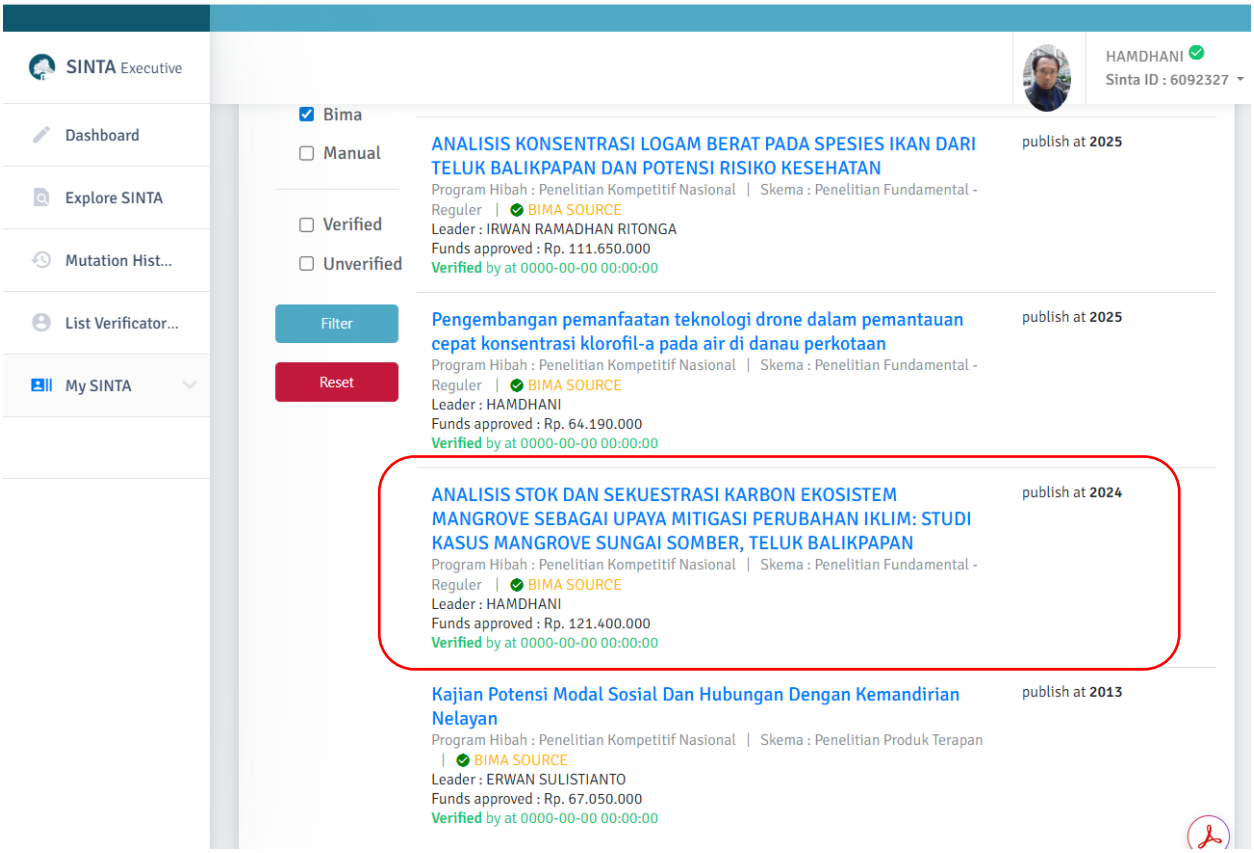
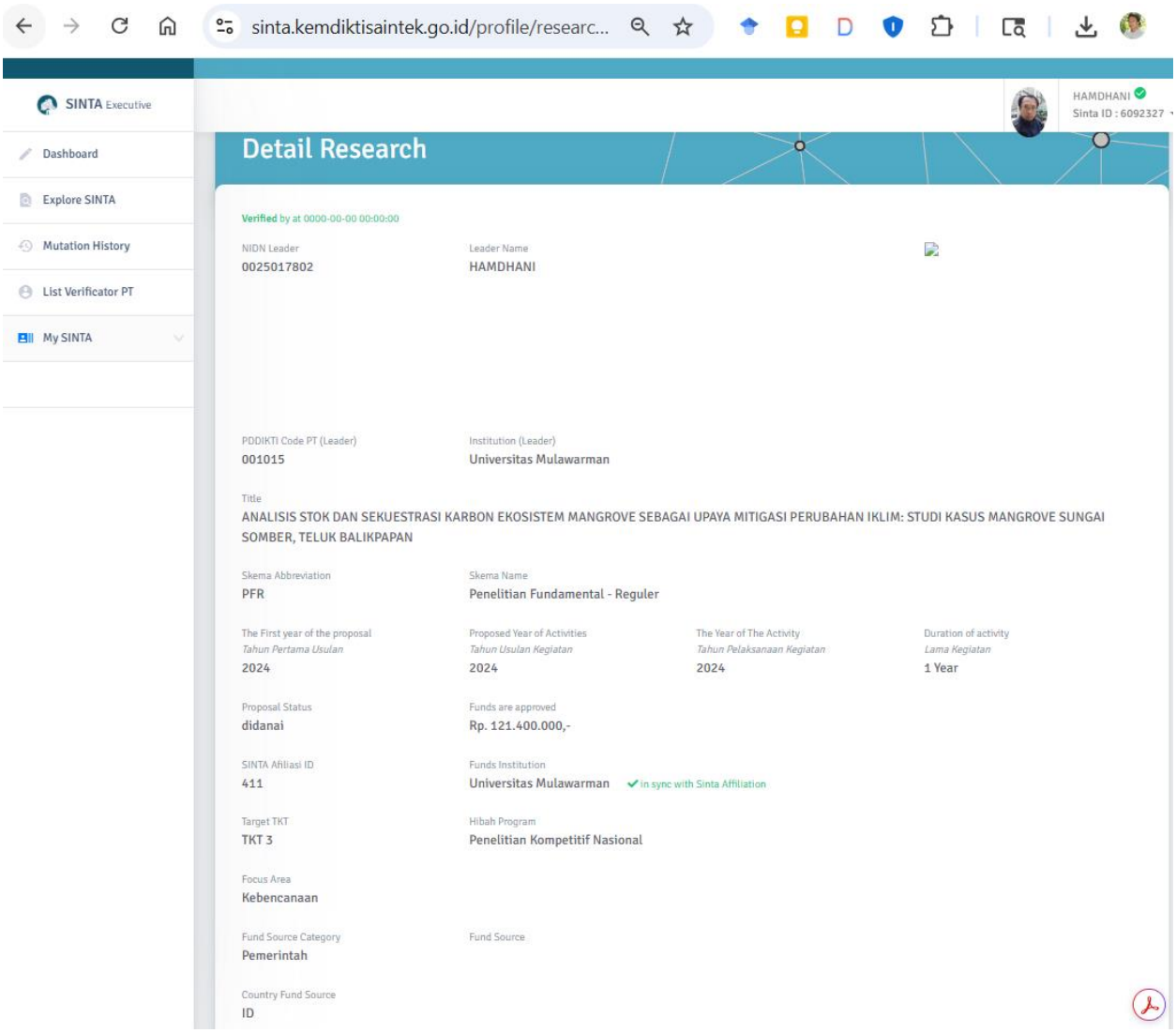
Bukti Hibah Penelitian di Laman BIMA

Nama Pengusul Jabatan : Hamdhani

Institusi : Universitas Mulawarman




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SINTA Executive
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Mutation History
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My SINTA
HAMDHANI
Sinta ID : 6092327
Detail Research
Verified by at 0000-00-00 00:00:00
NIDN Leader
0025017802
Leader Name
HAMDHANI
PDDIKTI Code PT (Leader)
001015
Institution (Leader)
Universitas Mulawarman
Title
ANALISIS STOK DAN SEKUESTRASI KARBON EKOSISTEM MANGROVE SEBAGAI UPAYA MITIGASI PERUBAHAN IKLIM: STUDI KASUS MANGROVE SUNGAI SOMBER, TELUK BALIKPAPAN
Skema Abbreviation
PFR
Skema Name
Penelitian Fundamental - Reguler
The First year of the proposal
Tahun Pertama Usulan
2024
Proposed Year of Activities
Tahun Usulan Kegiatan
2024
The Year of The Activity
Tahun Pelaksanaan Kegiatan
2024
Duration of activity
Lama Kegiatan
1 Year
Proposal Status
didanai
Funds are approved
Rp. 121.400.000,-
SINTA Afiliasi ID
411
Funds Institution
Universitas Mulawarman
in sync with Sinta Affiliation
Target TKT
TKT 3
Hibah Program
Penelitian Kompetitif Nasional
Focus Area
Kebencanaan
Fund Source Category
Pemerintah
Fund Source
Country Fund Source
ID

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN,
RISET, DAN TEKNOLOGI
**DIREKTORAT JENDERAL PENDIDIKAN TINGGI,
RISET, DAN TEKNOLOGI**
Jalan Jenderal Sudirman, Senayan, Jakarta 10270
Telepon (021) 57946104, Pusat Panggilan ULT DIKTI 126
Laman www.dikti.kemdikbud.go.id

Nomor : 0667/E5/AL.04/2024 30 Mei 2024
Lampiran : Tiga berkas
Hal : Pengumuman Penerima Pendanaan Program Penelitian dan Pengabdian kepada Masyarakat Tahun Anggaran 2024

Yth.
1. Kepala Lembaga Layanan Pendidikan Tinggi Wilayah I s.d. XVI
2. Ketua LP/LPM/LPPM/Lembaga Sejenis Perguruan Tinggi
di lingkungan Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi

Berdasarkan Keputusan Kuasa Pengguna Anggaran Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat Nomor 0459/E5/PG.02.00/2024 tanggal 30 Mei 2024 tentang Penerima Program Bantuan Operasional Perguruan Tinggi Negeri Program Penelitian dan Pengabdian kepada Masyarakat Tahun Anggaran 2024, bersama ini kami sampaikan **Daftar Nama Penerima Pendanaan Program Penelitian dan Pengabdian kepada Masyarakat Tahun Anggaran 2024** (Lampiran I dan II).

Berkenaan dengan hal tersebut, Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat (DRTPM) mengucapkan terima kasih kepada para pengusul yang telah berpartisipasi dan selamat kepada para penerima pendanaan program penelitian dan pengabdian kepada masyarakat tahun anggaran 2024. Selanjutnya, kami mohon bantuan Bapak/Ibu untuk menyampaikan informasi pengumuman ini kepada nama-nama penerima pendanaan yang tercantum pada lampiran surat pengumuman.

Perlu kami sampaikan bahwa mekanisme penyaluran dana akan dilakukan melalui kontrak. Berkaitan dengan hal ini, kami sampaikan beberapa hal sebagai berikut:
1. Kontrak dilakukan secara berjenjang. Untuk Perguruan Tinggi Negeri (PTN), kontrak dilakukan antara DRTPM dengan Ketua LP/LPM/LPPM/Lembaga Sejenis. Adapun untuk Perguruan Tinggi Swasta (PTS), kontrak dilakukan melalui Kepala Lembaga Layanan Pendidikan Tinggi (LLDIKTI) masing- masing wilayah;
2. Pencairan dana dilaksanakan dalam 2 (dua) tahap yakni 80% dan 20%;
3. Hal-hal lain yang terkait dengan penandatanganan kontrak, pencairan dana, dan pelaksanaan program penelitian dan pengabdian kepada masyarakat akan diinformasikan lebih lanjut melalui laman https://bima.kemdikbud.go.id/pengumuman.

Berkaitan dengan data yang diperlukan untuk penandatanganan kontrak, kami mohon perkenannya untuk dapat mengisi daftar isian kontrak (Lampiran III) dan mengunggahnya paling lambat tanggal **3 Juni 2024** melalui tautan berikut:
1. Kontrak Penelitian : https://bit.ly/KontrakLIT2024
2. Kontrak Pengabdian: https://bit.ly/KontrakPKM2024

PTN dapat mengunggah daftar isian yang sama pada kedua tautan di atas apabila tidak ada pemisahan antara lembaga penelitian dan pengabdian kepada masyarakat. PTS tidak perlu mengisi daftar isian kontrak karena kontrak akan dilakukan melalui LLDIKTI masing-masing wilayah.

Balai Sertifikasi Elektronik
Catatan :
1. UU ITE No. 11 Tahun 2008 Pasal 5 Ayat 1 "*Informasi Elektronik dan/atau Dokumen Elektronik dan/atau hasil cetakannya merupakan alat bukti yang sah.*"
2. Dokumen ini telah ditandatangani secara elektronik menggunakan sertifikat elektronik yang diterbitkan oleh BSrE

Demikian surat ini kami sampaikan. Atas perhatian dan kerja sama yang baik, kami ucapkan terima kasih.

Direktur Riset, Teknologi, dan
Pengabdian kepada Masyarakat,



M. Faiz Syuaib
NIP 196708311994021001

Tembusan:
Direktur Jenderal Pendidikan Tinggi, Riset,dan
Teknologi

Balai Sertifikasi Elektronik

Catatan :
1. UU ITE No. 11 Tahun 2008 Pasal 5 Ayat 1 "*Informasi Elektronik dan/atau Dokumen Elektronik dan/atau hasil cetakannya merupakan alat bukti yang sah.*"
2. Dokumen ini telah ditandatangani secara elektronik menggunakan sertifikat elektronik yang diterbitkan oleh BSrE

No	Kategori Institusi	Nama Institusi	NIDN	Nama	Judul	Ruang Lingkup
4421	PTN	Universitas Mulawarman	0003077305	Enos Tangke Arung	POTENSI PROPOLIS LEBAH TANPA SENGAT (Homotrigona apicalis) PADA SEDIAAN EMULGEL SEBAGAI ANTIAGING	PPS-PDD
4422	PTN	Universitas Mulawarman	0018047401	Erwiantono	STRATEGI INTEGRASI PERIKANAN UMUM DARATAN KE DALAM PENGELOLAAN DAS MAHAKAM BAGIAN TENGAH: PENDEKATAN SISTEM SOSIO-EKOLOGI DAS DAN SWOT (LANJUTAN)	PFR
4423	PTN	Universitas Mulawarman	0004018003	Esti Handayani Hardi	Intervensi Mikroba dalam Bioremediasi Kontaminan Logam Berat di Lahan Sawah	PPS-PDD
4424	PTN	Universitas Mulawarman	0011059004	Famala Eka Sanhadi Rahayu	Voices of Resilience: Perempuan dalam Penegakan Kesetaraan Gender, Pelestarian Budaya dan Bahasa Lokal di Kawasan Sekitar Ibu Kota Nusantara (IKN)	PFR
4425	PTN	Universitas Mulawarman	0023087902	Fitriyana	Strategi Pemberdayaan Keluarga Nelayan (Analisis Peran Ganda Istri Nelayan dalam Meningkatkan Pendapatan) di Desa Muara Telake Kecamatan Longkali Kabupaten Paser	PPS-PTM
4426	PTN	Universitas Mulawarman	0001098203	Hadi Kuncoro	Aplikasi Ekstrak Lygodium microphyllum Sebagai Obat herbal, Kosmetika dan Nutraseutikal dalam fungsi sebagai perawatan, pencegah, dan terapi Masalah Kesehatan (LANJUTAN).	PT
4427	PTN	Universitas Mulawarman	0018037806	Hairul Huda	OPTIMISASI INFRASTRUKTUR CO2 CAPTURE DALAM PENDISTRIBUSIANNYA UNTUK PROSES ENHANCED OIL RECOVERY DALAM MENINGKATKAN PRODUKSI MINYAK BUMI NASIONAL	PFR
4428	PTN	Universitas Mulawarman	0006067905	Hamdani	SISTEM CERDAS UNTUK IDENTIFIKASI PENYAKIT PADA BATANG TANAMAN KELAPA SAWIT DENGAN SUPERVISED LEARNING (LANJUTAN)	PFR
4429	PTN	Universitas Mulawarman	0025017802	Hamdhani	ANALISIS STOK DAN SEKUESTRASI KARBON EKOSISTEM MANGROVE SEBAGAI UPAYA MITIGASI PERUBAHAN IKLIM: STUDI KASUS MANGROVE SUNGAI SOMBER, TELUK BALIKPAPAN	PFR
4430	PTN	Universitas Mulawarman	0006127405	Haris Retno Susmiyati	MODEL AFFIRMATIVE ACTION PEMENUHAN HAK MASYARAKAT ADAT DI KAWASAN IBUKOTA NUSANTARA	PFR
4431	PTN	Universitas Mulawarman	0012126309	I Ketut Gunawan	Ethnic Fractionalization dan Ethnic Polarization di IKN: Studi Potensi Konflik Etnis di wilayah Ibu Kota Negara (Lanjutan)	PFR
4432	PTN	Universitas Mulawarman	0008107105	Idris	Penerapan Model Hidrodinamika - Ekosistem dan Kaitannya dengan Perubahan Iklim di Estuari Delta Berau Kalimantan Timur	PFR

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Telepon (021) 57946104, Pusat Panggilan ULT DIKTI 126
Laman www.dikti.kemdikbud.go.id

KONTRAK
PELAKSANAAN PROGRAM BANTUAN OPERASIONAL PERGURUAN TINGGI NEGERI PROGRAM PENELITIAN
TAHUN ANGGARAN 2024

ANTARA

DIREKTORAT RISET, TEKNOLOGI, DAN PENGABDIAN KEPADA MASYARAKAT
DIREKTORAT JENDERAL PENDIDIKAN TINGGI, RISET, DAN TEKNOLOGI

DENGAN
Universitas Mulawarman

NOMOR: 061/E5/PG.02.00.PL/2024

Pada hari ini Selasa tanggal Sebelas bulan Juni tahun dua ribu dua puluh empat, kami yang bertandatangan di bawah ini:

1. Yoga Dwi Arianda : Pejabat Pembuat Komitmen Direktorat Riset, Teknologi dan Pengabdian kepada Masyarakat Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi yang berkedudukan di Gedung D Lantai 3 Kompleks Kemendikbudristek, Jalan Jenderal Sudirman, Pintu I Senayan, Jakarta Pusat 10270, dalam hal ini bertindak untuk dan atas nama Direktorat Riset, Teknologi dan Pengabdian kepada Masyarakat Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi untuk selanjutnya disebut PIHAK KESATU;

2. Widi Sunaryo : Ketua Lembaga Penelitian dan Pengabdian Kepada Masyarakat(LP2M), Universitas Mulawarman yang berkedudukan di Jl. Kerayan No1 Gedung A8 Kampus Gunung Kelua Samarinda, dalam hal ini bertindak untuk dan atas nama peneliti di Universitas Mulawarman untuk selanjutnya disebut PIHAK KEDUA;

PIHAK KESATU dan PIHAK KEDUA secara bersama-sama selanjutnya disebut PARA PIHAK.

PARA PIHAK sepakat menandatangani Kontrak Pelaksanaan Program Bantuan Operasional Perguruan Tinggi Negeri Program Penelitian Tahun Anggaran 2024 yang selanjutnya disebut Kontrak, dengan ketentuan dan syarat sebagai berikut.

Pasal 1
RUANG LINGKUP

(1) Ruang lingkup Kontrak ini meliputi pelaksanaan penelitian tahun anggaran 2024 sebanyak 68 (enam puluh delapan) judul penelitian.
(2) Daftar judul penelitian, nama pelaksana penelitian, skema, jangka waktu penelitian, dan besarnya biaya masing-masing judul penelitian tercantum dalam Lampiran yang merupakan bagian tidak terpisahkan dari Kontrak ini.

Pasal 2
SUMBER DANA

Pendanaan program penelitian tahun anggaran 2024 berdasarkan kontrak ini bersumber pada Daftar Isian Pelaksanaan Anggaran Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat, Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Tahun Anggaran 2024, Nomor SP DIPA- 023.17.1.690523/2024 revisi ke-1 tanggal 4 Februari 2024.

Pasal 3
NILAI KONTRAK

(1) PIHAK KESATU memberikan pendanaan dengan nilai Kontrak sebesar Rp6.920.540.000,00 (Enam Milyar Sembilan Ratus Dua Puluh Juta Lima Ratus Empat Puluh Ribu Rupiah) kepada PIHAK KEDUA.
(2) Nilai kontrak sebagaimana dimaksud pada ayat 1 digunakan untuk pembiayaan pelaksanaan program penelitian, pajak, dan biaya lain yang sah.
(3) Pembayaran nilai kontrak sebagaimana dimaksud pada ayat (1) dilakukan melalui Kantor Pelayanan Perbendaharaan Negara dengan detail rekening Institusi sebagai berikut:

Nama Institusi	:	Universitas Mulawarman
Nomor Rekening	:	213883110
Nama penerima pada rekening	:	RPL 046 Universitas Mulawarman Dana Kelolaan 01
Nama Bank	:	BNI
Alamat Bank	:	Jl. Kuaro Kampus Gn. Kelua Samarinda 0541-748891
Kota	:	Samarinda
NPWP Instirusi	:	00.173.481.3-741.000

(4) PIHAK KESATU tidak bertanggungjawab atas keterlambatan dan/atau tidak terbayarnya sejumlah dana, yang disebabkan oleh kesalahan PIHAK KEDUA dalam menyampaikan informasi detail rekening institusi sebagaimana dimaksud pada ayat (3).

Pasal 4
NILAI DAN TAHAPAN PEMBAYARAN

(1) nilai kontrak sebagaimana dimaksud dalam Pasal 3 ayat (1) dibayarkan oleh PIHAK KESATU kepada PIHAK KEDUA secara bertahap melalui Kantor Pelayanan Perbendaharaan Negara (KPPN) Jakarta III kepada rekening Institusi melalui mekanisme transfer yaitu:
   a. tahap kesatu sebesar *Rp5.536.432.000,00 (Lima Milyar Lima Ratus Tiga Puluh Enam Juta Empat Ratus Tiga Puluh Dua Ribu Rupiah)* dan;
   b. tahap kedua sebesar *Rp1.384.108.000,00 (Satu Milyar Tiga Ratus Delapan Puluh Empat Juta Seratus Delapan Ribu Rupiah).*

(2) pembayaran tahap kesatu sebagaimana dimaksud pada ayat (1) huruf a, akan dibayarkan setelah revisi proposal penelitian dan surat pernyataan kesanggupan pelaksanaan penelitian diunggah oleh para peneliti dibawah koordinasi PIHAK KEDUA ke laman yang ditentukan oleh PIHAK KESATU.

(3) apabila pembayaran tahap kesatu sebagaimana dimaksud pada ayat (1) huruf a diterima oleh pelaksana penelitian setelah tanggal 23 September 2024, maka Surat Pernyataan Tanggung Jawab Belanja (SPTB) dapat diunggah paling lambat 2 (dua) minggu setelah dana diterima melalui laman yang ditentukan oleh PIHAK KESATU.

(4) pembayaran tahap kedua sebagaimana dimaksud pada ayat (1) huruf b dibayarkan setelah pelaksana penelitian mengunggah Laporan Kemajuan/Antara Penelitian dan Surat Pernyataan Tanggung Jawab Belanja (SPTB) ke laman yang ditentukan oleh PIHAK KESATU paling lambat tanggal 30 September 2024.

(5) PIHAK KEDUA harus mewajibkan pelaksana penelitian menyampaikan bukti telah menyelesaikan seluruh pekerjaan dengan mengunggah dokumen sebagai berikut:
   a. Surat Pernyataan Tanggung Jawab Belanja (SPTB); dan
   b. laporan akhir pelaksanaan penelitian.
   pada laman yang ditentukan oleh PIHAK KESATU paling lambat tanggal 16 Desember 2024.

(6) Pasal 4 ayat (5) menjadi dasar pelaporan keuangan tahunan Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat.

(7) Apabila pembayaran tahap kedua sebagaimana dimaksud pada ayat (1) huruf b diterima oleh pelaksana penelitian setelah tanggal 6 Desember 2024, maka Surat Pernyataan Tanggung Jawab Belanja (SPTB) dapat diunggah paling lambat 2 (dua) minggu setelah dana diterima melalui laman yang ditentukan oleh PIHAK KESATU.

Pasal 5
HAK DAN KEWAJIBAN

(1) PIHAK KESATU mempunyai hak:
   a. menerima catatan harian penelitian
   b. menerima laporan kemajuan penelitian;
   c. menerima laporan akhir tahun atau laporan akhir pelaksanaan penelitian;
   d. melakukan pemantauan dan evaluasi;
   e. menerima surat Pernyataan Tanggungjawab Belanja (SPTB) atas dana penelitian yang telah ditetapkan;
   f. menerima hasil laporan pemantauan dan evaluasi dari PIHAK KEDUA;

(2) PIHAK KEDUA mempunyai hak mendapatkan dana penelitian dari PIHAK KESATU.

(3) PIHAK KESATU mempunyai kewajiban:
a. memberikan pendanaan penelitian kepada PIHAK KEDUA;
b. melakukan pemantauan dan evaluasi; dan
c. melakukan validasi luaran penelitian;

(4) PIHAK KEDUA mempunyai kewajiban:
a. membuat Kontrak Pelaksanaan Penelitian dengan ketua pelaksana penelitian yang paling sedikit memuat:
   1. nama pelaksana;
   2. judul penelitian;
   3. ruang lingkup penelitian;
   4. sumber dana penelitian;
   5. nilai kontrak penelitian;
   6. tata cara dan tahapan pembayaran;
   7. jangka waktu pelaksanaan dan penyelesaian;
   8. hak dan kewajiban para pihak;
   9. batas akhir pelaporan;
   10. pencantuman pemberi dana penelitian dalam publikasi ilmiah;
   11. luaran penelitian;
   12. serah terima luaran penelitian;
   13. kesanggupan pelaksanaan penelitian; dan
   14. sanksi;
b. bertanggung jawab atas terlaksananya penelitian berdasarkan Kontrak ini yang dilakukan oleh para peneliti di lingkungan PIHAK KEDUA;
c. memantau pengunggahan ke laman yang ditentukan oleh PIHAK KESATU atas dokumen sebagai berikut:
   1. revisi proposal penelitian;
   2. surat pernyataan kesanggupan pelaksanaan penelitian;
   3. catatan harian pelaksanaan penelitian;
   4. laporan kemajuan pelaksanaan penelitian;
   5. Surat Pernyataan Tanggungjawab Belanja (SPTB) atas dana penelitian yang telah ditetapkan;
   6. laporan akhir pelaksanaan penelitian; dan
   7. luaran penelitian.
d. melakukan pemantauan dan evaluasi secara internal serta penilaian kemajuan pelaksanaan program penelitian setelah ketua pelaksana mengunggah laporan kemajuan pelaksanaan kegiatan ke laman yang ditentukan oleh PIHAK KESATU.
e. apabila dalam pelaksanaan penelitian terdapat sisa dana, maka PIHAK KEDUA wajib mengembalikan ke kas negara.

Pasal 6
PENGGANTIAN KEANGGOTAAN

(1) Apabila terjadi perubahan susunan tim pelaksana penelitian karena tidak dapat menyelesaikan penelitian atau mengundurkan diri, maka PIHAK KEDUA wajib menunjuk pengganti tim pelaksana peneliti serta mengirimkan surat permohonan perubahan kepada PIHAK KESATU.
(2) Perubahan terhadap susunan tim pelaksana penelitian dapat dibenarkan apabila telah mendapat persetujuan dari PIHAK KESATU.

(3) Dalam hal tidak terdapat pengganti ketua tim pelaksana penelitian sesuai dengan syarat dan ketentuan dalam panduan penelitian, maka penelitian dibatalkan dan dana dikembalikan ke Kas Negara.

Pasal 7
PAJAK

Ketentuan pengenaan pajak pertambahan nilai dan/atau pajak penghasilan dalam rangka pelaksanaan kegiatan penelitian ini wajib dilaksanakan oleh PIHAK KEDUA sesuai dengan ketentuan peraturan perundang-undangan di bidang perpajakan.

Pasal 8
KEKAYAAN INTELEKTUAL

(1) Hak Kekayaan Intelektual yang dihasilkan dari pelaksanaan penelitian berdasarkan Kontrak ini diatur dan dikelola sesuai dengan ketentuan peraturan dan perundang-undangan.
(2) Setiap publikasi, makalah, dan/atau ekspos dalam bentuk apapun yang berkaitan dengan hasil penelitian wajib mencantumkan PIHAK KESATU sebagai pemberi dana.
(3) Pencantuman nama PIHAK KESATU sebagaimana dimaksud pada ayat (2), paling sedikit mencantumkan nama Direktorat Riset, Teknologi dan Pengabdian kepada Masyarakat Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Pasal 9
INTEGRITAS AKADEMIK

(1) Pelaksana penelitian di bawah koordinasi PIHAK KEDUA wajib menjunjung tinggi integritas akademik yaitu komitmen dalam bentuk perbuatan yang berdasarkan pada nilai kejujuran, kredibilitas, kewajaran, kehormatan, dan tanggung jawab dalam kegiatan penelitian yang dilaksanakan.
(2) Penelitian dilakukan sesuai dengan kerangka etika, hukum, dan profesionalitas serta kewajiban sesuai dengan ketentuan peraturan perundang-undangan.
(3) Penelitian dilakukan dengan menjunjung tinggi standar ketelitian dan integritas tertinggi dalam semua aspek penelitian.

Pasal 10
KEADAAN KAHAR

(1) Apabila terjadi keadaan kahar (*force majeure*) suatu keadaan yang terjadi di luar kehendak PARA PIHAK dalam kontrak, dan tidak dapat diperkirakan sebelumnya, sehingga kewajiban yang ditentukan dalam kontrak menjadi tidak dapat dipenuhi, maka PARA PIHAK sepakat tidak akan saling menuntut pelaksanaan pemenuhan ketentuan dalam Kontrak Penelitian ini.
(2) Peristiwa atau kejadian yang dapat digolongkan keadaan kahar (*force majeure*) sebagaimana dimaksud pada ayat (1) meliputi bencana alam, wabah penyakit, kebakaran, perang, blokade, peledakan, sabotase, revolusi, pemberontakan, huru-hara, serta adanya tindakan pemerintah dalam bidang ekonomi dan moneter yang secara nyata berpengaruh terhadap pelaksanaan Kontrak Penelitian ini.

(3) Apabila terjadi keadaan kahar (*force majeure*) sebagaimana dimaksud pada ayat (2), maka pihak yang mengalami wajib memberitahukan kepada pihak lainnya secara tertulis, selambat-lambatnya dalam waktu 7 (tujuh) hari kerja sejak terjadinya keadaan kahar (*force majeure*), disertai dengan bukti-bukti yang sah dari pihak yang berwajib, dan PARA PIHAK dengan itikad baik akan segera membicarakan penyelesaiannya.

Pasal 11
JANGKA WAKTU KONTRAK DAN ADENDUM

(1) Kontrak ini berlaku sejak tanggal 11 Juni 2024 sampai dengan tanggal 16 Desember 2024.

(2) Kontrak ini dapat diubah berdasarkan kesepakatan tertulis PARA PIHAK yang dituangkan dalam suatu adendum dan merupakan bagian yang tidak terpisahkan dari Kontrak ini.

Pasal 12
PENYELESAIAN PERSELISIHAN

(1) Dalam hal terjadi perselisihan atau perbedaan penafsiran terkait Kontrak Penelitian ini, PARA PIHAK sepakat untuk menyelesaikannya secara musyawarah dan mufakat.

(2) Dalam hal musyawarah dan mufakat sebagaimana dimaksud pada ayat (1) tidak tercapai, PARA PIHAK sepakat untuk menyelesaikannya melalui Pengadilan Negeri Jakarta Pusat.

Pasal 13
SANKSI

(1) Apabila sampai dengan batas waktu yang telah ditetapkan untuk melaksanakan Pelaksanaan Program Bantuan Operasional Perguruan Tinggi Negeri Program Penelitian Tahun Anggaran 2024 telah berakhir, PIHAK KEDUA tidak melaksanakan kewajiban sebagaimana dimaksud dalam Pasal 6 ayat (2), maka PIHAK KEDUA dikenai sanksi administratif.

(2) Apabila dikemudian hari terbukti bahwa judul-judul proposal yang diajukan pada program penelitian sebagaimana dimaksud dalam Pasal 1 ditemukan adanya duplikasi dan/atau ditemukan adanya ketidakjujuran/itikad buruk yang tidak sesuai dengan kaidah ilmiah, maka kegiatan penelitian tersebut dinyatakan batal dan PIHAK KEDUA dikenai sanksi administratif.

(3) Sanksi administratif sebagaimana dimaksud pada ayat (1) dan (2) dapat berupa penghentian pembayaran dan/atau Ketua Tim Pelaksana Penelitian tidak dapat mengajukan proposal penelitian dalam kurun waktu 2 (dua) tahun berturut-turut.

Pasal 14
LAIN-LAIN

Dalam hal PIHAK KEDUA berhenti dari jabatannya sebelum Kontrak Penelitian ini selesai, maka PIHAK KEDUA wajib melakukan serah terima tanggung jawabnya kepada pejabat baru yang menggantikannya.

Pasal 15
PENUTUP

Kontrak Penelitian ini dibuat dan ditandatangani oleh PARA PIHAK dalam rangkap 3 (tiga) asli bermeterai cukup yang biayanya dibebankan kepada PIHAK KEDUA, untuk tiap-tiap PIHAK dan memiliki kekuatan hukum yang sama.

PIHAK KESATU,	PIHAK KEDUA,
Yoga Dwi Arianda	Widi Sunaryo
NIP 198203052008121003	NIP 197304021999031002

LAMPIRAN KONTRAK PELAKSANAAN PROGRAM PENELITIAN BARU
TAHUN ANGGARAN 2024

001015

NOMOR SPPK	:	**061/E5/PG.02.00.PL/2024**
PERGURUAN TINGGI/LLDIKTI	:	**Universitas Mulawarman**
TANGGAL DIPA	:	**04 Februari 2024**
NOMOR DIPA	:	**SP DIPA-023.17.1.690523/2024 revisi ke-1**
SATUAN KERJA	:	**Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat**
UNIT ORGANISASI	:	**Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi**
KEMENTERIAN NEGARA/LEMBAGA	:	**Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi**

Penelitian Fundamental - Reguler

41 Judul

Energi

NO	NAMA PENELITI	JUDUL PENELITIAN	DANA PENELITIAN
1	**HAIRUL HUDA** **0018037806** **PFR** **Durasi : Tahun ke-1 dari 1 Tahun**	OPTIMISASI INFRASTRUKTUR CO2 CAPTURE DALAM PENDISTRIBUSIANNYA UNTUK PROSES ENHANCED OIL RECOVERY DALAM MENINGKATKAN PRODUKSI MINYAK BUMI NASIONAL	Rp. 64.850.000 (100%) Rp. 51.880.000 (Tahap I) Rp. 12.970.000 (Tahap II)

Kebencanaan

NO	NAMA PENELITI	JUDUL PENELITIAN	DANA PENELITIAN
1	**YOSEP RUSLIM** **0030096105** **PFR** **Durasi : Tahun ke-1 dari 1 Tahun**	Potensi Biomassa, Cadangan Karbon dan Analisis Sosial Ekonomi Limbah Pemanenan Kayu sebagai Bahan Baku Rumah Kayu dalam Mendukung Program IKN	Rp. 129.160.000 (100%) Rp. 103.328.000 (Tahap I) Rp. 25.832.000 (Tahap II)
2	**IDRIS** **0008107105** **PFR** **Durasi : Tahun ke-1 dari 1 Tahun**	Penerapan Model Hidrodinamika - Ekosistem dan Kaitannya dengan Perubahan Iklim di Estuari Delta Berau Kalimantan Timur	Rp. 122.830.000 (100%) Rp. 98.264.000 (Tahap I) Rp. 24.566.000 (Tahap II)
3	**HAMDHANI** **0025017802** **PFR** **Durasi : Tahun ke-1 dari 1 Tahun**	ANALISIS STOK DAN SEKUESTRASI KARBON EKOSISTEM MANGROVE SEBAGAI UPAYA MITIGASI PERUBAHAN IKLIM: STUDI KASUS MANGROVE SUNGAI SOMBER, TELUK BALIKPAPAN	Rp. 121.400.000 (100%) Rp. 97.120.000 (Tahap I) Rp. 24.280.000 (Tahap II)

1	**SOPIALENA** **0009106303** **PT** **Durasi : Tahun ke-1 dari 1 Tahun**	Uji ekfektifitas mikrobia endofit sebagai bioproteksi tanaman padi untuk mendukung pertanian berkelanjutan	Rp. 347.520.000 (100%) Rp. 278.016.000 (Tahap I) Rp. 69.504.000 (Tahap II)

Teknologi Informasi dan Komunikasi

NO	NAMA PENELITI	JUDUL PENELITIAN	DANA PENELITIAN
1	**ANINDITA SEPTIARINI** **0001098205** **PT** **Durasi : Tahun ke-1 dari 1 Tahun**	SISTEM COMPUTER-AIDED DETECTION (CAD) UNTUK PENYAKIT GLAUKOMA BERDASARKAN OPTIC NERVE HEAD PADA CITRA FUNDUS	Rp. 227.260.000 (100%) Rp. 181.808.000 (Tahap I) Rp. 45.452.000 (Tahap II)
Subtotal Dana Penelitian Terapan			Rp. **1.121.050.000** (100%) Rp. **896.840.000** (Tahap I) Rp. **224.210.000** (Tahap II)

Total Dana Penelitian Baru Keseluruhan **Universitas Mulawarman**	**Rp. 6.920.540.000** (100%) **Rp. 5.536.432.000** (Tahap I) **Rp. 1.384.108.000** (Tahap II)
Total Judul Penelitian Baru Keseluruhan Universitas Mulawarman	**68 Judul**

Jakarta,

Pejabat Pembuat Komitmen
Direktorat Riset, Teknologi, dan
Pengabdian kepada Masyarakat

Yoga Dwi Arianda
NIP. 198203052008121003

KEMENTERIAN PENDIDIKAN, KEBUDAYAAN, RISET DAN TEKNOLOGI
UNIVERSITAS MULAWARMAN
LEMBAGA PENELITIAN DAN PENGABDIAN KEPADA MASYARAKAT
Alamat :Jl.Kerayan No. 1 Gedung A8, Kampus Gunung Kelua,Samarinda 75119
Laman : http://lp2m.unmul.ac.id Surel: lppm@unmul.ac.id

KONTRAK
PELAKSANAAN PROGRAM PENELITIAN BARU
TAHUN ANGGARAN 2024

NOMOR: 604/UN17.L1/HK/2024

Pada hari ini **Kamis** tanggal **Tiga Belas** bulan **Juni** tahun **dua ribu dua puluh empat,** kami yang bertandatangan dibawah ini :

1. WIDI SUNARYO : Ketua Lembaga Penelitian dan Pengabdian kepada Masyarakat Universitas Mulawarman, dalam hal ini bertindak untuk dan atas nama Universitas Mulawarman yang berkedudukan di Jl. Krayan no 1 kampus Gn. Kelua Samarinda untuk selanjutnya disebut **PIHAK KESATU;**

2. HAMDHANI :Dosen FAKULTAS PERIKANAN Universitas Mulawarman, dalam hal ini bertindak sebagai pengusul dan ketua Pelaksanaan Penelitian Tahun Anggaran 2024 untuk selanjutnya disebut **PIHAK KEDUA.**

PIHAK KESATU dan **PIHAK KEDUA,** secara bersama-sama selanjutnya disebut **PARA PIHAK,** yang sepakat mengikatkan diri dalam kontrak Pelaksanaan Program BARU Tahun Anggaran 2024, dengan ketentuan dan syarat sebagai berikut:

PASAL 1
RUANG LINGKUP

Ruang lingkup kontrak penelitian ini meliputi pelaksanaan kegiatan PFR dengan judul **"ANALISIS STOK DAN SEKUESTRASI KARBON EKOSISTEM MANGROVE SEBAGAI UPAYA MITIGASI PERUBAHAN IKLIM: STUDI KASUS MANGROVE SUNGAI SOMBER, TELUK BALIKPAPAN"** yang dibebankan pada DIPA Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Tahun Anggaran 2024.

PASAL 2
NILAI KONTRAK

PIHAK KESATU memberikan pendanaan penelitian sebesar Rp. **121400000,-** ***(Seratus Dua Puluh Satu Juta Empat Ratus Ribu Rupiah)*** yang dibebankan pada DIPA Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Tahun Anggaran 2024.

1) Pendanaan pelaksanaan program penelitian dengan nilai kontrak sebagaimana dimaksud pada ayat (1) dibayarkan oleh **PIHAK KESATU** kepada **PIHAK KEDUA** ke rekening sebagai berikut :

Nama	: Hamdhani
Nomor Rekening	: 0172559347
Nama Bank	: BNI

2) **PIHAK KESATU** tidak bertanggungjawab atas keterlambatan dan/atau tidak terbayarnya sejumlah dana yang dimaksud pada ayat (1) yang disebabkan oleh kesalahan **PIHAK KEDUA** dalam menyampaikan data berupa nama bank, nomor rekening, dan persyaratan lainnya yang tidak sesuai dengan ketentuan.
3) Nilai Kontrak sebagai mana dimaksud pada ayat (1) digunakan untuk pembiayaan pelaksanaan program penelitian lanjut, pajak, dan biaya lain yang sah.

PASAL 3
NILAI DAN TAHAPAN PEMBAYARAN

1) Dana pelaksanaan penelitian sebagaimana nilai kontrak yang dimaksud dalam pasal 2 ayat (1) dibayarkan **PIHAK KESATU** kepada **PIHAK KEDUA** secara bertahap melalui mekanisme transfer yaitu :
   a. tahap kesatu sebesar Rp. **97120000,-** ***(Sembilan Puluh Tujuh Juta Seratus Dua Puluh Ribu Rupiah)***
   b. tahap kedua sebesar Rp. **24280000,-** ***(Dua Puluh Empat Juta Dua Ratus Delapan Puluh Ribu Rupiah)***
2) Pembayaran tahap kesatu sebagaimana dimaksud pada ayat (1) huruf a, akan dibayarkan setelah revisi proposal penelitian dan surat pernyataan kesanggupan pelaksanaan penelitian telah diunggah ke laman yang ditentukan oleh **PIHAK KESATU**.
3) Apabila pembayaran tahap kesatu sebagaimana dimaksud pada ayat (1) huruf a cair setelah tanggal 23 September 2024, **PIHAK KEDUA** mengunggah Surat Pernyataan Tanggung Jawab Belanja (SPTB) ke laman yang ditentukan oleh **PIHAK KESATU** paling lambat 2 (dua) minggu setelah dana cair.
4) Pembayaran tahap kedua sebagaimana dimaksud pada ayat (1) huruf b dibayarkan setelah pelaksana penelitian mengunggah Laporan Kemajuan/Antara penelitian dan Surat Pernyataan Tanggung Jawab Belanja (SPTB) ke laman yang ditentukan oleh **PIHAK KESATU** paling lambat tanggal 30 September 2024.
5) **PIHAK KEDUA** harus menyampaikan surat pernyataan telah menyelesaikan seluruh pekerjaan yang dibuktikan dengan pengunggahan pada laman yang ditentukan oleh **PIHAK KESATU** paling lambat tanggal **16 Desember 2024**, dengan melampirkan dokumen sebagai berikut:
   a. Surat Pernyataan Tanggung Jawab Belanja (SPTB); dan
   b. Laporan akhir tahun untuk pendanaan multitahun yang dilaksanakan pada tahun berjalan; atau
   c. Laporan akhir pelaksanaan penelitian untuk pendanaan mono tahun dan multitahun pada tahun terakhir.
6) Apabila pembayaran tahap kedua sebagaimana dimaksud pada ayat (1) huruf b cair setelah tanggal 6 Desember 2014, pelaksana penelitian mengunggah Surat Pernyataan Tanggung Jawab Belanja (SPTB) ke laman yang ditentukan oleh **PIHAK KESATU** paling lambat 2 (dua) minggu setelah dana cair.

PASAL 4
HAK DAN KEWAJIBAN

1) **PIHAK KESATU** mempunyai hak menerima dokumen dalam bentuk softcopy hasil unggahan di laman yang akan diinformasikan oleh **PIHAK KESATU.** Dokumen sebagai berikut:
   a. Revisi proposal penelitian;
   b. Surat pernyataan kesanggupan pelaksanaan penelitian;
   c. Catatan harian pelaksanaan penelitian;
   d. Laporan kemajuan pelaksanaan penelitian;
   e. Surat Pernyataan Tanggungjawab Belanja (SPTB) atas dana penelitian yang telah ditetapkan;
   f. Laporan akhir tahun atau laporan akhir pelaksanaan penelitian; dan
   g. Luaran penelitian
2) **PIHAK KEDUA** mempunyai hak memperoleh dana penelitian sesuai nilai yang telah ditetapkan dari **PIHAK KESATU.**
3) **PIHAK KESATU** mempunyai kewajiban :
   a. Memberikan pendanaan kepada **PIHAK KEDUA;**
   b. Melakukan pemantauan dan evaluasi;
   c. Mengkoordinir dan bertanggungjawab atas terlaksananya Kontrak Penelitian yang dilakukan oleh **PIHAK KEDUA;**
   d. Memantau pengunggah ke laman yang akan diinformasikan oleh **PIHAK KESATU** atas dokumen sebagai berikut:
      1. Revisi proposal penelitian;
      2. Surat pernyataan kesanggupan pelaksanaan penelitian;
      3. Catatan harian pelaksanaan penelitian;
      4. Laporan kemajuan pelaksanaan penelitian;
      5. Surat Pernyataan Tanggungjawab Belanja (SPTB) atas dana penelitian yang telah ditetapkan;
      6. Laporan akhir tahun atau laporan akhir pelaksanaan penelitian; dan
      7. Luaran penelitian
   e. Melakukan penilaian kemajuan pelaksanaan program penelitian setelah ketua pelakasana mengunggah laporan kemajuan pelaksanaan kegiatan ke laman yang akan diinformasikan oleh **PIHAK KESATU,** dengan berpedoman kepada prinsip-prinsip dan/atau kaidah program penelitian.
4) **PIHAK KEDUA** mempunyai kewajiban:
   a. Mengunggah dokumen ke laman yang akan diinformasikan oleh **PIHAK KESATU**. Dokumen sebagai berikut:
      1. Revisi proposal penelitian;
      2. Surat pernyataan kesanggupan pelaksanaan penelitian;
      3. Catatan harian pelaksanaan penelitian;
      4. Laporan kemajuan pelaksanaan penelitian;
      5. Surat Pernyataan Tanggungjawab Belanja (SPTB) atas dana penelitian yang telah ditetapkan;
      6. Laporan akhir tahun atau laporan akhir pelaksanaan penelitian; dan
      7. Luaran penelitian
   b. Bertanggungjawab sepenuhnya dalam penggunaan dana penelitian dengan membuat dan menyerahkan softfile dan hardfile rekap SPJ beserta bukti penggunaan anggaran, bukti pembayaran pajak dan peralatan (aset) yang

dihasilkan dari kegiatan penelitian kepada **PIHAK KESATU** sebanyak 2 rangkap, 1 (satu) rangkap diserahkan kepada **PIHAK KESATU,** 1 (satu) rangkap disimpan oleh masing-masing peneliti

c. apabila dalam pelaksanaan penelitian terdapat sisa dana, maka **PIHAK KEDUA** wajib mengembalikan ke kas negara.

PASAL 5
PENGGANTIAN KEANGGOTAAN

1) Perubahan terhadap susunan tim pelaksana penelitian dapat dibenarkan apabila telah mendapat persetujuan dari Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat, Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi.
2) Apabila ketua tim pelaksana penelitian tidak dapat menyelesaikan penelitian atau mengundurkan diri, maka **PIHAK KEDUA** wajib menunjuk pengganti ketua tim pelaksana penelitian yang merupakan salah satu anggota tim setelah mendapat persetujuan dari Direktorat Riset, Teknologi, dan Pengabdian kepada Masyarakat, Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi.
3) Dalam hal tidak terdapat pengganti ketua tim pelaksana penelitian sesuai dengan syarat dan ketentuan dalam panduan penelitian, maka penelitian dibatalkan dan dana dikembalikan ke Kas Negara.

PASAL 6
PAJAK

Ketentuan pengenaan pajak pertambahan nilai dan/atau pajak penghasilan dalam rangka pelaksanaan kegiatan penelitian ini wajib dilaksanakan oleh **PIHAK KEDUA** sesuai dengan ketentuan peraturan perundang-undangan dibidang perpajakan.

PASAL 7
KEKAYAAN INTELEKTUAL

1) Hak Kekayaan Intelektual yang dihasilkan dari pelaksanaan penelitian diatur dan dikelola sesuai dengan ketentuan peraturan dan perundang-undangan.
2) Setiap publikasi, makalah, dan/atau ekspos dalam bentuk apapun yang berkaitan dengan hasil penelitian wajib mencantumkan paling sedikit nama **Direktorat Riset, Teknologi dan Pengabdian kepada Masyarakat Kementerian Pendidikan, Kebudayaan, Riset dan Teknologi.**

PASAL 8
KEADAAN KAHAR

1) Apabila terjadi keadaan kahar *(force majeure)* suatu keadaan yang terjadi di luar kehendak **PARA PIHAK** dalam kontrak, dan tidak dapat diperkirakan sebelumnya, sehingga kewajiban yang ditentukan dalam kontrak menjadi tidak dapat dipenuhi, maka **PARA PIHAK** sepakat tidak saling menuntut pelaksanaan pemenuhan ketentuan dalam kontrak penelitian ini.

2) Peristiwa atau kejadian yang dapat digolongkan keadaan kahar *(force majeure)* sebagaimana dimaksud pda ayat (1) meliputi bencana alam, wabah penyakit, kebakaran, perang, blockade, peledakan, sabotase, revolusi, pemberontakan, huru-hara, serta adanya tindakan pemerintah dalam bidang ekonomi dan moneter yang secara nyata berpengaruh terhadap pelaksanaan kontrak penelitian ini.
3) Apabila terjadi keadaan kahar *(force majeure)* sebagaimana dimaksud pada ayat (2), maka pihak yang mengalami wajib memberitahukan kepada pihak lainnya secara tertulis, selambat-lambatnya dalam waktu 7 (tujuh) hari kerja sejak terjadinya keadaan kahar *(force majeure)*, disertai dengan bukti- bukti yang sah dari pihak-pihak yang berwajib, dan **PARA PIHAK** dengan itikad baik akan segera membicarakan penyelesaiannya.

PASAL 9
PENYELESAIAN PERSELISIHAN

1) Dalam hal terjadi perselisihan atau perbedaan penafsiran terkait kontrak penelitian ini, **PARA PIHAK** sepakat untuk menyelesaikannya secara musyawarah dan mufakat.
2) Dalam hal musyawarah dan mufakat sebagaimana dimaksud pada ayat (2) tidak tercapai, **PARA PIHAK** sepakat untuk menyelesaikannya melalui Pengadialan Negeri Jakarta Pusat.

PASAL 10
JANGKA WAKTU PENYELESAIAN

1) Jangka waktu penyelesaian penelitian dimulai sejak tanggal 13 Juni 2024 hingga 16 Desember 2024.
2) Kontrak ini dapat diubah berdasarkan kesepakatan tertulis **PARA PIHAK** yang dituangkan dalam suatu addendum dan merupakan bagian yang tidak terpisahkan dari kontrak ini.

PASAL 11
SANKSI

1) Apabila sampai dengan batas waktu yang telah ditetapkan untuk melaksanakan Kontrak Penelitian telah berakhir, **PIHAK KEDUA** tidak melaksanakan kewajiban sebagaimana dimaksud dalam Pasal 6 ayat (2), maka **PIHAK KEDUA** dikenai sanksi administratif.
2) Apabila kemudian hari terbukti bahwa judul-judul proposal yang diajukan pda program penelitian sebagaimana dimaksud dalam pasal 1 ditemukan adanya duplikasi dan/atau ditemukan adanya ketidakjujuran/itikad buruk yang tidak sesuai dengan kaidah ilmiah, maka kegiatan penelitian tersebut dinyatakan batal dan **PIHAK KEDUA** dikenai sanksi administratif.
3) Sanksi administratif sebagaimana dimaksud pada ayat (1) dan (2) dapat berupa penghentian pembayaran dan/atau Ketua Tim Pelaksana Penelitian tidak dapat mengajukan proposal penelitian dalam kurun waktu 2 (dua) tahun berturut-turut.

PASAL 12
PENUTUP

Kontrak Penelitian ini dibuat dan ditandatangani oleh **PARA PIHAK** dalam rangkap 3 (tiga) asli bermaterai yang biayanya dibebankan kepada **PIHAK KEDUA,** untuk tiap-tiap PIHAK dan memiliki kekuatan hukum yang sama.

PIHAK KESATU,	PIHAK KEDUA,
WIDI SUNARYO	**HAMDHANI**
NIP. 197304021999031002	NIP. 197801252008121001

Kementerian Pendidikan Tinggi, Sains, dan Teknologi
Jalan Jenderal Sudirman, Senayan, Jakarta Pusat 10270
https://bima.kemdiktisaintek.go.id

PROTEKSI ISI LAPORAN AKHIR PENELITIAN FUNDAMENTAL - REGULER
Dilarang menyalin, menyimpan, memperbanyak sebagian atau seluruh isi proposal ini dalam bentuk apapun kecuali oleh pengusul dan pengelola administrasi penelitian dan pengabdian kepada masyarakat

LAPORAN AKHIR

Tahun Pelaksanaan 2024 | Tahun ke 1 dari 1

1. JUDUL PENELITIAN

ANALISIS STOK DAN SEKUESTRASI KARBON EKOSISTEM MANGROVE SEBAGAI UPAYA MITIGASI PERUBAHAN IKLIM: STUDI KASUS MANGROVE SUNGAI SOMBER, TELUK BALIKPAPAN

Bidang Fokus	Tema	Topik (jika ada)	Prioritas Riset
Kebencanaan	Mitigasi, perubahan iklim dan tata ekosistem	Kontribusi dan peran hutan dalam perubahan iklim	Blue Economy

Rumpun Ilmu Level 1	Rumpun Ilmu Level 2	Rumpun Ilmu Level 3
MATEMATIKA DAN ILMU PENGETAHUAN ALAM (MIPA)	ILMU IPA	Bidang IPA Lain Yang Belum Tercantum

Skema Penelitian	Strata (Dasar/Terapan/ Pengembangan)	Nilai SBK	Target Akhir TKT	Lama Kegiatan
Penelitian Fundamental - Reguler	Riset Dasar	150.000.000	3	1 Tahun

2. IDENTITAS PENGUSUL

Nama, Peran	Jenis	Program Studi/Bagian	Bidang Tugas	ID Sinta
HAMDHANI 0025017802 Ketua Pengusul Universitas Mulawarman	Dosen	Manajemen Sumber Daya Perairan	bertanggung jawab terhadap keseluruhan kegiatan serta koordinator dalam proses pemetaan dengan ArcGIS	6092327
IRWAN RAMADHAN RITONGA 0016068402 Anggota Universitas Mulawarman	Dosen	Ilmu Kelautan	bertanggung jawab dalam kegiatan di lapangan pada pengumpulan data biomassa pohon mohon, uji karbon organik pada tanah dan perhitungan stok karbon	6017966
MOHAMMAD SUMIRAN PAPUTUNGAN 0021099104 Anggota Universitas Mulawarman	Dosen	Ilmu Kelautan	bertanggung jawab dalam kegiatan di lapangan pada pengukuran produksi laju serasah mangrove, pengukuran umur lapisan tanah dan analisis laju sekuestrasi karbon	6779024
IWAN SUYATNA 0013085703 Anggota Universitas Mulawarman	Dosen	Ilmu Kelautan	bertanggung jawab dalam kegiatan di lapangan pada pengambilan data dan analisis struktur komunitas mangrove	6038750

3. MITRA KERJASAMA PENELITIAN (Jika Ada)

Pelaksanaan penelitian dapat melibatkan mitra kerjasama yaitu mitra kerjasama dalam melaksanakan penelitian, mitra sebagai calon pengguna hasil penelitian, atau mitra investor

Mitra	Nama Mitra	Dana

4. LUARAN DAN TARGET CAPAIAN

Luaran Wajib

Tahun Luaran	Kategori Luaran	Jenis Luaran	Status target capaian	Keterangan
1	Artikel di Jurnal	Artikel di Jurnal Bereputasi Internasional	Accepted/Published	https://link.springer.com/journal/10750

5. ANGGARAN

Rencana Anggaran Biaya penelitian mengacu pada PMK dan buku Panduan Penelitian dan Pengabdian kepada Masyarakat yang berlaku.

Total RAB 1 Tahun Rp 121.400.000,00

Tahun 1 Total Rp 121.400.000,00

Kelompok	Komponen	Item	Satuan	Vol.	Biaya Satuan	Total
Analisis Data	Biaya analisis sampel	Biaya uji Pb-210 (60 lapisan/layer sampel tanah)	Unit	60	650.000	39.000.000
Analisis Data	Biaya analisis sampel	Biaya uji konsentrasi karbon organik (LOI) pada sampel serasah (9 stasiun: per stasiun 3 ulangan dalam 3 kali pengambilan data)	Unit	81	60.000	4.860.000
Analisis Data	Biaya analisis sampel	Biaya uji konsentraski karbon organik (LOI) pada sampel tanah, 9 stasiun; per stasiun 20 layer sampel tanah	Unit	180	60.000	10.800.000
Bahan	ATK	Buku lapangan, kertas, tinta, penggaris 1 meter dan lain-lain	Paket	1	940.000	940.000
Bahan	Bahan Penelitian (Habis Pakai)	Alumunium foil	Unit	30	45.000	1.350.000
Bahan	Bahan Penelitian (Habis Pakai)	Ice pack	Unit	20	70.000	1.400.000
Bahan	Bahan Penelitian (Habis Pakai)	Jaring perangkap serasah (3 unit per stasiun)	Unit	27	70.000	1.890.000
Bahan	Bahan Penelitian (Habis Pakai)	Lakban anti air	Unit	10	50.000	500.000
Bahan	Bahan Penelitian (Habis Pakai)	Meteran jahit	Unit	3	15.000	45.000
Bahan	Bahan Penelitian (Habis Pakai)	mata gerinda	Unit	3	50.000	150.000
Bahan	Bahan Penelitian (Habis Pakai)	Pipa PVC 2,5 inch (4 batang)	Unit	5	250.000	1.250.000
Bahan	Bahan Penelitian (Habis Pakai)	Plastik klim ukuran kecil	Unit	3	35.000	105.000
Bahan	Bahan Penelitian (Habis Pakai)	Penutup pipa	Unit	24	10.000	240.000
Bahan	Bahan Penelitian (Habis Pakai)	Plastik klip ukuran besar	Unit	3	70.000	210.000
Pengumpulan Data	Biaya	Konsumsi Rapat hasil	OH	8	70.000	560.000

Kelompok	Komponen	Item	Satuan	Vol.	Biaya Satuan	Total
	konsumsi rapat	penelitian (8 orang)				
Pengumpulan Data	Biaya konsumsi	Konsumsi rapat dalam kantor: 2 kali rapat, jumlah peserta 9 orang	OH	18	70.000	1.260.000
Pelaporan Hasil Penelitian dan Luaran Wajib	Biaya Publikasi artikel di Jurnal Bereputasi Interasional	Publikasi 1 artikel pada jurnal internasional bereputasi	Paket	1	12.000.000	12.000.000
Pengumpulan Data	HR Pembantu Lapangan	5 orang mahasiswa, 7 hari efektif kegiatan pengambilan data di lapangan	OH	35	80.000	2.800.000
Pengumpulan Data	HR Sekretariat/ Administrasi Peneliti	honorarium administrasi peneliti	OB	2	310.000	620.000
Pengumpulan Data	Penginapan	Sewa 4 kamar hotel selama 1 malam pada kegiatan survei hari ke 1 dan ke 2	OH	4	600.000	2.400.000
Pengumpulan Data	Penginapan	Sewa 4 kamar hotel selama 2 malam pada kegiatan survei hari ke-3 hingga hari ke-5	OH	8	650.000	5.200.000
Pengumpulan Data	Transport	Transport dari Samarinda ke Balikpapan (PP) untuk pengambilan data dan sampel di lapangan: 4 kali PP, 9 orang	OK (kali)	36	430.000	15.480.000
Pengumpulan Data	Uang Harian	uang harian perjalanan dinas selama pengambilan data dan sampel di lapangan (tujuan kota Balikpapan): 4 peneliti, 7 hari efektif	OH	28	430.000	12.040.000
Sewa Peralatan	Kendaraan	perahu: sewa 1 perahu 7 hari	OK (kali)	7	900.000	6.300.000

***. KEMAJUAN PENELITIAN**

A. RINGKASAN

Degradasi hutan mangrove berpotensi manghasilkan emisi gas rumah kaca lebih besar dari degradasi tipe hutan lainnnya dengan luasan yang sama, oleh karena itu hutan mangrove menjadi salah satu ekosistem blue carbon yang penting dalam upaya penurunan emisi gas rumah kaca secara global. Indonesia yang memiliki luas hutan mangrove terbesar di dunia, perlu mengambil langkah strategis untuk mengelola hutan mangrove dalam upaya mengurangi emisi karbon. Pada kenyataannya, di level Provinsi Kalimantan Timur, dalam rencana aksi penurunan emisi gas rumah kaca daerah tahun 2010-2030, perhitungan emisi dari kompartemen stok karbon belum secara detail diperhitungkan, secara spesifik belum mempertimbangkan cadangan dan sekuestrasi yang ada di tanah (below ground) hutan mangrove. Penelitian ini perlu dilakukan, untuk menunjukan besaran potensi stok dan sequestrasi karbon secara menyeluruh (above and below ground) pada kawasan hutan mangrove di DAS Sungai Somber, Kota Balikpapan yang juga merupakan kota penyangga IKN.

Pada penelitian ini akan dilakukan pemetaan kondisi kesehatan mangrove berdasarkan citra satelit/ foto udara. Dalam pengukuran stok karbon, akan dilakukan identifikasi spesies, jumlah, dan diameter batang pohon, serta struktur komunitas, selain itu juga akan dilakukan pengambilan sampel tanah secara vertikal. Tingkat sekuestrasi karbon akan diduga dengan mengukur laju produksi serasah. Hasil pengukuran stok karbon akan dihitung dengan persamaan alometrik standar. Laju sekuestrasi karbon akan dihitung dari penjumlahan laju serapan karbon di biomassa mangrove (produktivitas primer bersih) dan laju akumulasi karbon di tanah mangrove akan dilakukan dengan metode carbon dating, yang kemudian dihitung dengan membagi jumlah karbon organik tiap lapisan sedimen dengan interval waktu pengendapan sedimen. Hasil menunjukkan laju serapan karbon pada pohon mangrove lebih tinggi dibandingkan laju penyimpanan karbon di sedimen. Area mangrove dengan tingkat kesehatan sedang memiliki laju serapan karbon tertinggi pada pohon. Hal tersebut juga diikuti oleh tingginya rata-rata konsentrasi karbon organik dan laju akumulasi karbon organik di sedimen dalam 10 tahun terakhir. Namun, tidak terdapat hubungan antara total karbon yang tersimpan di sedimen dengan kondisi kesehatan mangrove. Hasil penelitian ini telah disusun dalam sebuah manuscript yang telah diajukan untuk diterbitkan pada Ecological Engineering & Environmental Technology (Q3) dengan judul artikel “Simple Estimation of Carbon Sequestration Rate in Mangrove Trees Based on Litter Production Rate in the Somber River Estuary, Balikpapan, Indonesia”. Publikasi ini akan dapat digunakan oleh Pemprov. Kaltim sebagai naskah akademik acuan yang merupakan landasan perencanaan program mitigasi perubahan iklim dan perdagangan karbon dari kawasan hutan mangrove.

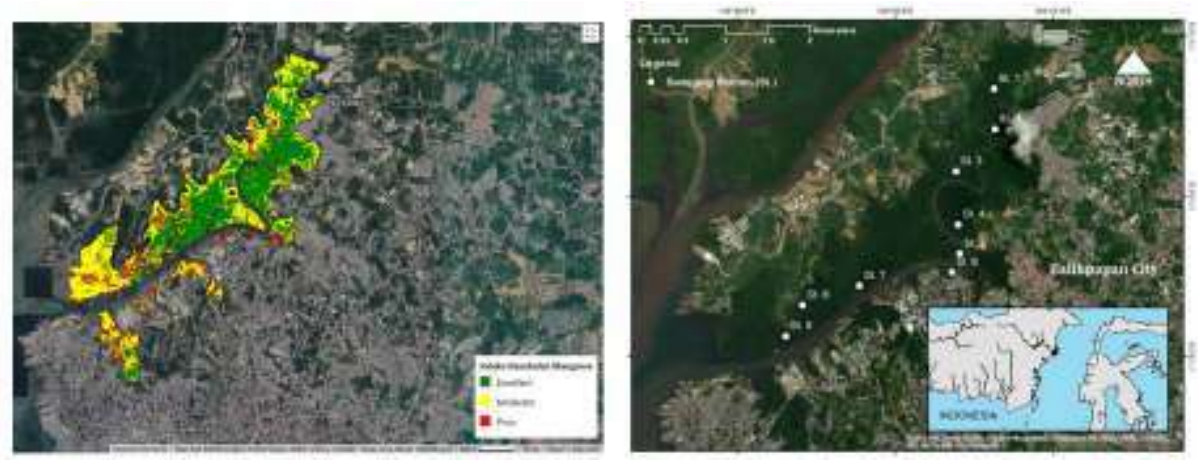
B. KATA KUNCI

hutan bakau; pemanasan global; Kalimantan Timur; cadangan karbon; gas rumah kaca

Pengisian poin C sampai dengan poin H mengikuti template berikut dan tidak dibatasi jumlah kata atau halaman namun disarankan seringkas mungkin. Dilarang menghapus/memodifikasi template ataupun menghapus penjelasan di setiap poin.

C. **HASIL PELAKSANAAN PENELITIAN:** Tuliskan secara ringkas hasil pelaksanaan penelitian yang telah dicapai sesuai tahun pelaksanaan penelitian. Penyajian meliputi data, hasil analisis, dan capaian luaran (wajib dan atau tambahan). Seluruh hasil atau capaian yang dilaporkan harus berkaitan dengan tahapan pelaksanaan penelitian sebagaimana direncanakan pada proposal. Penyajian data dapat berupa gambar, tabel, grafik, dan sejenisnya, serta analisis didukung dengan sumber pustaka primer yang relevan dan terkini.

ANALISIS STOK DAN SEKUESTRASI KARBON EKOSISTEM MANGROVE SEBAGAI UPAYA MITIGASI PERUBAHAN IKLIM: STUDI KASUS MANGROVE SUNGAI SOMBER, TELUK BALIKPAPAN



Gambar 1 Lokasi area penelitian. (Kiri) hasil model sebaran indeks kesehatan mangrove, (kanan) titik pengambilan data yang mewakili tingkat kesehatan mangrove: *excellent* (sangat baik)*, moderate* (sedang) dan *poor* (buruk)

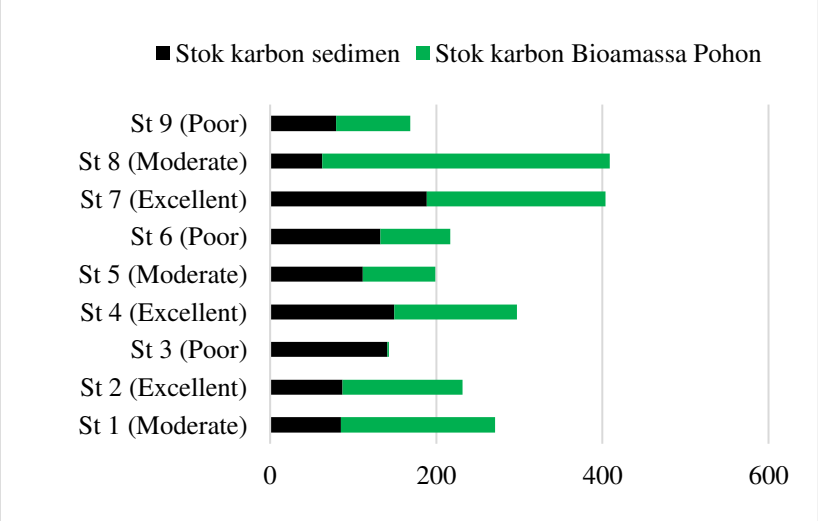
Hasil model sebaran tingkat kesehatan mangrove menggunakan model *Mangrove Heatlh Index* (MHI) menurut (1) menunjukkan bahwa area mangrove Sungai Somber memiliki sebaran kondisi dari buruk hingga sangai baik (Gambar 1). Hasil pengukuran lapangan (Tabel 1) bahwa kerapatan pohon pada zona mangrove yang tergolong buruk cenderung rendah (<1000 ind/ha), tutupan kanopi mangrove pada zona mangrove yang sangat baik cenderung tinggi (>90%). Titik lokasi yang didominasi oleh *Sonneratia alba* (Stasiun 8 dan 9) cenderung memiliki tutupan kanopi yang rendah, namun memiliki diameter pohon atau *diameter at breast height* (DBH) yang lebih tinggi apabila dibandingkan dengan stasiun dengan kondisi mangrove sangat baik yang didominasi oleh jenis *Rhizophora*.

Tabel 1 Komposisi vegetasi mangrove

Stasiun	Zona MHI (model)	Spesies	Kerapatan pohon (ind/ha)	DBH	Tutupan kanopi (%)
St 1	Moderate	*Rhizophora apiculata** *Xylocarpus granatum*	1200	15.66	83.02
St 2	Excellent	*Ceriops decandra** *Rhizophora apiculata*	2500	12.53	90.59
St 3	Poor	*Rhizophora apiculata*	200	4.14	12.01
St 4	Excellent	*Rhizophora apiculata** *Ceriops tagal* *Avicennia officinalis* *Avicennia marina*	2300	12.36	91.11

Stasiun	Zona MHI (model)	Spesies	Kerapatan pohon (ind/ha)	DBH	Tutupan kanopi (%)
St 5	Moderate	*Rhizophora mucronata** *Rhizophora apiculata* *Avicennia marina*	1600	10.61	75.24
St 6	Poor	*Rhizophora mucronata** *Sonneratia alba*	700	16.32	30.75
St 7	Excellent	*Rhizophora apiculata*	1800	15.20	90.93
St 8	Moderate	*Sonneratia alba** *Avicennia lanata* *Avicennia marina*	2500	16.95	69.10
St 9	Poor	*Sonneratia alba** *Avicennia marina*	800	15.75	18.78

Hasil perhitungan stok karbon di sedimen berkisar 62,60-149,54 MgC/ha dan stok karbon dibagian pohon berkisar 2,20-346,36 MgC/ha (Gambar 2). Secara rata-rata, persentasi simpanan karbon di sedimen dalam hasil penelitian ini lebih adalah 52% dari total simpanan karbon. Hasil tersebut lebih rendah dibandingkan temuan (2) yang mendapatkan 70% dari total simpanan karbon pada ekosistem mangrove terdapat di sedimen. Perbedaan ini disebabkan oleh perbedaan kedalaman sampel sedimen yang digunakan, yang mana dalam penelitian ini hanya menghitung konsentrasi karbon di sedimen hingga kedalaman 50 cm sedangkan penelitian (2) menghitung karbon hingga kedalaman 100 cm. Batasan penggunaan kedalaman 50 cm sedimen dalam penelitian ini bertujuan untuk mengukur laju sekuestrasi karbon pada sedimen terkini, mengikuti metode yang dijelaskan oleh (3). Berdasarkan rata-rata stok karbon per zona tingkat kesehatan mangrove, nilai total stok karbon tertinggi tersimpan pada area mangrove yang sangat baik.

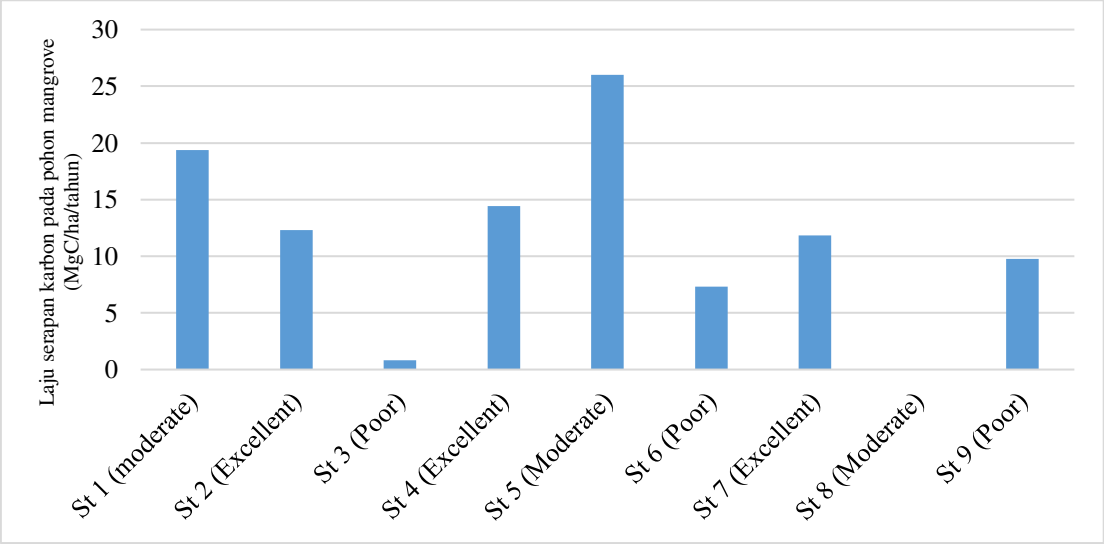


Gambar 2 Stok Karbon

Hasil pengukuran laju serapan karbon pada tegakan pohon menggunakan pendekatan produksi serasah menunjukkan bahwa pada kondisi mangrove dengan tingkat kesehatan sedang cenderung memiliki laju serapan karbon yang tinggi (Gambar 3). Laju serapan karbon pada pohon mangrove berkisar antara 0,80 – 26,01 MgC/ha/tahun, yang mana laju serapan karbon tertinggi terdapat pada mangrove kondisi sedang dan terendah terdapat pada area mangrove yang buruk.

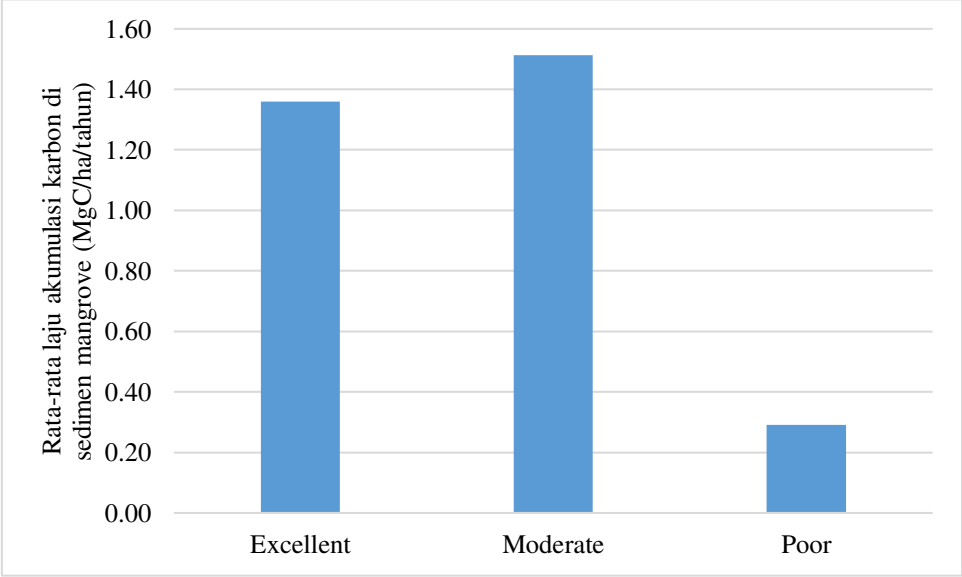
Stasiun 8 (moderate) tidak memiliki data yang dapat ditampilkan disebabkan oleh hilangnya perangkap serasah yang telah dipasang untuk mengukur laju produksi serasah. Hal yang sama juga terjadi pada Stasiun 9 (*poor*) yang mana data yang terambil hanya data pada periode pengambilan pertama data produksi serasah. Berdasarkan informasi yang didapatkan dari nelayan setempat, hilangnya jaring perangkap serasah tersebut

diduga diambil oleh pada nelayan yang melakukan aktivitas penangkapan ikan di sekitar lokasi penelitian tanpa sepengetahuan mereka terkait dengan alat penelitian yang terpasang di area tersebut.



Gambar 3 Laju serapan karbon pada pohon mangrove (MgC/ha/tahun)

Perhitungan laju akumulasi karbon di sedimen mangrove hanya dilakukan pada 3 core sedimen yang mewakili stasiun mangrove kondisi sangat baik, sedang dan buruk (Gambar 4). Rata-rata laju akumulasi karbon terkini menunjukkan tingkat akumulasi karbon yang tinggi terdapat pada mangrove kondisi sedang dan terendah berada di area mangrove yang buruk. Tidak terdapat perbedaan yang signifikan pada laju akumulasi karbon antara area mangrove kondisi sangat baik dengan kondisi yang sedang. Laju akumulasi karbon di sedimen mangrove berkisar 0,29 – 1,51 MgC/ha/tahun. Hasil kisaran nilai tersebut tidak berbeda jauh dengan yang ditemukan oleh (3) di area mangrove Teluk Bintuni, Papua dengan kisaran nilai 0,21 – 1,19 MgC/ha/tahun. Selain itu, laju akumulasi karbon organik di sedimen mangrove area Sungai Somber lebih tinggi dibandingkan dengan area mangrove alami dan rehabilitasi di Provinsi Banten yang secara berurutan nilainya adalah 0,50 MgC/ha/tahun dan 0,27 MgC/ha/tahun (4).



Gambar 4 Rata-rata laju akumulasi karbon di sedimen mangrove tahun 2017-2024 (MgC/ha/tahun)

Hasil penelitian menunjukkan bahwa berdasarkan tingkat kesehatan mangrove bahwa total laju sekuestrasi karbon di area mangrove perairan estuari Sungai Somber berkisar antara 6,25 – 24,20 MgC/ha/tahun dengan rata-rata 14,89 MgC/ha/tahun. Area mangrove dengan tingkat kesehatan *moderate* atau sedang memiliki laju serapan karbon tertinggi, sedangkan area mangrove dengan tingkat kesehatan mangrove buruk memiliki laju

serapan karbon terendah. Sebagai tambahan, laju sekuestrasi karbon pada pohon lebih tinggi dibandingkan laju sekuestrasi karbon di sedimen.

Hasil penelitian ini telah disusun dalam *manuscript* yang telah diajukan untuk diterbitkan pada *Ecological Engineering & Environmental Technology (Q3)* (Gambar 5) dengan judul artikel "Simple Estimation of Carbon Sequestration Rate in Mangrove Trees Based on Litter Production Rate in the Somber River Estuary, Balikpapan, Indonesia".



12/27/24, 3:13 PM Universitas Mulawarman Mail - New manuscript received by Editorial Office (EEET-02705-2024-01)

Hamdhani Hamdhani <hamdhani@fpik.unmul.ac.id>

New manuscript received by Editorial Office (EEET-02705-2024-01)

1 message

Ecological Engineering & Environmental Technology <kontakt@editorialsystem.com> Wed, Dec 25, 2024 at 2:06 PM

Reply-To: "gabriel@borowski.net.pl" <gabriel@borowski.net.pl>
To: Hamdhani Hamdhani <hamdhani@fpik.unmul.ac.id>

Dear Hamdhani Hamdhani,

Thank you for your manuscript: Simple Estimation of Carbon Sequestration Rate in Mangrove Trees Based on Litter Production Rate in the Somber River Estuary, Balikpapan, Indonesia.
The following number has been assigned to it: EEET-02705-2024-01.

The manuscript will be checked by Editors and then sent to the Reviewers.
You will be informed by email about any further decisions on this article.

Thank you for submitting your work to our journal.

Kindest regards,
Prof. Gabriel Borowski
Editor-in-Chief
Ecological Engineering & Environmental Technology

Gambar 5 Bukti *submit* luaran penelitian

D. **STATUS LUARAN**: Tuliskan jenis, identitas dan status ketercapaian setiap luaran wajib dan luaran tambahan (jika ada) yang dijanjikan. Jenis luaran dapat berupa publikasi, perolehan kekayaan intelektual, atau luaran lainnya yang telah dijanjikan pada proposal. Uraian status luaran harus didukung dengan bukti kemajuan ketercapaian luaran sesuai dengan luaran yang dijanjikan. Lengkapi isian jenis luaran yang dijanjikan serta mengunggah bukti dokumen ketercapaian luaran melalui BIMA.

Jenis luaran adalah 1 publikasi jurnal internasional bereputasi yang mana *manuscript* hasil penelitian ini telah diajukan (*submitted*) ke *Engineering & Environmental Technology (Q3)* pada tanggal 25 Desember 2024.

E**. PERAN MITRA:** Tuliskan realisasi kerjasama dan kontribusi Mitra baik *in-kind* maupun *in-cash* serta mengunggah bukti dokumen pendukung sesuai dengan kondisi yang sebenarnya. Bukti dokumen realisasi kerjasama dengan Mitra dapat diunggah melalui BIMA.

Catatan:
Bagian ini wajib diisi untuk penelitian terapan, untuk penelitian dasar (Fundamental, Pascasarjana, PKDN, Dosen Pemula) boleh mengisi bagian ini (tidak wajib) jika melibatkan mitra dalam pelaksanaan penelitiannya

Penelitian ini tidak memiliki mitra.

F. **KENDALA PELAKSANAAN PENELITIAN**: Tuliskan kesulitan atau hambatan yang dihadapi selama melakukan penelitian dan mencapai luaran yang dijanjikan, termasuk penjelasan jika pelaksanaan penelitian dan luaran penelitian tidak sesuai dengan yang direncanakan atau dijanjikan.

1. Waktu yang relatif singkat antara pencairan dana dengan pelaporan dan penyusunan luaran.

2. Terdapat kendala teknis dilapangan (peralatan yang hilang/diambil) oleh orang yang tidak bertanggung jawab

4. Kendala sumberdaya di laboratorium, seperti adanya antrian dalam proses analisis sampel dengan peneliti lainnya dan terjadinya proses pemindahan laboratorium (untuk lab uji Pb-210) sehingga perlu menunggu kesiapan laboratorium tersebut untuk melakukan analisis sampel

G. **RENCANA TAHAPAN SELANJUTNYA:** Tuliskan dan uraikan rencana penelitian selanjutnya berdasarkan indikator luaran yang telah dicapai, rencana realisasi luaran wajib yang dijanjikan dan tambahan (jika ada) di tahun berikutnya serta *roadmap* penelitian keseluruhan. Pada bagian ini diperbolehkan untuk melengkapi penjelasan dari setiap tahapan dalam metoda yang akan direncanakan termasuk jadwal berkaitan dengan strategi untuk mencapai luaran seperti yang telah dijanjikan dalam proposal. Jika diperlukan, penjelasan dapat juga dilengkapi dengan gambar, tabel, diagram, serta pustaka yang relevan. Jika laporan kemajuan merupakan laporan pelaksanaan tahun terakhir, pada bagian ini dapat dituliskan rencana penyelesaian target yang belum tercapai.

Penelitian selanjutnya akan melanjutkan pengukuran laju sekuestrasi karbon di ekosistem mangrove dengan memperluas area penelitian di area mangrove Teluk Balikpapan. Upaya ini diharapkan berdampak pada peningkatan inventarisasi data untuk perhitungan baseline emisi dan potensi serapan karbon oleh ekosistem mangrove yang belum terkuantifikasi secara keseluruhan pada peraturan Provinsi Kalimantan Timur. Oleh karena itu, kerjasama penelitian dengan institusi daerah Kalimantan Timur terhadap kajian *blue carbon* menjadi penting untuk dilakukan kedepan.

H. **DAFTAR PUSTAKA:** Penyusunan Daftar Pustaka berdasarkan sistem nomor sesuai dengan urutan pengutipan. Hanya pustaka yang disitasi pada laporan kemajuan yang dicantumkan dalam Daftar Pustaka.

1. Nurdiansah D, Dharmawan IWE. Struktur Dan Kondisi Kesehatan Komunitas Mangrove Di Pulau Middleburg-Miossu, Papua Barat. Jurnal Ilmu dan Teknologi Kelautan Tropis. 2021;13(1):81–96.
2. Rovai AS, Coelho-Jr C, de Almeida R, Cunha-Lignon M, Menghini RP, Twilley RR, et al. Ecosystem-level carbon stocks and sequestration rates in mangroves in the Cananéia-Iguape lagoon estuarine system, southeastern Brazil. Forest Ecology and Management. 2021;479(August 2020).
3. Sasmito SD, Kuzyakov Y, Lubis AA, Murdiyarso D, Hutley LB, Bachri S, et al. Organic carbon burial and sources in soils of coastal mudflat and mangrove ecosystems. Catena. 2020 Apr 1;187.
4. Kusumaningtyas MA, Kepel TL, Solihuddin T, Lubis AA, Putra ADP, Sugiharto U, et al. Carbon sequestration potential in the rehabilitated mangroves in Indonesia. Ecological Research. 2022 Jan 1;37(1):80–91.

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Original paper

Simple Estimation of Carbon Sequestration Rate in Mangrove Trees Based on Litter Production Rate in the Somber River Estuary, Balikpapan, Indonesia

Keywords (in English)
tropical forest, degradation, carbon sink, anthropogenic, climate change

Abstract (in English)
Mangroves are crucial as a unique ecosystem, providing essential services such as carbon storage. This study aims to assess species composition, tree density, and canopy cover, estimate carbon sequestration based on litter production, and analyze carbon sequestration across the upstream, midstream, and downstream segments of mangrove forests along the Somber River in Balikpapan City, Indonesia. The results identified nine mangrove species in the area, with Rhizophora and Avicennia being the most prevalent genera. No distinct patterns were found in mangrove tree density or canopy cover along the river. However, a positive correlation between tree density and canopy cover was observed, suggesting that higher tree density typically leads to greater canopy cover. Mangrove litter production levels varied from 0.58 to 18.76 Mg/ha/year, with an average of 9.98 Mg/ha/year. These data were used to calculate Net Primary Productivity (NPP), which helped estimate the carbon sequestration rate of mangrove trees. The study found an average carbon sequestration rate of 50.74 Mg CO□-eq/ha/year. Carbon sequestration analysis across the river's upstream, midstream, and downstream sections showed no significant differences between these segments. Furthermore, the study confirmed that a simplified calculation based on litter production provides a reliable, fast, cost-effective, and straightforward method for estimating mangrove tree carbon sequestration.

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Simple Estimation of Carbon Sequestration Rate in Mangrove Trees Based on Litter Production Rate in the Somber River Estuary, Balikpapan, Indonesia

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ABSTRACT

Mangroves are crucial as a unique ecosystem, providing essential services such as carbon storage. This study aims to assess species composition, tree density, and canopy cover, estimate carbon sequestration based on litter production, and analyze carbon sequestration across the upstream, midstream, and downstream segments of mangrove forests along the Somber River in Balikpapan City, Indonesia. The results identified nine mangrove species in the area, with *Rhizophora* and *Avicennia* being the most prevalent genera. No distinct patterns were found in mangrove tree density or canopy cover along the river. However, a positive correlation between tree density and canopy cover was observed, suggesting that higher tree density typically leads to greater canopy cover. Mangrove litter production levels varied from 0.58 to 18.76 Mg/ha/year, with an average of 9.98 Mg/ha/year. These data were used to calculate Net Primary Productivity (NPP), which helped estimate the carbon sequestration rate of mangrove trees. The study found an average carbon sequestration rate of 50.74 Mg CO_2-eq/ha/year. Carbon sequestration analysis across the river's upstream, midstream, and downstream sections showed no significant differences between these segments. Furthermore, the study confirmed that a simplified calculation based on litter production provides a reliable, fast, cost-effective, and straightforward method for estimating mangrove tree carbon sequestration.

Keywords: tropical forest, degradation, carbon sink, anthropogenic, climate change

INTRODUCTION

Mangrove forests are distinct coastal ecosystems found in tropical and subtropical regions, characterized by salt-tolerant trees and shrubs that grow in intertidal zones. These forests are known for their resilience in saline environments, fluctuating water levels, and muddy, low-oxygen soils (Kathiresan and Bingham, 2001). They are made up of a variety of plant species, each with specialized adaptations such as aerial roots, salt-excreting leaves, and viviparous propagules for reproduction (Malik et al., 2015). Beyond their unique physical and ecological traits, mangroves play a vital role in connecting land and sea, offering key ecosystem services like coastal protection, carbon storage, and habitats for both marine and terrestrial life (Mitra, 2020). Mangrove forests are essential for coastal communities, supporting livelihoods through fisheries, timber, and non-timber products (Das et al., 2022). Southeast Asia is recognized as a global hotspot for mangroves, home to the largest and most diverse mangrove forests worldwide (Richards and Friess, 2016). The region's warm climate, extensive coastlines, and rich river deltas create ideal

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conditions for mangrove growth, with countries like Indonesia, Malaysia, Thailand, the Philippines, and Myanmar contributing significantly to global mangrove coverage.

Indonesia is home to the world's largest mangrove forest area, covering 22.6% of the global total (Giri et al., 2011). Spanning over 3 million hectares, these mangroves are mainly located along the country's extensive coastline, which stretches across thousands of islands (Kusmana, 2014). These forests are crucial to Indonesia's ecological and economic stability, offering vital ecosystem services such as coastal protection (Damastuti et al., 2023), carbon storage (Sidik et al., 2018), and habitats for a wide range of marine and terrestrial species (Suhardi et al., 2024). Rich in biodiversity, Indonesia's mangroves support numerous mangrove species and are integral to the local economy, particularly through fisheries that sustain many communities (Arifanti et al., 2022).

Mangrove forests play a crucial role in sequestering carbon, acting as one of the most efficient natural carbon sinks on Earth. These coastal ecosystems store carbon in both their biomass and the sediments beneath them, with the latter accounting for a significant portion of the total carbon stock (Alongi, 2014). Mangroves are uniquely adapted to capture and retain large amounts of organic carbon due to their dense root systems, which stabilize sediments and slow down decomposition rates under waterlogged, low-oxygen conditions (Alongi, 2014). This process prevents the release of carbon dioxide into the atmosphere, contributing to climate change mitigation. However, deforestation and degradation of mangroves can release stored carbon back into the atmosphere, underscoring the importance of conserving and restoring these vital ecosystems to maintain their carbon sequestration capacity.

Quantifying mangrove forest sequestration rates helps assess their role in reducing atmospheric carbon dioxide (CO_2), a major greenhouse gas contributing to global warming (Dinilhuda et al., 2020). Understanding these rates supports the development of carbon offset projects under mechanisms like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) (Ahmed and Glaser, 2016). Additionally, by calculating their carbon storage and sequestration capacity, the economic value of mangroves in combating climate change can be more accurately assessed. This data is vital for promoting their conservation and securing funding for restoration efforts.

Calculating carbon sequestration using standard methods requires considerable effort and resources, often preventing estimations in various global locations (Alongi, 2011). According to the standard calculation by Chen et al. (2016), the CO_2 absorption rate can be calculated using an equation involving NPP (Net Primary Production) and carbon in vegetation, where NPP is derived from the sum of annual above-ground and below-ground increments, litter production, and grazing activities by herbivorous fauna. Given this complexity, innovative methods are needed to develop simpler and more cost-effective methods for calculating carbon sequestration, enabling easier implementation by stakeholders involved in mangrove forest monitoring and restoration.

One potential effort is to simplify carbon sequestration calculations, in this case, by measuring only the litter production of mangrove vegetation and verifying the results with studies that use standard methods. When estimating NPP, this approach is feasible because the proportion of carbon flow in mangrove ecosystems has been well-documented (Alongi, 2020). This study aims to identify the species composition, tree density, and canopy cover; estimate the rate of carbon sequestration from litter production data; and analyze the rate of carbon sequestration longitudinally: upstream, midstream, and downstream segments in the mangrove forests along the Somber River in Balikpapan City, Indonesia.

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METHODOLOGY

Study location description

The research was conducted in the mangrove forest located in the estuarine waters of the Somber River, Balikpapan, East Kalimantan, Indonesia (Figure 1). The population of Balikpapan City in 2022 reached 703,611 people, with a population density of 1,500 people per square kilometer (Central Agency of Statistics, 2024). In East Kalimantan Province, Balikpapan City is the second-largest city after Samarinda. The economy of Balikpapan City is primarily supported by the oil and gas industry (Obeng-Odoom, 2024).

Balikpapan Bay plays an important role in economic activities, not only for Balikpapan City but also for East Kalimantan Province in general. This bay serves as a strategic transportation route for people and goods, connecting various industrial activities along its upstream areas. One of the rivers flowing into Balikpapan Bay is the Somber River. Despite being close to the center of Balikpapan City, the mangrove forests around this river are still relatively well-preserved to this day.

In this study, a total of nine sampling stations were distributed across the mangrove area, representing upstream, midstream, and downstream mangrove zones along the Somber River. Stations (St.) 1–3 were located in the upstream mangrove zone, St. 4–6 in the midstream mangrove zone, and St. 7–9 in the downstream mangrove zone. Field sampling was conducted in August and September 2024. The rainfall in the city of Balikpapan during those two months was categorized as moderate, ranging from 100 to 300 mm (BMKG, 2024).

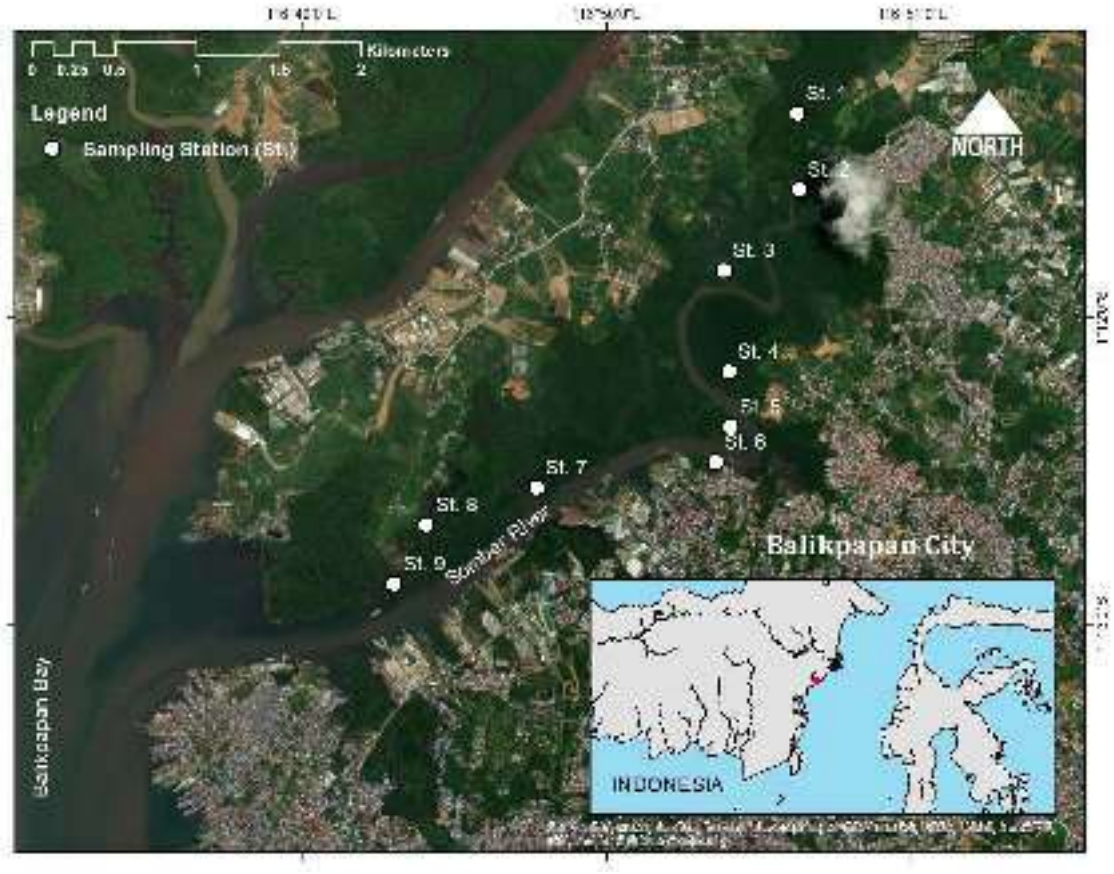


Figure 1. Map of sampling location

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Mangrove Vegetation Structure

Data on the number of mangrove individuals, tree trunk diameter, and canopy cover percentage were collected directly at each station using observation plots of 100 m². Smaller observation plots of 25 m² were used within these to specifically record small-sized trees. Tree trunk diameter was measured at breast height (DBH) or 130 cm, following a method modified by Howard et al. (2014). The DBH measurement accounted for tree stand size, categorizing trees with DBH >5 cm as tree stands and those with DBH <5 cm as saplings (Dharmawan et al., 2020).

The canopy cover data was collected using the *hemispherical photography* method with a smartphone camera (Dharmawan, 2020). This method involved taking multiple canopy photos based on variations in canopy cover distribution. The measurements of these parameters were recorded and entered into the MonMang 2.0 application on an Android smartphone, developed by the National Research and Innovation Agency of Indonesia.

Measurement of Above-Ground Biomass

DBH data was used to measure above-ground biomass. The allometric equations applied were based on the mangrove species found in the field. Biomass of *Rhizophora* and *Sonneratia* species was calculated using the allometric equation by Kauffman & Cole (2010). The allometric equation for *Ceriops tagal* was calculated using the equation developed by Clough & Scott (1989). Biomass of *Xylocarpus granatum* was calculated using the equation developed by Robertson & Alongi (1992). The equation by Dharmawan and Siregar (2008) was used for calculating the biomass of *Avicennia* species. The general allometric equation developed by Chave et al. (2005) was used for mangrove species without specific allometric equations. Wood density data used in the allometric equations for biomass calculations, based on the species identified, is presented in Table 1.

Table 1. Spesies, wood density and references

Species	Wood density (g/cm^3)	References
Rhizophora apiculata	1.05	(Simpson & Hidayat, 1994)
Rhizophora mucronata	0.83	(Howard et al., 2014)
Sonneratia alba	0.78	(Simpson & Hidayat, 1994)
Ceriops decandra	0.6	http://db.worldagroforestry.org/wd
Xylocarpus granatum	0.7	(Simpson & Hidayat, 1994)
Ceriops tagal	0.85	(Howard et al., 2014)

Mangrove Litter Production

Three litter traps were installed at each observation station to measure the litter production rate, following the method described by Sugiana et al. (2024). The litter traps used measured 1x1 m with a mesh size of 1 mm (Lin et al., 2023; Sugiana et al., 2024). These traps were placed 1.5 m above the ground to avoid being submerged during the highest tides (Rovai et al., 2021).

Litter captured in the traps was collected every two weeks, with three replications. The harvested litter was then separated into three components: leaves, twigs, and reproductive organs such as flowers and fruits. The samples were oven-dried at 60°C until they reached a stable dry weight. The litter production rate was calculated by dividing the dry weight of the litter by the area and the time interval between collections.

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Carbon Sequestration Rate of Trees

The carbon sequestration rate of mangrove biomass was calculated based on the net primary productivity (NPP) of mangroves (Equation 1). The equation used was as follows (Chen et al., 2016):

$$C_{seq} = NPP \times C \times 44/12 \quad (1)$$

Where:

C_{seq} : Carbon sequestration rate of biomass (Mg CO_2-eq/ha/year)
NPP : Net primary productivity of mangroves (Mg/ha/year)
C : Organic carbon concentration (%)
$44/12$: Conversion factor from C to CO_2

NPP was estimated using litter production, assuming that one-third of mangrove NPP returns as litterfall (Chen et al., 2016). Carbon allocation in mangrove ecosystems modeled by Alongi (2020) showed that 25.69% of NPP is distributed as litter production. Therefore, 25.69% was used to convert litter production rates into mangrove NPP values. The organic carbon concentration of litter (C) was calculated using a biomass-to-carbon conversion factor of 0.45 (Kauffman & Donato, 2012).

The differences in average carbon sequestration rates across longitudinal segments were analyzed using a one-way ANOVA, performed with Stata software (version 15.1) (Stata Statistical Software, 2017). F and *p-values* were calculated to assess whether there were significant differences in the average carbon sequestration rates among the observation segments.

RESULTS AND DISCUSSION

Mangrove species composition, tree density, and canopy cover

The mangrove species, composition, density, and percentage of canopy cover along the Somber River are presented in Table 2. In general, the identification results show that there are nine species of mangrove plants in the study area, including *Rhizophora apiculata, Rhizophora mucronata, Avicennia officinalis, Avicennia marina, Avicennia lanata, Sonneratia alba, Xylocarpus granatum, Ceriops decandra*, and *Ceriops tagal*. All of these mangrove species identified in this study were also documented by Poedjirahajoe et al. (2019) in the mangrove forests of Kutai National Park, East Kalimantan, Indonesia.

Table 2. Mangrove species, composition, tree density, and canopy cover

Station	Spesies	Species Composition (%)	Density (ind./ha)	Canopy cover (%)
St. 1	*Rhizophora apiculata*	83.3	1200	83.02
	Xylocarpus granatum	16.7		
St. 2	*Ceriops decandra*	80.0	2500	90.59
	Rhizophora apiculata	20.0		
St. 3	*Rhizophora apiculata*	100.0	200	12.01
St. 4	*Rhizophora apiculata*	52.2	2300	91.11
	Ceriops tagal	21.7		
	Avicennia officinalis	17.4		

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	Avicennia marina	8.7		
St. 5	*Rhizophora mucronata* *Rhizophora apiculata* *Avicennia marina*	56.3 31.3 12.5	1600	75.24
St. 6	*Rhizophora mucronata* *Sonneratia alba*	85.7 14.3	700	30.75
St. 7	*Rhizophora apiculata*	100.0	1800	90.93
St. 8	*Sonneratia alba* *Avicennia lanata* *Avicennia marina* *Rhizophora mucronata*	72.0 12.0 8.0 8.0	2500	69.10
St. 9	*Sonneratia alba* *Avicennia marina*	75.0 25.0	800	18.78
Average			1511	62.39

The genus *Rhizophora* is the most frequently encountered genus. Its dominance was similarly reported by Kristiningrum et al. (2019) during their study of mangrove forests in Mentawir Village, situated upstream of Balikpapan Bay near this study site. Among the nine observation stations, *Rhizophora* was absent only at Station 9. Within this genus, *R. apiculata* emerged as the most dominant species, comprising 100% of the composition at Stations 3 and 7. The genus *Avicennia* is the second most frequently encountered, particularly at Stations 4, 5, 8, and 9, where three species: *A. officinalis, A. marina,* and *A. lanata* were recorded. A smaller proportion of mangrove species found include *Ceriops decandra, Ceriops tagal, and Xylocarpus granatum.*

Based on the mangrove plant density, there is variation in density across the nine observation sites. The highest density was found at Stations 2 and 5, reaching 2500 individuals/ha, followed by density at Stations 4 and 7. Station 3 had the lowest mangrove plant density at 200 individuals/ha. The average density of mangrove trees in the mangrove forest along the Somber River is 1,511 individuals/ha. As a comparison, the mangrove density in Kutai National Park is around 1,200 individuals/ha (Poedjirahajoe et al., 2019). This indicates that the findings of mangrove tree density in this study align with previous research. Regarding canopy cover, Stations 2, 4, and 7 exhibited the highest percentages, each exceeding 90%, followed by Stations 1, 5, and 6 in descending order. Station 3 recorded the lowest canopy cover, with only 12%. The average percentage of canopy cover calculated overall is 62.39%.

The density of mangrove trees and canopy cover in mangrove forests is influenced by a range of interconnected environmental, ecological, and human factors. Abiotic factors such as salinity (Ahmed et al., 2022), soil type and nutrient availability (Alongi, 2018), hydrology (Alongi and Brinkman, 2011), light availability (Chen et al., 2013), and climate characteristics (Lovelock et al., 2016) all play a role in determining mangrove tree density. Biotic factors, including species interactions, seedling recruitment and survival, disease, and grazing by mangrove fauna, can have both positive and negative impacts (Robertson, 1991). Human pressures such as deforestation (Nordhaus et al., 2019), land-use changes (Sasmito et al., 2019), pollution (Manullang, 2020), and natural disturbances (Imbert, 2018) may reduce mangrove tree density.

The relationship between mangrove tree density and canopy cover along the Somber River is shown in Figure 2, where the linear regression results indicate a coefficient of

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determination ($R^2 = 0.7$). Higher tree density typically leads to a greater number of trees contributing to the canopy, thus increasing canopy cover. The ANOVA results for this regression show a significant positive relationship between density and mangrove canopy cover (*p-value* = 0.0052).

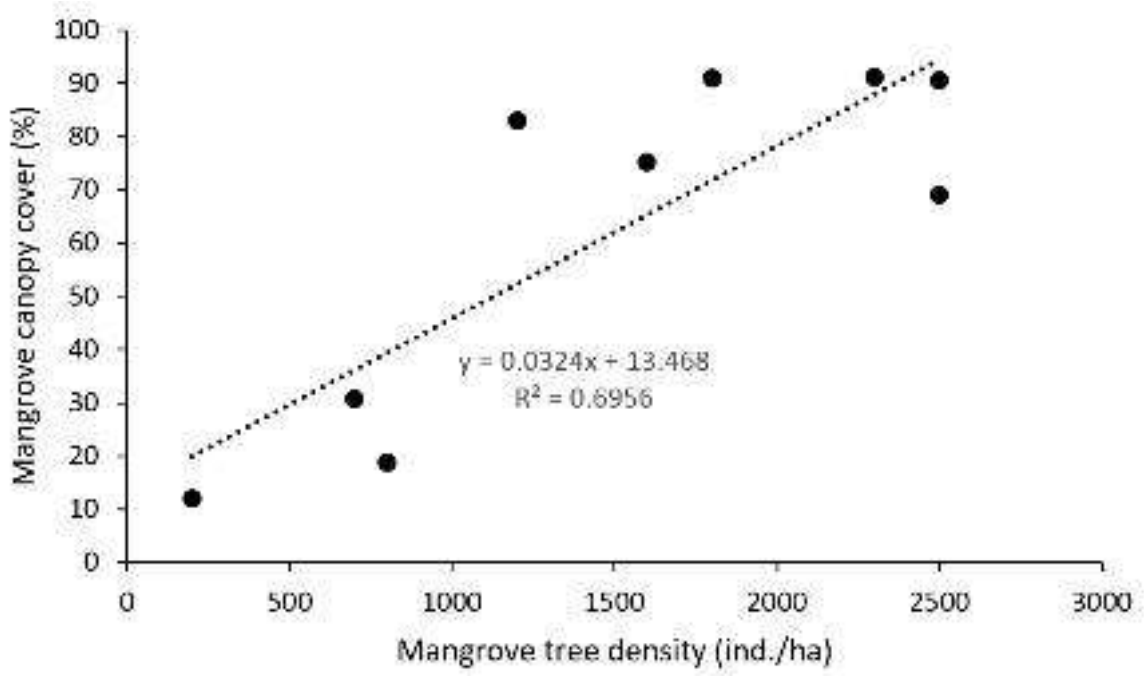


Figure 2. Relationship between mangrove tree density and canopy cover

The relationship between mangrove tree density and canopy cover is generally positive, meaning that an increase in tree density typically results in a larger canopy cover (Sraun et al., 2022). However, this relationship is affected by several factors, such as competition. In areas with high tree density, trees compete for resources like light, soil, and nutrients (Reef et al., 2010), which can slow growth rates and limit canopy expansion, despite the high density. On the other hand, in areas with lower tree density, the availability of resources may be greater, allowing for better canopy development (Sraun et al., 2022).

Mangrove litter production rate

The measurement results of mangrove litter production levels in the Somber River showed variations ranging from 0.58 to 18.76 Mg/ha/year (Table 3). The lowest litter production occurred at observation site St. 3, where the area is exclusively dominated by *Rhizophora apiculata*, with a mangrove density of 200 individuals/ha and a canopy cover percentage of only 12%. However, the highest litter production did not occur in the observation sites with the highest mangrove density and canopy cover (St. 1 and St. 8), but rather at an observation site with moderate density and canopy cover (St. 5). This is suspected to be due to the low productivity of mangrove seedlings and young stands in high-density areas caused by limited sunlight availability in the zone beneath the canopy of older stands. This trend aligns with findings reported by Kamruzzaman et al. (2019).

Several factors have been reported to potentially influence mangrove litter production, including species composition, tidal dynamics, weather/climate conditions, soil conditions, and nutrient availability. Each mangrove species has a different litter production rate (Woodroffe, 1982). Tidal dynamics in marine waters also have the

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potential to affect mangrove litter production (Sukardjo et al., 2013). Tides act as a natural conveyor, transporting mangrove litter (leaves, twigs, fruits, and flowers) into adjacent aquatic environments. High tides carry litter into estuaries and coastal areas, contributing to nutrient transfer and supporting detritus-based food webs (Martin et al., 2019). Similarly, soil conditions and nutrient availability have been reported to influence mangrove litter production (Keuskamp et al., 2015).

Table 3. Litter production rate, net primary productivity, and estimated carbon sequestration per stream segment and station

Stream's longitudinal segment	Station	Litter production rate (Mg/ha/y)	Net Primary Productivity (Mg/ha/y)	Carbon sequestration (Mg CO_2-eq/ha/y)
Upstream	St. 1	13.98	43.06	71.05
	St. 2	8.88	27.36	45.14
	St. 3	0.58	1.78	2.93
Midstream	St. 4	10.42	32.10	52.97
	St. 5	18.76	57.79	95.35
	St. 6	5.29	16.28	26.87
Downstream	St. 7	8.53	26.27	43.35
	St. 8	16.37	50.43	83.20
	St. 9	7.04	21.70	35.80
Average		9.98	30.75	50.74

The data on mangrove litter production rates were then used to calculate NPP, which was subsequently utilized to estimate the carbon sequestration rate of mangrove trees. The average estimated carbon sequestration value for mangrove trees in this study was 50.74 Mg CO_2-eq/ha/year. This average estimation is nearly equivalent to the value reported by Sidik et al. (2019) for natural mangrove forests in Bali, Indonesia, which was 56.83 Mg CO_2-eq/ha/year. The latter calculation was more comprehensive as it included growth increments in stems and roots, as well as mangrove litter, to determine NPP. In contrast, this study's NPP calculation relied solely on litter production data to estimate mangrove tree carbon sequestration.

This consistency in results demonstrates that using a simplified calculation based on litter production is sufficiently reliable as a rapid and straightforward preliminary approach to estimating mangrove tree carbon sequestration. In practice, standard carbon sequestration calculations require significant effort and resources, often posing a barrier to carbon sequestration estimation in various locations worldwide (Alongi, 2011).

Carbon trade/payment schemes, such as PES (Payment for Ecosystem Services) or REDD+ (Reducing Emissions from Deforestation and Forest Degradation), heavily depend on sequestration rate calculations rather than carbon stock amounts (Alongi, 2011). The success of these schemes relies on the availability of methods for ecosystem service valuation that are simple, low-cost, and accurate. In this regard, the simplified approach used in this study offers an easy-to-implement and cost-effective option for estimating ecosystem service values, particularly carbon sequestration, as part of climate change mitigation efforts (Sidik et al., 2018).

Longitudinal segmented carbon sequestration

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The results of the ANOVA test on the relationship of carbon sequestration across the upstream, midstream, and downstream segments along the Somber River indicate no significant differences between these segments ($F < F_{crit}$, $P\text{-}value = 0.76$). Field observations indicate that mangrove forest degradation along the Somber River occurs sporadically. This degradation is primarily driven by land-use changes influenced by the practices of landowners or managers. Human activities such as land clearing for fishponds, ports, shipyards, and tourism contribute significantly to the fragmentation of these mangrove forests, with impacts observed relatively evenly across the upstream, midstream, and downstream segments of the river.

On the other hand, the location of the Somber River, which intersects with Balikpapan City Center, makes these mangrove forests increasingly vulnerable to land-use conversion, especially given Balikpapan's position as the main gateway to Nusantara City, Indonesia's new capital city, replacing Jakarta. For example, the biodiversity preserved in the mangrove forests along the Somber River attracts tourists to visit and observe the mangrove forest and its wildlife. One of the animals frequently encountered in these mangroves is the proboscis monkey (*Nasalis larvatus*). This tourism potential encourages communities (investors) to establish resorts along the Somber River, contributing to mangrove forest conversion alongside other land conversion activities.

Efforts from policymakers and the community in Balikpapan City are necessary to preserve the mangrove forests along the Somber River. Proper management of these forests is essential to ensure that future utilization not only provides economic benefits to the community but also continues to offer ecological services and maintain their function as carbon sinks in continuous global warming mitigation efforts.

CONCLUSIONS

The identification results reveal the presence of nine mangrove plant species in the study area, namely *Rhizophora apiculata*, *Rhizophora mucronata*, *Avicennia officinalis*, *Avicennia marina*, *Avicennia lanata*, *Sonneratia alba*, *Xylocarpus granatum*, *Ceriops decandra*, and *Ceriops tagal*. The genus Rhizophora and Avicennia is the most commonly found genus. No pattern was found in the density levels and canopy cover of mangrove trees along the Somber River from upstream to downstream. There is a positive relationship between mangrove tree density and canopy cover, indicating that higher tree density generally leads to greater canopy cover.

The measurement results of mangrove litter production levels in the Somber River showed variations ranging from 0.58 to 18.76 Mg/ha/year, with an average of 9.98 Mg/ha/year. Mangrove litter production data were utilized to calculate Net Primary Productivity (NPP), which was then used to estimate the carbon sequestration rate of mangrove trees. The study estimated an average carbon sequestration rate of 50.74 Mg CO_2-eq/ha/year for mangrove trees. The analysis of carbon sequestration along the upstream, midstream, and downstream segments of the Somber River revealed no significant differences between these segments.

The study also demonstrated that using a simplified calculation based on litter production is a reliable, rapid, cost-effective, and straightforward preliminary method for estimating mangrove tree carbon sequestration.

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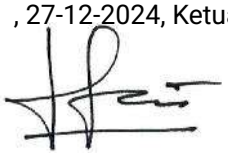
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Research Article

Structure of Mangrove Forest and Carbon Sequestration Potential in the Estuarine Region of the Somber River, Balikpapan Bay, Indonesia: A Preliminary Assessment

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Abstract

Mangroves are included in East Kalimantan's emission reduction programs, but carbon absorption data remain lacking due to limited studies. In Balikpapan Bay, particularly around the Somber River estuary, information on carbon accumulation rates is still limited. This study aimed to document the species composition, tree density, diameter at breast height (DBH), and canopy cover of mangrove forests, estimate their carbon sequestration capacity, and compare sequestration rates across the upstream, midstream, and downstream sections of the Somber River in Balikpapan City, Indonesia. Nine sampling stations were established along the river to represent each segment. At each, mangrove species were identified, tree density and canopy cover measured, and litterfall collected. Carbon sequestration was then estimated from litterfall-based Net Primary Productivity (NPP). Nine species were recorded, dominated by *Rhizophora* and *Avicennia*. The forest averaged 1,444 trees/ha, DBH of 13.3 cm, and 62.04% canopy cover. Midstream sites showed the highest density (1,533 trees/ha) and canopy cover (65.7%), though not in DBH. Litterfall averaged 9.28 Mg/ha/year (0.58–18.76), corresponding to 47.25 Mg CO_2-eq/ha/year, peaking midstream. Sequestration rates did not differ significantly among segments but correlated strongly with canopy cover, density, and DBH. This study provides initial estimates of mangrove carbon uptake in the Somber River estuary near the Kariangau industrial area, offering insights for management strategies to enhance blue carbon storage, provides externally relevant estimates, and a structure-to-sequestration linkage that can guide restoration targets, carbon accounting, and coastal policy in working estuaries. Further research should quantify sediment carbon accumulation and consider species-specific differences to better inform restoration efforts.

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1. Introduction

Southeast Asia is recognized as a global hotspot for mangroves, home to the largest and most diverse mangrove forests worldwide (Richards and Friess, 2016). The region's warm climate, extensive coastlines, and rich river deltas create ideal conditions for mangrove growth, with countries like Indonesia, Malaysia, Thailand, the Philippines, and Myanmar contributing significantly to global mangrove coverage. Indonesia is home to the world's largest mangrove forest area, covering 22.6% of the global total (Giri *et al*., 2011). Spanning over 3 million hectares, these mangroves are mainly located along the country's extensive coastline, which stretches across thousands of islands (Kusmana, 2014). These forests are crucial to Indonesia's ecological and economic stability, offering vital ecosystem services such as coastal protection (Damastuti *et al*., 2023), carbon storage (Murdiyarso *et al*., 2015; Alongi *et al*., 2016; Stankovic *et al*., 2023), and habitats for a wide range of marine and terrestrial species (Suhardi *et al*., 2024). Rich in biodiversity, Indonesia's mangroves support numerous mangrove species and are integral to the local economy, particularly through fisheries that sustain many communities (Arifanti *et al*., 2022).

Understanding the species composition, diameter at breast height (DBH), density, and canopy cover of mangrove forests is essential for conserving biodiversity (Huxham *et al*., 2004), maintaining ecosystem services (Friess, 2016), and supporting climate resilience (Alongi, 2008). Species composition reveals the ecological balance and health of mangrove ecosystems, as different species provide unique habitats and resources for a wide array of marine and terrestrial organisms (Nagelkerken *et al*., 2008). Larger mangrove trees, indicated by higher DBH values, potentially provide more complex habitat structures, including more extensive root systems and denser canopies (Aye *et al*., 2022).

Mangrove density influences soil stabilization, nutrient cycling, and the capacity of mangroves to act as nurseries for commercially valuable species, directly supporting fisheries and local livelihoods (Karimi *et al*., 2022). Canopy cover is a critical indicator of forest health, affecting carbon sequestration potential and the ability to shield coastal areas from extreme weather events (Schaduw *et al*., 2024). Together, these parameters provide insights into the functionality and sustainability of mangroves, guiding conservation efforts, restoration projects, and sustainable management practices to protect these vital coastal ecosystems.

The mangrove ecosystem has a high capacity to absorb and store carbon, making it a natural solution for climate change mitigation (Adame *et al*., 2021; Alongi, 2020; Stankovic *et al*., 2023). This capability makes mangroves highly suitable to be included in climate change mitigation policies (Howard *et al*., 2017; Taillardat *et al*., 2018). Quantifying mangrove forest sequestration rates helps assess their role in reducing atmospheric carbon dioxide (CO_2), a major greenhouse gas contributing to global warming (Dinilhuda *et al*., 2020).

The process of carbon accumulation in mangroves occurs in both the tree biomass and the soil (Alongi, 2012; McLeod *et al*., 2011). Based on recent research findings, the carbon sequestration rate in trees contributes more (>50%) compared to the sequestration rate in sediments (Kandasamy *et al*., 2021; Rovai *et al*., 2021; Sugiana *et al*., 2024). The carbon sequestration rate in mangrove trees is influenced by the structure of the mangrove vegetation (Kandasamy *et al*., 2021; Kathiresan *et al*., 2013) and the age of the trees (Suprayogi *et al*., 2022) 4, 6, 8, 10, 12 and 30-year restored mangroves were studied through non-destructive method by measuring their stem diameter and tree height. Two allometric references: (a. In addition, data on mangrove carbon sequestration rates represent a critical parameter in the context of national greenhouse gas inventories. Such data are essential when considering the integration of blue carbon ecosystems into strategies aimed at achieving national climate change mitigation targets (Howard *et al*., 2017; Taillardat *et al*., 2018).

Measurement of carbon sequestration rates in mangrove trees has been conducted in mangrove areas in Bali Province, specifically in Benoa Bay (Sugiana *et al*., 2024) and Perancak (Sidik *et al*., 2019), with average rates of 18.9 MgC/ha/year and 16.4 MgC/ha/year, respectively. Meanwhile, measurements of carbon sequestration rates in mangrove ecosystems in East Kalimantan Province, which has the fourth-largest dense mangrove area in Indonesia have so far been carried out in the mangrove area of Tanjung Batu, Berau (in sediment; Kusumaningtyas *et al*., 2019). Although mangrove ecosystems have been included in emission reduction programs at the provincial level in East Kalimantan, carbon absorption factor data have not yet been incorporated due to limited data availability (World Bank, 2019).

Although recent work around Balikpapan Bay has mapped mangrove conditions, it remains unclear how forest structure translates into tree-level carbon sequestration across the Somber River's upstream and downstream gradient, because prior studies emphasized mapping or genus-level stock comparisons with limited replication. The mangrove location in this area is important to monitor as it is situated near industrial activities and the development of Balikpapan City (Anwar *et al*., 2021), including the Nusantara Capital City, which has been designated as the new capital of Indonesia. Recent research around the Somber River mangrove area

has mostly been limited to mapping mangrove density and condition (Anwar *et al*., 2021; Pratama, 2018). The study of carbon sequestration in the mangrove area of the Somber River has thus far been limited to comparisons of carbon stocks between the genera *Rhizophora* and *Avicennia* (Paputungan *et al*., 2025). Therefore, the present study was undertaken to analyze the carbon sequestration rate of mangrove trees in this area. The results of this study will fill a gap in the greenhouse gas absorption inventory data for mangrove areas in East Kalimantan Province, particularly in the Somber River mangrove region of Balikpapan Bay. The availability of data on carbon stocks and carbon sequestration rates is essential for estimating the potential of carbon emissions and uptake (Rovai *et al*., 2021). Moreover, understanding these rates is crucial for supporting the development of carbon offset initiatives under mechanisms such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) (Ahmed and Glaser, 2016).

This study aims to identify mangrove species, density, diameter at breast height, and canopy cover, and examine their relationship with estimated carbon sequestration rates. Additionally, it analyzes the carbon sequestration rates across different segments (upstream, midstream, and downstream) and different aquatic fishery resources of the mangrove forests along the Somber River in Balikpapan City, Indonesia.

2. Materials and Methods

The research was conducted in the mangrove forest located in the estuarine waters of the Somber River, Balikpapan, East Kalimantan, Indonesia (Figure 1). The mangrove stands in this location are dense in some areas but degraded along parts of the Somber River estuary (Anwar *et al*., 2021). Anthropogenic activities in the vicinity include port operations, shipyards, and docking facilities (Syafira *et al*., 2023). This study involved nine sampling stations strategically distributed throughout the mangrove area to represent the upstream, midstream, and downstream segments of the Somber River estuary. The spatial distribution of stations or plots within each segment was determined using a stratified random sampling method based on the condition of mangrove stands observed in the field. Stations 1–3 were located in the upstream segment, Stations 4–6 in the midstream, and Stations 7–9 in the downstream segment. Within each segment, the stations represented a gradient of mangrove stand density, ranging from dense to sparse stands (Figure 2). Additional information obtained from the management of the Mangrove Center Graha Indah Balikpapan indicated that Station 3 was located in a former aquaculture pond, Stations 6 and 8 were situated in degraded mangrove areas, while Stations 1, 2, 4, 7, and 9 were in relatively undisturbed natural mangroves, each with varying species compositions (Figure 2). Field sampling was conducted in August and September 2024, during which Balikpapan experienced moderate rainfall, ranging between 100 mm and 300 mm (Meteorology Climatology and Geophysical Agency, 2024).

2.1 Materials

2.1.1 The equipment

Data on mangrove species, the number of individuals per plot, DBH, and canopy cover percentage were collected directly at each station using 100 m² observation plots delineated by rope. Within these, smaller 25 m² subplots were used to record small-sized trees. Species occurring in each plot were identified and taxonomically classified in accordance with the guidelines of Noor (1999).

2.1.2 The materials

The materials used in this study are biotic and abiotic aquatic resources, namely mangrove forest and fishery resources (crustaceans, mollusks, and fish) along the Somber River in Balikpapan.

2.1.3 Ethical approval

This study does not require ethical approval because it does not use experimental animals.

2.2 Methods

The DBH of trees was measured based on trunk circumference at 130 cm above ground level (Figure 3A), following the method described by Howard *et al.* (2014). Canopy cover data were obtained using the hemispherical photography method with a smartphone camera having a resolution exceeding 3 megapixels (Dharmawan, 2020; Sugiana *et al*., 2024). A total of nine canopy photographs were taken from a height equivalent to one-third of the mangrove stand height within each 100 m² plot, with each photograph representing a different side of the plot (Figure 3B). Measurements from these photographs were processed and analyzed using the MonMang 2.0 application on an Android smartphone (Dharmawan *et al*., 2022; Sugiana *et al*., 2024), developed by the National Research and Innovation Agency of Indonesia. The species composition and abundance of fishery resources were assessed using a cast net and by deploying five traps along the riverbank at each sampling station.

At each observation station, three litterfall traps were set up following the approach outlined by Sugiana *et al.* (2024) (Figure 3C). These traps consisted of 1x1 m nets with a mesh size of 1 mm (Lin *et al*., 2023; Sugiana *et al*., 2024). These traps were placed about 2 m above the ground to avoid being submerged during

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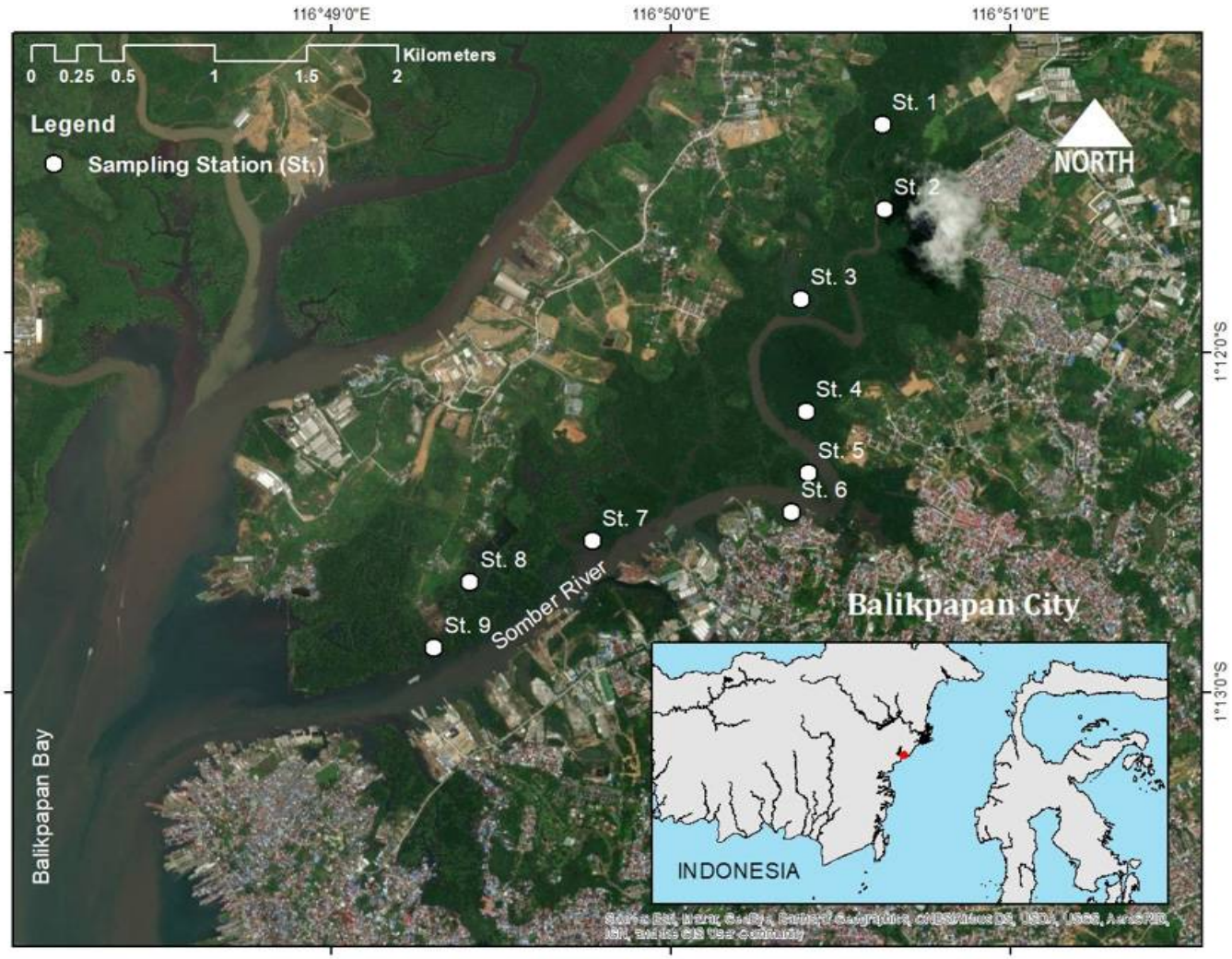


Figure 1. Map of sampling location.

the highest tides (Rovai *et al*., 2021). No differences in litterfall sampling methods were applied among the various species encountered in the field.

Litterfall captured in the traps was collected biweekly, with three replications per collection (Sugiana *et al*., 2024). The collected material was sorted into three categories: leaves, twigs, and reproductive organs (flowers and fruits). The samples were then oven-dried at 60°C until a constant dry weight was achieved. The litter production rate was determined by dividing the dry weight of the litter by the trap area and the collection time interval.

Species composition and abundance of fishery biota were assessed using a cast net deployed five times (Stein III *et al.,* 2014) and five traps set for 24 hours (Ambrose and Isangedighi, 2016) along the riverbank adjacent to each sampling station.

2.3 Analysis Data

The carbon sequestration rate of mangrove biomass was calculated based on the net primary productivity (NPP) of mangroves (Equation 1). The equation used was as follows (Chen *et al*., 2016):

$$C_{seq} = NPP \times C \times 44 / 12 \quad \text{.....(i)}$$

Where :

C_{seq} = Carbon sequestration rate of biomass (Mg CO_2-eq/ha/year)

NPP = Net primary productivity of mangroves (Mg/ha/year)

C = Organic carbon concentration (%)

44 / 12 = Conversion factor from C to CO_2

NPP was estimated using litter production, assuming that one-third of mangrove NPP returns as litterfall (Chen *et al*., 2016). Carbon allocation in mangrove ecosystems modeled by Alongi (2020) showed that 32.46% of NPP is distributed as litter production. Therefore, 25.69% was used to convert litter production rates into mangrove NPP values. The organic carbon concentration of litterfall (C) was calculated using a biomass-to-carbon conversion factor of 0.45 (Kauffman

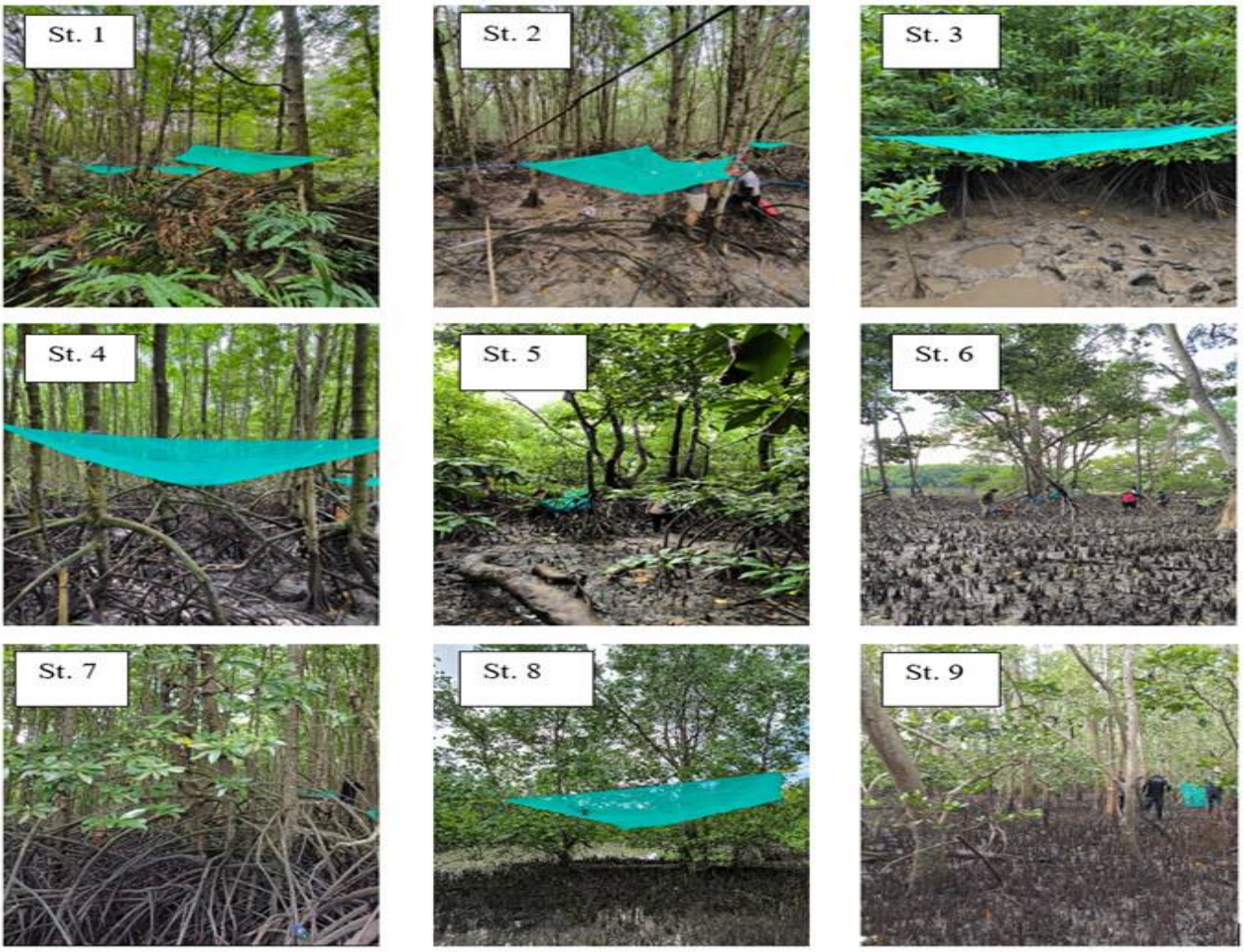


Figure 2. The condition of mangroves at each observation station.

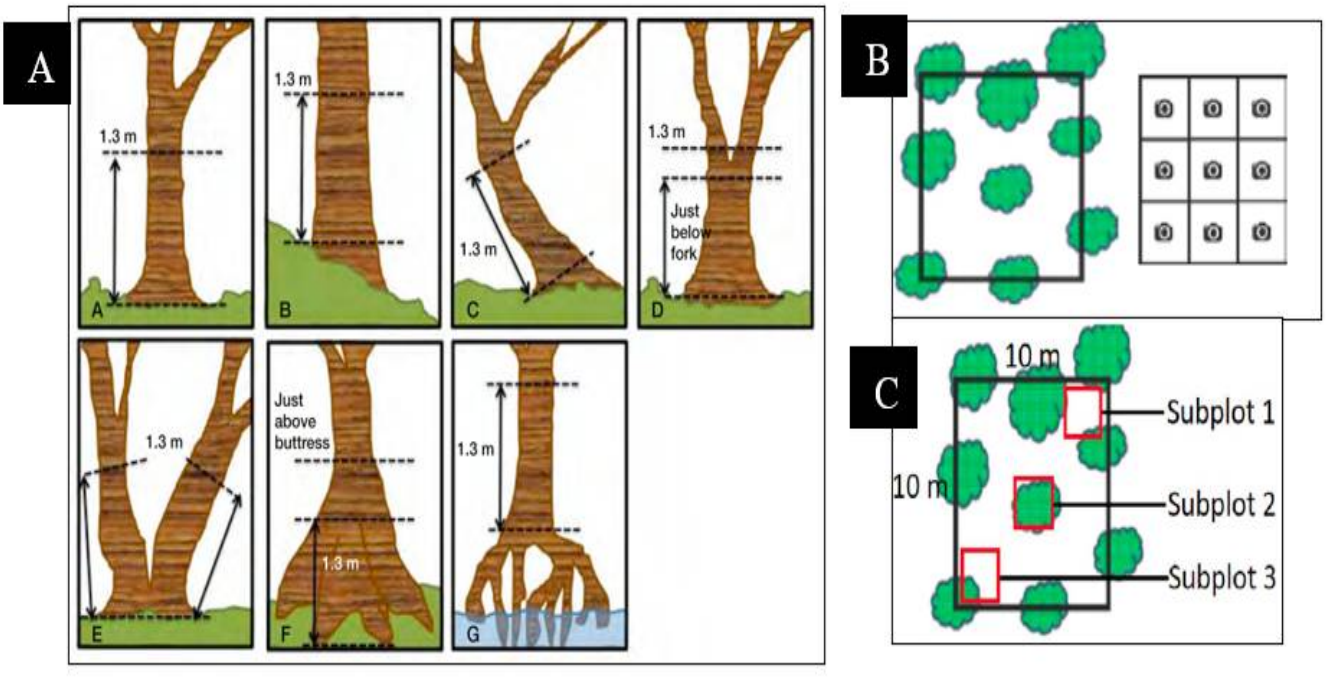


Figure 3. (A) Illustration of DBH measurement (modified from Howard *et al.,* 2014), (B) measurement of canopy cover percentage (modified from Dharmawan, 2020), and (C) placement of litter traps (modified from Sugiana *et al.,* 2024).

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and Donato, 2012).

The differences in average carbon sequestration rates across longitudinal segments were analyzed using a one-way ANOVA, performed with Stata software (version 15.1) (Stata Statistical Software, 2017). F and *p-values* were calculated to assess whether there were significant differences in the average carbon sequestration rates among the observation segments.

Data on the diversity of fishery resources were described descriptively by examining the variations observed at each station.

3. Results and Discussion

3.1 Results

3.1.1 Mangrove forest structure and fishery resources

The mangrove species, composition, density, DBH, and percentage of canopy cover along the Somber River are presented in Table 1. In general, the identification results show that there are nine species of mangrove plants in the study area, including *Rhizophora apiculata, Rhizophora mucronata, Avicennia officinalis, Avicennia marina, Avicennia lanata, Sonneratia alba, Xylocarpus granatum, Ceriops decandra*, and *Ceriops tagal*. *Rhizophora* was recorded at all observation stations except St. 9, with *R. apiculata* being the most dominant species, occurring across all segments of the river. As shown in Table 1, *R. apiculata* was more abundant in interior mangrove zones (midstream to upstream), while in downstream areas it was only present at St. 7.

Table 1. Mangrove forest structure, litterfall production rate and plant carbon sequestration rate

Stream Segment	Station	Species	Species Composition (%)	Tree Density (ind./ha)	DBH Average (cm)	Average of Canopy Cover (%)	Litterfall production rate (Mg/ha/y)	Plant Carbon sequestration rate (Mg CO^2-eq/ha/year)
Upstream	St. 1	*Rhizophora apiculata*	83.3	1200	15.7	79.82	13.98	71.05
		Xylocarpus granatum	16.7					
	St. 2	*Ceriops decandra*	80.0	2500	12.5	90.59	8.88	45.14
		Rhizophora apiculata	20.0					
	St. 3	*Rhizophora apiculata*	100.0	200	4.1	12.01	0.58	2.93
	St. 4	*Rhizophora apiculata*	52.2	2300	12.4	91.11	10.42	52.97
		Ceriops tagal	21.7					
		Avicennia officinalis	17.4					
		Avicennia marina	8.7					
Mid-stream	St. 5	*Rhizophora mucronata*	56.3	1600	10.6	75.24	18.76	95.35
		Rhizophora apiculata	31.3					
		Avicennia marina	12.5					
	St. 6	*Rhizophora mucronata*	85.7	700	16.3	30.75	5.29	27.49
		Sonneratia alba	14.3					
	St. 7	*Rhizophora apiculata*	100.0	1800	15.2	90.93	8.79	44.67
Down-stream	St. 8	*Sonneratia alba*	75.0	800	15.8	18.78	7.55	38.36
		Avicennia marina	25.0					
	St. 9	*Sonneratia alba*	63.2	1900	17.0	69.10	N/A	N/A
		Avicennia lanata	15.8					
		Avicennia marina	10.5					
		Rhizophora mucronata	10.5					
		Average		1444	13.3	62.04	9.28	47.25

Mangrove density varied across the nine observation sites, with the highest values recorded at St. 2 and 4 (>2000 ind./ha), followed by St. 9, 7, and 5. According to the criteria for mangrove condition outlined in the Decree of the State Minister for the Environment of the Republic of Indonesia No. 201 of 2004, these stations are categorized as being in good to very good condition, as tree density exceeds 1,500 ind./ha. The lowest density was found at St. 3 (200 ind./ha), a former fishpond area dominated by smaller trees, as reflected in the average DBH values (Table 1). According to Table 1 and Figure 5b, the average canopy cover percentage in the downstream segment is the lowest (59.60%) compared to the upstream (60.81%) and midstream segments (65.70%).

The variation of species and the number of fishery resources individuals recorded across sampling stations along the Somber River mangrove area shows clear differences in community composition and abundance (Table 3). At St. 1, only two species were observed, namely *Metapenaeus ensis* (6 individuals) and *Leiognathus equulus* (2 individuals), indicating relatively low diversity. In contrast, stations 2 and 3 exhibited higher species richness, with St. 2 hosting four species, including *Penaeus merguiensis* and *Scylla tranquebarica*, while St. 3 recorded the highest diversity with six species, notably bivalves such as *Anadara granosa* (5 individuals) and *Pilsbryoconcha exilis* (7 individuals) in addition to shrimp and crabs. Stations 4 and 5 also sup

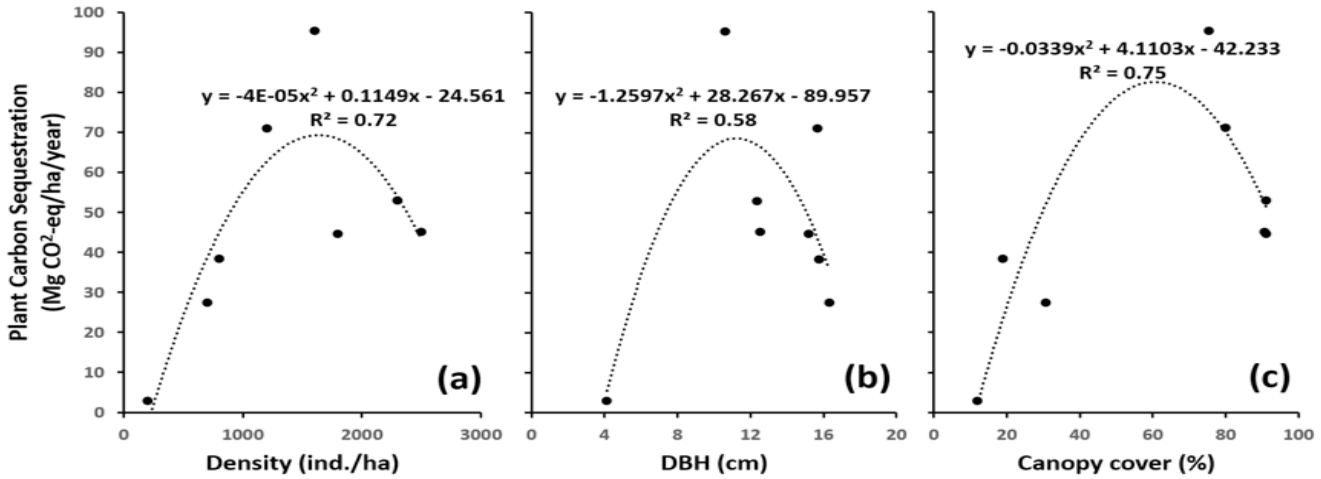


Figure 5. Relationships between plant carbon sequestration and mangrove vegetation structural attributes: Tree density (a), Diameter at breast height (b), and Canopy cover (c).

Table 2. Comparison of mangrove carbon sequestration rates across different locations

Location	Carbon sequestration ($MgCO_2$-eq/ha/year)	Reference
Somber River Estuary, East Kalimantan - Indonesia	47.25	This Study
Benoa Bay, Bali - Indonesia		(Sugiana *et al*., 2024)
Bruguiere zone	55.78	
Rhizophora zone	59.09	
Sonneratia zone	60.55	
Perancak estuary, Bali - Indonesia		(Sidik *et al*., 2019)
Natural mangrove	60.92	
Restored mangrove	59.45	
Northern Sumatra Coast - Indonesia	29.5 - 55.1	(Suprayogi *et al*., 2022)
Jiulong River Estuary - China	59.30	(Chen *et al*., 2016)
Vellar-Coleroon estuarine, Bengal Bay - India	3.60	(Kandasamy *et al*., 2021)
Cananéia-Iguape lagoon estuarine - Brazil	17.03	(Rovai *et al*., 2021)

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Table 3. Recorded fishery resource species at each station

Station	Species	Local name	Number of individuals
St. 1	*Metapenaeus ensis*	udang dogol/endeavour shrimp	6
	Leiognathus equulus	bete-bete/slipmouth	2
St. 2	*Metapenaeus ensis*	udang dogol/endeavour shrimp	3
	Leiognathus equulus	bete-bete/slipmouth	5
	Penaeus merguiensis	udang putih/banana prawn	7
	Scylla tranquebarica	kepiting bakau/purple mud crab	1
St. 3	*Metapenaeus ensis*	udang dogol/endeavour shrimp	4
	Leiognathus equulus	bete-bete/slipmouth	2
	Penaeus merguiensis	udang putih/banana prawn	6
	Scylla tranquebarica	kepiting bakau/purple mud crab	3
	Anadara granosa	kerang dara/blood cockle	5
	Pilsbryoconcha exilis	kijing/tropical swan mussel	7
St. 4	*Metapenaeus ensis*	udang dogol/endeavour shrimp	1
	Leiognathus equulus	bete-bete/slipmouth	6
	Penaeus merguiensis	udang putih/banana prawn	4
	Scylla tranquebarica	kepiting bakau/purple mud crab	2
St. 5	*Metapenaeus ensis*	udang dogol/endeavour shrimp	7
	Leiognathus equulus	bete-bete/slipmouth	3
	Lutjanus argentimaculatus	kakap merah/mangrove red snapper	5
	Penaeus merguiensis	udang putih/banana prawn	2
	Scylla tranquebarica	kepiting bakau/purple mud crab	6
St. 6	*Lutjanus argentimaculatus*	kakap merah/mangrove red snapper	1
	Leiognathus equulus	bete-bete/slipmouth	4
St. 7	*Lutjanus argentimaculatus*	kakap merah/mangrove red snapper	5
	Leiognathus equulus	bete-bete/slipmouth	7
St. 8	*Lutjanus argentimaculatus*	kakap merah/mangrove red snapper	2
	Leiognathus equulus	bete-bete/slipmouth	3
St. 9	*Lutjanus argentimaculatus*	kakap merah/mangrove red snapper	6
	Leiognathus equulus	bete-bete/slipmouth	1

ported multiple species, with Station 4 showing a higher abundance of *Leiognathus equulus* (6 individuals) and the presence of *Metapenaeus ensis* (7 individuals) in Station 6, reflecting the mangrove's role as a nursery ground for finfish and crustaceans. Meanwhile, stations 6 to 9 were dominated by finfish, particularly *Lutjanus argentimaculatus* and *Leiognathus equulus*, with St. 7 recording the highest combined abundance (12 individuals) among these sites. Overall, the data suggest spatial variation in species composition, where upstream to midstream stations (1–5) tend to harbor a more diverse assemblage of crustaceans, mollusks, and fish, while downstream stations (6–9) are characterized by fewer species but relatively higher dominance of finfish.

3.1.2 Mangrove litterfall production and sequestration rate

Unfortunately, this study was unable to obtain litterfall production data from St. 8, likely due to damage or theft of the litterfall trap net by irresponsible individuals. As a result, the data on tree density, DBH, and canopy cover from that station could not be included in the carbon sequestration estimation.

The mangrove litterfall production in the Somber River showed variations ranging from 0.58 to 18.76 Mg/ha/year, with an average of 9.28 Mg/ha/year (Table 1). Based on the components of litter production (Figure 4), leaves accounted for the largest proportion at 74.88%, followed by reproductive organs (14.37%), and twigs (10.74%). The lowest litterfall production was recorded at observation site St. 3, which is exclusively dominated by *Rhizophora apiculata*. This site exhibited the lowest mangrove density (200 individuals per hectare) and a canopy cover of only 12%.

At St. 5, mangrove leaf production was the highest, accompanied by substantial propagule and flower production (Figure 4). Although St. 2, St. 4, and St. 7 exhibited stronger vegetation structure in terms of density, DBH, and canopy cover (Table 1), these parameters did not correspond to higher litterfall production.

Mangroves at St. 6 (DBH 16.3 cm) and 8 (DBH 15.8 cm) exhibited relatively low carbon sequestration rates of 27.49 $MgCO_2$-eq/ha/year and 38.36 $MgCO_2$-eq/ha/year, respectively, compared to St. 2, 4, and 7, which had smaller DBH values (Table 1). Conversely, tree density at St. 2, 4, and 7 was greater than that at St. 6 and 8. This suggests that although St. 6 and 8 were characterized by larger tree diameters, their lower tree densities (Figure 2) resulted in reduced overall carbon sequestration rates. A similar pattern was observed at St. 1, which exhibited high tree density (>1000 ind/ha) and relatively large tree sizes (DBH 15.7 cm), accompanied by high sequestration rates (Table 1). These findings indicate that tree density (Figure 5a) exerts a stronger influence on carbon sequestration rates than tree diameter alone (Figure 5b).

Carbon sequestration rates along the Somber River were most strongly associated with canopy cover ($R^2 = 0.75$; Significance F = 0.03; x_{max} = 60.62 % canopy cover), followed by tree density ($R^2 = 0.72$; Significance F = 0.04; x_{max} = 1436.25 ind./ha) and DBH ($R^2 = 0.58$; Significance F = 0.11; x_{max} = 11.22 cm) (Figure 5).

3.1.3 Longitudinal segmented carbon sequestration

The plant density and canopy cover percentage are highest in the midstream segment (1,533 individuals/ha and 65.7%), but not for the DBH. This peak

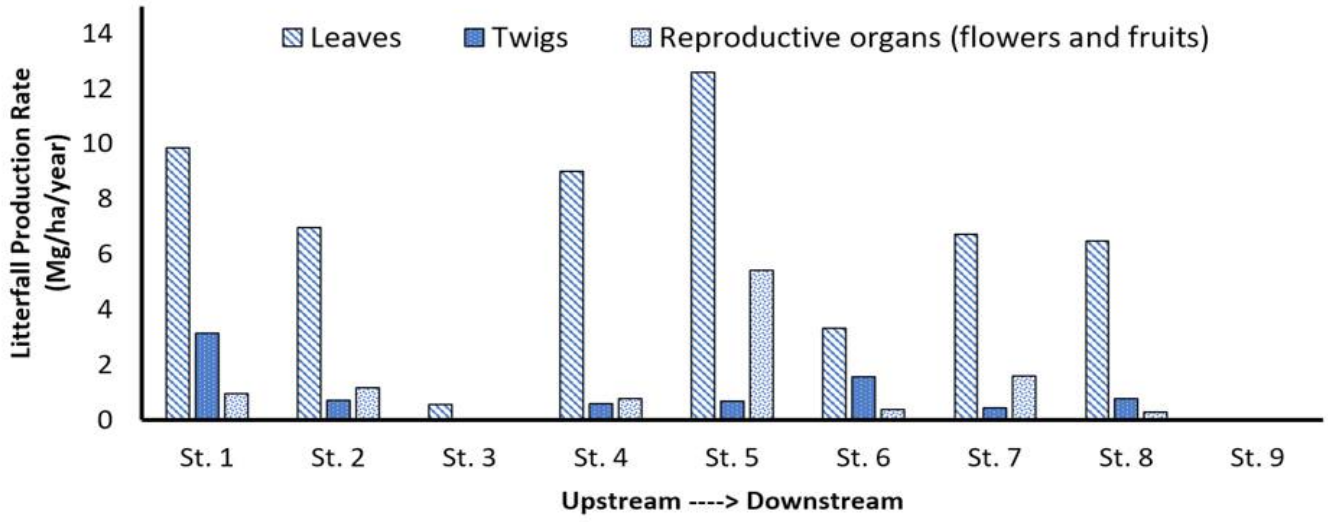


Figure 4. Longitudinal variation in litterfall production components (leaves, twigs, and reproductive organs) across stations.

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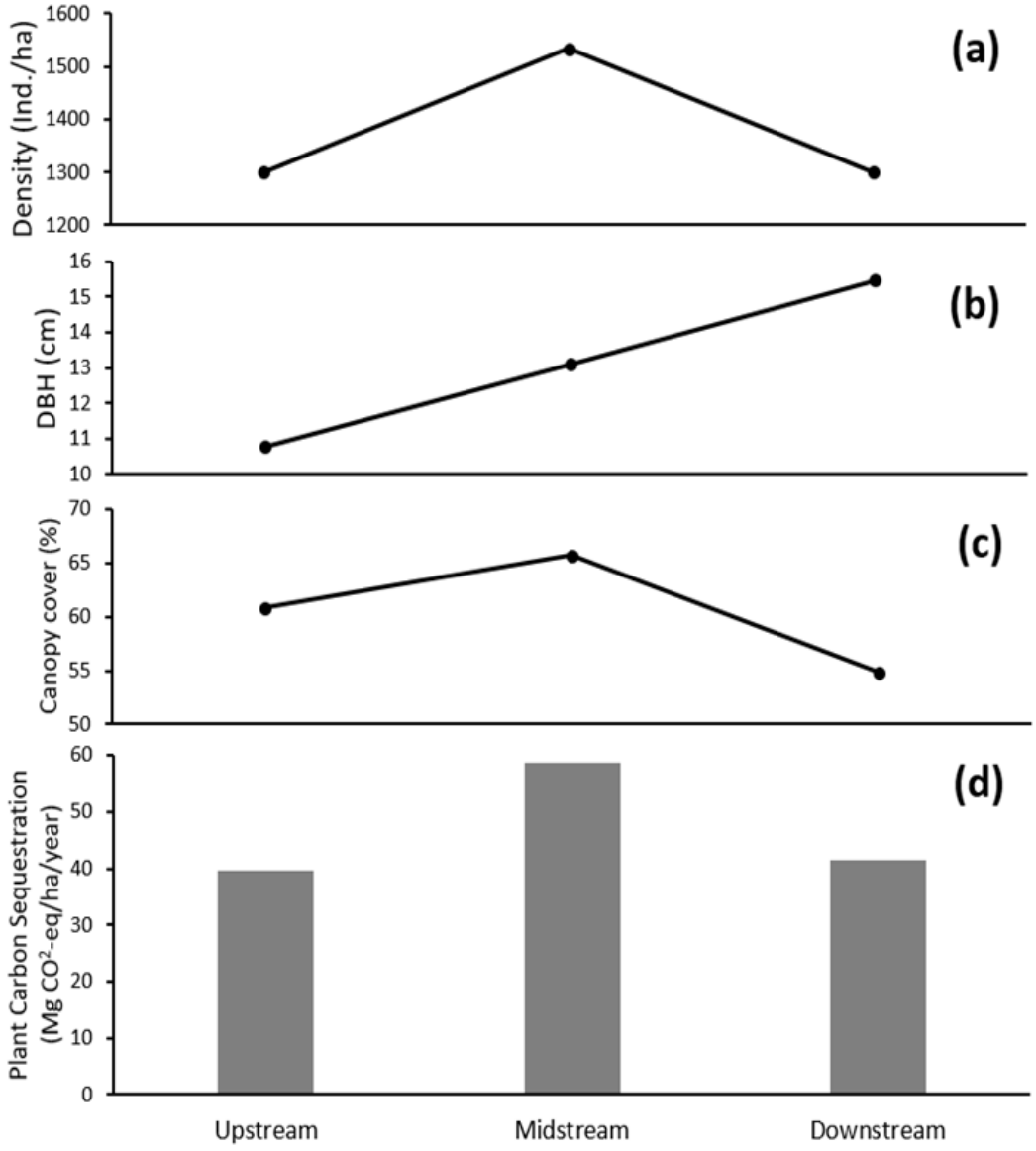


Figure 6. Comparative analysis of tree density (a), DBH (b), Canopy cover (c), and Carbon sequestration (d) across upstream, midstream, and downstream.

in density and canopy cover percentage at midstream coincides with the highest plant carbon sequestration (approximately 58.61 Mg CO_2-eq/ha/year). The higher number of individuals likely contributes to greater total biomass and, therefore, higher carbon uptake, showing a positive correlation between density and carbon sequestration.

In this case, the longitudinal variation in DBH shows a different pattern, where the highest DBH values are actually found in the downstream segment of the river, while the carbon sequestration values decrease compared to those in the midstream segment (Figure 6).

3.2 Discussion

3.2.1 Mangrove forest structure and fishery resources

All of these mangrove species identified in this study were also documented by Poedjirahajoe *et al.* (2019) in the mangrove forests of Kutai National Park, East Kalimantan, Indonesia. The genus *Rhizophora* was the most frequently encountered in the study area, consistent with findings by Kristiningrum *et al.* (2019) in mangrove forests of Mentawir Village, located upstream of Balikpapan Bay and near the present site. This distribution pattern is likely influenced by salinity conditions favorable to its growth, as *R. apiculata* typically occurs in medium tidal zones (Setyadi *et al.*, 2021) characterized by moderate salinity (15.1–25 ppt; Barik *et al.*, 2018). By contrast, St. 8 and 9, which are closer to the sea, were dominated by *Sonneratia* and *Avicennia*. These genera are more tolerant of prolonged inundation and higher salinity (Truong *et al.*, 2017), with *Avicennia* often serving as an indicator of salinity levels exceeding 25 ppt (Barik *et al.*, 2018). This suggests a salinity

gradient along the Somber River, increasing toward the estuary. Overall, the species distribution indicates that *R. apiculata* is highly tolerant of salinity fluctuations and exhibits strong adaptability to varying inundation regimes in the estuarine waters of the Somber River, Balikpapan Bay.

The average canopy cover percentage in the downstream segment is the lowest (59.60%) compared to the upstream (60.81%) and midstream segments (65.70%). This pattern is likely influenced by the differing dominant mangrove species across the segments. In the upstream segment, *Sonneratia* species were absent**,** whereas the areas from the upstream to the downstream segments were dominated by *Rhizophora* species**.** Dharmawan and Pramudji (2020) found that regions where *Sonneratia* is the dominant species typically have a lower canopy cover percentage than those dominated by *Rhizophora*. Overall, the average mangrove density along the Somber River was 1,444 ind./ha. This value is higher than that reported for Kutai National Park (1,200 ind./ha; Poedjirahajoe *et al*., 2019) and the Graha Indah mangrove area in Balikpapan (<1,000 ind./ha in 2014; Warsidi and Endayani, 2017). Compared to the average upstream density of 1,300 ind./ha, the present findings suggest an improvement in mangrove health in this area over the past decade.

The average DBH of trees in the mangrove area of the Somber River was 13.3 cm, ranging from 4 to 17 cm. The highest DBH value was recorded at St. 8, which is dominated by *Sonneratia alba*. This suggests that *S. alba* generally has a larger trunk diameter compared to other species found in the study area. The lowest DBH was observed at St. 3, where the mangrove stand structure comprises a mix of pioneer and young mangrove trees. In this station, a DBH of less than 10 cm indicates that the tree population is relatively young (Hidayah *et al*., 2022), with trees having a DBH < 4.5 cm classified into the smallest two size categories (Fromard *et al*., 2004). Additionally, St. 3 is located in a former aquaculture pond that is still undergoing natural recovery, resulting in a mean DBH of less than 10 cm, smaller than that of other stations. A similar pattern has been reported in abandoned pond areas in Perancak, Bali, where mangrove stands tend to have DBH values of less than 10 cm (Sidik *et al*., 2019).

Based on river segment classification, the average DBH of mangrove trees increases from the upstream to the downstream segments. This indicates that mangrove tree size in the estuarine waters of the Somber River tends to increase toward the sea. Interestingly, the trend in DBH does not correspond with patterns observed in mangrove density or canopy cover percentage.

The density of mangrove trees, DBH, and canopy cover in mangrove forests are influenced by a range of interconnected environmental, ecological, and human factors. Abiotic factors such as salinity (Ahmed *et al*., 2022), soil type and nutrient availability (Alongi, 2018), hydrology (Alongi and Brinkman, 2011), light availability (Chen *et al*., 2013), and climate characteristics (Lovelock *et al*., 2016) all play a role in determining mangrove tree density. Biotic factors, including species characteristics, seedling recruitment and survival, disease, and grazing by mangrove fauna, can have both positive and negative impacts (Robertson, 1991). Human pressures such as deforestation (Nordhaus *et al*., 2019), land-use changes (Sasmito *et al*., 2019), pollution (Suyadi and Manullang, 2020), and natural disturbances (Imbert, 2018) may alter mangrove forest structure.

The species composition observed reflects the ecological functions of mangrove waters in supporting both fishery resources and biodiversity. The dominance and wide distribution of *Leiognathus equulus* suggest that slipmouth plays an important role as a common demersal species in mangrove-associated ecosystems. The occurrence of penaeid shrimps (*Metapenaeus ensis* and *Penaeus merguiensis*) alongside *Scylla tranquebarica* highlights the significance of mangroves as nursery and feeding grounds for commercially important crustaceans. St. 3, which recorded the highest species richness, likely represents a more heterogeneous habitat that can support a wider range of taxa, including bivalves. Conversely, the limited diversity in St. 6–9, where only *Lutjanus argentimaculatus* and *Leiognathus equulus* were found, may indicate differences in habitat structure, salinity, or fishing pressure. These findings emphasize the role of mangrove ecosystems in maintaining species diversity and supporting local fisheries, while also highlighting spatial variations in community structure that warrant further ecological assessment.

3.2.2 Mangrove litterfall production and sequestration rate

Based on the components of litter production in this study, leaves accounted for the largest proportion at 74.88%, followed by reproductive organs (14.37%) and twigs (10.74%). A similar pattern of proportional contribution has also been reported in several other tropical mangrove areas, such as in Benoa Bay, Bali, Indonesia (Sugiana *et al*., 2024), in the Perancak estuary, Bali, Indonesia (Pradisty *et al*., 2022), and in mangrove areas dominated by *Rhizophora apiculata* in Sibuti, Malaysia (Hoque *et al*., 2015).

Station 5 exhibited the highest rate of mangrove leaf production, accompanied by considerable propagule and flower output. In contrast, although Stations 2, 4, and 7 demonstrated more developed vegetation structures reflected by greater stem density, larger DBH val-

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ues, and higher canopy cover, these structural attributes were not associated with increased litterfall production. This discrepancy may be explained by differences in the types of litterfall collected. For instance, at St. 5, litter traps contained fallen *Rhizophora* propagules, which are generally larger than those of other species, likely contributing to the higher total litter production observed at this site. In addition, elevated litterfall production at St. 5 may be associated with greater soil nutrient availability from river inflows compared to other stations (Hoque *et al*., 2015; Kamruzzaman *et al*., 2017).

The discrepancy of litterfall data may be explained by differences in the types of litterfall collected. For instance, at St. 5, litter traps contained fallen *Rhizophora* propagules, which are generally larger than those of other species, likely contributing to the higher total litter production observed at this site. In addition, elevated litterfall production at St. 5 may be associated with greater soil nutrient availability from river inflows compared to other stations (Hoque *et al*., 2015; Kamruzzaman *et al*., 2017).

The low litterfall production at St. 3 is presumed to be associated with the early growth stage of the mangroves. The DBH of trees observed at this site ranged from 2.86 to 5.09 cm. Based on previous studies on *Rhizophora* mangroves that incorporated both age and DBH parameters (Kathiresan *et al*., 2013; Sukardjo and Yamada, 1992; Wang'ondu *et al*., 2014), this DBH range corresponds to an age of approximately 5-8 years. This assumption is further supported by the absence of fruit components in the litterfall at St. 3 and the comparatively low leaf production relative to other sites, suggesting that the tree community at St. 3 is younger than those at other stations. A similar finding was reported in mangrove restoration areas in Gazi Bay, Kenya, where 5-year-old mangroves with an average DBH of 3.2 cm exhibited the lowest litterfall production and no fruit contribution compared to older mangrove stands with larger DBH values (Wang'ondu *et al*., 2014). Low tree density has also been identified as a factor contributing to reduced litterfall production (Mulya and Arlen, 2018).

Interestingly, the highest litterfall production was not observed at the sites with the greatest mangrove density, DBH, and canopy cover (St. 2, St. 4, and St. 7), but rather at St. 5, which exhibited moderate values for these parameters. Based on the relatively similar patterns of litterfall production rates and tree structure among these three stations, it can be inferred that the mangrove stands at these sites are in a mature condition, with litterfall production likely having reached a stable phase. However, to substantiate this assumption, long-term data on litterfall production, covering at least one year, are required (Hoque *et al*., 2015). Another possible explanation is that mangrove seedlings and young stands in high-density areas may exhibit reduced productivity due to limited light availability beneath the canopy of older stands. This trend is consistent with the findings of Kamruzzaman *et al*. (2019).

A study by Adame *et al*. (2021) in tropical mangroves of the Yucatán Peninsula, Mexico, also reported high litterfall production in areas with elevated soil phosphate concentrations. Similarly, Lovelock *et al*. (2004) demonstrated that nitrogen enhances leaf production, whereas phosphorus promotes an increase in leaf numbers. This pattern is consistent with the high leaf litter production recorded at St. 5. Soil phosphate has been recognized as a key factor driving spatial variation in mangrove productivity in riverine systems (Paoli and Curran, 2007). Moreover, tidal processes contribute to the export of litter into estuaries and coastal zones, thereby facilitating nutrient transfer and sustaining detritus-based food webs (Martin *et al*., 2019). Given the limited measurements available in this study, further research is required to examine nutrient concentrations and accumulation rates in the mangrove zone of the Somber River estuary.

The carbon sequestration rate of mangrove trees at the study sites ranged from 2.93 to 95.35 $MgCO_2$-eq/ha/year. The lowest rate was observed at St. 3, a former aquaculture pond dominated by young mangroves with small diameters (DBH < 5 cm), while the highest rate was recorded at St. 5, located near the river channel. Carbon sequestration rates generally increase with mangrove age (Sahu and Kathiresan, 2019). The low rate at St. 3 is likely attributable to the predominance of younger trees with small diameters (DBH < 5 cm).

This study employed litter production rates as a proxy for tree-level carbon sequestration. Carbon absorbed and stored by trees for growth, referred to as net primary production, can be estimated through litterfall (Alongi, 2009; Chen *et al*., 2016), with litterfall serving as an indicator of carbon sequestration rates (Choudhary *et al*., 2024). The average estimated carbon sequestration rate of mangrove trees in this study was 47.25 Mg CO_2-eq/ha/year. This value is comparable to those reported in other Indonesian mangrove sites, including Benoa Bay (Bali), the Perancak estuary (Bali), and the northern Sumatran coast, which range from 29.5 to 60.92 Mg CO_2-eq/ha/year (Table 2). Sugiana *et al*. (2024) reported that Sonneratia-dominated zones exhibit the highest sequestration rates, suggesting that values at the Somber River estuary may be underestimated due to the absence of data from St. 9, where litter traps were lost during sampling. In contrast, the average sequestration rate observed in this study was higher than those reported for the Vellar–Coleroon estuary (India) and the Cananéia–Iguape lagoon estuary (Brazil). This differ-

ence may be attributed to the smaller tree diameters in those systems, averaging 4.07 cm in the Vellar–Coleroon estuary (Kandasamy *et al*., 2021) and 4.56–6.50 cm in the interior and fringe zones of the Cananéia–Iguape lagoon estuary (Rovai *et al*., 2021), compared to an average DBH of 13.3 cm in the present study. Similar studies have reported a positive correlation between tree DBH and carbon sequestration rates (Kathiresan *et al*., 2013). However, in the present study conducted in the Somber River estuary, mangroves with higher DBH values did not necessarily correspond to higher carbon sequestration rates.

High carbon sequestration rates were observed in mangroves with intermediate forest structure, particularly. This suggests that factors beyond tree structure influence carbon uptake. Soil nutrient concentrations are likely a key driver, as nutrients support photosynthesis and regulate mangrove productivity and spatial distribution (Aprilia *et al*., 2022; Alongi, 2018). Mangroves absorb nitrogen for growth (Murphy *et al*., 2021), and stands in nutrient-rich soils, particularly with higher nitrogen and phosphate levels, tend to produce more seedlings (Lovelock *et al*., 2007). This may explain the high seedling production recorded at St. 5. The geomorphology of the Somber River further supports this interpretation, as St. 5 lies adjacent to the river channel where sediment and associated nutrients are likely to accumulate, especially during high-water conditions. Nutrient enrichment is often higher in landward mangroves, particularly in middle estuary zones, compared to upper and lower zones exposed to marine influence (Lovelock *et al*., 2007; Paul and Das, 2024). To confirm the role of nutrients in driving sequestration rates, further studies are needed to measure spatial nutrient concentrations along the downstream upstream gradient of the Somber River mangroves.

Although higher values of these structural attributes corresponded with greater sequestration, the relationships were not strictly linear. Canopy cover showed the strongest effect, likely reflecting greater leaf abundance and photosynthetic activity in denser canopies (Clough *et al*., 1995), which in turn enhances carbon storage in biomass (Alongi, 2012; Donato *et al*., 2011; Solomon *et al*., 2024). Interestingly, the highest sequestration rates were not found at St. 2, 4, and 7, despite canopy cover exceeding 90%. This likely reflects the maturity of these stands, where carbon sequestration has stabilized. Consistent with previous findings, sequestration tends to decline as mangrove forests age (Walcker *et al*., 2018). High carbon sequestration rates were observed in mangroves with intermediate forest structure, particularly at St. 5.

3.2.3 Longitudinal segmented carbon sequestration

A high DBH value indicates that, on average, older mangrove trees in the estuarine waters of the Somber River are located in the downstream segment. When compared with data on carbon sequestration rates in mangrove trees, this study found that in stands of older mangrove trees (DBH > 11 cm), there is a decrease in carbon uptake ($R^2 = 0.58$). This aligns with findings by Walcker *et al*. (2018), who reported that carbon sequestration in both mangrove trees and soil tends to decrease as tree age increases, in trees aged up to 66 years. Interestingly, the ANOVA test results for the variation in carbon sequestration across the upstream, midstream, and downstream segments of the Somber River show no significant differences between these segments ($F = 0.41$, *P-value* = 0.68), suggesting that mangrove forest condition along the Somber River is uniform across all segments.

This study provides an initial estimate of carbon uptake rates in mangrove trees within the Somber River estuary, located near the Kariangau industrial area in Balikpapan. These findings are valuable for guiding mangrove management strategies in the estuary to maximize blue carbon storage and sequestration. However, further research is needed to quantify carbon accumulation in sediments, which represents a critical component of blue carbon ecosystems. In addition, future studies should account for differences in dominant mangrove species to generate species-specific carbon sequestration rates, which would be particularly useful for evaluating carbon uptake in mangrove restoration initiatives.

4. Conclusion

The identification results reveal the presence of nine mangrove plant species in the study area, namely *Rhizophora apiculata*, *Rhizophora mucronata*, *Avicennia officinalis*, *Avicennia marina*, *Avicennia lanata*, *Sonneratia alba*, *Xylocarpus granatum*, *Ceriops decandra*, and *Ceriops tagal*. The genus Rhizophora and Avicennia are the most commonly found. No pattern was found in the density levels and canopy cover of mangrove trees along the Somber River from upstream to downstream. Mangrove ecosystems play a vital role in sustaining biodiversity and fisheries by serving as habitats, nurseries, and feeding grounds for diverse species, though variations in species richness across stations indicate differences in habitat conditions and ecological pressures. Mangrove litterfall production in the Somber River ranged from 0.58 to 18.76 Mg/ha/year, with an average of 9.28 Mg/ha/year. Based on these values, the estimated average carbon sequestration rate was 47.25 Mg CO_2-eq/ha/year, with the highest rates recorded in the midstream segment. Statistical analysis revealed no significant differences in sequestration rates among the upstream, midstream, and downstream segments.

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However, carbon sequestration was significantly correlated with canopy cover (*P-value* = 0.03) and tree density (*P-value* = 0.02), but not with DBH. This study provides an initial estimate of mangrove carbon uptake in the Somber River estuary, offering insights for blue carbon management. Further research should quantify sediment carbon storage and consider species-specific differences to better assess sequestration potential, especially for restoration efforts.

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Authors' Contributions

All authors have contributed to the final manuscript. The contribution of each author is as follows: HH and MSP formulated the main conceptual ideas, collected the data, drafted the manuscript, and designed the tables and figures. IRR and IS collected the data, provided a critical revision of the article. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

Declaration of Artificial Intelligence (AI)

The authors acknowledge the use of Gemini for generating some illustrations in the graphical abstract.

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Stock and Carbon Sequestration Analysis of the Mangrove Ecosystem as a Climate Change Mitigation Effort: a Case Study of Somber River Mangroves, Balikpapan Bay

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Introduction

Indonesia is home to the world's largest mangrove forest area, covering 22.6% of the global total (Giri et al., 2011). Spanning over 3 million hectares, these mangroves are mainly located along the country's extensive coastline, which stretches across thousands of islands (Kusmana, 2014). These forests are crucial to Indonesia's ecological and economic stability, offering vital ecosystem services such as carbon storage (Sidik et al., 2018).

Calculating carbon sequestration using standard methods requires considerable effort and resources, often preventing estimations in various global locations (Alongi, 2011). Given this complexity, innovative methods are needed to develop simpler and more cost-effective methods for calculating carbon sequestration, enabling easier implementation by stakeholders involved in mangrove forest monitoring and restoration.

Research Questions

This study aims to identify the species composition, tree density, and canopy cover; estimate the rate of carbon sequestration from litter production data; and analyze the rate of carbon sequestration longitudinally: upstream, midstream, and downstream segments in the mangrove forests along the Somber River in Balikpapan City, Indonesia.

Methods

A total of nine sampling stations were distributed across the mangrove area, representing upstream, midstream, and downstream mangrove zones. Stations (St.) 1–3 as upstream, St. 4–6 as midstream, and St. 7–9 as downstream. Field sampling was conducted in August and September 2024. Data on the number of mangrove individuals, tree trunk diameter, and canopy cover percentage were collected directly at each station using observation plots of 100 m² and 25 m². The canopy cover data was collected using the hemispherical photography. Three litter traps (1x1 m) were installed at each observation station to measure the litter production rate.

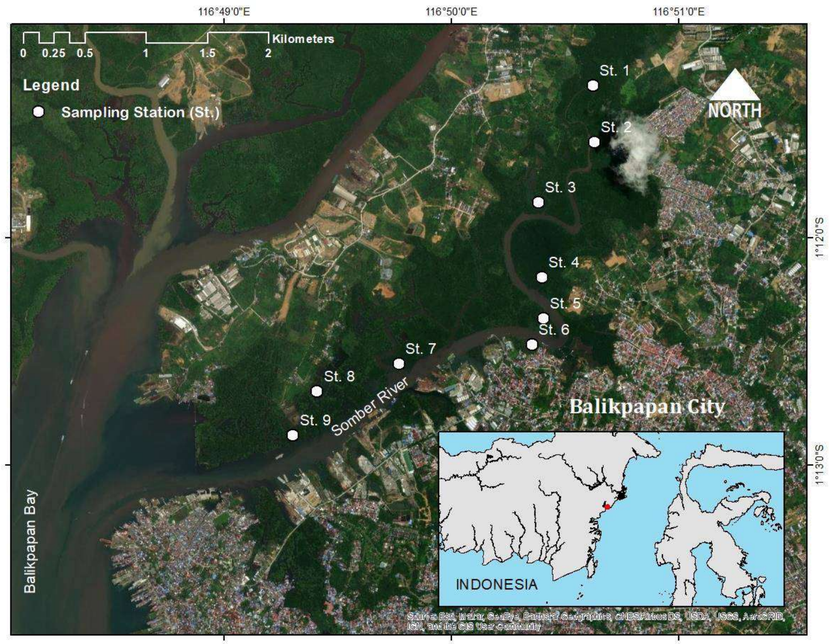
$$C_{seq} = NPP \times C \times 44/12$$

Where:

C_{seq}	: Carbon sequestration rate of biomass (Mg CO_2-eq/ha/year)
NPP	: Net primary productivity of mangroves (Mg/ha/year)
C	: Organic carbon concentration (%)
44/12	: Conversion factor from C to CO_2

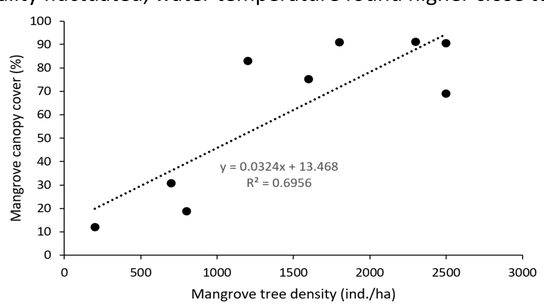


Sediment and mangrove litter sampling



Results

Water quality fluctuated, water temperature found higher close to the



Station	Spesies	Species Composition (%)	Density (ind./ha)	Canopy cover (%)
St. 1	*Rhizophora apiculata*	83.3	1200	83.02
	Xylocarpus granatum	16.7		
St. 2	*Ceriops decandra*	80.0	2500	90.59
	Rhizophora apiculata	20.0		
St. 3	*Rhizophora apiculata*	100.0	200	12.01
St. 4	*Rhizophora apiculata*	52.2	2300	91.11
	Ceriops tagal	21.7		
	Avicennia officinalis	17.4		
	Avicennia marina	8.7		
St. 5	*Rhizophora mucronata*	56.3	1600	75.24
	Rhizophora apiculata	31.3		
	Avicennia marina	12.5		
St. 6	*Rhizophora mucronata*	85.7	700	30.75
	Sonneratia alba	14.3		
St. 7	*Rhizophora apiculata*	100.0	1800	90.93
St. 8	*Sonneratia alba*	72.0	2500	69.10
	Avicennia lanata	12.0		
	Avicennia marina	8.0		
	Rhizophora mucronata	8.0		
St. 9	*Sonneratia alba*	75.0	800	18.78
	Avicennia marina	25.0		
Average			1511	62.39

Stream's longitudinal segment	Station	Litter production rate (Mg/ha/y)	Net Primary Productivity (Mg/ha/y)	Carbon sequestration (Mg CO_2-eq/ha/y)
Upstream	St. 1	13.98	43.06	71.05
	St. 2	8.88	27.36	45.14
	St. 3	0.58	1.78	2.93
Midstream	St. 4	10.42	32.10	52.97
	St. 5	18.76	57.79	95.35
	St. 6	5.29	16.28	26.87
Downstream	St. 7	8.53	26.27	43.35
	St. 8	16.37	50.43	83.20
	St. 9	7.04	21.70	35.80
Average		9.98	30.75	50.74

Conclusions

- The measurement results of mangrove litter production levels in the Somber River showed variations ranging from 0.58 to 18.76 Mg/ha/year, with an average of 9.98 Mg/ha/year. The study estimated an average carbon sequestration rate of 50.74 Mg CO_2-eq/ha/year for mangrove trees. The analysis of carbon sequestration along the upstream, midstream, and downstream segments of the Somber River revealed no significant differences between these segments.
- The study also demonstrated that using a simplified calculation based on litter production is a reliable, rapid, cost-effective, and straightforward preliminary method for estimating mangrove tree carbon sequestration.

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