 5 and 2050 Year

Total NDC contribution (to 2050)	**2,594,027**
Total NDC contribution (first 5 years)	985,344
Total Avoidance OxCC (to 2050)	1,215,351
Total Removals OxCC (to 2050)	857,416
Total OxCC per annum (avg to 2050)	71,475
OxCC to reserve per annum (avg to 2050)	17,974
Total OxCC per annum (first 5 years)	115,823
OxCC to reserve per annum (first 5 years)	81,246

Table 08: Total NDC, Conservation (Avoidance) and Removals (Reforestation)

	Avoidance OxCC	Removal OxCC	Reserve OxCC	**Total**	Total Reserve	Annual Issuance as % reserve	Annual NDC contribution	**Total NDC Contribution**
2022	108,939	0	133,148	**108,939**	133,148	81.82%	242087	**242,087**
2023	118,388	348	100,481	**118,736**	233,629	50.82%	219217	**461,305**
2024	120,012	711	75,038	**120,723**	308,667	39.11%	195760	**657,065**
2025	116,653	1,190	55,874	**117,843**	364,540	32.33%	173717	**830,782**
2026	110,423	2,452	41,688	**112,875**	406,228	27.79%	154563	**985,344**
2027	101,674	3,991	30,943	**105,666**	437,171	24.17%	136608	**1,121,953**
2028	91,425	7,526	22,855	**98,950**	460,026	21.51%	121805	**1,243,758**
2029	80,385	10,174	16,783	**90,559**	476,809	18.99%	107342	**1,351,100**
2030	69,023	14,435	12,220	**83,458**	489,028	17.07%	95678	**1,446,778**
2031	57,624	19,129	8,775	**76,753**	497,803	15.42%	85528	**1,532,306**
2032	46,339	23,211	6,153	**69,550**	503,956	13.80%	75703	**1,608,009**

2033	37,376	27,156	4,385	**64,532**	508,340	12.69%	68917	**1,676,925**
2034	30,223	32,247	3,172	**62,470**	511,513	12.21%	65642	**1,742,567**
2035	24,490	37,858	2,328	**62,347**	513,841	12.13%	64676	**1,807,243**
2036	19,878	40,451	1,731	**60,330**	515,572	11.70%	62061	**1,869,304**
2037	16,158	41,363	1,303	**57,522**	516,876	11.13%	58825	**1,928,129**
2038	13,150	43,465	992	**56,615**	517,868	10.93%	57607	**1,985,736**
2039	10,712	44,399	763	**55,110**	518,631	10.63%	55874	**2,041,610**
2040	8,733	46,566	592	**55,299**	519,223	10.65%	55891	**2,097,501**
2041	7,124	47,522	463	**54,646**	519,686	10.52%	55109	**2,152,610**
2042	5,815	49,117	365	**54,932**	520,051	10.56%	55296	**2,207,906**
2043	4,748	49,102	289	**53,850**	520,340	10.35%	54139	**2,262,045**
2044	3,878	49,073	230	**52,951**	520,571	10.17%	53181	**2,315,227**
2045	3,169	48,927	184	**52,096**	520,755	10.00%	52280	**2,367,507**
2046	2,590	47,998	148	**50,588**	520,903	9.71%	50736	**2,418,242**
2047	2,117	46,792	119	**48,909**	521,022	9.39%	49028	**2,467,271**
2048	1,731	43,591	96	**45,322**	521,118	8.70%	45418	**2,512,689**
2049	1,415	41,276	78	**42,691**	521,196	8.19%	42769	**2,555,458**
2050	1,158	37,348	63	**38,505**	521,260	7.39%	38569	**2,594,027**

Direct Removals

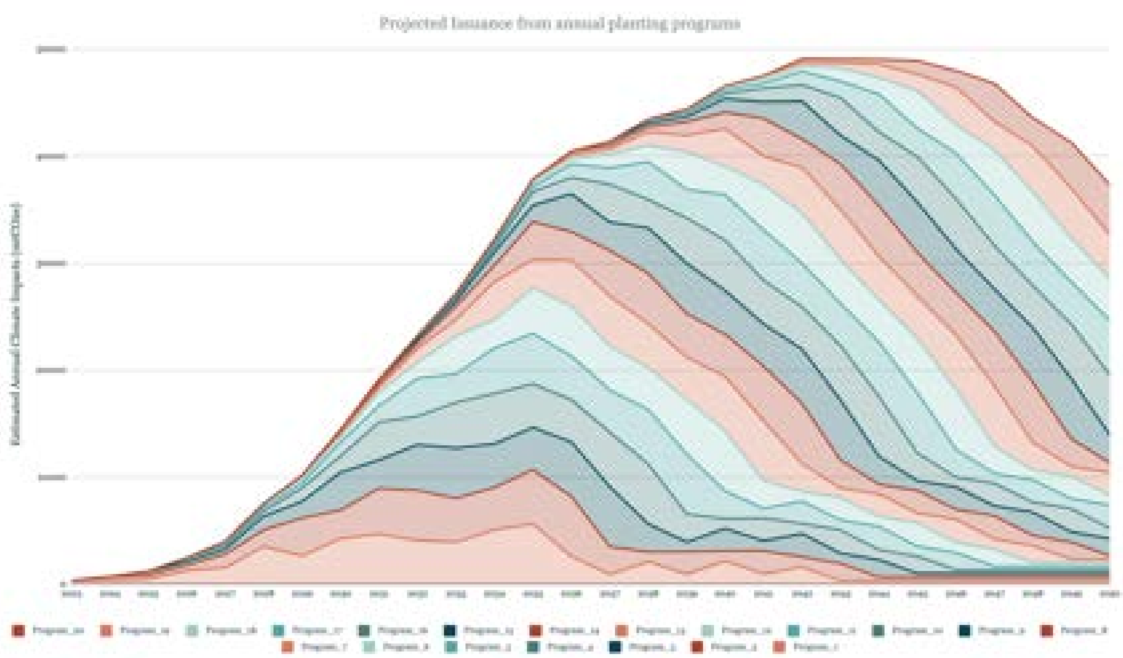
Climate impacts from restoration are largely a function of successful regeneration. Each cohort of new trees captures carbon in biomass and soil stock as they grow to maturity. Final estimates of carbon capture will be determined and published by OxCarbon Standard. The proponents provide the estimations below in line with scientific research and local ground truthing on biomass and soil carbon in growing and mature mangrove forest sites. The figures track projected carbon capture of annual cohorts of 125,000 mangroves over 20 years, in line with the expected annual restoration activity at 001-OxC. The table details the modelled survival profile and carbon sequestration impacts of a given planting program.

Figure 05. Carbon Removal Profile of a Single Cohort of 125,000 Mangroves, 20 yrs

Table 09: Single Planting Program CO2e Profile

Year	Post Mortality	Live Trees	Tree Carbon (mtCO2e)	Soil Carbon (mtCO2e)	Lifetime Removals mtCO2e
1	100%	125,000	15	333	348
2	98%	121,875	44	666	711
3	95%	118,750	190	1,000	1,190
4	93%	115,625	1,119	1,333	2,452
5	90%	112,500	2,325	1,666	3,991
6	88%	109,375	5,526	1,999	7,526
7	85%	106,250	7,841	2,333	10,174
8	83%	103,125	11,769	2,666	14,435
9	80%	100,000	16,130	2,999	19,129
10	78%	96,875	19,879	3,332	23,211
11	75%	93,750	23,490	3,666	27,156
12	75%	93,750	28,248	3,999	32,247
13	75%	93,750	33,526	4,332	37,858
14	75%	93,750	35,786	4,665	40,451
15	75%	93,750	36,365	4,999	41,363
16	75%	93,750	38,133	5,332	43,465
17	75%	93,750	38,733	5,665	44,399
18	75%	93,750	40,568	5,998	46,566
19	75%	93,750	41,190	6,332	47,522
20	75%	93,750	42,452	6,665	49,117

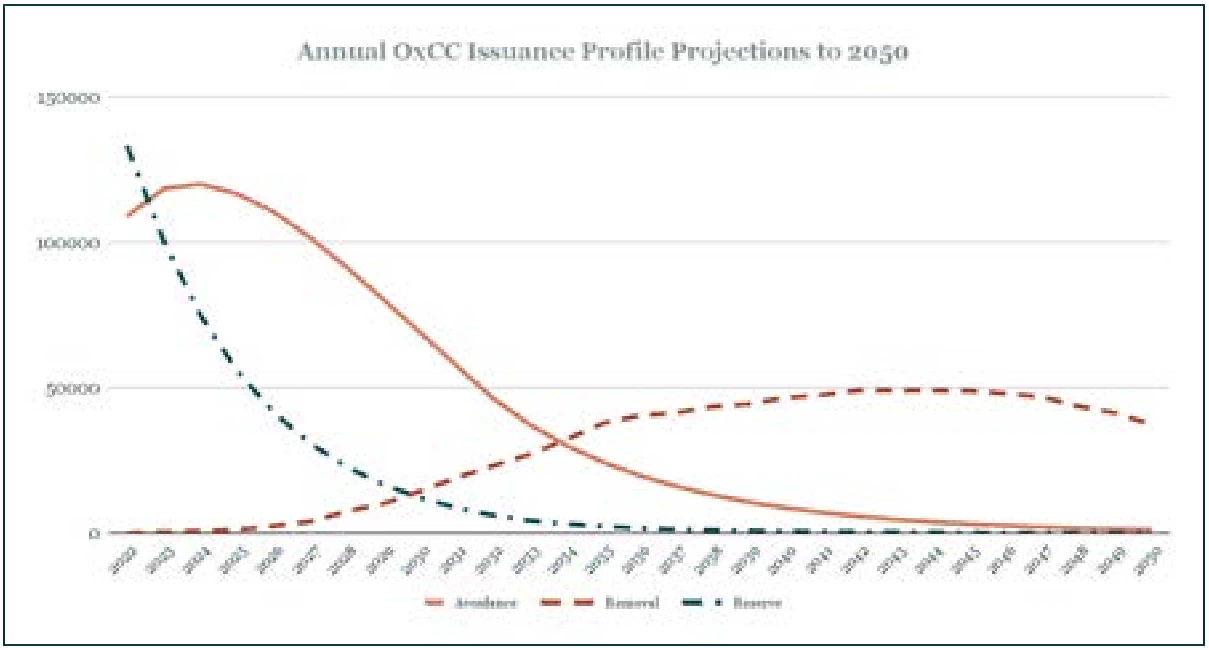
Figure 06. Estimated Project Climate Impacts from Direct Emissions Removals



Transition from Conservation to Removals

Through restoration, 001-OxC seeks a transition from climate impacts via avoided deforestation to active removals over the course of its project lifetime. This transition stands in line with the Oxford Offsetting Principles, to implement a rising focus on direct removals after stabilising the local ecosystem losses due to local deforestation pressures. The issuance of OxCCs is distinct from the calculation of NDC contribution, which is defined by relevant local regulations.

Figure 07. Project Climate Impact Pathway - Transition to Direct Removals


Annual OxCC Issuance Profile Projections to 2050
150000
100000
50000
0
Avoidance
Removal
Reserve

1.10 Legal structure

To establish and organise long-term mangrove conservation and restoration programs at these four villages, GMT has designed two agreements with pro-bono counsel from Hogan Lovells International LLP. First, a **Community Conservation and Benefit Sharing Agreement** organises the core conservation covenants between each of the Village Representatives of the four project villages and the local implementation partner, Yayasan Gajah Sumatera (YAGASU). The second contract, the **Project Developer Agreement,** sets the terms of collaboration between YAGASU and GMT as the international project developer.

Community Conservation and Benefits Agreement

The parties in this agreement are **Yagasu and the Village Representative**, and the contract organises around three central pillars:

A. YAGASU is a foundation duly established and validly existing under the laws of the Republic of Indonesia which focuses on biodiversity conservation, ecosystem restoration and protection, climate change mitigation and adaptation, capacity building, environmental education, and local economic reconstruction through the facilitation of generating income for local communities on green livelihoods;

B. The Village Representative is an individual representing the local community of each of the four villages, and who has the authority to act for and on behalf of, the respective Local Community in the Designated Area;

C. The Village Representative appoints YAGASU as Project Agent to manage, register, and finance a voluntary mangrove conservation and restoration project at Halaban, Pangkalan Siata, Pulau Kampai, and Salahaji villages in North Sumatra (the “Project”), and Yagasu accepts the appointment, on the terms of the Agreement.

Key Clauses of the Agreement include:

- The setting of the Agreement between Yagasu and the Head of each village;
- A Duration of five years, extending to 30 years in periodic renewals;
- YAGASU obtains full and exclusive rights and claims to all Environmental Credits from each and every Village representative in the Designated Areas;
- Yagasu serves as project management and financing agent: organising meetings, protecting and promoting human rights, and maintaining safety;

- Key Social Project Activities to offset opportunity costs of cutting mangroves include Women's Industries, Education and Field training, Silvofishery Groups, Mangrove Ecotourism Projects, Active Conservation Patrols, Nurseries, and Planting Jobs;
- Performance-based funding targets respond to satellite assessed losses in Canopy Density and understory biomass;
- Governing Law of Indonesia, with the Agreement executed in Bahasa and English.

Project Developer Management Agreement

The parties in this agreement are **GMT and YAGASU, acting as the agent of each of the four Village Representatives**, and the contract organises around four central pillars:

A. YAGASU is a foundation duly established and validly existing under the laws of the Republic of Indonesia which focuses on biodiversity conservation, ecosystem restoration and protection, climate change mitigation and adaptation, capacity building, environmental education, and local economic reconstruction through the facilitation of generating income for local communities on green livelihoods;

B. GMT is a not-for-profit public company limited by guarantee under the laws of the Republic of Singapore, which focuses on the development and financing of environmental conservation and restoration projects – particularly on mangrove forests. GMT works with local partners and teams around the world to ensure families and businesses are empowered and engaged in community-based mangrove forestry;

C. YAGASU is duly nominated and empowered to serve as an agent of the Local Communities to manage, register, and finance a voluntary mangrove conservation project in a 2305.6 hectare area of forest land at Halaban, Pangkalan Siata, Pulau Kampai, and Salahaji villages in North Sumatra (the "Project");

D. YAGASU intends to exclusively appoint GMT as its Project Development Agent, to register the Project in accordance with an international conservation and restoration standard with an internationally recognized entity so as to obtain international financing for the Project, and GMT accepts the appointment.

Key Clauses of the Agreement include:

- The setting of the Agreement between between GMT and Yagasu;
- Duration is five years, extending to 30 years in periodic renewals;
- YAGASU transfers full and exclusive rights and claims to all Environmental Credits from each and every Village representative in the Designated Areas to GMT;

- YAGASU has secured written commitments from each and every local Village Representative not to grant to any other party, or allow any other party to gain or obtain, any right to the Environmental Credits that may arise in the Designated Areas;
- A system of reporting performance from GMT to YAGASU to each village is established with clear performance-based targets for conservation, restoration, and funding;
- YAGASU undertakes to monitor performance in the day-to-day and alert GMT of any arising change and/or threat to the conservation and restoration efforts;
- For net conservation of biodiversity and carbon stocks, Yagasu undertakes to lead:
    - rehabilitation and regeneration of vegetation on the Designated Area designed to achieve reafforestation as closely as possible to that which approximates the natural canopy tree composition for the site;
    - Management of social benefit programs to offset opportunity costs of planned and unplanned deforestation;
- Governing Law is Indonesian, with the Agreement executed in Bahasa and English.

1.11 Project Risks

Three performance risks are typically associated with the operation of natural capital assets like carbon-sequestering forests:

Quantum of carbon credits that a forest can generate can be predicted using allometric models and validated using a combination of ground-truthing, remote sensing, and machine learning (KACSAT). It is naive to guarantee that a specific amount of carbon credits will be granted yearly for conservation and restoration projects - the growth of carbon sequestration tends to follow an S-shape, but various environmental factors remain unpredictable, such as leakage or acceleration due to human intervention, changes in the sea level, and climate. While adverse human intervention can be contractually stipulated, such contracts can never be binding for entire communities.

Valuations of carbon credits have historically risen sharply through preparation and deployment, especially for high-quality blue carbon credits. Blue carbon has proven popular in voluntary markets - thanks to the significant co-benefits for communities and livelihoods. As the climate agenda has increasingly entered board rooms globally, bullish expectations around the value of verified blue carbon units have multiplied. Looking ahead to 2030, many countries and companies are expected to accelerate climate commitments (carbon neutrality, net zero). Such expectations could see a continued increase in demand for carbon absorption and credits. A key indicator to track will be the decarbonization of the energy supply in-demand markets like Europe, the USA, Australia, and to a lesser extent, Singapore, China, and India. The feasibility of reforestation and avoiding deforestation climate projects must continuously be assessed against future price scenarios.

Permanence of carbon credits is a critical issue from an ecosystem and credibility perspective. Carbon credits that are sold for nature-based solutions that are wiped out by adverse weather events, fires, human intervention, or other disasters entirely lose the ecosystem value they created. Therefore, any organisation selling or buying carbon credits with high impermanence risks will face a significant price discount. It is advisable to consider various forms of parametric insurance against force majeure to protect against adverse weather events if and when possible. It is noteworthy that conservation and restoration projects, in general, have reduced impermanence risks. In restoration projects, 20 to 80% of trees are at risk of non-survival in the first year. Such low survival rates are significantly less likely in conservation and restoration projects, making conservation more predictable.

In addition, the project must engage two key technical risks in the measurement of the carbon-relevant forest change, one major operational risk, and limited partner risks:

Forest degradation events may not always be readily detected by remote sensing methods. Certain events on the ground, such as selective logging, may go unnoticed and can introduce an error in the estimation of carbon stocks and sequestration. In a broader sense, any unforeseen land use change or illegal activities (fires, logging, farming, etc) inside the project area can pose a risk to the project status. GMT works with KACSAT to address this risk via updated ground control collection, tuning of the machine learning models over time, and automating the detection of these activities. Via the use of high res imagery, activities are visible to the KACSAT engine. Non-detection of degradation risk is further reduced because the local partner Yagasu has done its due diligence on the land selected for the project and there is strong buy-in from the local community.

Low correlation between satellite spectral signatures and ground truth conditions: Discrepancies between model simulations and ground data may also arise in forest sensing situations due to insufficient ground control (or inaccurate control measurements) as well as a lack of sufficient cloud free satellite imagery. Where this emerges in the context of 001-OxC, GMT will mitigate the impact of rising discrepancies by collecting additional ground truth data and supporting KACSAT in acquiring additional satellite imagery scenes as well as expanding the time window for optical imagery beyond the initial target time period. Robust remote sensing and impact validation can manage this risk, so the impact is limited.

Operational Risks also include poor ground control collection. In earlier analyses of margrove projects, and despite anecdotal reporting of a growing forest, GMT and its partners have observed cases where project developers' reported data shows average tree heights and DBH falling year on year for large portions of project areas due to poor ground control data collection. To minimise risks of observational discrepancies in plot level tree heights, the teams employ consistent, robust measurement techniques with field teams, including near-real time data upload and sensitivity analysis to ensure robust tree-level data capture. This risk does not jeopardise the KACSAT measurement engine's accuracy; but systematic, stochastic discrepancies will lead to higher credit buffering by OxCarbon to manage larger uncertainties around accurate carbon stock assessments.

Local partner risks are minimal but are nevertheless well managed. GMT recognizes that our local partner, YAGASU, operates in Indonesia and that the country has a mixed record for ensuring adequate KYC/AML protocols. We have sought to minimise partner risk by engaging in preliminary due diligence from early 2020.

1.12 Project Road Map & Financial Sustainability

GMT has designed a budget to deliver variable rewards based on the communities' performance and project outcomes over the project lifetime. This budget accounts for:

- **Estimation of the initial Investments**: Initial capital is designed to execute the project activities during the first five years. This will be a periodic fund and subject to changing value over time. Loss of value results from increased deforestation and reduced carbon capture, which will adversely impact the project's carbon credits;
- **Estimation of Project Costs**: including conservation activities, labour, restoration, training workshops, silvo-fishery projects, and skills workshops for women's groups;
- **Estimation of the project incomes**: including income from annual credits sales.

Table 09: Project Road Map (Repeated every 5 years)

Activities	Year 1				Year 2				Year 3				Year 4				Year 5			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Village meetings for project implementations	■	■			■		■		■		■		■		■		■		■	
Community Patrol Unit (CPU), Training, Monitoring, and Materials	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Village Policy Initiatives, and Workshops	■	■			■				■				■				■			
Field and technical reporting works	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Nurseries work	■	■			■	■			■	■			■	■			■	■		
Planting Nurseries and Restoration activities			■				■				■				■				■	
Monitoring and conserving the newly planted mangrove trees				■	■	■		■	■	■		■	■	■		■	■	■		■
Silfo-fishery workshops, initiation, and reporting	■		■		■		■		■		■		■		■		■		■	
Silfo-fishery activities and monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Women's activities and workshops	■		■		■		■		■		■		■		■		■		■	
Mangrove Ecotourism program		■		■		■		■		■		■		■		■		■		■

Part II: Applied Methodology Report

2.1 Overview

The organisational structure of 001-OxC is intended to serve as a template for scaling up conservation finance to 25,000 hectares in regional mangrove forests. The immediate project area is a combination of Production and Protection Forest - as registered under the Indonesian land system. Geomorphological units present different origins and land identifications and include large mangrove areas covered by ocean water where serial flooding throughout the year due to tides influence soil characteristics.

In close consultation with GMT, YAGASU signed initial MOUs with the four village authorities in the Summer of 2021 and proceeded to procure relevant permissions from the Forest Department in Medan to commence field inventories. Project funds are slated to start disbursing for nurseries from August 2022.

Governance and Initial MOUs

The project MOUs *(see table 10)* set a foundation for project governance. These documents identify local leadership and set out the shared intent of the four villages to quantify and preserve the carbon sequestration value of the local mangrove forests (*see Annex D*). Final project areas were later identified within the areas specified under the MOUs.

Table 10. MOUs and Regulatory Permissions (See also Annex D).

Village	Representative	MOU Date	Area under MOU (ha)
Pulau Kampai	Amir Husin	05/07/2021	1035.76
Halaban	Tamaruddin, S.Ag.	03/09/2021	252.51
Salahaji	Mahyni	20/08/2021	257.67
Pangkalan Siata	Muhamad Yusuf	03/09/2021	876.88

Figure 08: Meetings with village authorities to sign MOUs.

2.2 Baseline Procedures

Meetings carried out in the Baseline Processes

Field meetings: Online video meetings were held in late 2021 and early 2022 between project stakeholders and project implementation partner, YAGASU, to organise fieldwork activities and budgets, confirm project governance, and review field inventory protocols for ground data collection for forest inventories and soil samples. YAGASU also coordinated in-person forestry workshops focused on the importance of mangroves as carbon sinks and best practices in community-based mangrove rehabilitation.

Stakeholder Consultations meetings: Consultations and decisions meetings occurred continuously since 2021 on project design process, procedures, and formulations.

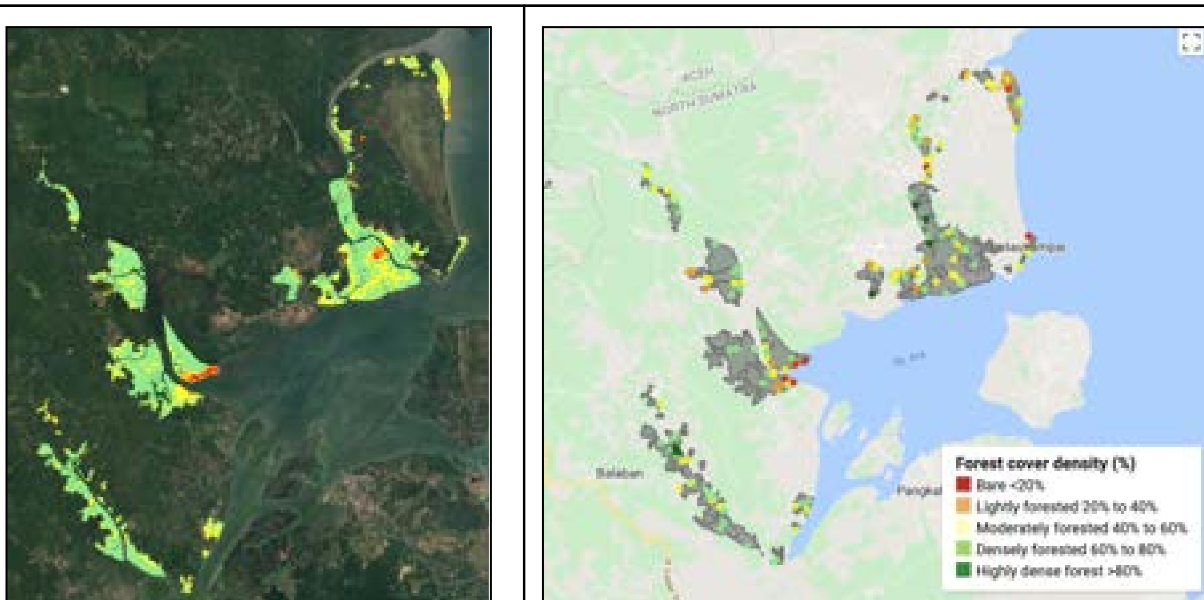
1. **Initiation and Roadmap discussions:** GMT, KUMI, and OxCarbon held virtual meetings to set up the project road map and baseline procedures with the stakeholders.
2. **Baseline Meetings**: GMT, KUMI, and Yagasu implemented the first and second forest inventories, selected plot locations, and discussed accessibility, budget, and field measurements required by the KACSAT engine.
3. **Technical sessions:** GMT, KUMI, and YAGASU set field and tree measurement requirements for allometric BGB formulas. Budget meetings were also held between GMT and YAGASU to specify the appropriate activities and costs.
4. **Legal work with Hogan Lovells International LLP:** Proponents engaged pro-bono counsel in September 2021. The team examined Indonesian maritime laws, SOWs, MOUs, land-use rights, and regulations for Land Management and Carbon Financing. GMT worked with Hogan Lovells in Hong Kong and Jakarta to draft the Community Benefit Sharing Agreements with YAGASU and the villages, delivering drafts to local stakeholders in English and Bahasa Indonesian in June of 2022.

Figure 09: Villages visits and training sessions for forest Inventories - Pangkalan Siata, 2021

First Round Field Inventories

First round field research in the four villages was completed in December 2021, tallying a total collection of 354 soil samples from 118 inventories plots. Tree inventories and soil sampling commenced in October 2021 at Pulau Kampai, where YAGASU teams spent two weeks collecting samples at 55 plots, before proceeding to work at Pangkalan Siata, Salahji, and Halaban. In setting plot locations, KACSAT used field data to initiate the forest canopy density (FCD) analysis over the entire project area using Sentinel-2 satellite imagery data. This analysis informed the inventory protocol based on local forest canopy characteristics.

Figure 10: Forest Canopy Density (FCD) over 118 First Round Plots - Aug-Dec 2021



Over the course of the baselining effort, the team expanded the scope of collection and analysis for soil sampling beyond standard practice so as to increase the pool of available high-quality data observations related to subsoil analysis. This served to tighten KACSAT's confidence intervals around predicted below-ground soil carbon based on machine learning estimators of below-ground and above-ground biomass.

All plots conformed to a 5 metre radius area based on KACSAT requirements and employed a standardised protocol for setting permanent centre points based on standard methodology (*Kauffman, 2012*) with small adaptations to the KACSAT monitoring requirements.

- Teams accessed GPS CenterPoint and - in areas not submerged - drove a permanent plot stake to set permanent centre points following the protocol and plot maps;

- To ensure relocation of submerged centre points, all centres were reconfirmed via high-precision GPS and recorded in project inventories;
- Teams used a rope to set the radius and circumference of the plot circles and tagged all trees within the boundaries for inventory;
- Teams measured all trees **≥ 2.5 cm** in breast-height diameter within a **500 cm** radius (A = 78.5 m) of the plot centre points;
- Downed trees and other vegetation components were also tagged and recorded;
- All tree species were assessed and flora classifications were recorded in the inventory *(a total of 4034 mangrove trees from different species had been sampled*).

Figure 11. Ground-truthing by YAGASU field teams - 118 First Round Plots - Aug-Dec 2021

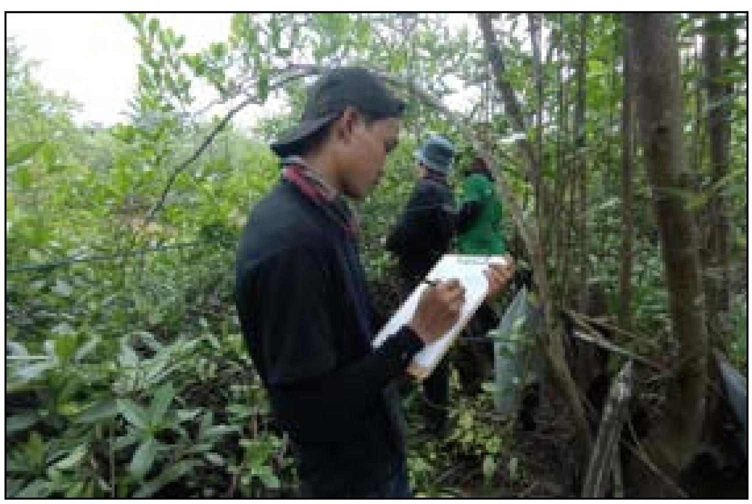
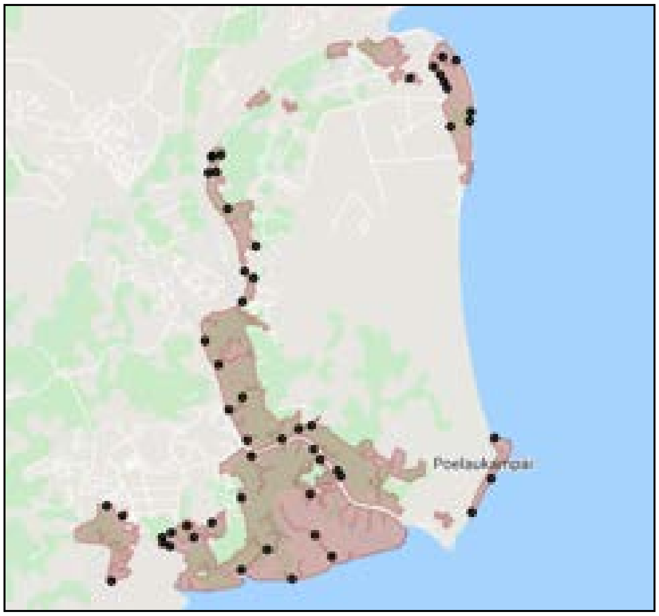
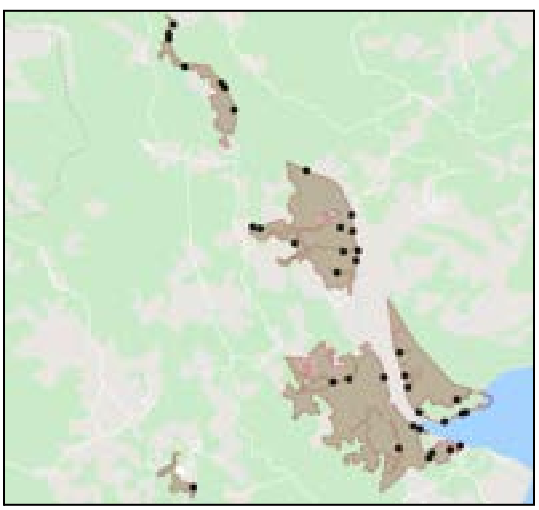
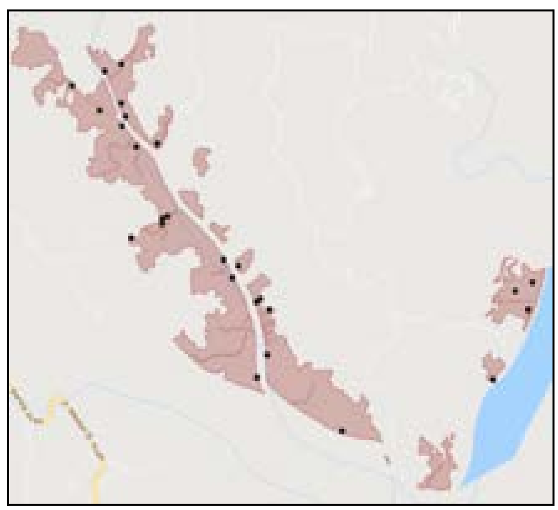


Figure 12. Inventories by Village - 118 First Round Plots - Aug-Dec 2021

Pulau Kampai



Salahaji & Pangkalan Siata (North)	**Salahaji & Pangkalan Siata (North)**
	

Second Round Field Inventories

The second field inventory was completed from 21 - 29 March 2022 on 25 plots in Pulau Kampai in 25 selected high-density plots. This work served to corroborate carbon sequestration data measured in the first round. Plot coordinates were again chosen based on the KACSAT strata and land classification criteria.

Table 11: Plots by stratum for the KACSAT engine - 1st and 2nd field Inventories.

Strata	Description	# Plots First Round	# Plots Second Round
5	Bare canopy & sea/river/road-ward (0 to 10 metres from sea, river or road)	3	0
6	Bare canopy & land-ward (10 to 15 metres from sea, river or road)	2	0
9	**Light canopy & sea/river/road-ward (0 to 10 metres from sea, river or road)**	**8**	**0**
10	Light canopy & land-ward (10 to 15 metres from sea, river or road)	8	0
13	**Moderate canopy & sea/river/road-ward (0 to 10 metres from sea, river or road)**	**19**	**0**
14	Moderate canopy & land-ward (10 to 15 metres from sea, river or road)	22	0
17	**Dense canopy & sea/river/road-ward (0 to 10 metres from sea, river or road)**	**25**	**0**
18	Dense canopy & land-ward (10 to 15 metres from sea, river or road)	25	0
21	High canopy & sea/river/road-ward (0 to 10 metres from sea, river or road)	3	25
22	High canopy & land-ward (10 to 15 metres from sea, river or road)	3	0
Total		118	25

Figure 13. Forest Canopy Density (FCD) and Plot Locations - Second Round

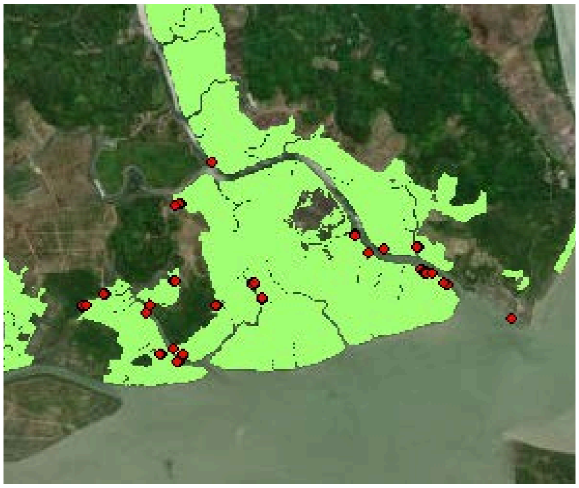
Pulau Kampai - 25 plots	Reaching plot coordinates using GPS tracker
	

Figure 14. Forest Canopy Density (FCD) Classes and Inventory Methods

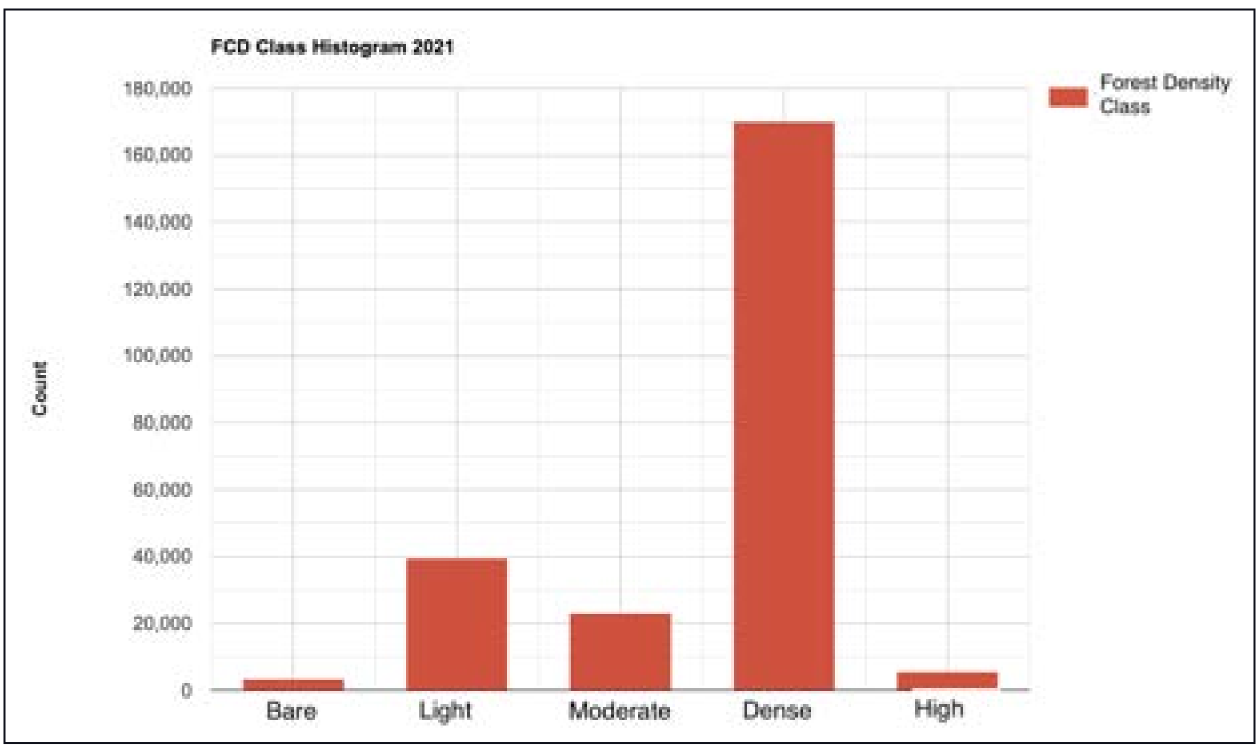


Figure 15. Observed Forest Density - Pulau Kampai - Second Round - Mar 2022

Measurements of Mangrove Characteristics

Approximately 4,034 mangrove trees were measured in the first and second round inventories. Field teams of 4-7 foresters confirmed each plot's GPS coordinate point and proceeded to mark all trees with nominal Diameter at Breast Height (DBH) ≥ 2.5 cm at 130cm height over the ground level within each 5m radius (A = 78.5 m) of each plot centre-point. Each tree was recorded in its DBH and categorised as *Living*, *Cut-Down*, and *Dead -Standing*. Total tree height (H) was estimated with the Forestry 550 hypsometer or with the SUUNTO clinometer or the Calibrated Stick for all trees.

Figure 16. Measuring the Breast Diameter (DBH) in Pangkalan Siata village - October 2021.

Collecting Soil Samples

Using a one-metre gouge auger, designed by the Institute of Pertanian Bogor (IPB), soil samples were collected from plot centre points, packed in plastic bags, stored in ice boxes, and sent to the laboratory.

Figure 17. Plot Layout and the designed Gauge Auger for collecting soil samples

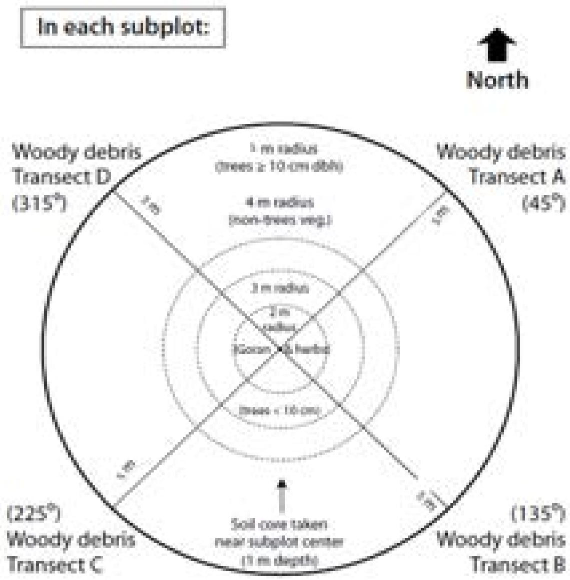


Figure 18. Collecting the Soil Samples in Pulau Kampai village - September 2021

2.3 Soil Analysis

In accordance with guidance from KACSAT, field teams collected and reported both in-situ measurements and laboratory results.

In-situ measurements

Field teams employed the HI98331 Soil Test pocket tester to measure soil conductivity (EC) and temperature. With a compact size, single button operation, and automatic calibration, the HI98331 Soil Test is effective for direct conductivity measurements. For water salinity, field teams employed the Water Tester 7 in 1 Salinity ORP S.G PH TDS EC Temperature COM600 a portable water analyser to collect data on 7 (seven) parameters:

1. Salinity - Salt content
2. PH - Acid-Base
3. TDS- Water cleanliness
4. EC - Electro Conductivity
5. Temp - Temperature
6. S.G - Specific Gravity
7. ORP - Oxidation Reduction Potential

Laboratory Measurements

For each soil sample, a laboratory work order was executed to establish a robust data set for water content, nitrogen content, and organic carbon. The methodologies used for laboratory measurements are described below:

Preparation of Samples

For each round of laboratory analysis, the lab administrators verify the Letter of Request from YAGASU and GMT containing an indexed list of submitted samples and the work order for each type of analysis required, so there is a clear map between each sample number and the analysis request number. A laboratory number is set for each sample and recorded on each carton label. The laboratory administration then reports the results of each analysis, returning the results together with the original request letter and the updated index list.

Determination of Absolute Dry Moisture (water) Content

In this analysis, staff heat soil samples at 105 ^{o}C for 3 hours to remove water. The moisture (water) content is known from the difference in sample weight before and after drying. The humidity correction factor is calculated from the moisture (water) content of the sample.

Appliances

- Aluminium plates
- Stainless steel tongs
- Excitor
- Oven
- Analytical balance to three decimal places

How it works

Lab staff weigh 5,000 g of air-dried soil samples in an aluminium dish of known weight, then dry in the oven at 105°C for 3 hours. Staff then lift the dish with tongs and place in the desiccator. The sample is allowed to cool then weighed. The weight lost is the weight of the water.

Calculation

- Moisture (Water) content (%) = (loss of weight / sample weight) x 100
- Moisture (water) correction factor (fk) = 100/ (100 – moisture (water) content)

Determination of Organic Carbon

Soil carbon is determined for each sample through a process of drying and spectrometry. As an organic compound, Carbon content will reduce from Cr^{6-} which is orange to Cr^{3+} which is green in an acidic atmosphere. The intensity of the green colour formed is equivalent to the carbon content and can be measured by a spectrophotometer at a wavelength of 561 nm.

Tools

- Analytical balance
- Spectrophotometer
- Volumetric flask 100 ml
- Dispenser 10 ml

Reagent

- Concentrated sulfuric acid
- Potassium dichromate 1 N

How it works

Drying: the samples are first distributed on a winnowing tray covered with cover paper. Fresh roots or plant debris, gravel, and other debris is removed, and staff squeeze out large chunks by hand and store on a rack in a special contaminant-free room that is protected from sunlight or in an oven at 40 "C.

Pounding / Sifting: staff next prepare dry, ground soil samples with particle sizes of < 2 mm and < 0.5 mm. Dried samples are ground in a mortar porcelain / milling machine and strain with a sieve of hole size of 2 mm. Dried ground samples are then stored in marked bottles with sample numbers. Analysis samples < 0.5 mm are taken from samples < 2 mm, and completely sieved using a 0.5 mm Mortar. The sieve and other tools are cleaned before being used for the next sample

The Reagent: staff dissolve 98.1g of potassium dichromate with 600 ml of ionised-free water in a beaker. 100 ml of concentrated sulfuric acid is then added, heated until wholly dissolved, and then diluted in a 1 litre measuring flask with deionized water. Last, 12,510g of glucose pa is dissolved with distilled water in a 1l volumetric flask and compressed.

Distillation and Measurement: staff weigh 0.500 g of soil sample <0.5 mm in size and pour into a 100 ml volumetric flask. Staff then add 5 ml of $K_2Cr_2O_7$ I N, then shake, then add 7.5 ml of concentrated H_2SO_4, shake, and let stand for 30 minutes, before diluting with ionised water, allowing to cool, and then squeeze. After one day, staff measure the clear solution with a spectrophotometer at a wavelength of 561 nm. Staff compare 0 and 250 ppm standards by pipetting 0 and 5 ml of the 5,000-ppm standard solution into a 100 ml volumetric flask with the same treatment as the sample.

Note: If the sample reading exceeds the highest standard, staff repeat the determination with a smaller sample and adjust the factor accordingly.

Determination of Nitrogen content

Oxidised organic nitrogen compounds are measured in a concentrated sulfuric acid environment with a catalyst mixture of selenium to form $(NH_4)_2SO_4$. Ammonium levels in the extract can be determined by distillation or spectrophotometry. In the distillation method, an extract is liberated by adding NaOH solution. Then, the liberated NH is bound by boric acid and titrated with standard H.SO solution, using Conway's indicator. Alternatively, a spectrophotometric method employs the indophenol blue colour generator method.

Instruments

- Analytical balance three decimal places
- Digestion tube & digestion block
- Boiling flask 250 ml
- Erlenmeyer 100 ml with flask
- Burette 10 ml
- Magnetic stirrer
- Dispenser
- Test tube
- Shaker tube
- Distillation apparatus or Spectrophotometer

How it works

Staff weigh out a 0.5 g soil sample size < 0.5 mm and place within a digest tube. Staff then add a mixture of 1 g selenium and 3 ml of concentrated sulfuric acid, and digest to a temperature of 350 ^{o}C (3-4 hours). Staff then remove the tube and cool, and the extract is then diluted with free water ions to exactly 50 ml. The mix is then shaken until homogeneous and left overnight for the particles to settle. The extract is used to measure N by distillation or colorimetric method.

Measurement of N by Distillation

Staff transfer the sample extract to a boiling flask of ion-free water, add boiling rock powder equal to half the flask volume, and prepare a container for NH: Erlenmeyer containing 10 ml of 1% boric acid plus three drops of Conway indicator, and connect to a distillation apparatus. With a measuring cup, staff add 10% NaOH 40% about 10 ml into the boiling flask and immediately close. This is distilled until reservoir volume reaches 50-75 ml (green), when staff titrate the distillate with H_2SO4 0.050N until a pink, and finally record the volume of the sample titer (V_c) and the blank (V_b).

Measurement of N by Spectrophotometer

Staff pipette each extract into a test tube of 2 ml following the standard implementation series: adding the Tartrate and Na-phenate buffer solution successively at 4 ml each, shaking, and leaving for 10 minutes. Staff then add 4 ml of 5% NaOCl, shake and measure with a spectrophotometer at wavelength of 636 nm after 10 minutes of administering the reagent.

2.4 The Leakage belt and Reference Region

GMT and YAGASU coordinated to establish a Leakage Belt around the Project Area - being the area under the control of the project participants in which the project activities will be implemented and carbon impacts will be assessed for crediting. Within the surrounding Leakage Belt, future deforestation above a projected baseline is to be considered “leakage”, marginal losses to forest generated by displaced consumption and conversion. The projected baseline deforestation rate for the leakage area is drawn from a much larger ReferenceRegion, being the analytical domain from which information on historical deforestation is extracted and projected into the future to quantify areas that will be deforested in the baseline case.

Surveying deforestation drivers

YAGASU and GMT completed an extensive series of consultations with local village leaders to effect rural appraisals and gather expert knowledge by which to define the likely channels of ex-ante activity-shifting leakage from out of the project area. These consultations followed the *BioCarbon Methodology* (2008) to define the leakage drivers and deforestation agents in 001-OxC. Remote sensing of deforestation/degradation will then be used to identify the ex-post leakage impacts in the leakage belt.

Understanding the leakage agents and drivers behind land-use decisions is necessary to inform an initial estimate of the likely quantity and location of possible future deforestation. This understanding further serves to also inform future measures and activities to avoid deforestation and forest degradation in the project area. The proponents completed this assessment via the following steps:

1. Define leakage agents causing increased deforestation/degradation rates.
2. Demarcate the leakage belts' location and size using GIS analysis.
3. Estimate forest deforestation and degradation rates in the leakage belts.
4. Calculate total deforestation and degradation rates in the leakage belts by adding the leakage-induced increases in deforestation/degradation to the baseline deforestation/degradation rates in the leakage belts.

Estimating Leakage based on geographical characteristics

Leakage from geographic features is estimated as an ex-ante driver by calculating the forest deforestation rates inside the boundaries of the leakage belts of project areas. The following geographically constrained drivers were identified as being present in the leakage belt area:

- Conversion of forest land to cropland by local communities;
- Cattle grazing within the mangrove forests;

- Conversion of forest land to build settlements for locals;
- Logging of timber for domestic use and businesses;
- Fuelwood collection for domestic and local industrial energy needs;
- Mangrove wood harvesting for conversion to charcoal for sale;
- Historical incidences of forest fires are not part of natural ecosystem dynamics.

Deforestation Agents

The main deforestation agents were identified in consultations combining leakage belt maps and field survey questions. Survey items sought to ascertain the relative importance of each individual agent in driving deforestation outcomes and collected the following information:

- Local working name of the agent group;
- Description of the primary social characteristics, source of income, economic activities, cultural, and other relevant features of each leading agent group.
- Brief assessment of the most likely development of the population size of the identified main agent groups in the reference region, project area, and leakage belt.
- Statistics on historical deforestation rates and causes related to each agent group in the reference region, project area, and leakage belt.

Deforestation Drivers

The team next analysed factors driving land-use decisions for each identified agent group. First, survey consultations solicited local experts' and representatives' assessments of factors that might explain the various anticipated quantities of planned and unplanned deforestation measured in hectares. Second, survey items sought experts' identification of specific locations of possible future deforestation areas, as well as assessments of related 'predisposing factors' that might explain the location of anticipated deforestation and degradation pressures. These ranged from access to travel routes, proximity to community centres, businesses, or industrial facilities (e.g., sawmills, pulp and paper mills, agricultural plantations, future settlements), as well as influences of other infrastructure projects like national parks and reserves, etc.

Structural and Underlying Causes

Lastly, survey items addressed ways in which deforestation agents' behaviours and decisions may have been and/or may in the future be influenced by structural forces, such as:

- Land-use policies and governance enforcement;

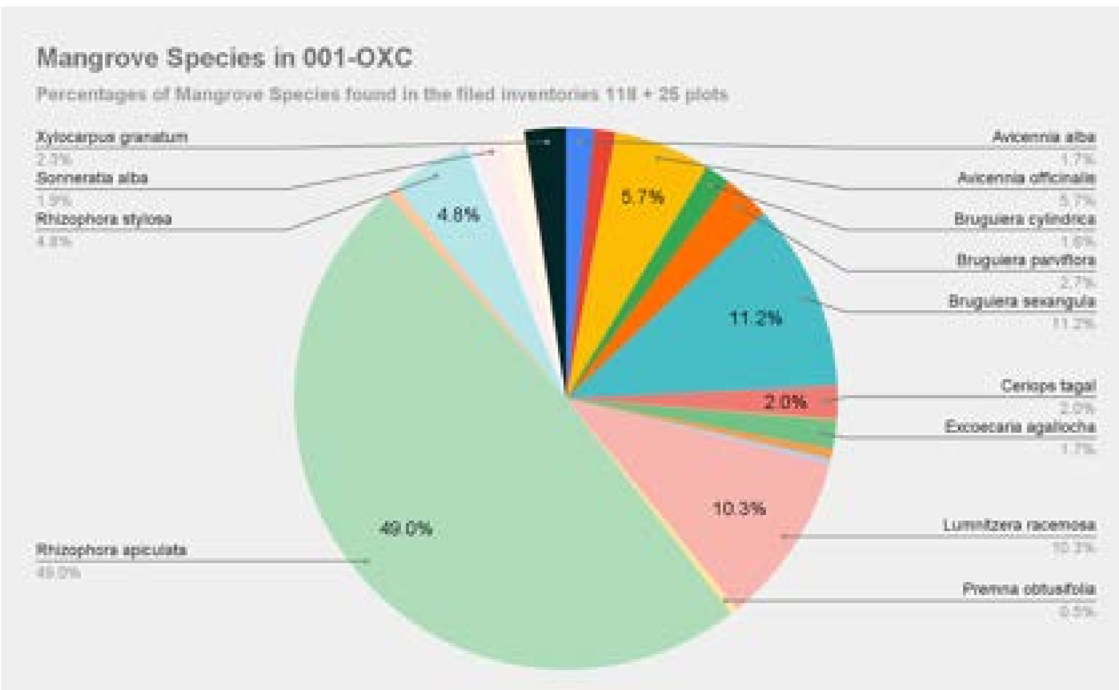
- Population pressures;
- Average levels of poverty and wealth in local communities;
- Conflicts, historical incidents of natural disasters, forest fires, etc.

Part III: Data Report

3.1 Prevalent Mangrove Species

Distribution of mangrove tree species is not homogenous throughout the 001-OxC project area due to the terrain and climate. Of the 13 varieties, the Rhizophora Apiculata is the dominant tree species covering 49% of the mangrove forests. Other species include the Bruguiera Sexangula at 11.2%, and Lumnitzera Racemosa 10.3%. Figure 14 shows the breakdown of species found in both field inventories.

Figure 19: Mangrove Species Analysis in the 1st and 2nd Inventories in 001-OxC



Each identified species was fitted with an established allometric equation within the machine learning and estimation process to establish above-ground biomass across the whole project area. Where a species specific model was unavailable, a generic mangrove model was utilised in place. This estimation, alongside below-ground biomass using shoot-to-root equations, generates a robust estimate for total carbon storage.

Table 12: Allometric Models Utilised in Biomass Estimates

Species	AGB Allometric Equation (where p is wood density and D is the diameter at breast height)	Wood Density, p
Avicennia alba	$0.251*p*(D)^{2.46}$	0.62
Avicennia marina	$0.1848*p*D^{2.3524}$	0.65
Avicennia officinalis	$0.251*p*(D)^{2.46}$	0.67
Bruguiera cylindrica	$0.251*p*(D)^{2.46}$	0.72
Bruguiera parviflora	$0.251*p*(D)^{2.46}$	0.74
Bruguiera sexangula	$0.251*p*(D)^{2.46}$	0.741
Cerbera manghas	$0.251*p*(D)^{2.46}$	0.47
Ceriops tagal	$0.251*p*(D)^{2.46}$	0.758
Excoecaria agallocha	$0.251*p*(D)^{2.46}$	0.45
Heritiera littoralis	$0.251*p*(D)^{2.46}$	0.79
Hibiscus tiliaceus	$0.251*p*(D)^{2.46}$	0.54
Lumnitzera littorea	$0.251*p*(D)^{2.46}$	0.744
Lumnitzera racemosa	$0.251*p*(D)^{2.46}$	0.71
Premna obtusifolia	$0.251*p*(D)^{2.46}$	0.55
Rhizophora apiculata	$0.043*p*D^{2.63}$	0.85
Rhizophora mucronata	$0.251*p*(D)^{2.46}$	0.82
Rhizophora stylosa	$0.251*p*(D)^{2.46}$	0.84
Sonneratia alba	$0.251*p*(D)^{2.46}$	0.78
Sonneratia caseolaris	$0.251*p*(D)^{2.46}$	0.49
Sonneratia ovata	$0.251*p*(D)^{2.46}$	0.37
Thespesia populnea	$0.251*p*(D)^{2.46}$	0.52
Vitex pubescens	$0.251*p*(D)^{2.46}$	0.88
Xylocarpus granatum	$0.1832*D^{2.21}$	0.7

Additional data points collected include mangrove trees status, height, and Diameter at Breast Height (DBH). In the two forest inventories, 75.9% of the mangrove trees are alive, 22.5% are felled, and 1.5% are dead trees *(see Figures below).* KACSAT's machine learning conducted Land-Cover mapping with satellite imagery for 2017 and 2021. Owing to high cloud cover in the region, a one year period of imagery was needed to ensure at least one cloud-free pixel for every 10m Sentinel pixel in the entire coastal zone. Sentinel-2 images of coastal Sumatra were compiled annually into a cloud-free composite through the Google Earth Engine (GEE) platform. Machine-learning based classification serves to identify mangrove forests using remote sensing data. The classification effort utilised satellite imagery from Sentinel-1 and Sentinel-2 and NASA SRTM DEM data, and these inputs were integrated within the Google Earth Engine application. The field inventories found that the average canopy height for the live mangrove trees are 3.9 and 3.84 metres for the first and second field inventories respectively (*see Table below*), while the maximum recorded height was between 13- 15 metres.

Table 13: Mangrove Analysis: Average values for first and second Forest Inventories

	Average per plot - First round (118 plots)	Average per plot - Second round (25 plots)	Total Average per plot
Avg no of Species	2.73	2.16	2.44 == 3
Total Trees	28.2	28.4	28.3
Avg Total DBH	5.6	4.69	5.2
Avg Total height	3.2	3.53	3.4
No. of Live trees	20.5	25.6	23.1
Avg live DBH	5.0	4.43	4.7
Avg live Height	3.9	3.84	3.9
No. of Cut down trees	7.1	2.84	5.0
Avg Cut down DBH	6.5	4.00	5.2
Avg Cut down height	0.7	0.41	0.6
No. of Dead trees	0.5	0.0	0.3
Avg Dead DBH	1.1	0.0	0.6
Avg Dead height	0.9	0.0	0.4

Pulau Kampai had the largest number of cut down trees compared to the other villages and regional forests, with 429 of 1309 trees (32.77%) in the first round and 71 out of 711 trees (9.9%) in the second round. The second field inventory survey percentages were acceptable and produced additional AGB sequestration results.

Figure 20: Mangrove Trees Analysis based on tree status in 1st and 2nd field inventories

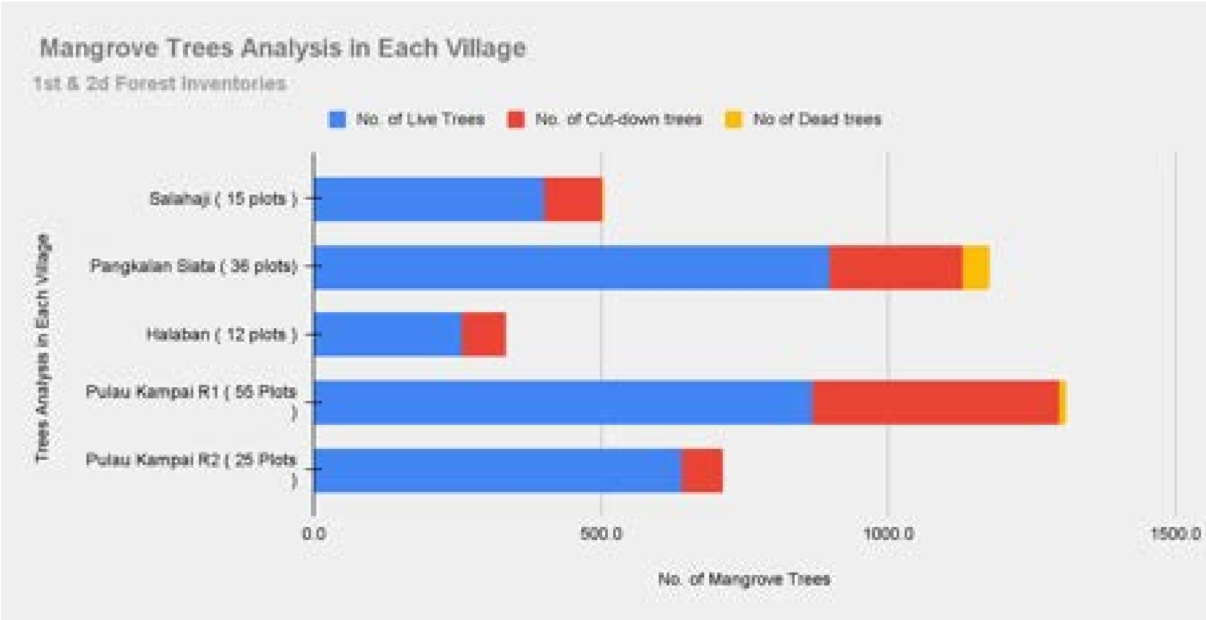
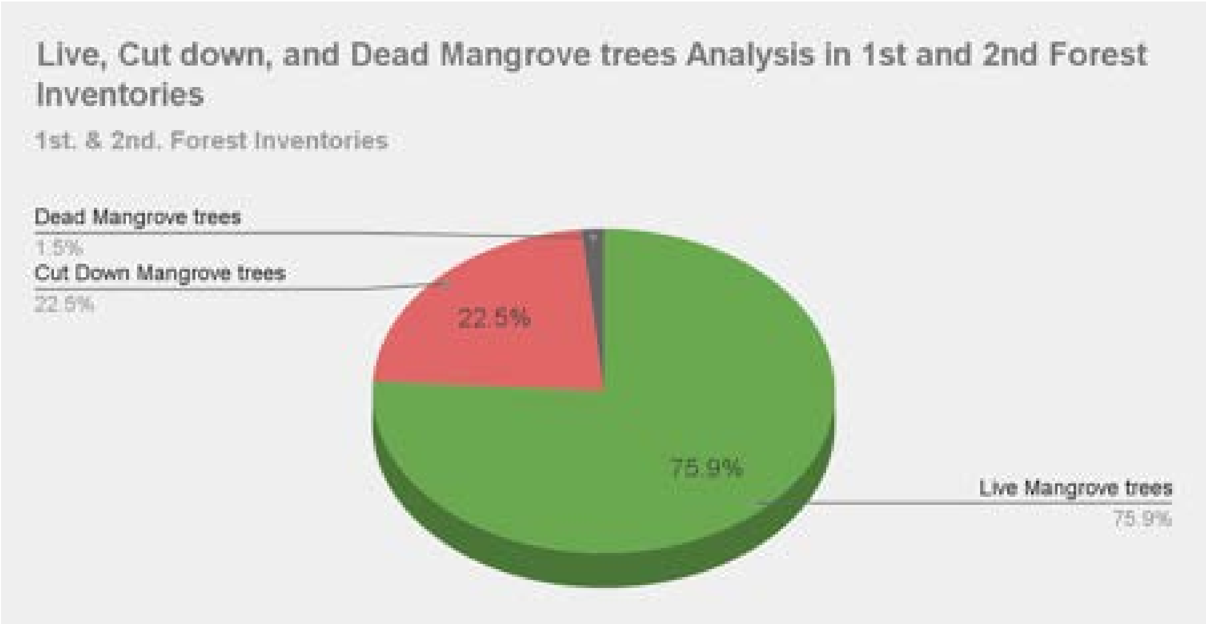


Figure 21: Mangrove Trees Status Analysis in 001-OxC



3.2 Soil Measurements Outcomes

Both in-situ and laboratory measurements were conducted to determine the average carbon, nitrogen, and water contents of the field inventories. This also established soil structure, consistency, texture, and bulk density due to the history of volcanic eruptions on Sumatra island. Elements like sand and clay were considered to understand the coastal environment. Findings from both soil measurements are detailed below.

3.2.1 In-Situ Measurements

In-situ measurements were conducted in the field. Teams collected soil samples and tree data while collecting and measuring the DBH, field measurements, soil pH, temperature, soil conductivity, and soil moisture. Water measurements collected included PH/Temperature of water, TDS/EC water, and water salinity *(see Table below).*

Table 14: In-Situ Average field Measurements using HI98331 Soil test device and Salinity ORP S.G PH TDS EC Temperature COM600 device

	Pulau Kampai			Pangkalan Siata			Halaban		
Depths	0 - 15	15 - 30	30 - 50	0 - 15	15 - 30	30 - 50	0 - 15	15 - 30	30 - 50
Wet Weight (gr)	167.5	156.5	184.5	232	248	272	272	233	254
pH	6	6	6	5.90	5.50	6.00	5.6	5.4	5.8
Temp (oC)	28.6	28.6	28.6	30.10	30.10	30.20	30.3	30.6	30.6
S.Conduct (mS/cm)	4	4	4	4	4	4	4	4	4
Moisture	5.2	5.2	5.2	4.00	4.50	3.50	4	4	4
PH / Temp Water	6.05/ 31.6 °C	6.05/ 31.6 °C	6.05/ 31.6 °C	5.53/ 27.5 °C	5.53/ 27.5 °C	5.53/ 27.5 °C	6.10/ 31.6 °C	6.10/ 31.6 °C	6.10/ 31.6 °C
TDS / EC Water	38/ 36.5	38/ 36.5	38/ 36.5	35.6/ 154	35.6/ 154	35.6/ 154	1282/ 129	1282/ 129	1282/ 129
Water Salinity (ppm)	18	18	18	16.10	16.10	16.10	36.4	36.4	36.4

3.2.2 Laboratory Measurements

Laboratory measurements quantified soil carbon stock, water contents, soil fraction (sand, silt, and clay), and the soil nitrogen content. Experts at Pusat Penelitian Kelapa Sawit

Laboratory (PPKS) in Medan, North Sumatera, performed these test using the Indonesian essential reference "ANALISIS KIMIA TANAH, TANAMAN, AIR, DAN PUPUK"[6].

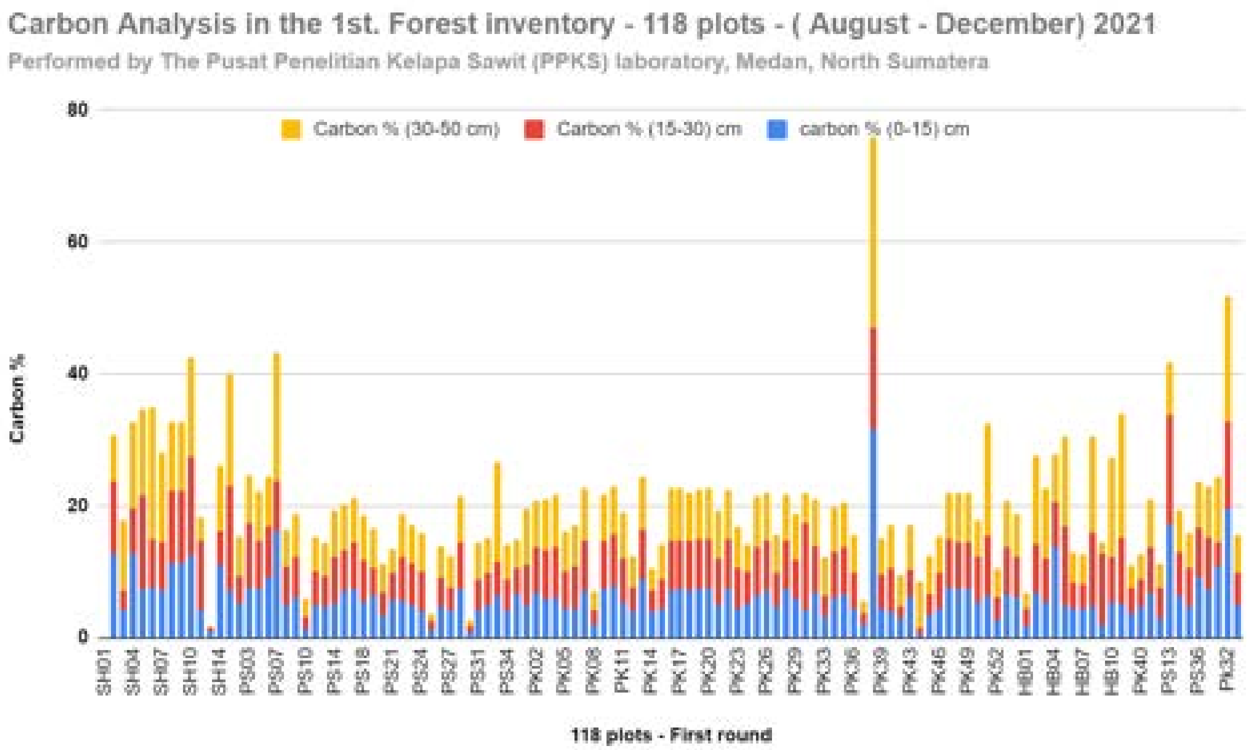
Table 15. Lab Results of the Avg percentages of Organic Carbon, Nitrogen, and Water contents from the First Round of field research (118 collected soil samples).

Depth	Avg Carbon content (%)	Avg Nitrogen content (%)	Avg water content (%)
0 - 15 cm	6.32	0.27	7.15
15 - 30 cm	6.54	0.27	6.87
30 - 50 cm	7.66	0.27	8.03

Soil samples were stored in ice boxes and sent to PPKS, where they were dried immediately in preparation for organic carbon content tests. The figures below show the organic carbon, nitrogen, and water content analysis of the 354 collected soil samples in the 1st forest inventory campaign between August and December 21.

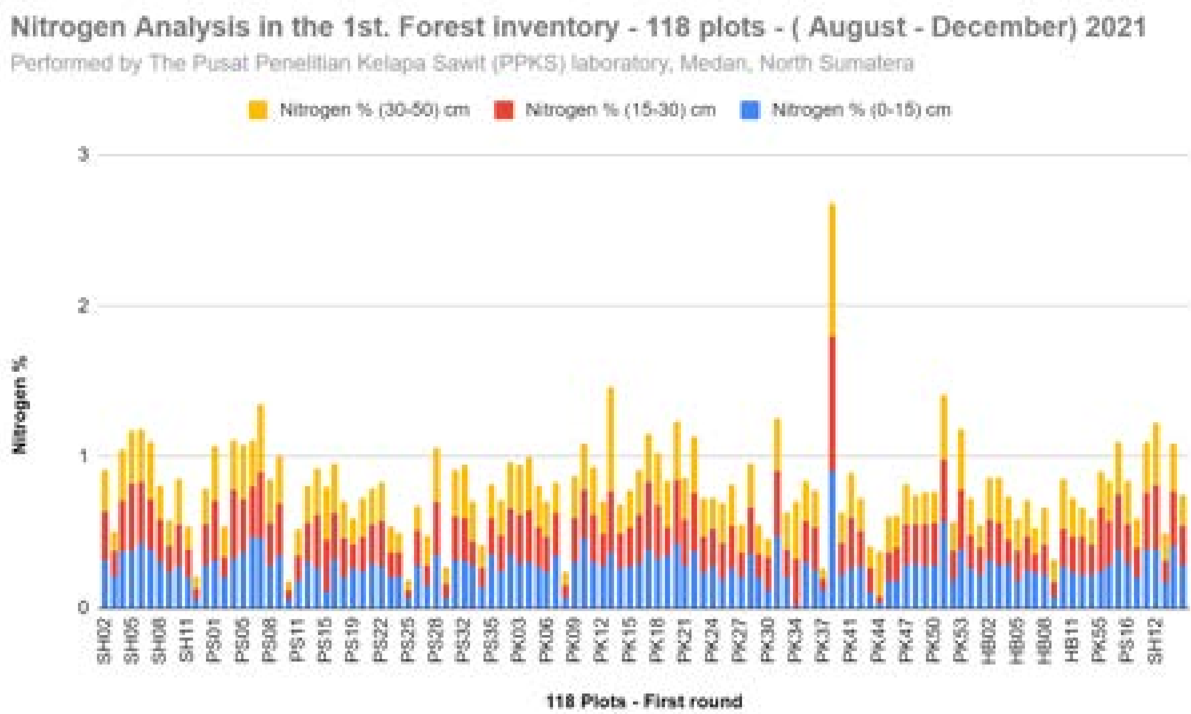
[6] https://balittanah.litbang.pertanian.go.id/ind/dokumentasi/juknis/juknis_kimia.pdf

Figure 22: Organic Carbon Content at variable depths - 1st round



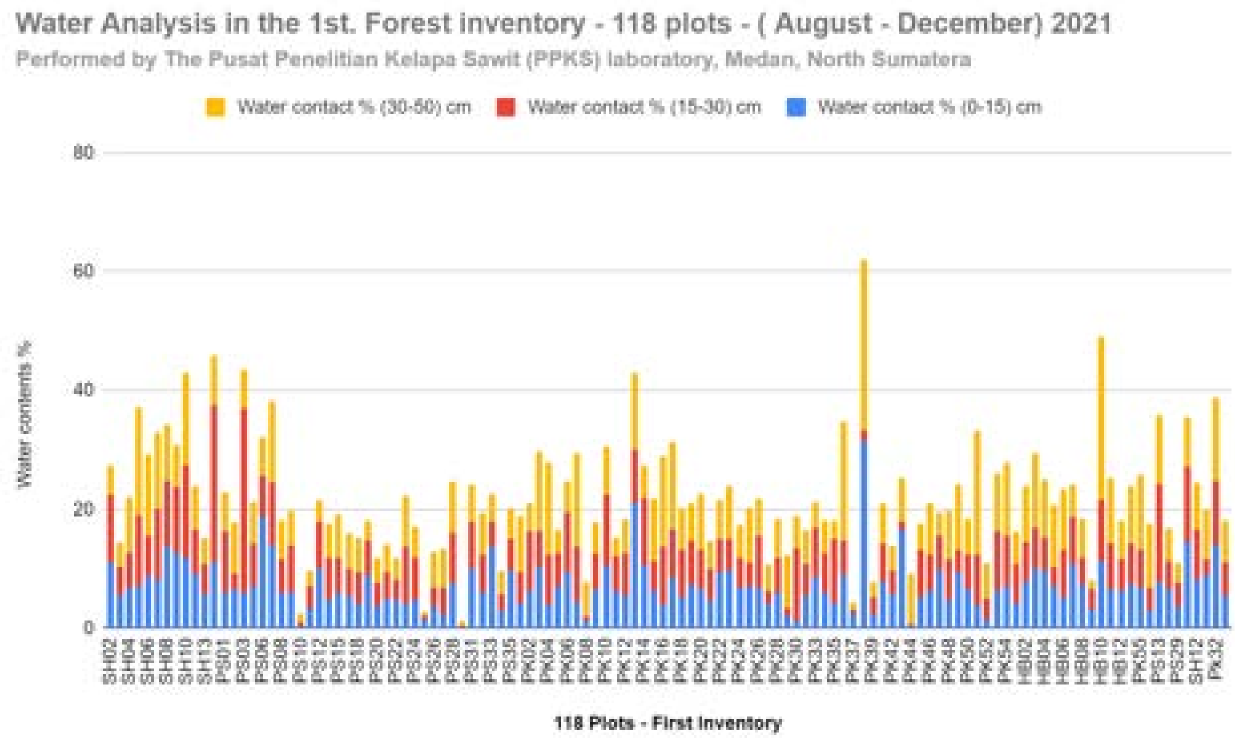
Note: Carbon analysis was measured in the Medan laboratory for the 118 first round plots collected at three different depths (0-15cm, 15-30cm, 30-50cm), with results shown here in 3 colours.

Figure 23: Organic Nitrogen Content at variable depths - 1st round



Note: Nitrogen analysis was measured in the Medan laboratory for the 118 first round plots collected at three different depths (0-15cm, 15-30cm, 30-50cm), with results shown here in 3 colours.

Figure 24: Water Content at variable depths - 1st round



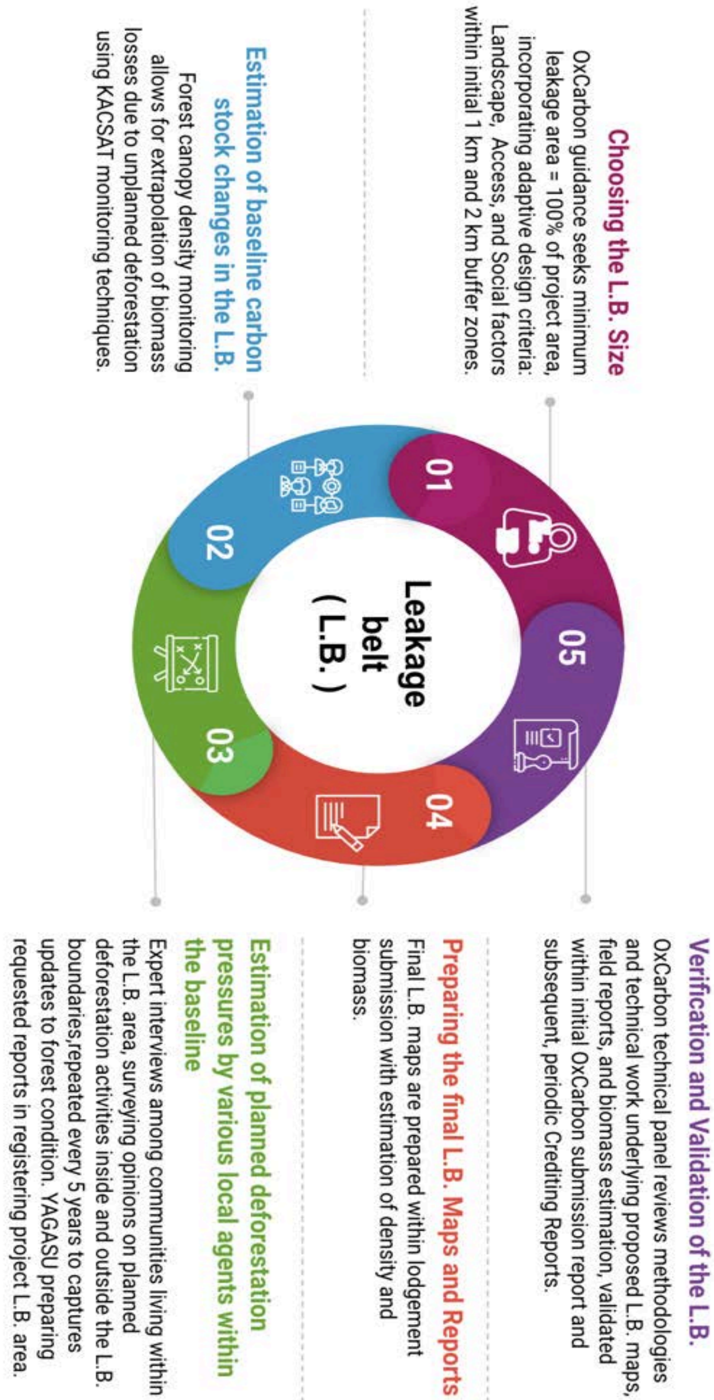
Note: Water analysis was measured in the Medan laboratory for the 118 first round plots collected at three different depths (0-15cm, 15-30cm, 30-50cm), with results shown here in 3 colours.

3.3 OxCarbon Leakage Belt Protocol

The OxCarbon Leakage belt protocol is designed to respond to anticipated and unanticipated displacement of deforestation activities from within the conservation project area to its neighbouring environments.

Anticipated deforestation activities are when designed projects have been announced prior and landowners have the ability, intent, and legal permission to undertake deforestation; while unanticipated deforestation activities are when someone other than the landowner, such as a local community, is undertaking said activities. These areas are earmarked for the development within the next 5 years, and determined by experts based on their experience, estimations, and forest/land knowledge.

Figure 25. OxCarbon Leakage Belt Protocol



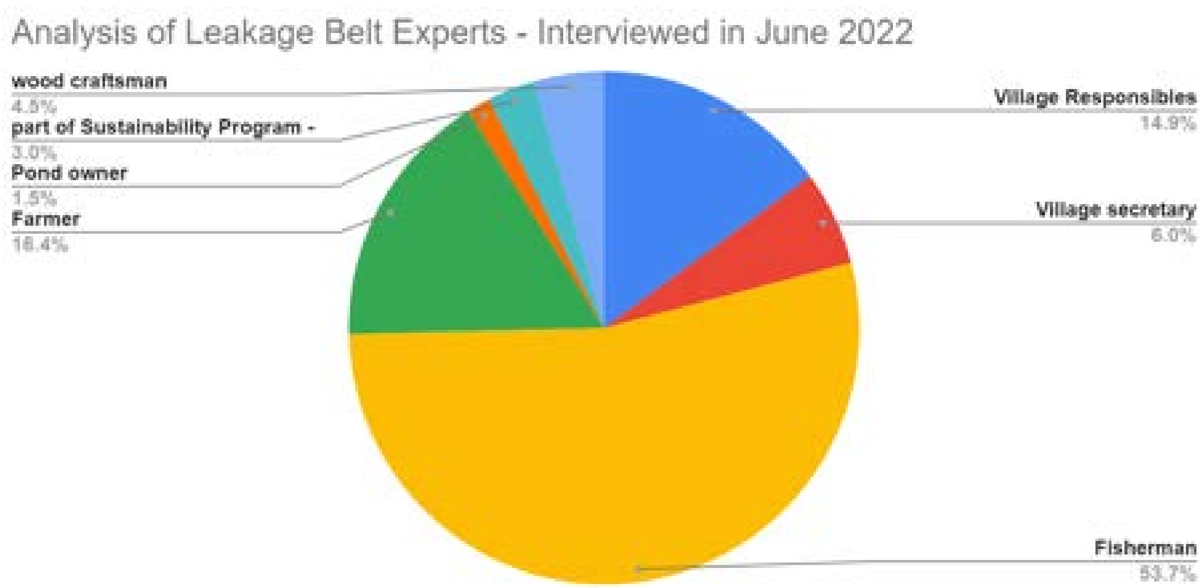
3.3.1 Establishing the 001-OxC Leakage Belt

In collaboration with OxCarbon, GMT worked with the YAGASU team to prepare the suitable Leakage belt maps for the 001-OxC project area. YAGASU led interviews with local experts to ascertain the condition of forests in the leakage belt, identify anticipated and unanticipated displacement of deforestation activities in the vicinity (see figure below).

Figure 26: YAGASU interviewing Local Experts

A total of 70 experts were interviewed: 20 in Pulau Kampai, 20 in Halaban, 15 in Salahaji, and 15 in Pangkalan Siata. Majority were farmers and fishermen who previously relied on mangrove forests and ponds as a source of income (see figure below). Almost all experts had been trained in mangrove plantation, restoration, and conservation activities.

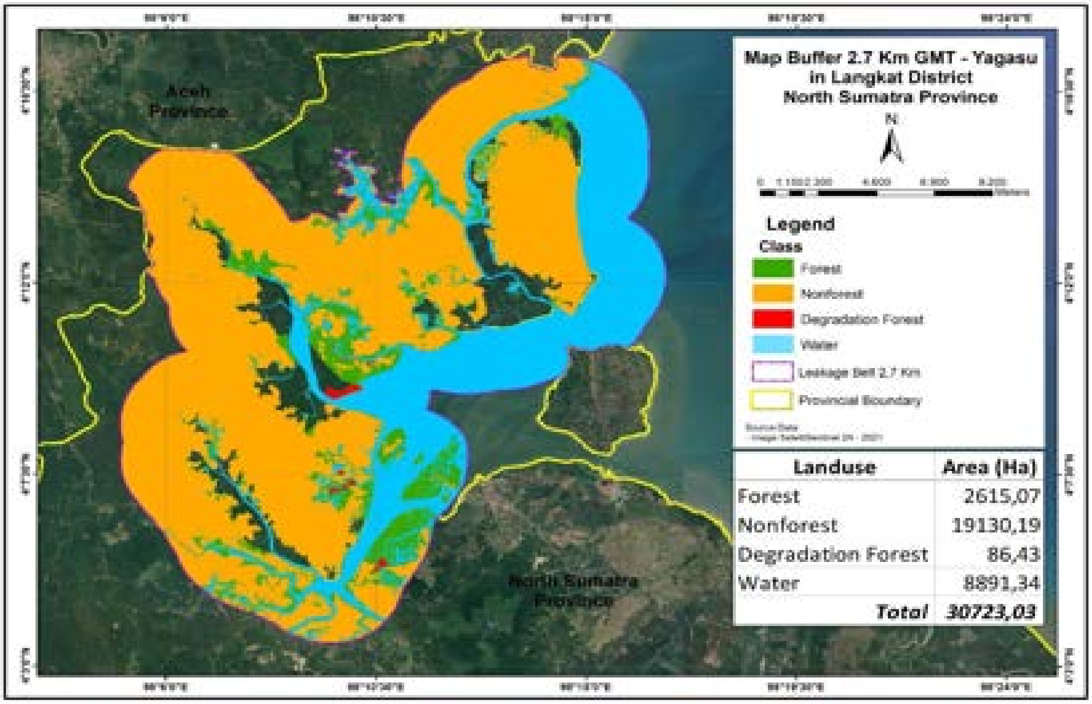
Figure 27: Occupations of Local Experts Interviewed

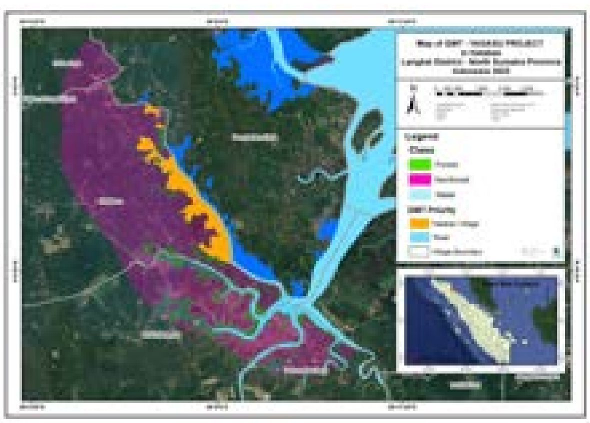
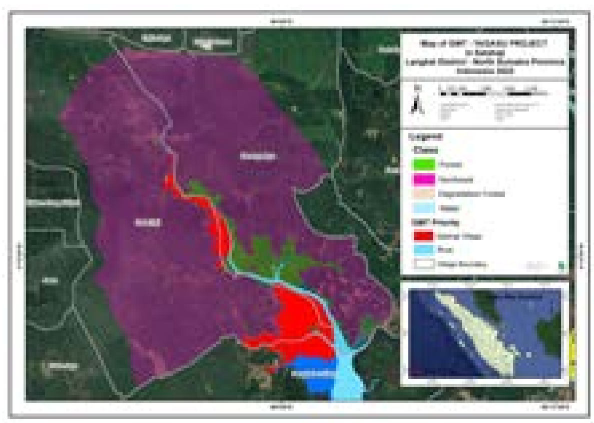


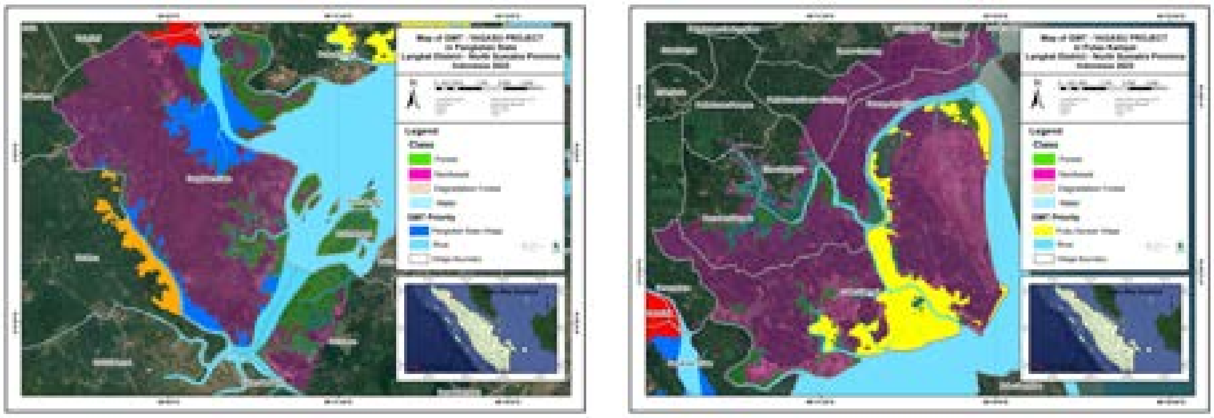
Based on the Leakage Belt Experts' interview, only 56.7% of the locals are worried about Forest Law Enforcement and the consequences of cutting protected mangrove forests as they know it is illegal. Though fishery jobs tend to earn higher revenue, many locals with no alternative sources of income have to resort to selling mangrove wood for their livelihoods. One of 001-OxC's main objectives, therefore, is to train local communities on conservation and provide alternative sources of mangrove-friendly income opportunities, such as management of crediting projects and sustainable harvesting of mangrove resources.

The direction provided to the project participants is to cover 100% of the area in the conservation project area in the leakage belt outside of the project area, resulting in a 2.7km buffer around the project area's borders. Individual leakage belts around each village project area were also demarcated. (Figure 22) Activities inside the leakage belt area affects deforestation rate and the carbon stocks measurements. These metrics aid the team in planning for future forest changes, identify areas that are facing threat of deforestation and designing the proper restoration activities.

Figure 28: Leakage Belt, 2.7 km buffer Leakage Belt



The Leakage belt surrounding the project area in Halaban village	The Leakage belt surrounding the project area in Salahaji village
	
The Leakage belt surrounding the project area in Pangkalan Siata village	**The Leakage belt surrounding the project area in Pulau Kampai village**



The highlighted areas in the Figure above were selected by experts as areas that would potentially see planned / unplanned deforestation activities occur. These areas are not reserved for infrastructure or settlement projects - they are generally cut down by local communities for income. For instance, in Salahaji and Pangkalan Siata, village representatives established a rotational system to assign farmers specific days they can gather wood so authorities retain control over and are able to monitor deforestation rates. However, local governance alone is not 100% effective to control deforestation by individuals and small wood industries, some of which cut down up to 1500 kg of wood monthly.

Finished maps were uploaded to a database to generate shapefiles for further analysis.

3.4 Deforestation rates

Apart from establishing Leakage belts in consultation with local experts, KACSAT also identifies deforestation rates based on changes in land use and leverages the Foreign Agricultural Office (FAO) calculation methodology of deforestation to define the final deforestation rate. This historical deforestation is critical in estimating future unplanned deforestation rates in the project area and the Leakage belt. For 001-OxC, the engine was applied to a 250 km x 20 km reference area along the east coast of North Sumatra.

Figure 29: Reference Region Map, Monitored by KACSAT

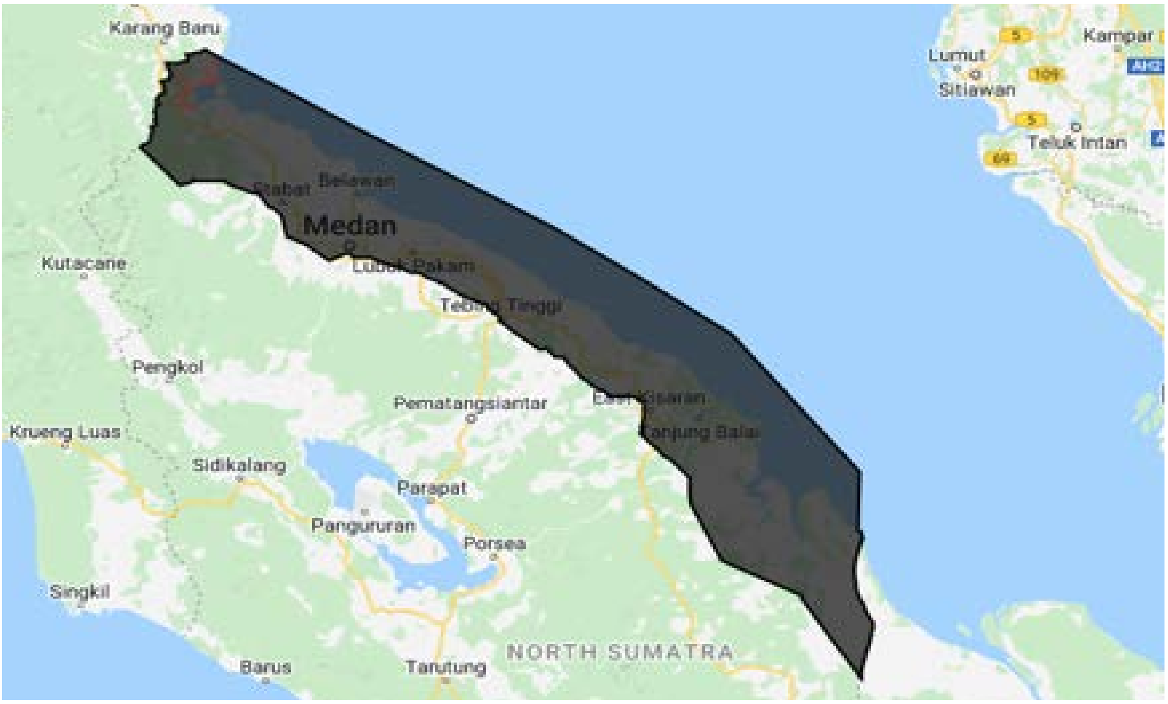


Table 16: Forest extent (area in hectares) from 2017 to 2021 with Annual Deforestation Rate based on FAO Calculation Method. KACSAT Engine.

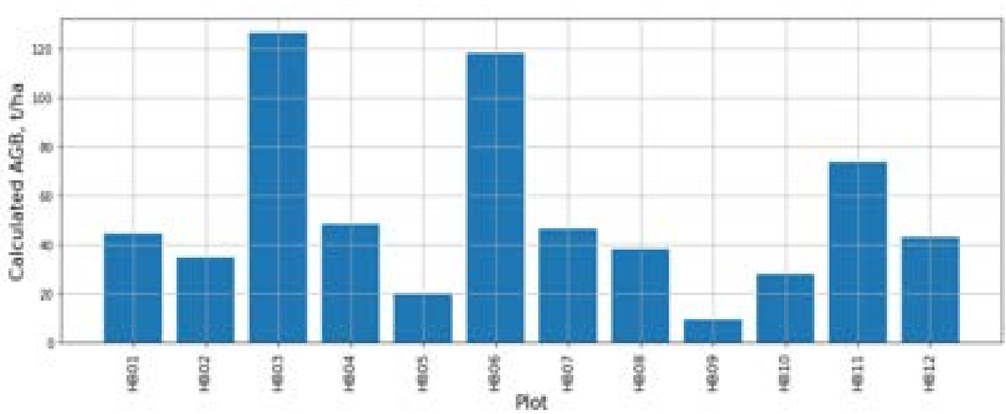
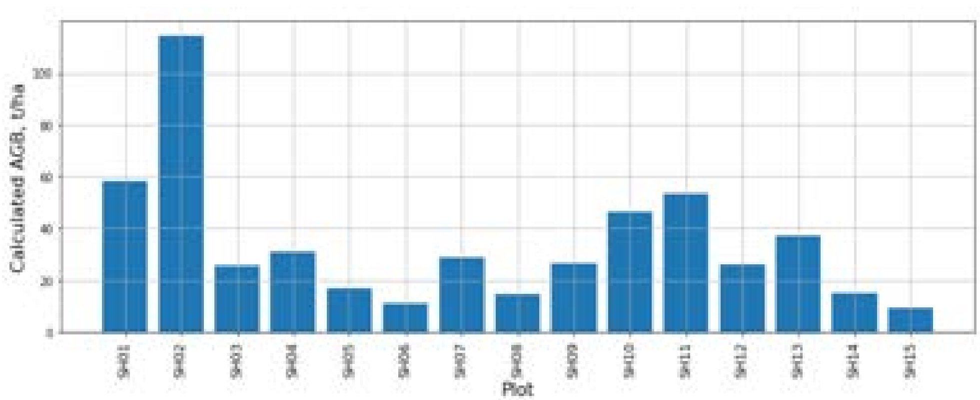
Land cover type	2017	2021	Annual deforestation rate by FAO
Mangrove forest	30215.57	27896.00	1.98%
Tropical forest	20799.26	17996.76	3.55%
Swamp forest	65588.82	40651.57	11.27%
All forest	116603.65	86544.34	7.18%

KACSAT will continue to provide a dynamic assessment of the historic deforestation rate throughout the life-time of the project in order to ensure avoided emissions claims continue to have science-based evidence of additionality. The window will become a ‘moving’ ten year period after 2026 in accordance with the OxCarbon principles.

3.5 Above & Below Ground Biomass Sequestrations

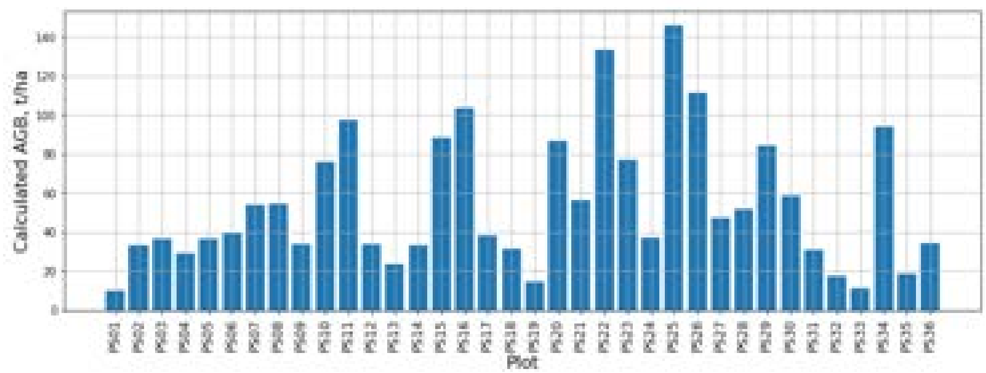
The combination of high accuracy satellite input data and high quality ground data on tree species is central to the core assessment advance of the KACSAT engine. Ground truthing by local observers enabled AGB estimations through the use of allometric models, which combined with BGB sequestrations operates two core applications: generating and using land cover classification for forest density analysis, and developing, calibrating, and deploying the carbon estimation engine to assess stocks of dynamic mangrove forests.

Figure 30: Agb calculations of the 1st & 2nd forest inventories (t/ha)

Halaban (HB) *<u>1st Inventory</u>*	
Salahaji (SH) *<u>1st Inventory</u>*	

Pangkalan Siata (PS)

1st Inventory



Pulau Kampai (PK)

1st & 2nd Inventories

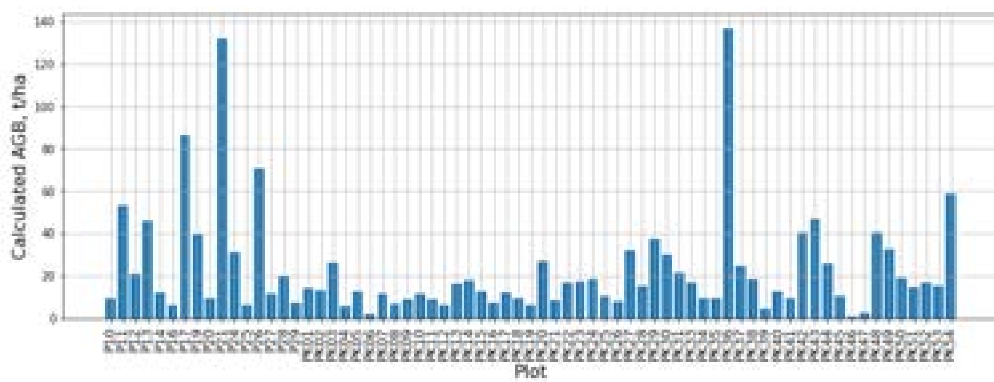
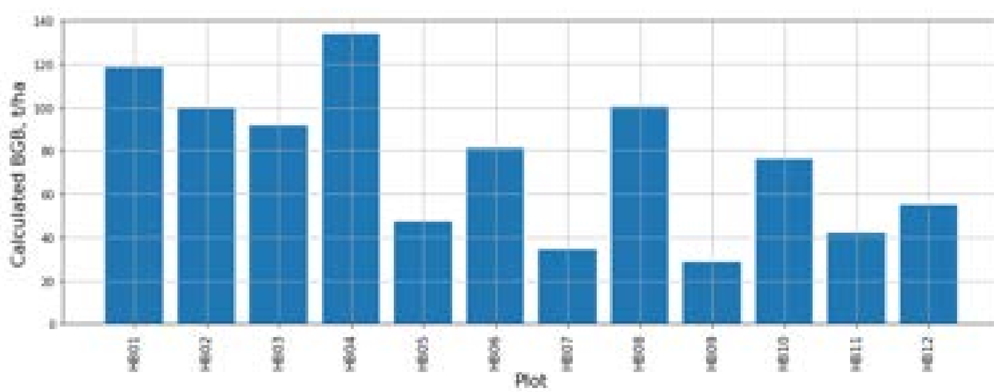
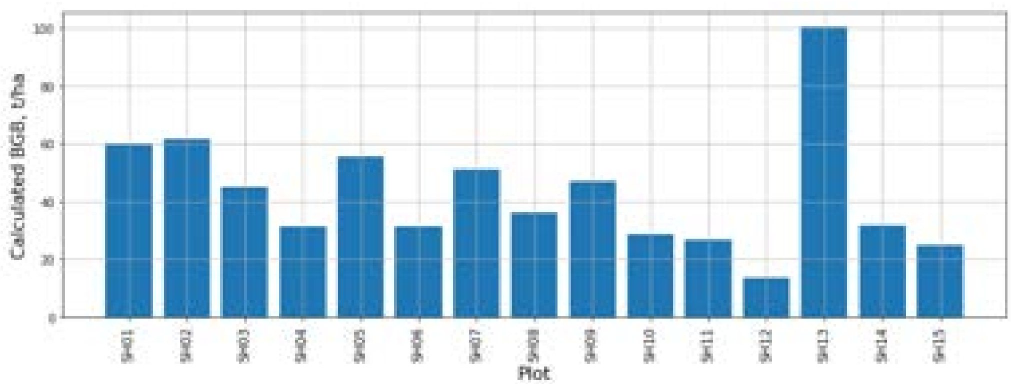
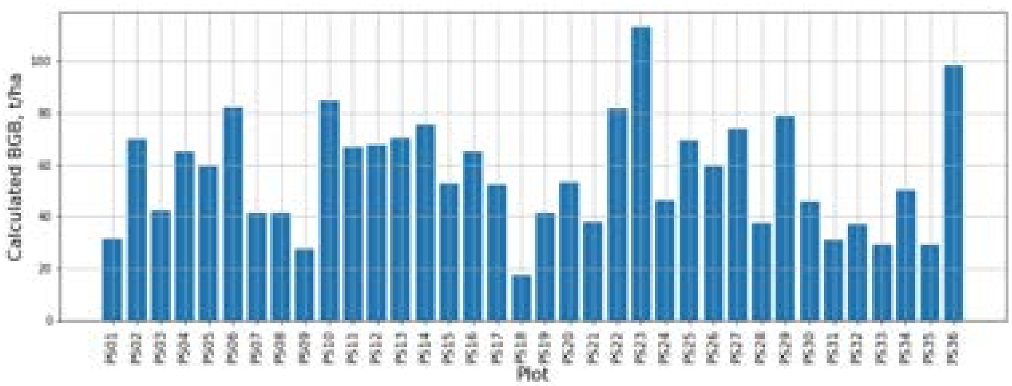
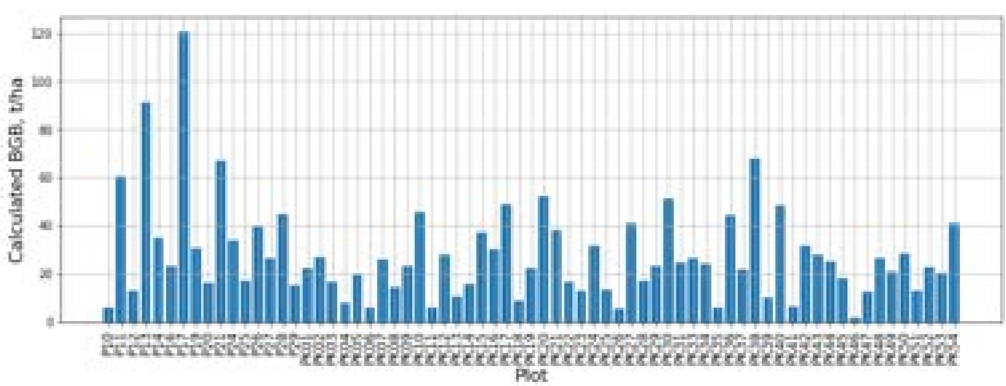


Figure 31: BGB calculations of the 1st & 2nd forest inventories (t/ha)

Halaban (HB)

1st Inventory



Salahaji (SH) *1st Inventory*	
Pangkalan Siata (PS) *1st Inventory*	
Pulau Kampai (PK) *1st & 2nd Inventories*	

Through the integration of Above Ground Carbon, Below Ground Carbon, and Soil Carbon Saturation levels, the total carbon stock is calculated with the following formula:

$$tCO_2e = (AGC + BGC + SCS) * (44/12)$$

Where:
tCO_2e = Total Carbon Dioxide Equivalent
AGC = Above Ground Carbon, where AGC = AGB * 0.47

BGC = Below Ground Carbon, where BGC = AGB * 0.39[7]
SCS = Soil Carbon Saturation

The KACSAT team adhered to a strict image preprocessing protocol on the satellite imagery to assess AGB and BGB for the full project area. This included applying different filters and generation of spectral indices to reduce the effect of atmospheric conditions, removing clouds and cloud-shadows to every multispectral stack. Another critical step was detecting clouds and cloud shadows from the multispectral worldview image through a series of image processing steps to create cloud and shadow masks. Average biomass and carbon stock measurements from field observations and the KACSAT machine learning process are detailed below.

Table 16: Biomass Measurements and tCO2e/ha

Village	AGB, Mg/ha	BGB, Mg/ha	SCS, MgC/ha	tCO_2e
Halaban	52.5738	75.71	380.69	1594.73
Pangkalan Siata	54.5508	56.29	331.55	1390.19
Salahaji	34.2964	42.98	559.9	2173.53
Pulau Kampai	22.8299	27.96	329.4	1287.13
Conservation Area Average	38.32	44.60	361.20	1454.1925

Table 17: Biomass Measurements and tCO2e per hectare based on machine learning model using Worldview and Radarsat-2 imagery and field observations

Village	AGB, Mg/ha	BGB, Mg/ha	SCS, MgC/ha	tCO_2e
Halaban	54.1924	58.4830	380.69	1572.89
Pangkalan Siata	50.8017	56.2581	331.55	1383.68
Salahaji	57.9463	65.7612	559.9	2246.87
Pulau Kampai	34.6548	21.2421	329.4	1297.90
Conservation Area Average	44.9445	42.3419	361.20	1462.3912

[7] Source: WP86CIFOR Protocol of carbon measurement - CIFOR- Kauffman Donato, Section 3.1

Table 18: Observed areas and masked areas of villages with average tCO2e per hectare estimated from high resolution machine learning model

Village	Observed Areas	Masked Area Due to Clouds and Shadows	Total Area In hectares	Average tCO2e per hectare observed
Halaban	230.63	16.89	247.52	1572.89
Pangkalan Siata	656.53	144.68	801.21	1383.68
Salahaji	202.49	53.01	255.50	2246.87
Pulau Kampai	895.1	106.27	1,001.37	1297.90

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Appendix

Annex A:

The lab results of the measured Carbon, Nitrogen, And Water contents in different depths (1-15 cm , 15-30 cm , 30-50 cm)

Plot No	C*_15 (%)	N*_15 (%)	H2O_15 (%)	C*_30 (%)	N*_30 (%)	H2O_30 (%)	C*_50 (%)	N*_50 (%)	H2O_50 (%)
SH01	12.78	0.31	11.18	11.03	0.33	11.18	6.95	0.28	4.96
SH02	4.08	0.21	5.46	3.06	0.17	4.7	10.78	0.13	4.36
SH03	12.82	0.38	6.8	6.83	0.33	5.78	13.09	0.34	9.67
SH04	7.32	0.38	7.04	14.22	0.44	11.83	13.21	0.36	18.35
SH05	7.58	0.43	8.97	7.35	0.4	6.52	20.07	0.36	13.92
SH06	7.12	0.39	8.16	7.32	0.33	11.92	13.76	0.38	12.94
SH07	11.16	0.3	13.77	11.05	0.28	10.94	10.46	0.23	9.71
SH08	11.19	0.23	12.55	11.03	0.18	11.3	10.5	0.17	7.1
SH09	12.5	0.27	11.89	14.83	0.28	15.44	15.19	0.3	15.69
SH10	4.17	0.2	9.21	10.63	0.19	7.32	3.53	0.15	7.36
SH11	0.87	0.05	5.8	0.52	0.08	5.07	0.29	0.08	4.34
SH13	11.02	0.28	10.92	5.05	0.27	26.5	10.19	0.24	8.44
SH14	7.16	0.31	5.91	15.86	0.4	10.44	17.18	0.36	6.65
PS01	5.06	0.2	6.63	4.17	0.14	2.56	6.06	0.2	8.79
PS02	7.49	0.32	6.04	9.97	0.46	30.98	7.35	0.33	6.57
PS03	7.36	0.37	7.02	7.44	0.35	7.08	7.45	0.36	7.2
PS05	9.04	0.47	18.7	7.74	0.33	6.93	7.62	0.31	6.65
PS06	16.16	0.46	13.96	7.58	0.44	10.48	19.49	0.45	13.8
PS07	4.94	0.28	6	5.73	0.28	5.52	5.71	0.29	6.68
PS08	6.2	0.35	6.06	5.97	0.34	8.02	6.68	0.32	5.77
PS09	1.25	0.05	0.42	2.04	0.07	0.54	2.5	0.06	1.63
PS10	4.87	0.18	3.46	5.06	0.17	3.52	5.48	0.17	2.8
PS11	4.66	0.3	10.06	4.67	0.26	7.89	5.15	0.25	3.56
PS12	5.03	0.26	4.66	7.21	0.36	7.09	7.13	0.31	5.94
PS14	7.07	0.11	6.12	6.06	0.34	5.67	7.28	0.35	7.5
PS15	7.22	0.33	5.51	7.21	0.3	4.57	6.74	0.33	5.98

PS17	5.36	0.2	4.07	6.41	0.26	5.39	6.86	0.25	5.76
PS18	6.42	0.26	8.98	4.09	0.16	5.88	6.15	0.17	3.4
PS19	3.33	0.24	3.51	3.55	0.23	4.09	4.36	0.26	4.36
PS20	5.57	0.29	4.94	4.25	0.26	4.54	3.71	0.24	4.8
PS21	5.62	0.27	4.61	6.69	0.3	3.48	6.55	0.26	3.74
PS22	4.89	0.2	4.12	6.25	0.17	9.64	5.89	0.17	8.57
PS23	3.94	0.21	4.65	6.08	0.16	7.1	5.86	0.13	5.48
PS24	1.15	0.07	1.4	1.28	0.05	0.72	1.33	0.07	0.77
PS25	4.72	0.28	3.72	4.45	0.23	3.18	4.67	0.17	6.03
PS26	4.07	0.15	2.34	3.59	0.13	4.58	4.93	0.2	6.4
PS27	7.24	0.35	7.59	7.18	0.35	8.45	7.17	0.36	8.69
PS28	0.83	0.07	0.17	0.84	0.09	0.36	1.06	0.11	0.63
PS30	4.25	0.31	9.9	4.59	0.3	8.01	5.49	0.31	6.27
PS31	4.98	0.31	6.11	4.81	0.28	6.33	5.32	0.36	6.96
PS32	6.45	0.28	13.58	4.97	0.16	4.32	15.34	0.27	4.71
PS33	3.81	0.14	2.79	4.96	0.12	3.07	5.5	0.16	3.95
PS34	6.69	0.36	9.85	3.8	0.23	5.27	4.42	0.23	5.08
PS35	4.99	0.24	4.22	5.93	0.24	5.26	8.54	0.24	9.39
PK01	6.96	0.36	6.4	6.69	0.3	9.88	7.03	0.31	4.72
PK02	5.97	0.29	10.3	7.13	0.33	6.01	7.94	0.33	13.54
PK03	6.2	0.3	4.02	7.49	0.35	8.33	8.06	0.35	15.61
PK04	4.49	0.27	7.15	5.54	0.26	5.59	6.18	0.28	3.93
PK05	4.5	0.24	9.37	6.22	0.23	10.04	6.44	0.24	5.49
PK06	7.19	0.35	4.35	7.51	0.28	9.38	8.02	0.2	15.84
PK07	1.86	0.07	1.19	2.31	0.08	0.88	2.85	0.09	5.8
PK08	7.33	0.3	6.61	7.34	0.3	5.94	7.19	0.28	5.42
PK09	7.93	0.46	10.63	7.62	0.32	11.7	7.38	0.31	8.23
PK10	5.3	0.3	6.36	6.73	0.32	5.65	7.08	0.32	3.38
PK11	3.98	0.27	5.42	3.59	0.22	7.11	4.79	0.22	5.96
PK12	8.81	0.37	21.14	7.6	0.4	8.86	8.1	0.7	12.99
PK13	3.89	0.26	10.48	3.2	0.23	11.5	3.49	0.2	5.54
PK14	4.39	0.27	6.24	4.53	0.26	5.12	5.39	0.25	10.63

PK15	7.15	0.29	4.02	7.64	0.33	9.69	7.87	0.3	15.35
PK16	7.33	0.39	8.39	7.45	0.44	8.25	8.01	0.33	14.74
PK17	7.2	0.33	5.14	7.57	0.35	8.04	7.35	0.35	7.23
PK18	7.44	0.35	7.24	7.49	0.18	7.63	7.47	0.31	6.3
PK19	7.53	0.43	6.6	7.47	0.41	6.44	7.85	0.4	9.75
PK20	5.01	0.28	4.62	6.94	0.3	5.36	7.37	0.29	4.82
PK21	7.46	0.38	9.38	7.43	0.38	5.57	7.62	0.38	6.81
PK22	4.47	0.23	9.69	6.12	0.24	5.37	6.4	0.26	8.92
PK23	5.23	0.27	6.73	4.89	0.25	5.22	4.02	0.21	5.36
PK24	6.44	0.19	7.1	7.32	0.24	3.85	7.69	0.27	9.4
PK25	7.2	0.26	6.78	7.46	0.28	8.84	7.33	0.28	6.25
PK26	4.66	0.2	4.28	5.22	0.17	2	5.82	0.18	4.44
PK27	7.28	0.36	5.98	7.49	0.31	5.79	6.91	0.29	6.6
PK28	5.98	0.2	2.01	5.88	0.16	1.46	6.87	0.19	8.97
PK29	4.21	0.12	1.29	13.1	0.22	12.27	4.61	0.12	5.42
PK30	6.94	0.47	5.6	6.95	0.44	5.29	7.23	0.35	5.64
PK31	3.3	0.2	8.55	2.97	0.19	8.2	5.86	0.25	4.6
PK33	6.18	0.01	5.96	6.69	0.32	6.65	6.9	0.38	5.46
PK34	6.61	0.3	4.07	7.15	0.27	11.04	6.7	0.27	3.14
PK35	4.32	0.25	8.9	5.55	0.28	5.93	5.81	0.25	20
PK36	1.94	0.12	2.47	1.72	0.07	0.54	1.89	0.07	1.48
PK37	31.65	0.91	31.49	15.43	0.89	1.85	31.31	0.88	28.81
PK38	4.46	0.22	2.22	5	0.21	3.13	5.73	0.21	2.54
PK39	3.8	0.26	7.87	6.73	0.34	6.24	6.52	0.3	7.03
PK41	2.99	0.27	5.8	1.59	0.24	3.95	4.96	0.22	4.28
PK42	6.2	0.11	16.51	4.13	0.15	1.51	6.8	0.15	7.43
PK43	0.57	0.03	0.38	0.94	0.05	0.36	6.98	0.3	8.5
PK44	3.34	0.18	5.1	3.36	0.19	8.01	5.76	0.24	4.55
PK45	4.38	0.18	6.21	5.29	0.22	6.05	5.75	0.22	8.87
PK46	7.56	0.28	9.68	7.27	0.27	5.99	7.25	0.27	3.93
PK47	7.23	0.29	4.6	7.26	0.26	6.88	7.51	0.2	8.22
PK48	7.33	0.27	9.43	6.99	0.28	3.67	7.8	0.22	11.18

PK49	5.27	0.28	6.58	7.04	0.28	5.72	5.62	0.21	6.27
PK50	6.43	0.57	3.88	8.87	0.41	8.52	17.32	0.44	20.89
PK51	2.76	0.19	1.41	3.39	0.19	3.64	4.25	0.19	5.97
PK52	6.62	0.39	6.34	7.05	0.39	9.93	7.11	0.41	9.93
PK53	6.17	0.26	6.96	6.04	0.22	8.54	6.74	0.25	12.43
PK54	1.66	0.22	4.09	2.67	0.18	6.69	2.63	0.15	5.59
HB01	6.94	0.31	7.76	7.16	0.27	6.7	13.45	0.28	9.5
HB02	5.49	0.28	9.89	6.51	0.28	7	10.8	0.3	12.61
HB03	13.63	0.29	9.85	6.93	0.16	5.53	7.38	0.29	9.62
HB04	4.9	0.18	7	12.01	0.2	3.17	13.74	0.21	10.54
HB05	4.31	0.25	5.18	3.93	0.22	7.98	4.84	0.25	10.43
HB06	4.46	0.23	10.75	3.6	0.13	7.96	4.54	0.17	5.55
HB07	4.59	0.22	7.3	11.27	0.2	4.54	14.71	0.25	6.53
HB08	1.91	0.08	3.22	10.86	0.09	3.26	1.66	0.15	1.71
HB09	5.46	0.27	11.34	6.84	0.25	10.36	15	0.33	27.34
HB10	5.11	0.23	6.48	10.1	0.24	7.72	18.75	0.26	11.2
HB11	3.62	0.22	6.25	3.94	0.25	5.21	3.56	0.2	6.78
HB12	4.77	0.22	7.22	4.02	0.2	6.95	3.91	0.17	9.79
PK40	6.69	0.24	6.94	6.92	0.43	6.28	7.4	0.24	12.68
PK55	2.83	0.28	2.95	4.79	0.29	3.86	3.63	0.27	10.86
PS04	17.18	0.39	7.92	16.67	0.36	16.24	7.9	0.35	11.68
PS13	6.46	0.29	6.67	6.59	0.26	4.67	6.19	0.29	5.47
PS16	4.75	0.2	3.61	5.71	0.2	3.95	5.32	0.19	3.49
PS29	9.04	0.39	14.45	7.48	0.37	12.64	7.2	0.34	8.45
PS36	7.43	0.39	8.04	7.68	0.42	8.58	7.96	0.42	7.86
SH12	10.85	0.17	9.05	3.59	0.14	2.49	10.13	0.19	8.53
SH15	19.46	0.41	14	13.4	0.36	10.82	18.95	0.32	14.02
Pk32	4.86	0.28	5.41	4.9	0.26	5.58	6.01	0.21	7.11

Annex B :

First Round Mangrove Forest Inventory - Trees Analysis (No of trees, DBH, Height) classified to (Life, Cut Down, Dead) - 118 plots in (Pulau Kampai, Halaban, Salahaji, Pangkalan Siata) - (August 2021 - December 2021)

plot	latitude	longitude	location	No of Species	No. of total trees	Total Avg DBH	Total Avg height	No. of Life trees	Avg Life DBH	Avg Life height	No. of Cut down trees	Avg Cut down DBH	Avg Cut down height	No. of Dead trees	Avg Dead DBH	Avg Dead height
SH01	4.217625	98.119885	Salahaji	4	46.0	6.3	3.9	36.0	5.7	4.8	10.0	8.5	0.5	0.0	0.0	0.0
SH02	4.228626	98.110856	Salahaji	4	32.0	6.7	4.7	30.0	6.3	5.0	0.0	12.6	0.7	0.0	0.0	0.0
SH03	4.212578	98.122219	Salahaji	3	63.0	4.6	3.0	45.0	4.5	4.1	18.0	4.9	0.5	0.0	0.0	0.0
SH04	4.216715	98.12055	Salahaji	3	40.0	4.5	3.0	28.0	4.4	4.0	10.0	5.2	0.6	0.0	0.0	0.0
SH05	4.186273	98.142572	Salahaji	1	65.0	4.8	3.0	49.0	4.1	3.8	16.0	6.9	0.6	0.0	0.0	0.0
SH06	4.190768	98.142062	Salahaji	3	46.0	4.3	2.6	35.0	3.7	3.3	11.0	6.0	0.4	0.0	0.0	0.0
SH07	4.201269	98.135644	Salahaji	4	39.0	5.1	2.7	31.0	4.0	3.3	8.0	9.6	0.3	0.0	0.0	0.0
SH08	4.19003	98.144153	Salahaji	1	29.0	5.1	4.3	27.0	5.0	4.6	2.0	6.7	0.7	0.0	0.0	0.0
SH09	4.193041	98.144116	Salahaji	2	16.0	7.4	7.0	16.0	7.4	7.0	0.0	0.0	0.0	0.0	0.0	0.0
SH10	4.225963	98.110103	Salahaji	3	12.0	7.7	6.3	9.0	7.5	6.8	1.0	9.2	1.7	2.0	7.8	6.3
SH11	4.220737	98.113015	Salahaji	2	9.0	5.7	5.9	9.0	5.7	5.9	0.0	0.0	0.0	0.0	0.0	0.0
SH12	4.226885	98.110094	Salahaji	2	17.0	4.9	3.8	17.0	4.9	3.8	0.0	0.0	0.0	0.0	0.0	0.0
SH13	4.190616	98.126989	Salahaji	3	46.0	7.1	3.6	30.0	5.7	5.1	16.0	9.6	1.0	0.0	0.0	0.0
SH14	4.190903	98.125654	Salahaji	2	16.0	6.4	4.4	12.0	6.4	5.7	4.0	6.4	0.7	0.0	0.0	0.0
SH15	4.187821	98.133471	Salahaji	1	28.0	4.5	3.6	26.0	4.4	3.8	2.0	5.2	0.6	0.0	0.0	0.0
PS01	4.186515	98.145185	Pangkalan Siata	2	39.0	4.4	2.5	28.0	3.7	3.1	11.0	8.3	1.0	0.0	0.0	0.0
PS02	4.184534	98.144852	Pangkalan Siata	2	86.0	4.8	2.8	64.0	4.3	3.3	18.0	6.6	0.8	4.0	4.9	3.9

PS03	4.18239	98.141377	Pangkalan Siata	4	55.0	4.2	2.7	47.0	3.6	3.1	8.0	7.6	0.4	0.0	0.0	0.0
PS04	4.156071	98.16457	Pangkalan Siata	3	27.0	6.9	3.7	18.0	5.8	4.9	9.0	9.1	1.3	0.0	0.0	0.0
PS05	4.154646	98.161394	Pangkalan Siata	2	17.0	7.7	4.1	10.0	7.1	6.1	7.0	9.7	1.4	0.0	0.0	0.0
PS06	4.163178	98.154007	Pangkalan Siata	5	60.0	5.2	3.4	47.0	4.3	3.9	11.0	9.1	0.9	2.0	5.6	5.3
PS07	4.162006	98.140582	Pangkalan Siata	5	55.0	4.5	3.0	40.0	5.0	3.6	7.0	6.1	1.7	8.0	5.1	3.0
PS08	4.160875	98.154467	Pangkalan Siata	4	21.0	6.2	4.5	17.0	6.0	5.3	4.0	7.1	0.8	0.0	0.0	0.0
PS09	4.153781	98.15548	Pangkalan Siata	8	19.0	5.5	3.3	17.0	5.0	3.5	2.0	9.4	1.2	0.0	0.0	0.0
PS10	4.149563	98.152887	Pangkalan Siata	6	37.0	6.3	4.7	29.0	6.0	5.6	6.0	7.9	0.9	2.0	5.3	3.5
PS11	4.162525	98.143551	Pangkalan Siata	4	47.0	5.6	3.1	38.0	4.9	3.6	9.0	8.5	0.6	0.0	0.0	0.0
PS12	4.158677	98.163687	Pangkalan Siata	4	32.0	6.2	2.9	21.0	5.4	4.0	11.0	7.7	0.7	0.0	0.0	0.0
PS13	4.129342	98.119107	Pangkalan Siata	1	35.0	6.6	4.3	25.0	5.6	5.5	10.0	9.2	1.3	0.0	0.0	0.0
PS14	4.130176	98.121127	Pangkalan Siata	1	39.0	6.2	4.9	37.0	6.1	5.1	2.0	7.6	1.3	0.0	0.0	0.0
PS15	4.124434	98.121627	Pangkalan Siata	2	28.0	6.8	5.3	24.0	6.3	5.9	3.0	9.7	1.2	1.0	3.5	2.5
PS16	4.095501	98.165312	Pangkalan Siata	5	23.0	7.4	5.1	14.0	7.1	6.6	6.0	9.1	0.8	3.0	5.9	7.0
PS17	4.104067	98.13717	Pangkalan Siata	2	16.0	6.8	4.6	14.0	6.1	5.1	2.0	11.5	1.0	0.0	0.0	0.0
PS18	4.103164	98.1695	Pangkalan Siata	1	30.0	5.0	4.4	24.0	5.0	5.4	6.0	5.1	0.5	0.0	0.0	0.0
PS19	4.108002	98.13502	Pangkalan Siata	5	31.0	5.3	3.8	24.0	4.9	4.7	7.0	6.8	0.6	0.0	0.0	0.0
PS20	4.098211	98.138444	Pangkalan Siata	2	34.0	6.5	4.0	22.0	5.9	5.8	12.0	7.4	0.7	0.0	0.0	0.0
PS21	4.14877	98.159021	Pangkalan Siata	3	27.0	6.0	3.2	18.0	5.9	4.1	6.0	7.9	0.6	3.0	3.2	3.5
PS22	4.147808	98.158448	Pangkalan Siata	3	38.0	6.6	3.8	31.0	6.5	4.4	5.0	8.0	0.3	2.0	4.9	3.8
PS23	4.149254	98.162476	Pangkalan Siata	5	48.0	6.9	3.7	38.0	6.4	4.5	9.0	9.5	0.5	1.0	3.2	2.0
PS24	4.104349	98.137693	Pangkalan Siata	3	31.0	6.1	4.3	25.0	5.8	4.9	5.0	7.4	0.8	1.0	6.7	5.9
PS25	4.106147	98.170036	Pangkalan Siata	1	22.0	7.2	3.5	12.0	8.1	4.9	4.0	10.5	0.6	6.0	3.2	2.7
PS26	4.105281	98.167988	Pangkalan Siata	3	32.0	7.3	4.9	26.0	6.6	5.6	5.0	10.8	0.9	1.0	9.6	6.0
PS27	4.156306	98.156561	Pangkalan Siata	3	35.0	7.2	3.6	22.0	6.2	5.1	13.0	9.1	1.0	0.0	0.0	0.0
PS28	4.153196	98.156762	Pangkalan Siata	2	31.0	5.6	5.1	25.0	5.7	5.6	3.0	6.8	1.6	3.0	4.2	4.8

PS29	4.167488	98.152906	Pangkalan Siata	5	54.0	5.2	3.0	37.0	3.4	3.0	13.0	6.2	0.6	4.0	12.3	6.9
PS30	4.162846	98.149994	Pangkalan Siata	4	20.0	6.4	4.1	17.0	6.2	4.6	2.0	10.1	0.9	1.0	3.0	2.5
PS31	4.121437	98.125399	Pangkalan Siata	4	15.0	6.2	4.6	14.0	6.2	4.9	1.0	6.2	0.8	0.0	0.0	0.0
PS32	4.125865	98.121128	Pangkalan Siata	1	17.0	6.8	5.8	16.0	6.7	6.1	1.0	7.6	1.1	0.0	0.0	0.0
PS33	4.103166	98.138712	Pangkalan Siata	2	14.0	6.8	3.8	10.0	5.4	4.7	4.0	8.7	0.4	0.0	0.0	0.0
PS34	4.089808	98.147357	Pangkalan Siata	3	29.0	6.6	5.0	24.0	6.0	4.6	0.0	0.0	0.0	4.0	9.6	7.1
PS35	4.15011	98.164291	Pangkalan Siata	4	14.0	5.3	3.3	12.0	4.9	3.6	2.0	7.5	1.2	0.0	0.0	0.0
PS36	4.156374	98.165289	Pangkalan Siata	1	18.0	9.2	4.1	10.0	7.7	6.1	8.0	11.1	1.5	0.0	0.0	0.0
PK01	4.200712	98.225304	Pulau Kampai	3	21.0	4.3	2.4	14.0	3.7	3.4	7.0	5.6	0.5	0.0	0.0	0.0
PK02	4.19047	98.204914	Pulau Kampai	3	20.0	5.2	2.4	12.0	4.1	3.1	8.0	6.7	1.3	0.0	0.0	0.0
PK03	4.192531	98.248178	Pulau Kampai	2	5.0	6.2	3.4	4.0	6.6	3.5	0.0	0.0	0.0	1.0	4.5	3.0
PK04	4.189116	98.224398	P. Kampai	3	9.0	3.6	2.1	8.0	3.1	2.3	1.0	7.5	0.4	0.0	0.0	0.0
PK05	4.205189	98.222056	P. Kampai	3	25.0	4.1	2.0	18.0	3.1	2.7	7.0	6.7	0.2	0.0	0.0	0.0
PK06	4.186965	98.217221	P . Kampai	2	8.0	4.6	1.4	4.0	3.5	2.2	4.0	5.7	0.7	0.0	0.0	0.0
PK07	4.205724	98.223798	P. Kampai	3	12.0	5.8	2.8	6.0	5.0	5.0	6.0	6.6	0.7	0.0	0.0	0.0
PK08	4.203656	98.219476	P. Kampai	2	31.0	3.6	2.2	27.0	3.4	2.5	4.0	5.2	0.5	0.0	0.0	0.0
PK09	4.20222	98.224131	Pulau Kampai	3	29.0	4.3	2.1	21.0	4.0	2.8	8.0	5.3	0.5	0.0	0.0	0.0
PK10	4.188754	98.205986	Pulau Kampai	2	41.0	4.3	1.6	21.0	3.4	2.8	20.0	5.2	0.5	0.0	0.0	0.0
PK11	4.198998	98.227803	Pulau Kampai	6	25.0	3.0	2.6	24.0	3.1	2.7	1.0	2.6	1.7	0.0	0.0	0.0
PK12	4.203485	98.214076	P. Kampai	1	34.0	4.9	1.5	12.0	4.1	2.1	22.0	5.3	1.1	0.0	0.0	0.0
PK13	4.198149	98.228333	Pulau Kampai	4	31.0	3.2	2.8	30.0	3.1	2.8	0.0	0.0	0.0	1.0	5.1	1.8
PK14	4.185982	98.226914	P. Kampai	4	20.0	2.9	2.6	19.0	2.9	2.6	0.0	0.0	0.0	1.0	2.6	2.0
PK15	4.182192	98.193509	P. Kampai	1	17.0	5.5	3.3	13.0	5.0	3.9	4.0	7.0	1.3	0.0	0.0	0.0
PK16	4.201145	98.214786	P. Kampai	1	30.0	4.3	2.3	20.0	3.3	3.0	10.0	6.3	0.9	0.0	0.0	0.0
PK17	4.208245	98.211285	P. Kampai	1	41.0	7.3	1.9	20.0	6.7	2.9	21.0	7.9	0.9	0.0	0.0	0.0
PK18	4.244091	98.208318	Pulau Kampai	2	6.0	3.6	1.8	5.0	3.1	1.9	1.0	5.7	1.3	0.0	0.0	0.0

PK19	4.215081	98.209783	P. Kampai	1	62.0	3.4	2.4	44.0	3.2	3.2	18.0	3.8	0.6	0.0	0.0	0.0
PK20	4.224599	98.213355	Pulau Kampai	3	30.0	5.3	0.8	6.0	3.0	2.7	24.0	5.9	0.4	0.0	0.0	0.0
PK21	4.21014	98.213355	P. Kampai	1	50.0	4.7	1.6	19.0	3.4	3.0	31.0	5.5	0.8	0.0	0.0	0.0
PK22	4.261692	98.243794	Pulau Kampai	4	26.0	4.3	1.6	15.0	3.4	2.7	11.0	5.4	0.2	0.0	0.0	0.0
PK23	4.25199	98.247935	Pulau Kampai	8	38.0	3.6	2.6	32.0	3.4	2.9	5.0	4.6	0.3	1.0	3.0	3.0
PK24	4.229174	98.213795	Pulau Kampai	4	18.0	5.6	1.4	7.0	3.6	2.7	11.0	7.0	0.6	0.0	0.0	0.0
PK25	4.246605	98.208767	Pulau Kampai	3	14.0	4.1	3.4	10.0	3.5	4.4	4.0	5.6	0.8	0.0	0.0	0.0
PK26	4.188839	98.201232	Pulau Kampai	1	6.0	3.9	2.3	3.0	3.5	2.3	1.0	3.7	2.1	2.0	4.6	2.4
PK27	4.192095	98.195198	P. Kampai	5	23.0	6.0	1.5	10.0	4.9	2.3	13.0	6.9	0.9	0.0	0.0	0.0
PK28	4.189464	98.202657	Pulau Kampai	3	29.0	3.7	4.2	22.0	3.4	4.1	2.0	4.3	4.0	5.0	3.8	3.8
PK29	4.187411	98.202391	Pulau Kampai	4	14.0	4.6	3.7	13.0	4.6	3.7	0.0	0.0	0.0	1.0	3.6	3.3
PK30	4.238712	98.21109	P. Kampai	4	26.0	5.0	1.5	15.0	3.3	2.4	11.0	7.3	0.3	0.0	0.0	0.0
PK31	4.26026	98.242371	Pulau Kampai	4	22.0	4.4	1.7	14.0	3.2	2.6	8.0	6.6	0.2	0.0	0.0	0.0
Pk32			P. Kampai	0	0	0	0	0	0	0	0	0	0	0	0	0
PK33	4.191002	98.208763	Pulau Kampai	2	31.0	4.6	1.4	16.0	3.9	2.5	15.0	5.3	0.3	0.0	0.0	0.0
PK34	4.193603	98.192771	P. Kampai	3	10.0	6.3	2.2	5.0	4.7	2.6	5.0	5.7	1.8	0.0	0.0	0.0
PK35	4.19531	98.223763	P. Kampai	2	10.0	3.1	2.7	10.0	3.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0
PK36	4.197753	98.251105	Pulau Kampai	2	2.0	23.8	11.0	2.0	23.8	11.0	0.0	0.0	0.0	0.0	0.0	0.0
PK37	4.182459	98.22099	P. KAMPAI	4	10.0	3.8	3.0	9.0	3.9	3.2	1.0	2.9	1.5	0.0	0.0	0.0
PK38	4.183817	98.21326	Pulau Kampai	3	42.0	15.4	1.5	24.0	11.6	2.3	18.0	20.5	0.5	0.0	0.0	0.0
PK39	4.2467	98.208783	Pulau Kampai	2	23.0	3.5	2.2	16.0	3.3	2.7	6.0	4.2	0.9	1.0	3.1	2.2
PK40	4.218671	98.207692	P. Kampai	1	70.0	4.2	2.1	40.0	3.5	3.2	30.0	5.2	0.6	0.0	0.0	0.0
PK41	4.258993	98.243457	Pulau Kampai	3	4.0	5.8	3.9	4.0	5.8	3.9	0.0	0.0	0.0	0.0	0.0	0.0
PK42	4.261335	98.245867	Pulau Kampai	5	46.0	4.6	2.7	35.0	4.4	3.4	11.0	5.1	0.4	0.0	0.0	0.0
PK43	4.253425	98.248027	P. Kampai	4	39.0	4.6	2.6	36.0	4.5	2.8	3.0	5.8	0.4	0.0	0.0	0.0
PK44	4.256932	98.244428	Pulau Kampai	2	54.0	3.5	1.5	31.0	2.9	2.3	23.0	4.2	0.3	0.0	0.0	0.0

PK45	4.203941	98.251705	Pulau Kampai	1	3.0	13.1	1.1	1.0	6.6	2.5	2.0	16.4	0.4	0.0	0.0	0.0
PK46	4.257922	98.243882	Pulau Kampai	2	6.0	3.0	1.7	6.0	3.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0
PK47	4.194861	98.213181	Pulau Kampai	1	6.0	5.9	1.1	1.0	3.7	2.8	5.0	6.4	0.8	0.0	0.0	0.0
PK48	4.188037	98.201399	Pulau Kampai	3	29.0	3.4	3.2	29.0	3.4	3.2	0.0	0.0	0.0	0.0	0.0	0.0
PK49	4.246868	98.210104	P. Kampai	3	17.0	5.9	3.3	13.0	5.8	4.3	4.0	6.2	0.2	0.0	0.0	0.0
PK50	4.228203	98.215051	P. Kampai	4	21.0	5.3	4.3	21.0	5.3	4.3	0.0	0.0	0.0	0.0	0.0	0.0
PK51	4.23302	98.215442	Pulau Kampai	4	18.0	4.2	1.3	10.0	3.4	2.1	8.0	5.3	0.2	0.0	0.0	0.0
PK52	4.244364	98.209473	P. Kampai	3	24.0	4.3	2.1	13.0	3.2	3.4	11.0	5.5	0.6	0.0	0.0	0.0
PK53	4.251189	98.244969	P. Kampai	3	29.0	4.2	2.0	20.0	3.5	2.7	9.0	5.7	0.7	0.0	0.0	0.0
PK54	4.258548	98.238865	Pulau Kampai	2	52.0	4.6	1.4	37.0	4.3	1.8	15.0	5.2	0.2	0.0	0.0	0.0
PK55	4.263048	98.22889	P. Kampai		0	0	0	0	0	0	0	0	0	0	0	0
HB01	4.121099	98.122883	Halaban	1	18	7.9	4.2	12	6.4	5.6	6	10.9	1.4	0	0	0
HB02	4.112573	98.125942	Halaban	1	41.0	6.4	3.8	32.0	5.7	4.6	8.0	9.6	0.9	1.0	3.9	3.2
HB03	4.123353	98.12118	Halaban	1	25	7.5	3.5	15	6	5.3	10	9.7	0.8	0	0	0
HB04	4.127827	98.115218	Desa Halaban	1	57.0	6.7	3.9	41.0	5.7	5.1	16.0	9.2	1.0	0.0	0.0	0.0
HB05	4.106692	98.134274	Halaban	2	17.0	5.8	4.6	16.0	5.6	4.9	1.0	9.3	0.7	0.0	0.0	0.0
HB06	4.113225	98.126	Desa Halaban	1	34.0	6.7	4.0	26.0	5.7	4.9	8.0	9.7	1.0	0.0	0.0	0.0
HB07	4.142272	98.114686	Halaban	2	20.0	6.0	4.2	16.0	5.0	4.8	4.0	9.6	1.8	0.0	0.0	0.0
HB08	4.111053	98.122293	Desa Halaban	1	33.0	7.5	4.4	26.0	6.7	5.3	7.0	10.6	0.9	0.0	0.0	0.0
HB09	4.113472	98.126576	Halaban	1	20.0	5.5	3.5	15.0	4.6	4.2	5.0	8.5	1.3	0.0	0.0	0.0
HB10	4.12506	98.11847	Pangkalan Siata	2	32.0	5.5	4.0	29.0	5.0	4.3	3.0	10.7	1.4	0.0	0.0	0.0
HB11	4.108632	98.133265	Halaban	1	10	10	6.4	8	9.4	7.9	2	12.2	0.5	0	0	0
HB12	4.095763	98.137234	Halaban	2	27.0	6.0	3.8	22.0	4.5	3.7	5.0	7.8	0.8	0.0	0.0	0.0

Annex C:

Second Round Mangrove Forest Inventory - Trees Analysis (No of trees, DBH, Height) classified to (Life, Cut Down, Dead) - 25 plots in (Pulau Kampai) - (21-29) March 2022.

plot	latitude	longitude	location	No of Species	No. of total trees	Total Avg DBH	Total Avg height	No. of Life trees	Avg Life DBH	Avg Life height	No. of Cut down trees	Avg Cut down DBH	Avg Cut down height	No. of Dead trees	Avg Dead DBH	Avg Dead height
P01	N 04°11,19.56	E 098°12,04.64"	Pulau Kampai	1	28	5.6	5.6	28	5.6	5.6	0	0	0	0	0	0
P02	4°11'41.09"N	98°14'3.17"E	Pulau Kampai	3	34	4	3	27	4.3	3.7	7	3.2	0.5	0	0	0
P03	4°11'28.18"N	98°14'12.80"E	Pulau Kampai	4	22	6	3.8	19	5.8	4.3	3	7.3	0.6	0	0	0
P04	N 04,19198	E 098,23566	Pulau Kampai	4	30	4	3.2	30	4	3.2	0	0	0	0	0	0
P05	N 04,19219	E 098,23501	Pulau Kampai	3	32	3	2.6	32	3	2.6	0	0	0	0	0	0
P06	N 04,19244	E 098,23464	Pulau Kampai	2	47	3.4	3.5	47	3.4	3.5	0	0	0	0	0	0
P07	N 04.11°24,21	E 098.12°49	Pulau Kampai	5	30	4	2.5	23	4	3	7	3.9	0.8	0	0	0
P08	N 04,19459	E 098,23098	Pulau Kampai	3	35	3.8	4	35	3.8	4	0	0	0	0	0	0
P09	N 04,19416	E 098,22937	Pulau Kampai	1	28	3.7	3.5	28	3.7	3.5	0	0	0	0	0	0
P10	N 04,1959	E 098,2280	Pulau Kampai	1	22	3.2	3.1	22	3.2	3.1	0	0	0	0	0	0
P11	4,189,512	98,219,007	Pulau Kampai	2	31	4.8	2.4	24	3.6	3	7	8.7	0.6	0	0	0
P12	4,191,005	982,181	Pulau Kampai	2	36	3.1	2.9	36	3.1	2.9	0	0	0	0	0	0
P13	418,877	98,214,531	Pulau Kampai	1	31	7.8	8.2	29	7.8	8.8	2	8.1	0.5	0	0	0
P14	N 04°10,59.13	E 098°12,38"	Pulau Kampai	1	29	4.3	3.2	25	4.2	3.6	4	5.3	0.7	0	0	0
P16	4,183,806	98,211,105	Pulau Kampai	1	25	4.4	2.7	16	3.9	3.8	9	5.3	0.8	0	0	0

P17	4,184,518	98,210,231	Pulau Kampai	3	28	6.6	1.6	13	3.9	3	15	8.8	0.4	0	0	0
P19	N 04°11'17.09	E 098°12'97.01	Pulau Kampai	2	30	5.3	3.5	25	5	4	5	7.2	1	0	0	0
P20	N 04.11°19,82	E 098.12°28.42	Pulau Kampai	2	22	4.7	2.9	19	4.3	3.3	3	6.9	0.9	0	0	0
P21	N 04°11'19.72	E 098°12'06.12	Pulau Kampai	1	22	5.5	3.9	22	5.5	3.9	0	0	0	0	0	0
P24	4,183,901	98,208,959	Pulau Kampai	4	21	5.1	2.4	18	4.5	2.7	3	8.9	0.7	0	0	0
P25	98°12'50.58"	4°12'11.53"	Pulau Kampai	1	27	4	3	24	4.1	3.3	3	3.8	0.9	0	0	0
P26	98°12'39.05"	4°11'56.71"	Pulau Kampai	2	35	4.5	3.3	35	4.5	3.3	0	0	0	0	0	0
P27	4°11'56.18"N	98°12'37.21"E	Pulau Kampai	1	18	5.1	4.3	18	5.1	4.3	0	0	0	0	0	0
P28	N 04°11,28.79	E 098°12,37"29	Pulau Kampai	2	33	5.9	5	31	5.5	5.3	2	11.9	0.9	0	0	0
P29	N 04.11°24,21	E 098.12°49	Pulau Kampai	2	15	5.3	4.1	14	4.9	4.3	1	10.8	1	0	0	0

Annex D: Signed MOUs and Forest Department permissions

Yagasu represented by **Melinda Suriani the Program Director,** signed MOUs with the head of Each village as follow:

1. Pulau Kampai

On Monday, 05/07/2021, in Pulau Kampai Village, Pangkalan Susu subdistrict, Langkat DIstrict, the MOU signed by the representative of Pulau Kampai Village:

Name: **Amir Husin**	Position : **Head of Pulau Kampai Village**
The Signed MOU: **Pulau Kampai village MOU - Yagaus-GMT village conservation program, No: 002-DS/LK-PKP/PDK/VII/2021** https://drive.google.com/file/d/1vZMFs_JL-sl-_b8Uyx4RAG4RwsOFU_ip/view?usp=sharing	
Carbon research Permission from the head of the village : **No: 145.45/PK/X/2021** https://drive.google.com/file/d/1YEDqUZeyf3ZaF8YB8d_xn0Oxrn2Et0Bp/view?usp=sharing	

2. Halaban

On Friday, 03/09/2021, in Halaban Village, Besitang subdistrict, Langkat DIstrict, the MOU signed by the representative of Halaban Village:

Name: **Tamaruddin, S.Ag.**	Position : **Head of Halaban Village**
The Signed MOU: **Halaban village MOU - Yagaus-GMT village conservation program No: 003-DS/LK-SLH/PDK/IX/2021** https://drive.google.com/file/d/1QlWNrVHjaUP0ze9bT7TRvSUHimLhMrdW/view?usp=sharing	

3. Salahaji

On Friday, 20/08/2021, in Salahaji Village, Pematang Jaya subdistrict, Langkat DIstrict, the MOU signed by the representative of Salahaji Village:

Name: **Mahyni**	Position : **Head of Salahaji Village**
The Signed MOU: **Salahaji village MOU - Yagaus-GMT village conservation program No: 001-DS/LK-SLH/PDK/VIII/2021** https://drive.google.com/file/d/1MNKAr-eV8pZODr-U1rzoRWrg10ZCrgwV/view?usp=sharing	

4. Pangkalan Siata

On Friday, 03/09/2021, in Pangkalan Siata Village, Pangkalan Susu subdistrict, Langkat DIstrict, the MOU signed by the representative of Salahaji Village, and carbon research permission in Pangakalan Siata secured from the forest department of Sumatera Utara Province:

Name: **Muhamad Yusuf**	Position : **Head of Pangkalan Siata Village**
The Signed MOU: **Pangkalan Siata village MOU - Yagaus-GMT village conservation program No: 004-DS/LK-PKP-PDK/IX/2021** https://drive.google.com/file/d/1fxiRIO55PEu-o9s3V8zUYkk3BSNu9A3m/view?usp=sharing	
Name : **Puji Hartono, M.Si**	Position: **The head of UPT pengelolaan hutan wilayah, Dinas Kehutanan, Provinsi Sumatera Utara.** [*head of UPT for regional forest management, Forest Department, Sumatera Utara Province*]
Carbon research Permission from the Forest Department : No: **EXT/197/YGS-MDN/IX/2021** https://drive.google.com/file/d/1npHTicT6lhc6Gg2aYxQX6saEQnlXTsOA/view?usp=sharing	

Annex E: Project Participants and Leadership

1. Marex Spectron Asia Pte Ltd: (https://www.marex.com/) is a subsidiary of Marex Group plc, incorporated under the laws of Singapore (company no. 200416106H and LEI no. 549300Q45UQMVBSR3Z76) and is regulated by the Monetary Authority of Singapore (CMS Licence no. CMS100396-1). Spectron Energy (Asia) Pte Ltd is incorporated in Singapore (company no. 199200681K and LEI 549300UFPPKZDO4PUJ23) and exempted under the Commodity Trading Act (para. 1(aa) of the Schedule) from the need to be regulated by International Enterprise (IE) Singapore and from the Monetary Authority of Singapore.

   Ian Lowitt: Group Chief Executive Officer - Ian Lowitt joined Marex in 2012 as CFO, becoming CEO in 2016.

   Dr. Guy Wolf: Global Head of Market Analytics at Marex

   Robert Watts: Chief Operating Officer (COO) - APAC at Marex

2. **OxCarbon Limited**: (http://oxcarbon.org/) UK-Non-trading company (UK SIC Classification 2007), registered under the Companies Act 2006 as a private Company, through Registrar of Companies for England and Wales, on a mission to combat global warming by providing academic review for forestry projects around the world, OxCarbon is a private company limited by guarantee,, and the situation of its registered office with number 13398658.

   Dr. Atif Ansar: Dr. Ansar serves as Founder and Director of OxCarbon in consultation with the Oxford Smith School of Enterprise and the Environment. Dr. Ansar also serves as Director of the Oxford Programme on the Sustainable Future of Capital Intensive Industries and Senior Teaching Fellow on the MSc in Major Programme Management and the Australian Major Projects Leadership Academy (AMPLA).

3. **Global Mangrove Trust (GMT)** : (https://globalmangrove.org/) A Singaporean non-profit founded in 2017 to develop technology solutions for reforestation projects in South-East Asia, GMT serves as the project coordinator. Leveraging a two-year collaboration with DBS Bank and Zilliqa, GMT has developed various tools to help communities enter carbon markets. GMT's initial designs for a prototype space-based carbon assessment solution drew international recognition in 2020 as the Top Idea

for India by the Climate Policy Initiative (CPI) Climate Lab. The NGO was named a Fintech Finalist in Singapore in 2020.

Dr. Ryan Merrill: Dr. Merrill serves as Co-Founder and Executive Secretary of GMT. Before founding GMT, Dr. Merrill served as a Doctoral Research Fellow in Sustainability, Strategy and Innovation and an Adjunct Professor at Singapore Management University. He holds a PhD in Environmental Policy from the University of Southern California and publishes on sustainable development innovation and the promise of blue carbon mangrove forestry to lead the fight against climate change.

Dr. Simon Schillebeeckx: Dr. Schillebeeckx serves as Co-Founder and Director of GMT, as well as an Assistant Professor of Strategy and Innovation at the Lee Kong Chian School of Business of Singapore Management University. He holds a PhD in Management from Imperial College London alongside advanced degrees in Corporate Social Responsibility and Commercial Engineering. Simon founded GMT in partial inspiration from his ongoing academic study in Digital Sustainability and Sustainable Resource Management.

Mohamed Elsayed S. Abdelwareth: Mohamed has served as the project coordinator and GMT Optimisation Research and Analysis Lead. An electric engineer specialising in optimisation theory and artificial intelligence, Mr. Abdelwareth is passionate about the science of remote sensing for renewable energy grids and regenerative land use.

4. **KUMI Analytics:** (https://kumianalytics.com/) Kumi Analytics is a team of remote sensing and machine learning professionals dedicated to helping people and businesses better understand the natural world. The company has a range of satellite imagery based products including carbon dioxide, nitrogen dioxide, and sulphur dioxide measurements, robust economic growth estimates, agricultural production estimates, and recently completed the Kumi Analytics Carbon Sequestration Assessment Tool (KACSAT) which is the monitoring tool in the PKS project.

   Clinton Libbey: Managing Director of Kumi Analytics, Mr. Libbey has been pioneering advances in mapping and computer vision insight for 30 years. Early in his career, Mr. Libbey helped create the first global satellite imagery browsing system and the first international very high resolution satellite imagery joint venture. He now leads a team of engineers in crafting intelligence services for global land use innovations.

Dr. Mong Suan Yee: Co-founder of Kumi Analytics and Head of Engineering, Dr. Yee recently led the engineering team at COSS.io. She previously founded a software development firm, Insight Software Pte. Ltd. (Malaysia), acquired by Vericardsys (https://www.vericardsys.com). Insight Software provides product development and consultancy firm for wireless and software projects. She previously served as CTO of SweetSpot, a proximity based marketing platform, and as CTO of BLoyalty. Ms. Yee holds a PhD in the Application of Neural Networks from Southampton University.

5. **Yayasan Gajah Sumatera (YAGASU), Indonesia**: (https://yagasu.or.id/) YAGASU Aceh is a Local Implementing Partner and project developer of mangrove reforestation work in Indonesia, initiated as a Non-Government Organisation (NGO) under the name of Yayasan Gajah Sumatera at public notary "Risna Rahmi Arifa, SH" in Medan on July 17, 2001 ("Akte No 7"). YAGASU is also registered under the name of Yayasan Gajah Sumatera (YAGASU) Aceh at the Public Notary "Sabaruddin Salam, S.H., SpN on 11 May 2006 ("Akte No. 81") and certified by the Decree of Ministry of Law and Human Right Republic of Indonesia No. C-1192.HT.01.02.TH2007.

   Bambang Suprayogi: Founder and CEO of YAGASU NGO since its launch in 2001. As Indonesian citizen, Dr. Suprayogi has worked until pension in the Indonesian Forest Department, has a rich scientific background, and strong vision on how to couple mangroves sustainability with income generating activities for the coastal inhabitants

   Meilinda Suriani Harefa: YAGASU Program Director and Lecturer in Universitas Negeri Medan, North Sumatera, Indonesia. Dr. Harefa is an expert in regenerative mangrove aquaculture and sustainable community development. She leads the YAGASU team in Medan, Indonesia, and has represented YAGASU in 2021 and 2022 in Singapore and London.

   Grace Yanti Panjaitan: Yagasu Research & Monitoring Manager. Ms. Grace has served in a variety of key roles through the baseline process, coordinating field measurements, laboratory analysis, and mapping work with her colleagues, Mr. Maulana Gogo and Mr. Anton.