

ISSN 2355-7079
E-ISSN 2406-8195
No: 200/M/KPT/2020

Indonesian Journal of Forestry **Research**

Vol. 8 No. 1, April 2021



Ministry of Environment and Forestry
Research, Development and Innovation Agency
Indonesia

Indonesian Journal of Forestry Research

Vol. 8 No. 1, April 2021

ANNALS OF THE INDONESIAN JOURNAL OF FORESTRY RESEARCH

Indonesian Journal of Forestry Research (IJFR) was first published as Journal of Forestry Research (JFR) in November 2004 (ISSN 0216-0919). The last issue of JFR was Volume 10 Number 2, published in December 2013. The Journal of Forestry Research has been accredited by the Indonesian Institute of Sciences since 2008 and by the Ministry of Research, Technology and Higher Education since 2018. IJFR has also obtained accreditation “Peringkat 1” or “Rank 1” from the Ministry of Research and Technology /National Research and Innovation Agency in 2020 (Decree number: 200/M/KPT/2020) which will be valid until October 2024. IJFR will be issued in one volume every year, including two issues which will be delivered every April and October.

Research, Development and Innovation Agency publish this Journal, Ministry of Environment and Forestry, formerly known as Forestry Research and Development Agency (FORDA), the Ministry of Forestry Republic of Indonesia. The publisher's name has been changed due to the amalgamation of the Ministry of Forestry with the Ministry of Environment into the Ministry of Environment and Forestry, Republic of Indonesia (Perpres No. 16/2015). Consequently, the Forestry Research and Development Agency was transformed into Research Development and Innovation Agency for Forestry and Environment. The logo of the ministry was reformed accordingly.

AIM AND SCOPE

Indonesian Journal of Forestry Research is a scientific publication of the Research, Development and Innovation Agency - Ministry of Environment and Forestry, Republic of Indonesia. The journal publishes state of the art results of primary findings and synthesized articles containing significant contribution to science and its theoretical application in areas related to the scope of forestry research.

IMPRINT



IJFR is published by Research, Development and Innovation Agency (FOERDIA), Ministry of Environment and Forestry, formerly known as Forestry Research and Development Agency, the Ministry of Forestry Republic of Indonesia.

ISSN print: 2355-7079

ISSN electronics: 2406-8195

Electronic edition is available at:

<http://ejournal.forda-mof.org/ejournal-litbang/index.php/IJFR>



All published article are embedded with DOI number affiliated with Crossref DOI prefix
<http://dx.doi.org/10.20886/ijfr>

PUBLICATION FREQUENCY

Journal is published in one volume of two issues per year (April and October).

PEER REVIEW POLICY

IJFR reviewing policies are: Every submitted paper will be reviewed by at least two peer reviewers. Reviewing process will consider novelty, objectivity, method, scientific impact, conclusion and references.

ACCREDITATION

Indonesian Journal of Forestry Research (IJFR) has been accredited by the Indonesian Institute of Sciences (LIPI) since 2008 and by the Ministry of Research, Technology and Higher Education since 2018. IJFR has also been recommended as a “journal with an international reputation”, according to the Head of Indonesian Institute of Science’s Decree No. 1026/E/2017. The last accreditation was from the Ministry of Research and Technology /National Research and Innovation Agency in December 2020, which will be valid until October 2024 according to Decree Number: 200/M/KPT/2020. The decree also has recognized IJFR as “Peringkat 1” or “Rank 1” scientific journal.

Indonesian Journal of Forestry Research

Vol. 8 No. 1, April 2021

POSTAL ADDRESS

IJFR Secretariat:

Sub Bagian Diseminasi Publikasi dan Perpustakaan

Sekretariat Badan Litbang dan Inovasi, Kementerian Lingkungan Hidup dan Kehutanan

Perpustakaan R.I Ardi Koesoema, Jl. Gunung Batu No.5 Bogor 16610, West Java, Indonesia

Tel: +62-0251-7521671

Fax: +62-0251-7521671

Business hour: Monday to Friday, 08:00 to 16:00 (WIB)

e-mail: ijfr.forda@gmail.com

website: <http://ejournal.forda-mof.org/ejournal-litbang/index.php/IJFR/>

ONLINE SUBMISSIONS

For first time user, please register at:

<http://ejournal.forda-mof.org/ejournal-litbang/index.php/IJFR/user/register>

For user who already register, please login at:

<http://ejournal.forda-mof.org/ejournal-litbang/index.php/IJFR/login>

The author is required to submit manuscript online and controlling the status of online submission and reviewing process by login in the journal website.

SUBMISSION PREPARATION CHECKLIST

As part of the submission process, authors are required to check their submission's compliance with all of the following items:

1. Manuscript must be written based on IJFR template and meet the guideline for authors.
2. References must be formatted based on APA style 6th edition and applied referencing software Mendeley or Endnote.
3. Eight percent of total references must be considered as current primary references (published in the last 5 years)
4. Ethical statement form (IJFR Form 01_paper) and copyright transfer from (IJFR Form 06_copyright transfer agreement) must be attached during manuscript submission.
5. If manuscript does not meet the journal guideline, it might be declined or subjected to author review.

COPY EDITING AND PROOFREADING

Every article accepted by IJFR shall be an object to Grammarly® writing enhancement program conducted by IJFR Editorial Team.

Indonesian Journal of Forestry Research

Vol. 8 No. 1, April 2021

PLAGIARISM CHECK

Plagiarism screening will be conducted by IJFR Editorial Team.

REFERENCE MANAGEMENT

To properly credit the information sources, please use citation tools such as **Mendeley** or **EndNote** to create a bibliography, references and in-text citations. Mendeley is a free reference manager that can be downloaded at <https://www.mendeley.com/download-mendeley-desktop>.

OPEN ACCESS POLICY



This journal provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

CC LICENSE



IJFR allows re-use and re-mixing of its content under a CC BY-NC-SA Creative Commons Attribution Non

Commercial-Share Alike 4.0 International License.

Permissions beyond the scope of this license may be available at <http://ejournal.forda-mof.org/ejournal-litbang/index.php/IJFR/>

If you are a non-profit or charitable organization, your use of an NC-licensed work could still run a foul of the NC restriction, and if you are a for-profit entity, your use of an NC-licensed work does not necessarily mean you have violated the term.

PROCESSING CHARGES

This journal does not charge any article processing charges (APCs) or submission charges. All manuscripts submitted to IJFR are assumed to be submitted under the Open Access publishing model. In this publishing model, papers are peer-reviewed in the normal way under editorial control. Published papers appear electronically and are freely available from our website. Authors may also use their published .pdf's for any non-commercial use on their personal or non-commercial institution's website. Users have the right to read, download, copy, distribute, print, search, or link to the full texts of IJFR articles.

INDEXING & ABSTRACTING

The following indexing has covered IJFR services: Scopus, Directory of Open Access Journals (DOAJ), Centre for Agriculture and Biosciences International (CABI), Indonesian Science and Technology Index (SINTA), Cross Ref, Google Scholar, Indonesian Scientific Journal Database (ISJD), and Bielefeld Academic Search Engine (BASE). IJFR has also accepted for inclusion at EBSCO and Asian Citation Index.

Indonesian Journal of Forestry Research

Vol. 8 No. 1, April 2021

©2021 Research, Development and Innovation Agency, Ministry of Environment and Forestry
All rights reserved.

This journal and the individual contributions contained in it are protected under copyright by Research, Development and Innovation Agency, Ministry of Environment and Forestry, and the following terms and conditions apply to their use:

Open Access Policy

IJFR provides immediate open access to its content on the principle that making research freely available to the public to support a greater global exchange of knowledge.

Copyright Notice

Authors who publish with this journal agree to the following terms:

1. Authors retain copyright and grant the journal right of first publication with the work simultaneously licensed under a Creative Commons Attribution License that allows others to share the work with an acknowledgement of the work's authorship and initial publication in this journal.
2. Authors are able to enter into separate, additional contractual arrangements for the non-exclusive distribution of the journal's published version of the work (e.g., post it to an institutional repository or publish it in a book), with an acknowledgement of its initial publication in this journal.

3. Authors are permitted and encouraged to post their work online (e.g., in institutional repositories or on their website) after the acceptance and during the editing process, as it can lead to productive exchanges, as well as earlier and greater citation of published work

Privacy Statement

The names and email addresses entered in this journal site will be used exclusively for the stated purposes of this journal and will not be made available for any other purposes or to any other party.

Notice

No responsibility is assumed by the publisher for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in the material herein.

Although all advertising material is expected to conform to ethical (medical) standards, inclusion in this publication does not constitute a guarantee or endorsement of the quality or value of such product or of the claims made of it by its manufacturer.

Indonesian Journal of Forestry Research

Vol. 8 No. 1, April 2021

EDITORIAL TEAM

Editor in Chief

Prof. Dr. Haruni Krisnawati
Forest Assesment and Biometrics
Forest Research & Development Center, Indonesia

International Editors

Prof. Dr. Peter Kanowski
Forest Genetic, Forestry Management and
Environment
Australian National University, Australia

Dr. Yutaka Tamai
Forest Biology, Edible Mushroom, Mycorrhiza
Hokkaido University, Japan

Assoc. Prof. Seca Gandaseca
Forest Engineering
University Putra Malaysia, Malaysia

Prof. Chairil Anwar Siregar,
Hydrology and Soil Conservation
Forest Research & Development Center, Indonesia

Prof. Dr. Ani Mardiasuti
Conservation and Biodiversity
Bogor Agricultural University, Indonesia

Prof. Dr. I. Nengah Surati Jaya
Forest Inventory, GIS
Bogor Agricultural University, Indonesia

Prof. Dr. Ganis Lukmandaru
Wood Science and Forest Product Technology
Gadjah Mada University, Indonesia

Prof. Dr. Anto Rimbawanto
Molecular Biology and Forest Genetic
Center for Biotechnology and Forest Tree
Improvement Research & Development, Indonesia

Prof. Dr. Antonius Y.P.B.C Widyatmoko
Forest Genetic
Center for Biotechnology and Forest Tree
Improvement Research & Development, Indonesia

Prof. Dr. Maman Turjaman
Forest Microbiology
Forest Research & Development Center, Indonesia

Prof. Dr Tyas Mutiara Basuki
Remote Sensing and Biodiversity Management
Forestry Technology and Watershed Management
Research Institute, Indonesia

Dr. Made Hesti Lestari Tata
Microbiology and Silviculture
Forest Research & Development Center, Indonesia

Dr. Leti Sundawati
Social Forestry
Bogor Agricultural University, Indonesia

Dr. Krisdianto
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Dr. Niken Sakuntaladewi
Socio-Economic, Policy and Climate Change
Research and Development Center, Indonesia

Dr. Chay Asdak
Forest Hidrology, Soil Science, Water Science and
Watershed Management
Padjajaran University, Indonesia

Dr. Tatang Tiryan
Forest Biometrics and Forest Management,
Bogor Agricultural University, Indonesia

Indonesian Journal of Forestry Research

Vol. 8 No. 1, April 2021

Advisory Editor

Dr. Agus Justianto
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Managing Editors

Dr. Sylvana Ratina
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Dr. Yayuk Siswiyanti
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Section Editors

Tutik Sriyati, S.Sos.
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Dian Anggraeni Indrawan, S.Hut., MM.
Forest Products Research & Development Center,
Indonesia

M. Iqbal, S.Hut., MSi.
Socio-Economic, Policy and Climate Change
Research and Development Center, Indonesia

Ane Dwi Septina, S.Sos., MA.
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Language Editor

Jozsef Micski, M.For.Sc.
Forestry Swedish Academic Association

Proofreaders

Dr. Krisdianto
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Layout Editor

Suhardi Mardiansyah, A.Md
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Web Admin

Suhardi Mardiansyah, AMd.
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Secretariat

Dr. Ignatius Adi Nugroho, S.Hut, M.Si.
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Tutik Sriyati, S.Sos
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Rr. Lies Widyowati
Research, Development and Innovation Agency
Ministry of Environment and Forestry, Indonesia

Acknowledgement

The Indonesian Journal of Forestry Research expresses sincere appreciation to all reviewers for selflessly contributing their expertise and time to the reviewing process, which is crucial to ensure the quality and substantive impact of the journal. The journal's editors and authors are grateful for the reviewers' efforts in evaluating and assessing the articles submitted for publication, regardless of the outcome (acceptance or rejection).

Prof. Dr. Sri Suharti

Social Economics of Forestry
Forest Research and Development Centre
Bogor, Indonesia

Prof. Mark Reed

Rural Entrepreneurship
Scotland's Rural College, Edinburgh, United
Kingdom

Prof. Dr. Peter Kanowski

Forest Genetic, Forestry Management and
Environment
The Australian National University
Canberra, Australia

Dr. Tatang Tiryana

Forest Biometrics and Forest Management,
IPB University, Bogor, Indonesia

Prof. Dr. Tyas Mutiara Basuki

Remote Sensing and Biodiversity Management
Forestry Technology and Watershed Management
Research Institute, Surakarta, Indonesia

Prof. Dr. Chairil Anwar Siregar,

Hydrology and Soil Conservation
Forest Research and Development Center, Bogor,
Indonesia

Prof. Dr. Subarudi

Forestry Sociology
Socio-Economic, Policy and Climate Change
Research and Development Center, Bogor,
Indonesia

Dr. Retno Maryani

Forest Policy, Forest Management
Socio-Economic, Policy and Climate Change
Research and Development Center, Indonesia

Prof. Dr. Sri Wilarso Budi

Biotechnology, Silviculture, Microbiology
IPB University, Bogor, Indonesia

Prof. Dr. Liliana Baskorowati

Reproductive Biology and Tree Improvement
Center for Biotechnology and Forest Tree
Improvement Research and Development,
Indonesia

Dr. Krisdianto

Wood Science and Forest Product Technology
Forest Product Research and Development Center,
Bogor, Indonesia

Himlal Baral. Ph.D.

Sustainable Forest Management
Center for International Forestry Research, Bogor,
Indonesia

Prof. Dr. Maman Turjaman

Forest Microbiology
Forest Research and Development Center,
Indonesia

Prof. Dr. Mohammad Basyuni

Mangrove and Plant Biotechnology
Universitas Sumatera Utara, Medan, Indonesia

Prof. Dr. Ani Mardiasuti

Conservation and Biodiversity
IPB University, Bogor, Indonesia

Prof. Dr. Hendra Gunawan

Biodiversity Conservation
Forest Research and Development Center, Bogor,
Indonesia

Prof. Dr. Seca Gandaseca

Forest Engineering
University Putra Malaysia, Malaysia

Dr. Ratih Damayanti

Wood Anatomy
Forest Product Research and Development Center,
Bogor, Indonesia

Indonesian Journal of Forestry Research

Vol. 8 No. 1, April 2021

Contents

Titles	Pages
THE IMPORTANCE OF THE UTILISATION OF FOREST FRUITS IN BATAK TOBA COMMUNITY Alfonsus H. Harianja, Anisse M. Sinaga, Ferry A. Hawari and Ridwan Fauzi	1-12
THE INFLUENCE OF STAND DENSITY AND SPECIES DIVERSITY INTO TIMBER PRODUCTION AND CARBON STOCK IN COMMUNITY FOREST Pandu Yudha Adi Putra Wirabuana, Rahmanta Setiahad, Ronggo Sadono, Martin Lukito, and Djoko Setyo Martono	13-22
RAINFALL VARIABILITY IN GUNUNG SEWU KARST AREA, JAVA ISLAND, INDONESIA Ahmad Cahyadi, Eko Haryono, Tjahyo Nugroho Adji , Margaretha Widyastuti, Indra Agus Riyanto, Dzakwan Taufiq Nur Muhammad, and Naufal Fattah Tastian	23-35
STAKEHOLDERS' MAPPING AND STRATEGY FOR RESTORING PEAT LAND FOREST IN WEST TANJUNG JABUNG JAMBI, INDONESIA Ignatius Adi Nugroho, Darwo, and Dhany Yuniarti	37-57
EARLY GROWTH OF JABON (<i>Anthocephalus cadamba</i> Miq) IN A DRAINED PEATLAND OF PELALAWAN, RIAU Ahmad Junaedi, Nina Mindawati, and Yanto Rochmayanto	59-72
PROBIOTIC CANDIDATE PROTEOLYTIC <i>Bacillus</i> sp. COLLECTED FROM MANGROVE OF MARGASARI, LAMPUNG Sumardi, Komang Rima, Salman Farisi, and Endang Linirin Widiastuti	73-82
REVIEW ASSESSMENT OF BIODIVERSITY LOSS OF SUNDARBAN FOREST: HIGHLIGHTS ON CAUSES AND IMPACTS Md. Shohel Khan, Shahriar Abdullah, Mohammed Abdus Salam, Tanwee Rani Mandal, and Md. Rajib Hossain	85-97
ANATOMICAL AND PHYSICAL CHARACTERISTICS OF <i>Cephalostachyum manni</i> (Gamble) STAPLETON – AN ENDEMIC SCRAMBLING BAMBOO OF NORTHEAST INDIA Chaman Lal Sharma, Madhubala Sharma, Dahunirikitre M. Lamare, Mahesh Wangkhem, and Govinda Pangging	99-110
WORK MEASUREMENT STUDY ON MOTOR-MANUAL PINE TAPPING OPERATION: THE APPLICATION OF THE CONCEPT OF LEAN MANUFACTURING AND ALLOWANCES Efi Yuliati Yovi, Diah Prasetiana, and Natasha Aquilla Nirmalasari	111-125

Indonesian Journal of Forestry Research

ABSTRACTS	
ISSN 2355-7079	Vol. 8 No. 1, April 2021
<i>Keywords given are free term. Abstracts may be reproduced without permission or charge</i>	
<p>UDC/ODC 630*28:594.42</p> <p>Alfonsus H. Harijanja, Anisse M. Sinaga, Ferry A Hawari and Ridwan Fauzi</p> <p>THE IMPORTANCE OF THE UTILISATION OF FOREST FRUITS IN BATAK TOBA COMMUNITY</p> <p>(NILAI PENTING PEMANFAATAN BUAH HUTAN DI MASYARAKAT BATAK TOBA)</p> <p>Komunitas Batak Toba yang mayoritas bermukim di sekitar hutan mengkonsumsi buah-buahan di sekitar pemukiman mereka. Penelitian ini bertujuan untuk mengkuantifikasi nilai penting buah-buahan hutan tersebut dengan menggunakan metode penilaian LUVI (Local User's Value Index) karena sebagian besar buah-buahan tersebut belum diperjualbelikan di pasar. Penelitian dilakukan pada tahun 2015 dengan mengambil sampel penelitian pada Desa Sitoluama dan Simardangiang di wilayah Kabupaten Tapanuli Utara. Responden dipilih secara purposif, berdasarkan umur dan jenis kelamin (n=65 orang). Hasil penelitian menunjukkan bahwa terdapat 29 jenis buah-buahan yang dimanfaatkan, untuk empat kategori, yakni sebagai buah segar, bumbu masak, buah olahan dan obat-obatan. Pada Desa Simardangiang, lima buah yang mempunyai nilai terpenting berdasarkan nilai LUVI adalah kapundung (<i>Baccaurea racemose</i>) (0,56), hopong (<i>Macaranga lowii</i>) (0,52), sotul (<i>Sandorium koetjape</i>) (0,48), harimonting (<i>Rhodomyrtus tomentosa</i>) (0,47) dan habo (<i>Archidendron bubalinum</i>) (0,42). Sedangkan untuk Desa Sitoluama adalah kapundung (<i>Baccaurea racemosa</i>) (0,50), hopong (<i>Macaranga lowii</i>) (0,41), sihim (<i>Calamus manan</i>) (0,32), handis (<i>Garcinia xanthochymus</i>) (0,32) dan mobe (<i>Artocarpus dadah</i>) (0,19). Berdasarkan temuan tersebut, buah-buahan hutan yang mempunyai potensi domestikasi tertinggi adalah kapundung (<i>Baccaurea racemose</i>), hopong (<i>Macaranga lowii</i>), sihim (<i>Calamus manan</i>), handis (<i>Garcinia xanthochymus</i>), mobe (<i>Artocarpus dadah</i>), harimonting (<i>Rhodomyrtus tomentosa</i>), sotul (<i>Sandorium koetjape</i>) dan habo (<i>Archidendron bubalinum</i>).</p> <p>Kata kunci: <i>Artocarpus dadah</i>, <i>Baccaurea racemosa</i>, buah-buahan hutan, <i>Calamus manan</i> <i>Miq.</i>, <i>Rhodomyrtus tomentosa</i>, LUVI</p>	<p>metode Kruskal-Wallis dan dilanjutkan dengan metode Kruskal-Nemenyi. Pengaruh kepadatan tegakan dan diversitas jenis terhadap produksi kayu dan simpanan karbon dievaluasi secara terpisah untuk setiap parameter menggunakan metode generalized least square regression. Pengujian statistik dilakukan dengan tingkat signifikansi 5%. Hasil penelitian menunjukkan terdapat perbedaan signifikan pada volume tegakan, biomassa permukaan, dan simpanan karbon antar lokasi ($P < 0,05$). Penelitian ini juga menemukan adanya pengaruh penting kepadatan tegakan dan diversitas jenis terhadap produksi kayu dan simpanan karbon di hutan rakyat, dimana kepadatan tegakan memperlihatkan pengaruh yang lebih tinggi ($R^2 = 0,68$; $P < 0,05$) dibandingkan diversitas jenis ($R^2 = 0,26$; $P < 0,05$).</p> <p>Kata kunci: Hutan rakyat, simpanan karbon, kepadatan tegakan, diversitas jenis, produksi kayu</p>
<p>UDC/ODC 630*53:594.59</p> <p>Pandu Yudha Adi Putra Wirabuana, Rahmanta Setiahad, Ronggo Sadono, Martin Lukito, and Djoko Setyo Martono</p> <p>THE INFLUENCE OF STAND DENSITY AND SPECIES DIVERSITY INTO TIMBER PRODUCTION AND CARBON STOCK IN COMMUNITY FOREST</p> <p>(PENGARUH KERAPATAN TEGAKAN DAN KEANEKARAGAMAN JENIS TERHADAP PRODUKSI KAYU DAN SIMPANAN KARBON DI HUTAN RAKYAT)</p> <p>Kerapatan tegakan dan keanekaragaman jenis adalah dua indikator yang berkaitan erat dengan produktivitas hutan. Namun, pengaruh kedua variabel tersebut terhadap produktivitas hutan rakyat jarang didokumentasikan. Penelitian ini bertujuan untuk mengevaluasi pengaruh kepadatan tegakan dan diversitas jenis terhadap produksi kayu dan simpanan karbon di hutan rakyat. Lokasi penelitian terletak di Kabupaten Madiun. Survey lapangan dilakukan di empat lokasi hutan rakyat yang berbeda, yaitu Morang, Kuwiran, Randualas, dan Kare. Survey dilaksanakan dengan metode kuadrat menggunakan plot sampel 25 m x 25 m. Jumlah plot sampel yang digunakan dalam penelitian ini sekitar 64 unit yang tersebar merata di setiap lokasi. Perbandingan rerata karakteristik tegakan antar lokasi diuji dengan</p>	<p>UDC/ODC 551.577:594.55</p> <p>Ahmad Cahyadi, Eko Haryono, Tjahyo Nugroho Adji, Margaretha Widyastuti, Indra Agus Riyanto, Dzakwan Taufiq Nur Muhammad, and Naufal Fattah Tastian</p> <p>RAINFALL VARIABILITY IN GUNUNG SEWU KARST AREA, JAVA ISLAND, INDONESIA</p> <p>(VARIABILITAS CURAH HUJAN DI KAWASAN KARST GUNUNGSEWU, PULAU JAWA, INDONESIA)</p> <p>Kawasan karst merupakan kawasan yang sangat sensitif terhadap perubahan parameter iklim, salah satunya adalah pada variabilitas curah hujan. Variabilitas curah hujan menjadi sangat penting dikaji di kawasan karst Gunung Sewu karena selain sangat mempengaruhi kondisi sumber daya air, curah hujan akan berpengaruh terhadap sektor pertanian dan peternakan yang menjadi sektor ekonomi utama bagi masyarakat di kawasan karst Gunung Sewu. Variabilitas curah hujan di kawasan karst juga mempengaruhi kondisi bencana seperti kekeringan dan banjir. Namun demikian, analisis variabilitas di kawasan karst Gunung Sewu belum dilakukan karena ketersediaan data meteorologis yang kurang baik dari sisi kualitas ataupun kuantitas. Penelitian ini bertujuan untuk menganalisis variabilitas curah hujan di kawasan karst Gunung Sewu pada tahun 1979–2013 dengan memanfaatkan data prediksi dari citra satelit yang telah diuji oleh banyak peneliti di lokasi lain dan memiliki kualitas yang baik. Analisis variabilitas hujan yang dilakukan dalam penelitian ini meliputi perhitungan rerata hujan bulanan, analisis trend hujan tahunan, analisis hujan musim kemarau dan penghujan, analisis jumlah hari hujan, analisis trend rata-rata intensitas hujan dan analisis pengaruh ENSO (<i>El Niño Southern Oscillation</i>) terhadap curah hujan di kawasan karst Gunung Sewu. Data yang digunakan dalam penelitian ini berasal dari <i>The National Centers for Environmental Prediction</i> (NCEP) <i>Climate Forecast System Reanalysis</i> (CFSR). Data yang digunakan berupa data harian selama 35 tahun. Hasil analisis menunjukkan bahwa rerata curah hujan, jumlah hari hujan dan intensitas hujan memiliki trend kenaikan. Selain itu diketahui bahwa hujan di kawasan karst Gunung Kidul secara kualitatif nampak sangat dipengaruhi oleh peristiwa <i>El Niño</i>.</p> <p>Kata kunci: Variabilitas hujan, Karst, ENSO, Gunungsewu, NCEP, CFSR</p>

<p>UDC/ODC 630*114.444:594.46</p> <p>Ignatius Adi Nugroho, Darwo, and Dhany Yuniarti</p> <p>STAKEHOLDERS' MAPPING AND STRATEGY FOR RESTORING PEATLAND FOREST IN WEST TANJUNG JABUNG JAMBI, INDONESIA</p> <p>(PEMETAAN PARA PIHAK DAN STRATEGI UNTUK MERESTORASI HUTAN LAHAN GAMBUT DI TANJUNG JABUNG BARAT PROPINSI JAMBI, INDONESIA)</p> <p>Hutan rawa gambut yang terdapat di Indonesia menjadi isu besar setelah 33% dari 2,4 juta hektar terbakar pada tahun 2014. Tujuan penelitian ini adalah untuk memberikan gambaran mengenai posisi para pihak dan strategi logis yang dipilih oleh mereka pada kawasan hutan rawa gambut. Penelitian ini menghasilkan sembilan pihak yang terlibat secara aktif pada restorasi hutan rawa gambut di Kabupaten Tanjung Jabung Barat. Analisis kategorisasi yang digunakan dalam penelitian ini menunjukkan bahwa semua pihak yang terdapat pada area penelitian merupakan pemain kunci. Analisis lebih lanjut menggunakan kriteria tangga partisipasi menemukan bahwa ada dua model partisipasi yang digunakan oleh para pihak yaitu tokenisme dan <i>citizen power</i>. Nilai <i>citizen power</i> dibandingkan dengan tokenisme lebih tinggi yaitu 56% berbanding 44%. Hal ini berarti bahwa kemitraan dan model-model lain yang terdapat di dalam <i>citizen power</i> akan dikembangkan oleh para pihak untuk mencapai target mereka. Hal ini juga berarti bahwa kepercayaan merupakan variabel penting dalam relasi di antara para pihak dan harus dikembangkan dalam restorasi hutan rawa gambut. Konsekuensi dari penelitian ini bahwa para pihak dapat membangun dua strategi yaitu pengelolaan hutan kolaboratif dan pengelolaan hutan berbasis masyarakat.</p> <p>Kata kunci: Kolaborasi, para pihak, rawa gambut, partisipasi, strategi pemungkin</p>	<p>UDC/ODC 630*579.26:594.49</p> <p>Sumardi, Komang Rima, Salman Farisi, and Endang Linirin Widiastuti</p> <p>PROBIOTIC CANDIDATE PROTEOLYTIC <i>Bacillus</i> sp. COLLECTED FROM MANGROVE OF MARGASARI, LAMPUNG</p> <p>(KANDIDAT PROBIOTIK PADA <i>Bacillus</i> sp. PROTEOLITIK DIKOLEKSI DARI HUTAN MANGROVE DI MARGASARI, LAMPUNG)</p> <p>Budidaya udang dengan cara intensif telah menyebabkan banyak masalah seperti penurunan kualitas air yang mengakibatkan munculnya mikroba patogen, sehingga mempengaruhi kematian. Tujuan dari penelitian ini adalah untuk menemukan <i>Bacillus</i> sp. yang diisolasi dari beberapa sampel di mangrove dan mengkaraktirisasi mikroba terisolasi tersebut untuk penggunaan probiotik. Studi ini merupakan penelitian deskriptif dan koleksi data bakteri dari berbagai jenis sampel mangrove. Dari penelitian ditemukan lima <i>Bacillus</i> sp. yang terisolasi dan memiliki sifat potensial untuk probiotik, yaitu KPP212, IP121, UJ131, UJ132, dan SB141, dengan masing-masing isolat memiliki karakteristik bersifat proteolitik, pertumbuhan dalam rentang pH yang luas (4–10) dan tahan pada tekanan osmotik (0–6% NaCl), tidak patogen, kemampuan untuk fermentasi glukosa, tidak motil, serta tidak memiliki aktivitas katalase. Kelima bakteri <i>Bacillus</i> sp. tersebut dapat digunakan untuk probiotik pada budidaya udang.</p> <p>Kata kunci : Karakterisasi, <i>Bacillus</i> sp., mangrove, probiotik</p>
<p>UDC/ODC 630*53:594.44</p> <p>Ahmad Junaedi, Nina Mindawati, and Yanto Rochmayanto</p> <p>EARLY GROWTH OF JABON (<i>Anthocephalus cadamba</i> Miq) IN A DRAINED PEATLAND OF PELALAWAN, RIAU</p> <p>(PERTUMBUHAN AWAL JABON (<i>Anthocephalus cadamba</i> Miq.) PADA LAHAN GAMBUT YANG DIDRAINASE DI PELALAWAN, RIAU)</p> <p>Dorongan untuk mencari jenis pohon sebagai pengganti <i>A. crassicaarpa</i> di hutan tanaman semakin meningkat. Salah satu informasi awal yang perlu diketahui adalah mengenai pertumbuhan calon pohon yang akan dipilih pada kondisi pertanaman yang sama dengan <i>A. crassicaarpa</i>. Penelitian ini mengevaluasi pertumbuhan jabon (<i>A. cadamba</i>) dan hubungannya dengan sifat tanah di lahan gambut yang didrainase. Penelitian dilakukan dengan membangun plot eksperimen penanaman jabon di lahan gambut yang didrainase, menggunakan rancangan acak kelompok dengan tiga jarak tanam (2 x 2 m; 2,5 m x 3 m; 3 m x 3 m) sebagai perlakuan dan diulang sebanyak tiga blok ulangan. Parameter yang diamati meliputi kemampuan hidup, pertumbuhan dan sifat kimia tanah. Sampai umur 24 bulan setelah tanam (BST), jabon menunjukkan tingkat kematian yang tinggi (62%) dan rerata pertumbuhan yang lambat (tinggi 259 cm dan diameter 3,74 cm) di lahan gambut yang didrainase dikarenakan salah satunya oleh keracunan hara mikro berlebih. Meskipun demikian, sebanyak 7% jabon mempunyai pertumbuhan tinggi yang baik pada umur 24 BST, yakni berkisar 401–660 m. Hasil tersebut menunjukkan bahwa secara keseluruhan jabon tidak menunjukkan pertumbuhan yang baik di lahan gambut yang didrainase. Namun, adanya sebagian jabon (7%) yang menunjukkan performa yang menjanjikan, diharapkan jenis ini dapat dikembangkan melalui program pemuliaan pohon dan perlakuan silvikultur untuk mengatasi permasalahan keracunan hara mikro berlebih dan tekanan gulma.</p> <p>Kata kunci: Pertumbuhan, <i>Anthocephalus cadamba</i>, <i>Acacia crassicaarpa</i>, keracunan hara mikro, pemuliaan pohon</p>	<p>UDC/ODC 630*46:54</p> <p>Md. Shohel Khan, Shahriar Abdullah, Mohammed Abdus Salam, Tanwee Rani Mandal, and Md. Rajib Hossain</p> <p>REVIEW ASSESSMENT OF BIODIVERSITY LOSS OF SUNDARBAN FOREST: HIGHLIGHTS ON CAUSES AND IMPACTS</p> <p>(TINJAUAN PENILAIAN HILANGNYA KEANEKARAGAMAN HAYATI HUTAN SUNDARBAN: PENYEBAB DAN DAMPAK)</p> <p>Sundarban merupakan hutan bakau terbesar di dunia dan telah diumumkan sebagai Warisan Dunia pada tahun 1997 dan Situs Ramsar pada tahun 2007. Sebanyak 62% terletak di Bangladesh (Wilayah Khulna, Bagerhat, Satkhira, Pirojpur, dan Barguna) dan 38% di India, yang menjadi perintis bagi masyarakat pesisir. Struktur flora dan fauna ekosistem ini mencakup 334 flora, 300 burung, 120 ikan, 35 reptil, dan 32 spesies mamalia. Sundarban menyumbang 41% dari total pendapatan hutan Bangladesh. Tulisan ini bertujuan mempelajari dampak nyata berkurangnya keanekaragaman hayati dan pengaruhnya pada kehidupan dan degradasi lingkungan. Sebanyak 105 artikel dan laporan yang diterbitkan diidentifikasi berdasarkan empat kata kunci: degradasi, keanekaragaman hayati, Sundarban, dan Bangladesh. Dengan mempertimbangkan ruang lingkupnya, 28 artikel dan 17 laporan dimasukkan untuk memenuhi tujuan. Hasil penelitian mengungkapkan bahwa penyebab utama hilangnya keanekaragaman hayati di Sundarban disebabkan oleh peningkatan budidaya udang, peningkatan ketergantungan pada hutan dan penebangan liar, perubahan pola penggunaan lahan, tumpahan minyak dan polusi, kebakaran hutan, praktik pengelolaan yang tidak tepat, penyakit tanaman, kegiatan pariwisata, pengambilan air sungai di hulu, intrusi salinitas, perubahan iklim, dan beberapa penyebab alami. Dampaknya adalah hilangnya keanekaragaman jenis flora dan fauna yang terancam punah secara regional, terancam punah, hampir punah, rentan, terancam, dan kondisi paling tidak mengkhawatirkan. Perubahan pekerjaan dan penurunan kualitas hidup masyarakat sekitar diidentifikasi sebagai dampak. Hasil studi merekomendasikan perumusan kebijakan khusus hutan bakau dan praktik pengelolaan Sundarban yang tepat dengan beberapa strategi perlindungan lingkungan yang harus diadopsi untuk melestarikan ekosistem yang unik ini.</p> <p>Kata kunci: Hutan Bakau, instabilitas lingkungan, perlindungan lingkungan, tambak udang</p>

<p>UDC/ODC 630*287:54</p> <p>Chaman Lal Sharma, Madhubala Sharma, Dahunirikitre M. Lamare, Mahesh Wangkhem, and Govinda Pangging</p> <p>ANATOMICAL AND PHYSICAL CHARACTERISTICS OF <i>Cephalostachyum mannii</i> (Gamble) STAPLETON – AN ENDEMIC SCRAMBLING BAMBOO OF NORTHEAST INDIA</p> <p>(KARAKTERISTIK ANATOMIS DAN FISIK <i>Cephalostachyum mannii</i> (Gamble) STAPLETON–SEBUAH BAMBU PENGERIKAN ENDEMIK DARI INDIA TIMUR)</p> <p><i>Cephalostachyum mannii</i> adalah jenis bambu tinggi, skanden lentur dengan batang yang kokoh. Jenis ini tersebar di negara bagian Arunachal Pradesh, Meghalaya, Mizoram, dan Nagaland di India Timur Laut. Penelitian ini dilakukan untuk mengetahui variasi radial dan vertikal dalam sifat anatomis dan fisik batang spesies bambu ini. Batang dewasa berumur 3-4 tahun dipilih dari hutan Desa Amkassar Amlarem, Distrik Perbukitan Jaintia Barat, Meghalaya, India. Ruas batang yang dipilih dibagi secara radial menjadi zona luar, tengah dan dalam, dan posisi bawah, tengah dan atas secara vertikal. Hasil penelitian menunjukkan bahwa batangnya padat. Bundel vaskular tipe II dan berkembang dengan baik di zona tengah dari posisi bawah dan tengah. Jumlah dan ukuran ikatan pembuluh meningkat dari zona dalam ke zona luar dan menurun dari bawah ke atas. Panjang kapal dan diameter kapal menurun baik secara radial maupun vertikal. Di antara karakteristik serat, ketebalan dinding serat meningkat, sedangkan panjang serat, diameter serat, dan diameter lumen serat menurun secara signifikan baik pada arah radial maupun vertikal. Diantara sifat fisik, densitas meningkat, dan kadar air menurun baik secara radial maupun vertikal. Penyusutan radial lebih tinggi dari susut tangensial. Penyusutan radial dan tangensial menurun secara signifikan dari bawah ke atas. Seratnya panjang, ber dinding tebal dan sangat kaku, dan indeks turunannya tidak memenuhi persyaratan sebagai bahan baku berserat unggul untuk pembuatan pulp dan kertas. Namun, jenis bambu ini berpotensi untuk dijadikan kerajinan tangan dan keranjang berkualitas baik.</p> <p>Kata kunci: Batang padat, serat, kepadatan, kadar air, penyusutan, ikatan pembuluh</p>	<p>dibandingkan dengan alat sadap genggam konvensional. Namun, karena manusia memiliki keterbatasan dalam dimensi fisik, fisiologis, dan mental yang membatasi kemampuannya untuk melaksanakan pekerjaan pada tingkat tertentu, maka tingkat produktivitas kerja yang ditemukan juga harus divalidasi dengan ambang batas lainnya, antara lain beban kerja fisik dan persepsi terhadap risiko.</p> <p>Kata kunci: Ergonomi, getah pinus, penelitian waktu, waktu standar, produktivitas kerja</p>
<p>UDC/ODC 630*892.61</p> <p>Efi Yulianti Yovi, Diah Prasetyana, and Natasha Aquilla Nirmalasari</p> <p>WORK MEASUREMENT STUDY ON MOTOR-MANUAL PINE TAPPING OPERATION: THE APPLICATION OF THE CONCEPT OF LEAN MANUFACTURING AND ALLOWANCES</p> <p>(PENGUKURAN KERJA PADA OPERASI PENYADAPAN GETAH PINUS SECARA MOTOR-MANUAL: APLIKASI KONSEP LEAN MANUFACTURING DAN KELONGGARAN)</p> <p>Produk turunan getah pinus telah diakui sebagai komoditas yang kompetitif dalam perdagangan global, hal ini mendorong peningkatan efisiensi penggunaan sumber daya. Salah satu upaya yang dilakukan untuk menjawab tantangan tersebut adalah penggunaan secara luas mesin sadap dengan pemotong berbentuk cangkul kecil yang disebut “mujitek”. Dalam penelitian ini, serangkaian data waktu kerja yang diamati (waktu kerja aktual) diukur dan dianalisis dengan mengadopsi konsep lean manufacturing untuk menghitung waktu dasar dan waktu standar dan menentukan produktivitas kerja penyadapan. Elemen kerja diidentifikasi berdasarkan kontribusinya dalam proses mengubah atau mentransformasikan produk, dan dikategorikan sebagai elemen kerja dengan nilai tambah, non-nilai tambah, dan kelonggaran khusus. Data kuantitatif produktivitas kerja pada operasi penyadapan dapat digunakan sebagai salah satu data dasar dalam menentukan rencana kerja untuk melangsungkan proses perbaikan yang berkelanjutan. Variabel kelonggaran kelelahan yang diperhitungkan dalam penelitian ini adalah postur berdiri, postur abnormal, energi yang dikeluarkan, kondisi atmosfer, dan kebisingan. Studi ini menunjukkan bahwa elemen pekerjaan yang tidak memiliki nilai tambah (memperbaiki mesin, mengobrol, dan merokok) menyebabkan ketidakefisienan dalam kegiatan penyadapan. Analisis terhadap elemen kerja bernilai tambah membuktikan bahwa penggunaan mesin sadap genggam menawarkan produktivitas kerja yang lebih tinggi (1,7 kali lipat)</p>	

THE IMPORTANCE OF THE UTILIZATION OF FOREST FRUITS IN BATAK TOBA COMMUNITY

Alfonsus H. Harianja^{1*}, Anisse M. Sinaga², Ferry A. Hawari³ and Ridwan Fauzi¹

¹Research and Development Center for Environmental Quality and Laboratory, Research, Development and Innovation Agency, The Ministry of Environment and Forestry, Republic of Indonesia
PUSPIPTEK, Building 210 Serpong, South Tangerang, Indonesia

²Aek Nauli Environmental and Forestry Research and Development Institute,
Jl. Parapat KM. 10 Sibaganding Village, Parapat City, North Sumatra, 21174 Indonesia

³Orangutan Information Centre,
Jalan Bunga Sedap Malam XVIIIc No. 10 Medan Selayang, North Sumatra, 20131 Indonesia

Received: 2 July 2020, Revised: 2 March 2021, Accepted: 3 March 2021

THE IMPORTANCE OF THE UTILISATION OF FOREST FRUITS IN BATAK TOBA COMMUNITY. Batak Toba community who live in the surrounding forests utilise forest-fruits that grow around their settlement. This research aims to describe the important value of the forest fruits using the Local Users Value Index (LUVI) assessment as most of the fruits have not yet been traded. The research was conducted in Simardangiang and Sitoluama Villages in North Tapanuli Regency, 2015. Data collection was done by interviewing 65 respondents selected purposively based on gender and age classification. The results showed that there were 29 species of forest fruits utilised by the community. They were categorised into four utilisation types: fresh fruit, flavouring fruit, processed fruit, and medicines. In Simardangiang Village, the five most important fruits were kapundung or menteng (*Baccaurea racemose*) (0.56), hopong (*Macaranga lowii*) (0.52), sotul, santol or sentul (*Sandoricum koetjape*) (0.48), harimonting or kemunting (*Rhodomyrtus tomentosa*) (0.47), and habo or kabau (*Archidendron bubalinum*) (0.42). Meanwhile, in Sitoluama Village, the five most important fruits were kapundung (*Baccaurea racemosa*) (0.50), hopong (*Macaranga lowii*) (0.41), sihim or rotan manau (*Calamus manan*) (0.32), handis or gamboge (*Garcinia xanthochymus*) (0.32), and mobe (*Artocarpus dadah*) (0.19). The numbers in parentheses are the important value based on LUVI. The forest fruits that have domestication potency are kapundung (*Baccaurea racemose*), hopong (*Macaranga lowii*), sihim (*Calamus manan*), handis (*Garcinia xanthochymus*), mobe (*Artocarpus dadah*), harimonting (*Rhodomyrtus tomentosa*), sotul (*Sandoricum koetjape*) and habo (*Archidendron bubalinum*).

Keywords: *Artocarpus dadah*, *Baccaurea racemosa*, *Calamus manan*, forest fruits, *Rhodomyrtus tomentosa*, LUVI

NILAI PENTING PEMANFAATAN BUAH HUTAN DI MASYARAKAT BATAK TOBA. Komunitas Batak Toba yang mayoritas bermukim di sekitar hutan mengkonsumsi buah-buahan di sekitar pemukiman mereka. Penelitian ini bertujuan untuk mengkuantifikasi nilai penting buah-buahan hutan tersebut dengan mempergunakan metode penilaian LUVI (Local User's Value Index) karena sebagian besar buah-buahan tersebut belum diperjualbelikan di pasar. Penelitian dilakukan pada tahun 2015 dengan mengambil sampel penelitian pada Desa Sitoluama dan Simardangiang di wilayah Kabupaten Tapanuli Utara. Responden dipilih secara purposif, berdasarkan umur dan jenis kelamin (n=65 orang). Hasil penelitian menunjukkan bahwa terdapat 29 jenis buah-buahan yang dimanfaatkan, untuk empat kategori, yakni sebagai buah segar, bumbu masak, buah olahan dan obat-obatan. Pada Desa Simardangiang, lima buah yang mempunyai nilai terpenting berdasarkan nilai LUVI adalah kapundung (*Baccaurea racemose*) (0,56), hopong (*Macaranga lowii*) (0,52), sotul (*Sandoricum koetjape*) (0,48), harimonting (*Rhodomyrtus tomentosa*) (0,47) dan habo (*Archidendron bubalinum*) (0,42). Sedangkan untuk Desa Sitoluama adalah kapundung (*Baccaurea racemosa*) (0,50), hopong (*Macaranga lowii*) (0,41), sihim (*Calamus manan*) (0,32), handis (*Garcinia xanthochymus*) (0,32) dan mobe (*Artocarpus dadah*) (0,19). Berdasarkan temuan tersebut, buah-buahan hutan yang mempunyai potensi domestikasi tertinggi adalah kapundung (*Baccaurea racemose*), hopong (*Macaranga lowii*), sihim (*Calamus manan*), handis (*Garcinia xanthochymus*), mobe (*Artocarpus dadah*), harimonting (*Rhodomyrtus tomentosa*), sotul (*Sandoricum koetjape*) dan habo (*Archidendron bubalinum*).

Kata kunci: *Artocarpus dadah*, *Baccaurea racemosa*, buah-buahan hutan, *Calamus manan*, *Rhodomyrtus tomentosa*, LUVI

* Corresponding author: alfonso_hrj@yahoo.com

I. INTRODUCTION

Forest fruits are widely spread in the tropical forests (Abdel-rahman, Nawal, Awad, & Babiker, 2014b), including in Indonesia, such as in the Tapanuli forests in North Sumatera Province (Noviady & Siwi, 2015). Because of their great variety, forest fruits have enormous potential to meet humans' nutritional needs. Containing excellent quality and high nutritive value such as minerals, amino acids, and vitamins (Abdel-rahman et al., 2014b; Abdel-rahman, Innam, & Elshafe, 2014a; Ayessou Ndiaye, Cissé, Gueye, & Sakho, 2011; Basyuni, Siagian, Wati, Putri, Yusraini, & Lesmana, 2019; Tokairin, da Silva, Spricigo, de Alencar, & Jacomino, 2018), forest fruits are commonly used in the human's dietary, medicinal and industrial processes (Bošnjaković et al., 2012; Fungo et al., 2019; Okan, Serencam, Baltas, & Can, 2019; Smanalieva, Iskakova, Ozbekova, Oskonbaeva, & Darr, 2018).

Indonesia although known as an agricultural country cultivating lots of fruit plants (Istiqamah, 2017), but still imports fruits. Fruits ranked as the most significant imported agricultural products in 2018, worth US\$ 1.28 million (Satriana & Prayoga, 2019). It is mainly caused by the insufficient production and supply of local fruits. Secondly, the price of some of the local fruits is more expensive than the cost of imported fruits. Therefore, production of local fruits, including forest fruits, has great potential to succeed and meet the demand.

The local community in Indonesia has developed the utilisation of forest fruits for a long time. Some researchers noted that the use of forest fruits is usually done by the community in the surrounding forest. They consume forest fruits as fresh fruit, processed fruit, flavours, and medicines (Fitmawati, Saputra, Sinaga, Roza, & Isda, 2018; Jemi et al., 2015; Rujehan, 2012; Silalahi & Nisyawati, 2015; 2018; Utami, Rahayuningsih, Abdullah, & Haka, 2019). There are many studies in Indonesia that explore the distribution of forest fruits (Noviady & Siwi, 2015; Suwardi & Harmawan, 2019), ethnobotany (Ibo & Arimukti, 2019; Jemi et al.,

2015; Murniati, Padmanaba, & Basuki, 2009; Silalahi & Nisyawati, 2015, 2018; Suwardi & Harmawan, 2019; Utami et al., 2019) and its benefit value (Murniati, Padmanaba, Basuki, 2009; Rujehan, 2012). However, the study of the importance of the value of the forest fruits is still minimal. On the contrary, it has been widely studied by other researchers abroad. They concluded that harvesting and domesticating various fruit plants emerge significant economic benefits (Agbelade & Onyekwelu, 2013; Man & Januszewska, 2010; Onyekwelu, Olusola, Stimm, Mosandl, & Agbelade, 2014). Besides, forest fruit plants also provide ecological benefits for species conservation (Bolakhe & Ghimire, 2019; Estoque et al., 2019; De Souza et al., 2018) and the environment (Khair, Purnomo, & Sumaryoto, 2017; Sardeshpande & Shackleton, 2019; Wang, Sun, Xiong, Yang, Hou, & Sheng, 2019).

Knowledge and utilisation of forest fruits by the local community vary based on the location and experience living in the area. Ecology and culture are two important factors that influence its utilisation (Pinedo-Vasquez, Zarin, Jipp, & Chota-Inuma, 1990; Prance, Balee, Boom, & Carneiro, 1987). Batak Toba communities, a sub-ethnic of Batakese in North Sumatera Province (Borualogo & Vijver, 2016) that are living in the Bukit Barisan mountains and surrounding forests, historically used to utilise many forest fruits for many purposes, including for medicine in their daily life (Silalahi, Nisyawati, & Anggraeni, 2018). However, nowadays, the utilisation of forest fruits is rarely done by the community. Modernisation has influenced young age villagers to go to the city to increase their standard of living (Borualogo & Vijver, 2016; Chandra, 2004) and it has resulted in that much local wisdom is slowly diminishing and affect the sustainability and existence of plants and fruits.

Research or efforts to preserve local wisdom and the potential of forest fruits is limited. In contrast, the pressure on the forest and its surrounding communities tend to increase. It is essential to provide data and transparent

information about the local wisdom and the potential of forest fruits. This study describes the critical value of forest fruits in Batak Toba society. The research aims to record the types of forest fruits using the ethnobotany framework (Ibo & Arimukti, 2019; Murniati et al., 2009; Shigaeva, Darr, Sulaiman, & Polesny, 2019), with the approach of the valuation of the direct benefits of forest (Rujehan, 2012) obtained from the local community living around the forests.

II. MATERIAL AND METHOD

A. Location and Time of the Study

This research was done in 2015, employing field data collection in Pahae Julu Sub-district, Tapanuli Regency, North Sumatera Province. Research focused on two villages, Sitoulama and Simardangiang, in Pahae Julu Sub-district, selected purposively, based on the distance to the adjacent forest (Figure 1). Sitoluama and Simardangiang villages are located nearby primary and secondary forests in Pahae Julu Sub-district. Located 6,5 km from Onan Hasang (the capital of Pahae Julu Sub-district), Sitoluama is closer than Simardangiang. The agricultural system has been more developed in

Sitoluama than in Simardangiang, although the total area of Sitoluama is smaller (600 hectares) than Simardangiang's (859 hectares). On the contrary, Sitoluama has a higher population (713 persons) than Simardangiang (664 persons).

Cultivation of fruit trees is commonly found in the Pahae Julu subdistrict. Statistical Bureau of North Tapanuli Regency in 2015 reported that the horticulture system was commonly developed in the form of home gardens. The six highest fruit production in this area were alpukat (*Persea americana*), duku (*Lansium parasiticum*), durian (*Durio zibethinus*), jambu air (*Syzygium aqueum*), papaya (*Carica papaya*), pisang (*Musa* sp.), and nenas (*Ananas comosus*). The products of cultivated fruits were sold in the local market, namely in Onan Hasang or in Tarutung. Forest fruit production is not recorded since the products have not yet been traded in the market, although commonly consumed in all villages, especially those living in nearby forests such as Sitoluama and Simardangiang.

The community in Simardangiang Village is still very dependent on the forest to meet their daily needs. Their ancestors were used to be frankincense farmers with high productivity. Today, the household income of some villagers

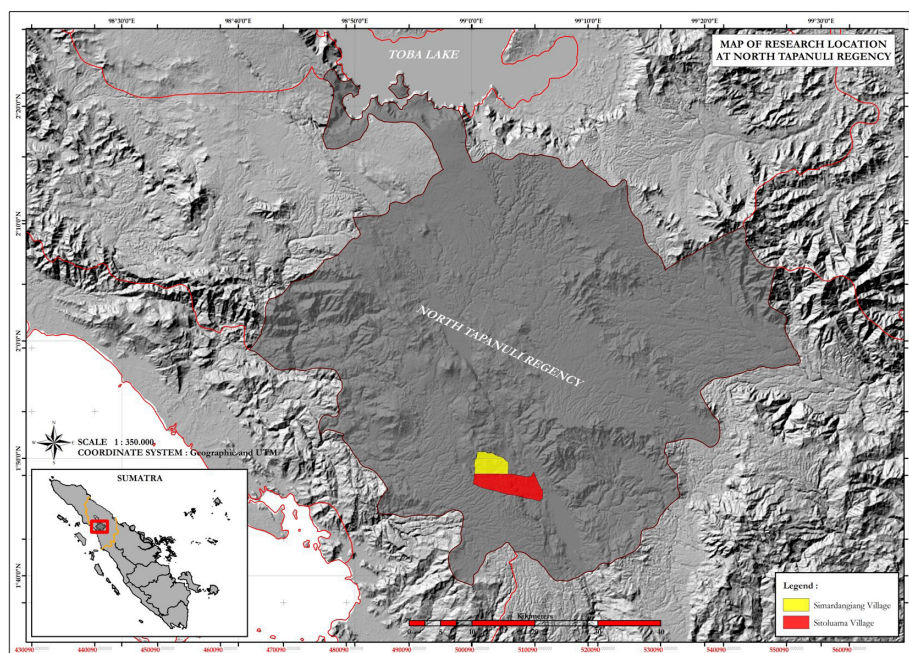


Figure 1. Research location

still depend on the income from incense even though their forest productivity started to decline (Ambarita & Sitorus, 2015; Phanith, 2019). Forest conservation based on indigenous knowledge of this community was still very high, as commonly found in the social forestry system (Bolakhe & Ghimire, 2019). Land clearing by cutting down trees and destroying the forest almost did not happen in this village.

A different situation occurred in Sitoluama Village. Community's dependency upon the forest in Sitoluama is less than of Simardangiang Village. The community in Sitoluama Village is more familiar with the developed farming system. Thus, the forest's condition is more open, and a lot of forest fruit trees began to be scarce.

B. Methods

Some assessments were used to obtain data and information. Since the forest fruits are not yet traded in the market, we constructed an important valuation based on the ethnobotany process. First, we traced the significance of forest fruits by interviewing critical respondents in Sitoulama and Simardangiang Villages. This interview was done using a semi-structured questionnaire and observation to identify plants of forest fruits in the forest. The information gathered included the local name of the forest fruits, fruiting season, utilisation, and plants description. The observation was done to explore the fruits' availability in the forests and the plants' description was cross-checked.

The second phase was Focused Group Discussion (FGD). FGD was set up in both villages, involving four groups of villagers. This grouping has adopted the local user valuation system methods, developed by (Sheil et al., 2003) and has also been employed by Murniati et al.(2009. In Batak Toba culture, preservation of food such as vegetable and fruit are commonly done by women in a family. Man, normally has the responsibility for harvesting them from the garden or forest. Based on this situation, we assume that different knowledge exists according to gender; thus, the valuation

of fruit is also related to gender and age, as suggested by previous research (Murniati et al., 2009; Sheil et al., 2003). Then, the group of FGD was divided into four groups, namely older men (OM), older women (OW), young men (YM) and young women (YW). Each group consisted of 8-12 persons.

During the FGD, participants were facilitated to resume forest fruits, followed by an important valuation based on four categories: fresh fruit, flavoring fruit, processed fruit, and medicine. The valuation was ranked using the Local User's Valuation Index (LUVI); the method is named Pebble Distribution Method (PDM), developed by Sheil et al. (2003). In this method, each participant has valued the significance of forest fruits by distributing 100 counters (small stones or nuts) over labelled cards (using the names of the forest fruits). This judgment resulted in the important value of the forest fruits based on the valuation of the villagers.

C. Analysis

The forest fruit's important value was calculated and analysed using LUVI (Sheil et al., 2003). This method is started by scoring the important value of a type of use (j) of a species (i) represented as an individual value (Gij). Every respondent valued every species' importance by putting a pebble on the species they thought was the most important based on their daily utilisation of the fruit. The Gij value represents the important value of one species for one purpose or cumulative value for several purposes. LUVI then was calculated as the sum of all species, based on Gij values, using the following formula:

$$LUVI = \sum_{i=species\ for\ all\ j}^j Gij \dots\dots\dots(1)$$

The calculated values were then tabulated and analysed using the hierarchy of important value. The score or rank of the forest fruits based on LUVI can be used as scientific evidence of species conservation or domestication for increasing its future availability.

III. RESULT AND DISCUSSION

A. Utilisation of Forest Fruits in Sitoluama and Simardangiang Villages

The criteria of respondents based on age and gender were met in Simardangiang Village. While in the Sitoluama Village, the age group of young men (YM) was not present since YM in this village tends to work outside the village. The number of respondents in both villages is presented in Table 1.

Based on FGD, both villagers identified the same species of forest fruits obtained from the surrounding forest. There are four means of forest fruits utilisation. Those which are consumed directly, processed or mixed with other ingredients, used as flavours or spices and used for medicines. A list of the forest fruits is presented in Table 2.

During the FGD, both villages' respondents stated that almost all the fruits were not sold

Table 1. Respondents' distribution in both villages

No.	Group	Simardangiang Village	Sitoluama Village
1.	Young Men (YM)	8	-
2.	Older Men (OM)	21	8
3.	Young Women (YW)	6	8
4.	Older Women (OW)	8	6

Table 2. Utilised forest fruits.

No	Local Name	Scientific Name	Fruiting Season	Mean of utilisation
1.	Rau	<i>Ficus</i> sp.	Once a year	Fr
2.	Torop	<i>Artocarpus elasticus</i>	Once a year, in December	Pr
3.	Dumon-dumon	<i>Ficus carica</i>	Twice a year	Fr
4.	Mobe	<i>Artocarpus dadab</i>	Once a year	Fr, Fv or Pr
5.	Sihim	<i>Calamus manan</i>	Once a year, April	Fr, Fv, Pr or Md
6.	Hopong	<i>Macaranga Iowii</i>	Twice a year	Fv, Pr or Md
7.	Cempedak hutan	<i>Artocarpus integer</i>	Once a year	Fr or Pr
8.	Habo	<i>Archidendron bubalinum</i>	Once a year	Fr, Fv, Pr or Md
9.	Bosi-bosi	<i>Timonius flavescens</i>	Twice a year	Fr, Fv, Pr or Md
10.	Attarudan	<i>n.a</i>	Once a year	Fr
11.	Ruham	<i>Flacourtia rukam</i>	Once a year	Fr, Pr or Md
12.	Buah baja	<i>Rhodannia</i> sp.	Once a year	Fr
13.	Tungir-tungir	<i>Baccaurea polynura</i>	Once a year	Fr, Pr or Md
14.	Hau dolok	<i>Syzigium</i> sp.	Once a year	Fr
15.	Rambutan ramba	<i>Nephelium juglandifolium</i>	Once a year	Fr
16.	Sotul	<i>Sandorium koetjape</i>	Once a year	Fr, Fv, Pr or Md
17.	Baruas	<i>Garcinia celebica</i>	Once a year	Fr
18.	Hapundung	<i>Baccaurea racemosa</i>	Once a year	Fr, Fv, Pr or Md
19.	Gorbus	<i>Mangifera caesia</i>	Once a year	Fr
20.	Pirdot	<i>Saurauia bracteosa</i>	Along the year	Fr
21.	Riuk-riuk	<i>n.a.</i>	Once a year	Fr
22.	Mayang	<i>Areca catechu</i>	Once a year	Fr
23.	Handis	<i>Garcinia xanthochymus</i>	Once a year	Fr, Fv, Pr or Md
24.	Durian hutan	<i>Durio</i> sp.	Once a year	Fr
25.	Pining bodat	<i>Pinanga kublii</i>	Once a year	Fr, Pr or Md
26.	Handuduk	<i>Clidemia birta</i>	Along the year	Fr
27.	Harimonting	<i>Rhodomyrtus tomentosa</i>	Along the year	Fr, Pr or Md
28.	Barangan	<i>Castanea</i> sp.	Once a year	Fr
29.	Gabura	<i>n.a.</i>	Twice a year	Fr

Remarks: Fr = Fresh fruit, Fv = Flavoring fruit, Pr = Processed fruit and Md = Medicine

in the market yet, except for *Baccaurea polyneura*, *Artocarpus dadab*, and *Archidendron bubalinum*. The market price of *Baccaurea polyneura* was IDR 12,000/kg, while the price of *Artocarpus dadab* and *Archidendron bubalinum* were IDR 5,000/kg and IDR 8,000/kg, respectively. Fruit availability depends on the fruiting season where the majority of the fruits are only available once a year, except for dumon-dumon, hopong, bosibosi, and gabura which has two fruit seasons in one year or pirdot, handuduk, and harimonting that bear the fruit throughout the year. All the forest fruits listed in Table 2 also have not yet been cultivated. The villagers harvest them directly from the nearby forest.

B. Important Value

The important value that LUVI presents were differentiated using age and gender category, namely older men (OM), older women (OW), young men (YM), and young women (YW) in both villages. Respondents below 40 years old

age are categorised as young, and ≥ 40 years old are classified as older. The means of utilisation are divided into four groups, namely fresh fruit (Fr), processed fruit (Pr), flavouring fruit (Fv), or medicine fruit (Md). During the FGD, the respondents were asked to rank the ten most important forest fruits based on PDM's four means. The value given is presented in Table 3.

Table 3 indicated that some of the ten important forest fruits were different in the two villages. It is influenced by the village's forest and the forest fruit species that still exist in it. The inhabitant's knowledge also characterises it. The villagers of Simardangiang know the forest fruits and their utilisation better than those of Sitoluama. This research also quantified the value of the utilization of the ten most important forest fruits across gender and age (Table 4).

Table 4 shows the different values of forest fruits for each group of respondents in Simardangiang Village. The older men group

Table 3. The ten most important forest fruits.

No.	Simardangiang Village	Sitoluama Village
1.	<i>Bosi-Bosi</i>	<i>Barangan</i>
2.	<i>Cempedak Hutan</i>	<i>Handis</i>
3.	<i>Habo</i>	<i>Hopong</i>
4.	<i>Harimonting</i>	<i>Kapundung</i>
5.	<i>Hopong</i>	<i>Mobe</i>
6.	<i>Kapundung</i>	<i>Rambutan Hutan</i>
7.	<i>Pining Bodat</i>	<i>Riuk-Riuk</i>
8.	<i>Rubam</i>	<i>Rubam</i>
9.	<i>Sotul</i>	<i>Sibim</i>
10.	<i>Tungir-Tungir</i>	<i>Tungir-Tungir</i>

Table 4. Value of forest fruit utilisation

No	Means of utilisation	Simardangiang				Sitoluama		
		OM	YM	OW	YW	OM	OW	YW
1.	Fresh fruit	0.30	0.22	0.28	0.20	0.26	0.32	0.36
2.	Processed fruit	0.20	0.22	0.24	0.40	0.29	0.22	0.21
3.	Flavoring fruit	0.29	0.20	0.11	0.30	0.22	0.20	0.21
4.	Medicine	0.21	0.36	0.37	0.10	0.23	0.26	0.22
	Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Remarks: OM = Older men, YM = Young men, OW = Older women, YW = Young women

knows the ten fruits mainly as fresh fruit (30%). The younger men and older women know them as medicines, 36% and 37%, respectively. Different from all groups, the younger women group dominantly knows them as processed fruits (40%). The contrary situation was found in Sitoluama. In this village, the older men group knows the ten fruits mainly as processed fruits (29%). Meanwhile, both women groups recognise the ten fruits as fresh fruit (32% in older women and 36 % in younger women) (see Table 4).

This different value is influenced by a different level of knowledge and experience of each age group. Older age groups certainly have broadened understanding than the younger age groups. According to (Sembiring, Utomo, & Batubara, 2013), community knowledge of medicinal plants is inherited from their ancestors and developed well in a particular community. People obtain medicinal plants from their home garden, and if not found, they will look for it in the forest. In some cases, the younger age groups also do not recognise some types of fruit trees. This knowledge is also likely to disappear along with the changed lifestyle (Man & Januszewska, 2010). The communities are no longer relying on forest resources, as occurring in Sitoluama.

Ethnobotany knowledge is widely found in Indonesia's traditional life, resulting from interacting, working, and utilising forest plants. Knowledge of ethnobotany is an indication of sustainable utilisation of forest plants (Murniati

et al., 2009; Sheil et al., 2003; Suwardi et al., 2019). The declining knowledge of ethnobotany is the beginning of forest degradation because of the declining role of a local institution in sustainable forest utilisation (Milow, Ramli, & Chooi, 2010).

Knowledge in utilisation of forest fruits is vital to develop conservation or domestication strategy. It also provides the benchmark of fruit commercialisation in form of agribusiness system in the future (Onyekwelu et al., 2014; Phanith, 2019; Subhilhar, 2018). Based on the LUVI, the important value of ten forest fruits is presented in Table 5 (Simardangiang) and Table 6 (Sitoluama).

The majority of respondents of Simardangiang Village have chosen kapundung (*Baccaurea racemose*) (0.56), hopong (0.52), sotul (*Sandorium koetjape*) (0.48), harimonting (*Rhodomyrtus tomentosa*) (0.47), and habo (*Archidendron bubalinum*) (0.42) as essential fruits based on LUVI. The highest value of the five-forest fruit is likely related to the abundance of those fruits in nearby forests and means of utilisation. Table 5 indicated that each age group could utilise one fruit in two categories. The high LUVI show high demand for the fruit, then the fruit is vital to be conserved or domesticated.

A different situation was found in Sitoluama. The five highest LUVI of forest fruits in this village are kapundung (*Baccaurea racemosa*) (0.50), hopong (0.41), sihim (*Calamus manan*) (0.32), handis (*Garcinia xanthochymus*) (0.31) and

Table 5. LUVI of the ten most important forest fruits in Simardangiang

No	Species	Gender and age group																Total LUVI
		Older Men				Young Men				Older Women				Young Women				
		Fr	Fv	Pr	Md	Fr	Fv	Pr	Md	Fr	Fv	Pr	Md	Fr	Fv	Pr	Md	
1.	<i>Baccaurea polyneura</i>	0.08	0.00	0.02	0.00	0.03	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.07	0.00	0.00	0.00	0.26
2.	<i>Archidendron bubalinum</i>	0.00	0.00	0.08	0.00	0.02	0.09	0.06	0.00	0.02	0.00	0.00	0.04	0.00	0.00	0.12	0.00	0.42
3.	<i>Baccaurea racemosa</i>	0.06	0.08	0.00	0.00	0.04	0.02	0.06	0.00	0.01	0.02	0.04	0.03	0.01	0.10	0.10	0.00	0.56
4.	<i>Hopong</i>	0.00	0.13	0.05	0.00	0.00	0.09	0.03	0.00	0.03	0.00	0.01	0.10	0.03	0.00	0.00	0.03	0.52
5.	<i>Pinanga kuhlii</i>	0.00	0.00	0.00	0.03	0.02	0.00	0.02	0.00	0.02	0.00	0.02	0.09	0.01	0.00	0.00	0.00	0.20
6.	<i>Rhodomyrtus tomentosa</i>	0.05	0.00	0.00	0.08	0.02	0.00	0.02	0.22	0.02	0.00	0.03	0.00	0.01	0.00	0.00	0.04	0.47
7.	<i>Bosi-bosi</i>	0.00	0.00	0.00	0.10	0.01	0.00	0.03	0.14	0.03	0.02	0.05	0.00	0.00	0.00	0.00	0.03	0.39
8.	<i>Artocarpus integer</i>	0.02	0.00	0.05	0.00	0.05	0.00	0.04	0.00	0.04	0.02	0.03	0.04	0.01	0.00	0.00	0.00	0.34
9.	<i>Filacourtia rukam</i>	0.04	0.00	0.00	0.00	0.01	0.00	0.05	0.00	0.05	0.00	0.00	0.04	0.00	0.10	0.10	0.00	0.34
10.	<i>Sandorium koetjape</i>	0.05	0.06	0.00	0.00	0.02	0.00	0.05	0.00	0.05	0.03	0.03	0.02	0.10	0.10	0.08	0.00	0.48

Table 6. LUVI of the ten most important forest fruits in Sitoluama

No	Species	Gender and Age Group												Total LUVI
		Older Men				Older Women				Young Women				
		Fr	Fv	Pr	Md	Fr	Fv	Pr	Md	Fr	Fv	Pr	Md	
1.	<i>Calamus manan</i>	0.05	0.00	0.00	0.00	0.05	0.03	0.03	0.00	0.04	0.07	0.12	0.07	0.32
2.	<i>Rink-rink</i>	0.06	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06	0.00	0.07	0.00	0.14
3.	<i>Nepbelium juglandifolium</i>	0.02	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.07	0.01	0.00	0.01	0.17
4.	<i>Baccaurea polynetra</i>	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.04	0.03	0.01	0.03	0.08
5.	<i>Flacourtia rukam</i>	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.06	0.01	0.03	0.01	0.11
6.	<i>Garcinia xanthochymus</i>	0.01	0.04	0.00	0.00	0.03	0.04	0.04	0.00	0.03	0.05	0.01	0.01	0.31
7.	<i>Hopong</i>	0.01	0.09	0.07	0.00	0.03	0.06	0.06	0.00	0.00	0.06	0.01	0.00	0.41
8.	<i>Baccaurea racemosa</i>	0.06	0.08	0.10	0.00	0.03	0.06	0.06	0.00	0.06	0.05	0.09	0.01	0.50
9.	<i>Artocarpus dadab</i>	0.00	0.02	0.06	0.00	0.01	0.03	0.03	0.00	0.07	0.05	0.00	0.00	0.19
10.	<i>Castanea sp.</i>	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.03

Remarks: Fr = Fresh fruit, Fv = Flavoring fruit, Pr = Processed fruit and Md = Medicine

mobe (*Artocarpus dadab*) (0.19). Having lower dependence on forest resources, the villagers in Sitoluama also have more inadequate knowledge and utilisation value of forest fruits expressed in LUVI of forest fruits. Situated nearby the main road of Pahae Julu, Sitoluama tends to be influenced by a more modernised lifestyle. This is the cause of the disappearing local knowledge, which is also exacerbated by deforestation (Estoque et al., 2019).

This study found that villagers' preference for utilisation of forest fruits in the two villages has both similarities and differences. However, they come from the same sub-ethnic community, Batak Toba. The similarity is that the respondents in Simardangi and Sitoluama rank kapundung and hopong as the most valuable forest fruit. The difference is the use of some medicinal fruits such as hopong and harimonting. These fruits are used as a medicinal plant in Simardangi but not in Sitoluama.

It can be resumed that the important forest fruits to be conserved and domesticated are kapundung (*Baccaurea racemose*), hopong, sihim (*Calamus manan*), handis (*Garcinia xanthochymus*), mobe (*Artocarpus dadab*), harimonting (*Rhodomyrtus tomentosa*), sotul (*Sandorium koetjape*), and habo (*Archidendron bubalinum*). If the important factor is considered as the main factor, forest fruits that have the highest potential are kapundung (*Baccaurea racemose*),

hopong, sotul (*Sandorium koetjape*), harimonting (*Rhodomyrtus tomentosa*), and habo (*Archidendron bubalinum*). These research findings can be used to determine the basis for domestication of forest fruit (Isik, Kumar, Martínez-García, Iwata, & Yamamoto, 2015; Milow, Ramli, & Chooi, 2010). The results of the research will contribute to the strategy of forest fruit preservation (Čurović, Jovančević, & Balijagić, 2019; Man & Januszewska, 2010) to meet human needs. Development of forest fruits can be carried out in the agroforestry system, as most forest fruits need a forest ecosystem to grow (Sundawati, Purnaningsih, & Purwakusumah, 2012).

This study indicates that based on villagers' utilisation, forest fruits have important value. Forest fruit consumption may add a variety to their daily intake and contribute to their improved health (Bosnjakovic et al., 2012). However, the villagers have not cultivated these trees yet; they harvest them from the forest around their settlement. Considering the high rate of deforestation, the existence of these fruits in the future will likely not be sustainable. Therefore, domestication is needed to increase availability and ensure future generations' sustainability (Murniati et al., 2009).

The other benefits of domesticating forest fruits are to support biodiversity conservation (Čurović, Jovančević, & Balijagić, 2019; de Souza, Maurício, Dias-Guimarães, Guimarães, & Braga,

2018), to diversify rural products, to sustain local wisdom and culture (Man & Januszewska, 2010), to develop local economy (Agbelade & Onyekwelu, 2013; Jemi et al., 2015; Schunko, Lechthaler, & Vogl, 2019), and to preserve the forested landscape and environment (Čurović et al., 2019). Domestication requires more research on various topics such as selection of fruit trees, germplasm collection, tree planting, integration to existing farming systems such as agroforestry, as well as economic and social benefits (Onyekwelu et al., 2014).

The findings of this research are necessary as the baseline for the domestication of forest fruits, although it provides the potential economic value of the fruits. On the policy side essential support from the government is needed to initiate the stages of domestication of forest fruit trees. The government also needs to build a system that accommodates participation of the communities (Onyekwelu et al., 2014), both in decision making and in the implementation process.

IV. CONCLUSION

Important value consideration is useful to provide a benchmark for domestication strategies and the development of utilisation of forest fruits on Toba, sub-ethnic community. Fruits are utilised as fresh fruit, flavouring fruit, processed fruit, and medicinal fruit. Based on LUVI the important forest fruits are kapundung (*Baccaurea racemose*), hopong, sihim (*Calamus manan*), handis (*Garcinia xanthochymus*), mobe (*Artocarpus dadab*), harimonting (*Rhodomyrtus tomentosa*), sotul (*Sandorium koetjape*), and habo (*Archidendron bubalinum*). Domestication is important to maintain the availability of the fruits because not all fruit types are available all year round, most of them fruiting once up to twice a year. The benefits generated by the forest fruits align with the values of social importance in the community and provision of nutrition value. Future research in various topics related to the domestication of fruit trees such as selection of trees, germplasm collection,

silviculture, farming system, and socio-economic feasibility, are needed to conserve the important forest fruits. The government needs to support it by providing necessary policies and systems that ensure local communities' participation and rights in assessing these forest resources.

ACKNOWLEDGEMENT

We appreciate the valuable support from local governments in North Tapanuli Regency, especially for assistance in the data collection process. We also express our gratitude for Aek Nauli Environmental and Forestry Research and Development Institute, Research, Development and Innovation Agency (FORDA), Ministry of Environment and Forestry of the Republic of Indonesia for funding this research.

REFERENCES

- Abdel-rahman, N.A., Innam, I. A. & Elshafe, E., (2014a). Characterisation of some sudanese edible forest fruits. *Journal of Agri-Food and Applied Sciences*, 2(2), 39–44.
- Abdel-rahman, N. A. Innam I. A., & Babiker. E. B. (2014b). Nutritional value of some edible forest fruits. *Journal of Agri-Food and Applied Sciences*, 2(3),72–76.
- Agbelade, A. D., & Onyekwelu. J. C.(2013). Poverty alleviation through optimising the marketing of *Garcinia kola* and *Iringia gabonensis* in Ondo State, Nigeria. *ISRN Forestry*, 2013(January),1–5. doi://10.1155/2013/376247.
- Ambarita, E. C., & Sitorus, H. (2015). Modal sosial komunitas petani kemenyan dalam pelestarian hutan kemenyan di Desa Pandumaan, Kecamatan Pollung, Kabupaten Humbang Hasundutan. *Perspektif Sosiologi*, 3(1),42–57.
- Ayessou, C., Ndiaye, N., Cissé, C., Gueye, M. & Sakho. M (2011). Nutritional contribution of some Senegalese forest fruits running across Soudano-Sahelian zones. *Food and Nutrition Sciences*, 02(06),606–12. doi://10.4236/fns.2011.26085.

- Basyuni, M., Siagian, Y. S. Wati, R. Putri, I. A. P. Yusraini, E. & Lesmana, I. (2019). Fruit nutrition content, hedonic test, and processed products of pidada (*Sonneratia caseolaris*). p. 7 in *IOP Conference Series: Earth and Environmental Science*. 251.
- Bolakhe, S., & Ghimire. P. (2019). Promotion of trees outside forest for chure conservation in Nepal. p. 2 in *South Asian Agroforestry Conference*.
- Borualogo, S., I. & Van De Vijver. F. J. R. (2016). Values and migration motives in three ethnic groups in Indonesia. *The International Association for Cross-Cultural Psychology Conferences*. p. 252- 60
- Bošnjaković, D., Ognjanov, V. Ljubojević, M. Barać, G. Predojević, M. Mladenović, E. & Čukanović. J. (2012). Biodiversity of wild fruit species of Serbia. *Genetika*, 44(1),81–90. doi:// 10.2298/GENSR1201081B.
- Chandra, Suleeman. J. (2004). Notions of critical thinking in Javanese, Batak Toba and Minangkabau Culture. Pp. 275–93 in *International Association for Cross-Cultural Psychology Conferences*.
- Čurović, M., Jovančević, M. & Balijagić. J. (2019). Wild fruit tree species of Montenegrin forests. *Advances in Global Change Research*. 65, Switzerland: Springer. Pp, 21-28.
- De Souza, R. G., Maurício L., & Dias-Guimarães, M. A. Guimarães, L.A.O.P. & Braga. J.M.A (2018). Fruits of the Brazilian atlantic forest: Allying biodiversity conservation and food security. *Anais Da Academia Brasileira de Ciencias*, 90(4),3583–95. doi:// 10.1590/0001-3765201820170399.
- Estoque, R. C., Ooba, M., Avitabile, V., Hijioka, Y., DasGupta, R., Togawa, T., & Murayama, Y. (2019). The future of Southeast Asia's forests. *Nature communications*, 10(1), 1829. doi://10.1038/s41467-019-09646-4.
- Fitmawati, J. E. , Saputra, A. Sinaga, P. Roza, R. M., & Isda, M. N. (2018). The Potential of wild mango leaves from Sumatera as the immunostimulant agent. *Journal of Biology & Biology Education*, 10(3),671–77. doi://10.15294/biosaintifika.v10i3.16549.
- Fungo, R. Muyonga, J. H. Ngondi, J. L. Mikolo-Yobo, C. Iponga, D. M., Erasmus, A. N. Tang, N. & Tieguhong, J. C. (2019). Nutrient and bioactive composition of five gabonese forest fruits and their potential contribution to dietary reference intakes of children aged 1-3 years and women aged 19-60 years. *Forests*, 10(2),19. doi://10.3390/f10020086.
- Ibo, L. K. & Arimukti, S. D. (2019). Studi etnobotani pada masyarakat sub-etnis Batak Toba di Desa Martoba, Kabupaten Samsir, Sumatera Utara. *Prosiding Seminar Nasional Masyarakat Biodiversity Indonesia*. 5. p. 234–41
- Isik, F. S. K., Martínez-García, P. J., Iwata, H., & Yamamoto, T. (2015). Acceleration of forest and fruit tree domestication by genomic selection. (74th ed). Amsterdam: Elsevier B.V.
- Jemi, R., Joni, H, Toni, H, Aguswan, J, Triyadi, A, Putir, P. E, Jagau, Y, Gohong, G, Tara, E, & Lusiana, H. (2015). Kaleka lapetan sgroforestry masyarakat dayak di Desa Bahu Palawa Kabupaten Pulang Pisau. P. 9 SEMIRAT Bidang Ilmu Pertanian BKS PTN Barat 2015.
- Khair, M, Purnomo, A.H, & Sumaryoto. (2017). Aplikasi konsep eko-arsitektur pada obyek rancangan agrowisata di Kabupaten Demak. *Region*, 12(2),159–67.
- Man, A, & Januszewska. R. (2010). Forest fruits' purchase and consumption motives by the urban Romanians: An application of the theory of planned behaviour. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca - Horticulture*, 67(2),144–49. doi://10.15835/buasvmcn-hort:5055.
- Milow, P., Ramli, M. R, & Chooi. O. H. (2010). Preliminary survey on plants in home gardens in Pahang, Malaysia. *Journal of Biodiversity*, 1(1),19–25. doi:// 10.1080/09766901.2010.11884715.
- Murniati, Padmanaba, M, & Basuki. I. (2009). The importance of forest and landscape resource for community around Gunung Lumut protected forest, East Kalimantan. *Indonesian Journal of Forestry Research*, 6(1),53–73. doi://10.20886/ijfr.2009.6.1.53-73.
- Noviady, I, & Siwi. S. N.(2015). Komposisi vegetasi di Robian Tongah-Tongah, hutan lindung Gunung Sibuatan, Sumatera Utara. *Prosiding Seminar Nasional Masyarakat Biodiversity Indonesia*. p. 1380–84.
- Okan, O.T, Serencam, H, Baltas, N, & Can. Z. (2019). Some edible forest fruits their in vitro

- antioxidant activities, phenolic compounds and some enzyme inhibition effects. *Fresenius Environment Bulletin*, 28(8), 090–98.
- Onyekwelu, J. C., Olusola, J. A., Stimm, B. Mosandl, R. & Agbelade, A.D, (2014). Farm-level tree growth characteristics, fruit phenotypic variation and market potential assessment of three socio-economically important forest fruit tree species. *Forests Trees and Livelihoods*, 24(1),27–42. doi://10.1080/14728028.2014.942386.
- Phanith, C. (2019). The hidden value of non-timber forest products towards poverty alleviation and forest conservation: A case of phnom prich wildlife sanctuary, Mandulkri Province, Cambodia. Nagoya University.
- Pinedo-Vasquez, M., Zarin, D., Jipp, P., & Chota-Inuma. J. (1990). Use-values of tree species in a communal forest reserve in Northeast Peru. *Conservation Biology*, 4(4),405–16. doi://10.1111/j.1523-1739.1990.tb00315.x.
- Prance, G. T., Balee, W., Boom, B. M., & Carneiro. R. L. (1987). Quantitative ethnobotany and the case for conservation in Amazonia, *Conservation Biology*, 1(4),296–310. doi://10.1111/j.1523-1739.1987.tb00050.x.
- Rujehan, (2012). Nilai manfaat langsung ekosistem dipterokarpa bagi masyarakat setempat di hutan lindung Sungai Wain. *Jurnal Penelitian Dipterokarpa*, 6(1),51–66. doi://10.20886/jped.2012.6.1.51-66.
- Sardeshpande, M., & Shackleton. C. (2019). Wild edible fruits: A systematic review of an under-researched multifunctional NTFP (Non-Timber Forest Product). *Forests*, 10(467),1-24. doi://10.3390/f10060467.
- Satriana, E. D., & Prayoga A. (2019). Menelusik impor pertanian Indonesia. Seminar Nasional: Membangun Kedaulatan Pangan Nasional Berbasis Kearifan Lokal (March):1.
- Schunko, C., Lechthaler, S., & Christian R. V. (2019). Conceptualising the factors that influence the commercialisation of non-timber forest products: The Case of wild plant gathering by organic herb farmers in South Tyrol (Italy). *Sustainability*, 11(7)1-21. doi://10.3390/su11072028.
- Sembiring, R, Utomo, B, & Batubara. R, (2013). Keanekaragaman vegetasi tanaman obat di hutan pendidikan Universitas Sumatera Utara kawasan taman hutan raya Tongkoh Kabupaten Karo Sumatera Utara. *Peronema Forestry Science*, 2(2),19–22.
- Sheil, D, Puri, R. K, Van Heist, M, Wan, M, Liswanti, N, Rukmiyati, M. A. S., Sidiyasa, K, Chrisnandini, Permana, E. Mangopo, E. Angi, Gatzweiler, F, Johnson, B, & Wijaya. A, (2003). Exploring biological diversity, environment and local people's perspectives in forest landscapes: Methods for a multidisciplinary landscape assessment.
- Shigaeva, J, Darr, D, Sulaiman, N, & Polesny, Z. (2019). Ethnobotany of wild plants and crop wild relatives in the walnut-fruit forests of Kyrgyzstan. *Filling gaps and removing traps for sustainable resources development*. Tropentag, September 18 - 20, 2019.
- Silalahi, M, & Nisyawati. (2015). Etnobotani pasak bumi (*Eurycoma longifolia*) pada Etnis Batak, Sumatera Utara. *Prosiding Seminar Nasional Masyarakat Biodiversity Indonesia*, 1. Pp. 743–46
- Silalahi, M, & Nisyawati. (2018). The ethnobotanical study of edible and medicinal plants in the home garden of Batak Karo sub-ethnic in North Sumatera, Indonesia. *Biodiversitas*, 19(1),229–38. doi://10.13057/biodiv/d190131.
- Silalahi, M, Nisyawati, & Anggraeni.R. (2018). Studi etnobotani tumbuhan pangan yang tidak dibudidayakan oleh masyarakat lokal sub-etnis Batak Toba, di Desa Peadungdung Sumatera Utara, Indonesia. *Journal of Natural Resources and Environmental Management*, 8(2),241–50. doi://10.29244/jpsl.8.2.241-250.
- Smanalieva, J, Iskakova, J, Ozbekova, Z, Oskonbaeva, Z, & Darr. D. (2018). Investigation of physiochemical characteristics of wild fruits and berries from the walnut-fruit forests of Southern Kyrgyzstan. *Tropentag Conference*, 11, P. 2018
- Subhilhar. (2018). The role of small agribusiness in regional development: The case of Sumatera Utara province. *IOP Conference Series: Earth and Environmental Science*, 126(012070):4. doi://10.1088/1755-1315/126/1/012070.
- Sundawati, L, Purnaningsih, N, & Purwakusumah. E.D. (2012). Pengembangan agroforestry berbasis biofarmaka dan kemitraan pemasaran untuk pemberdayaan masyarakat

- di Kabupaten Sukabumi, Propinsi Jawa Barat. *Seminar Nasional Agroforestri*. Pp.443-47
- Suardi, A. B. & Harmawan. T. (2019). The diversity of wild edible fruit plants and traditional knowledge in West Aceh Region, Indonesia. *Journal of Medicinal Plants Studies*, 7(4),285–90.
- Tokairin, T., O., da Silva, G. A.P., Spricigo, P. C, de Alencar, S. M., & Jacomino. A. P. (2018). Cambuci: A native fruit from the Brazilian atlantic forest showed nutraceutical characteristics. *Revista Brasileira de Fruticultura*, 40(5),8. doi: //10.1590/0100-29452018666.
- Utami, N. R., Rahayuningsih, M., Abdullah, M., & Haka. F. H. (2019). Etnobotani tanaman obat masyarakat sekitar di Gunung Ungaran, Jawa Tengah. *Prosiding Seminar Nasional Masyarakat Biodiversity Indonesia*. Vol. 5. Pp. 205–8
- Wang, Q., Sun, B. Xiong, M. Yang, Y., Hou, J. & Yuzhang, S. (2019). Effects of different economic fruit forests on soil nutrients in Qingxi small watershed. P. 7 in *IOP Conference Series: Earth and Environmental Science*. Vol. 295.

THE INFLUENCE OF STAND DENSITY AND SPECIES DIVERSITY INTO TIMBER PRODUCTION AND CARBON STOCK IN COMMUNITY FOREST

Pandu Yudha Adi Putra Wirabuana^{1*}, Rahmanta Setiahad², Ronggo Sadono¹, Martin Lukito², and Djoko Setyo Martono²

¹Department of Forest Management Faculty of Forestry, Universitas Gadjah Mada, Jln. Agro No.1 Bulaksumur, Sleman, Yogyakarta, Indonesia

²Department of Agrotechnology, Faculty of Agriculture, Universitas Merdeka Madiun, Jln. Serayu No.79 Pandean, Taman, Madiun, Indonesia

Received: 20 June 2020, Revised: 19 March 2021, Accepted: 4 April 2021

THE INFLUENCE OF STAND DENSITY AND SPECIES DIVERSITY INTO TIMBER PRODUCTION AND CARBON STOCK IN COMMUNITY FOREST. Stand density and species diversity are two indicators that are highly related to forest productivity. However, the effect of those variables on the productivity of community forest is rarely documented. This study evaluates the influence of stand density and species diversity on timber production and carbon stock in the community forest. The study area was located in Madiun District. A field survey was conducted in four different community forest sites, i.e. Morang, Kuwiran, Randualas, and Kare. The sampling technique was by quadrat method using a sample plot size of 25 m x 25 m. The number of sample plots used in this study was 64 units, which were evenly distributed in every site. Comparison of stand attributes among sites was examined by Kruskal-Wallis test and followed by Kruskal-Nemenyi test on the effects of stand density and species diversity on timber production and carbon stock were assessed separately for each parameter using the generalized least square regression test. The process of statistical analysis was applied using a significance level of 5%. Results show a significant difference in stand volume, aboveground biomass, and carbon stock among sites ($P < 0.05$). This study also recorded a meaningful effect of stand density and species diversity on timber production and carbon stock of community forest, wherein stand density provided a higher effect ($R^2 = 0.68$; $P < 0.05$) than species diversity ($R^2 = 0.26$; $P < 0.05$).

Keywords: Community forest, carbon stock, stand density, species diversity, timber production

PENGARUH KERAPATAN TEGAKAN DAN KEANEKARAGAMAN JENIS TERHADAP PRODUKSI KAYU DAN SIMPANAN KARBON DI HUTAN RAKYAT. Kerapatan tegakan dan keanekaragaman jenis adalah dua indikator yang berkaitan erat dengan produktivitas hutan. Namun, pengaruh kedua variabel tersebut terhadap produktivitas hutan rakyat jarang didokumentasikan. Penelitian ini bertujuan untuk mengevaluasi pengaruh kepadatan tegakan dan diversitas jenis terhadap produksi kayu dan simpanan karbon di hutan rakyat. Lokasi penelitian terletak di Kabupaten Madiun. Survey lapangan dilakukan di empat lokasi hutan rakyat yang berbeda, yaitu Morang, Kuwiran, Randualas, dan Kare. Survey dilaksanakan dengan metode kuadrat menggunakan plot sampel 25 m x 25 m. Jumlah plot sampel yang digunakan dalam penelitian ini sekitar 64 unit yang tersebar merata di setiap lokasi. Perbandingan rerata karakteristik tegakan antar lokasi diuji dengan metode Kruskal-Wallis dan dilanjutkan dengan metode Kruskal-Nemenyi. Pengaruh kepadatan tegakan dan diversitas jenis terhadap produksi kayu dan simpanan karbon dievaluasi secara terpisah untuk setiap parameter menggunakan metode generalized least square regression. Pengujian statistik dilakukan dengan tingkat signifikansi 5%. Hasil penelitian menunjukkan terdapat perbedaan signifikan pada volume tegakan, biomassa permukaan, dan simpanan karbon antar lokasi ($P < 0,05$). Penelitian ini juga menemukan adanya pengaruh penting kerapatan tegakan dan diversitas jenis terhadap produksi kayu dan simpanan karbon di hutan rakyat, dimana kepadatan tegakan memperlihatkan pengaruh yang lebih tinggi ($R^2 = 0,68$; $P < 0,05$) dibandingkan diversitas jenis ($R^2 = 0,26$; $P < 0,05$).

Kata kunci: Hutan rakyat, simpanan karbon, kepadatan tegakan, diversitas jenis, produksi kayu

* Corresponding author: pandu.yudha.a.p@ugm.ac.id

I. INTRODUCTION

Integration of industry development and climate change mitigation has become a fascinating challenge in sustainable forest management worldwide, particularly in tropical countries such as Vietnam, Malaysia, the Philippines, and Indonesia (Matsumoto, Oka, Mitsuda, Hashimoto, Kayo, Tsunetsugu, & Tonosaki, 2016). In this context, the existence of forests is expected to stabilize timber supply as raw materials for commercial industries and reduce greenhouse gas emissions into the atmosphere (Nunes, Meireles, Gomes, & Ribeiro, 2019). To realize those objectives, maximizing community forest management practice may provide an important contribution to ensure the stability of timber production and increase carbon stocks.

Several studies have documented the important role of community forest in maintaining industry's future viability and improving carbon sequestration (Sakurai, Rayamajhi, Pokharel, & Otsuka, 2004; Duguma et al., 2018; Luintel, Bluffstone, & Scheller, 2018; Poudyal, Maraseni, & Cockfield, 2020). A study recorded community forests, mainly in Java, supplies approximately 26% of timber demand for commercial industries such as construction, furniture, and plywood (Hakim, Dwiprabowo, & Effendi, 2009). This trend has been increasing rapidly since the declining productivity of state forests in the 1990s. The majority of Java industries nowadays highly depend on community forests for obtaining timber materials (Fujiwara, Awang, Widayanti, Septiana, Hyakumura, & Sato 2016). Furthermore, another study conducted in Madiun, East Java, reported that around 684.99 Mg CO₂ ha⁻¹ had been absorbed by community forest per year (Setiahadi, 2017). These examples indicate the bargaining position of community forest to support the industry's sustainability and reduce emissions. However, community forest capability for timber production and carbon stock is affected by certain factors, like stand density and species diversity.

Many studies confirm that stand density and species diversity are two indicators of stand characteristics that strongly relate to timber production and carbon stock in the forest (Moore, Limited, Cown, Mckinley, & Sabatia, 2015; Uhl et al., 2015; Wegiel, Bembenek, Lacka, & Mederski, 2018). In general, stand density is defined as a degree of trees crowding per unit area, which is commonly determined based on the growth dimension or growing space ratio (Zeide, 2001; Lu, Zhang, Zhang, Duan, & Zhang, 2018; Padilla-Martínez, Corral-Rivas, Briseño-Reyes, Paul, López-Serrano, & Gadow, 2020).

Species diversity is the grade of biodiversity that is frequently assessed by considering individual members of species, population size, and species composition (Chen, 2006; Hu, Su, Li, Li, & Ke, 2015; Li, Su, Lang, Liu, & Ou, 2018). However, the relationship among stand density and species diversity with both parameters vary depending on the forest ecosystem type. A study conducted in a Korean pine forest (*Pinus koraensis*) located in China observed that higher stand density linearly increases timber production and carbon stock. The relationship between species diversity with both indicators creates hump-shaped curves (Cai, Di, Chang, & Jin, 2016). A study from the dry savannah forest in South-Eastern Tanzania reported that higher stand density and species diversity significantly improved timber production and carbon stock. Those variables have a linear relationship (McNicol, Ryan, Dexter, Ball, & Williams, 2018) Those explanations indicate that higher stand density and species diversity are not always followed by improved timber production and carbon stock.

This study investigates the effect of stand density and species diversity on timber production and carbon stock in the community forest. The research objects are focused on a type of community forest called *alas*, a kind of community forest located far from village settlement. It is hypothesized that the higher stand density and species diversity significantly increase timber production and carbon stock in

the community forest, wherein both parameters show the linear pattern.

II. MATERIAL AND METHOD

A. Study Site

This study was conducted in four different community forest sites located in Sub District Kare, Madiun. It consisted of several villages, i.e. Morang, Kuwiran, Randualas, and Kare (Setiahadi, 2017). The geographic position of the study site was at 7°41'1.42" to 7°45'31.14" S and 111°39'19.27" to 111°42'17.30" E (Figure 1). Topography was relatively gradient between 0–25%. Altitude varied from 100 to 500 m above sea level. The average daily temperature reached 29°C with a mean minimum of 25°C

and a maximum of 35°C. Annual rainfall ranged from 1,554 to 1,754 mm yr⁻¹ during the last ten years. Most of the rainfalls were recorded in December and January. The study sites had a dry period for almost five months, from July to October. Air humidity ranged from 70.5% to 85.6%. Soil types were dominated by alfisol. The details of soil properties in each site are presented in Table 1.

B. Methods

Data from Setiahadi (2017) were used to examine the effect of stand density and species diversity on timber production and carbon stock in the location. The data were collected using the quadrat method. The sample plot's shape was square with a size of approximately 25 m

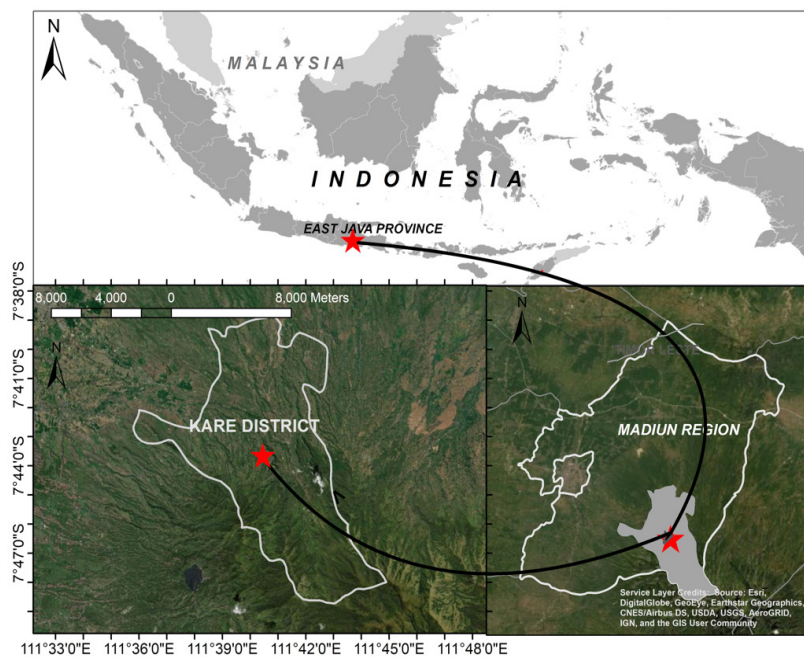


Figure 1. Study locations of community forests in Kare District

Table 1. Description of soil properties in four sites of community forests

Soil parameter	Site of community forest			
	Kuwiran	Morang	Randualas	Kare
Clay fraction (%)	39.00 ± 3.46	37.40 ± 3.13	36.80 ± 4.27	36.40 ± 2.88
Silt fraction (%)	24.60 ± 0.55	23.40 ± 0.55	27.00 ± 0.71	31.40 ± 0.89
Sand fraction (%)	36.20 ± 3.11	39.00 ± 2.74	36.40 ± 3.36	32.80 ± 1.92
Cation exchange capacity (cmolc kg ⁻¹)	15.00 ± 1.41	14.80 ± 1.64	14.40 ± 1.52	28.20 ± 2.28
Soil organic matter (%)	17.20 ± 7.82	14.00 ± 7.58	17.60 ± 9.66	23.60 ± 11.24
Soil acidity	5.46 ± 0.13	5.46 ± 0.13	5.36 ± 0.09	5.26 ± 0.09

x 25 m (Setiahadi, 2017). Sixteen observation plots have been established in every community forest; each site had a total sampling area of about 1 ha. The total measured plots used in this study were 64 units. Several parameters of individual trees were measured in each sample plot, including species, tree diameter (*d*), tree height (*h*), and tree volume (*v*). Tree diameter was measured using a phi band at 1.3 m from the aboveground, while tree height was estimated from above ground to top of the crown using a Haga altimeter. Then, individual tree volume was calculated by the following equation:

$$v = 0.25\pi d^2 h f \dots\dots\dots(1)$$

Where *f* was a constant form factor (0.6) for tropical tree species (Akossou, Arzouma, Attakpa, Fonton, & Kokou, 2013), to convert individual tree volume into tree biomass (B), the value of individual tree volume would be multiplied by the specific wood density (WD) and the biomass expansion factor (BEF) (Krisnawati, Imanuddin, & Adinugroho 2012). The detailed information about WD and BEF are presented in Table 2. Then, the tree biomass results were used to estimate carbon storage in every tree species (C) since approximately 50% of biomass is composed of carbon (Wirabuana et al., 2019). The detailed equations were:

$$B = V * WD * BEF \dots\dots\dots(2)$$

$$C = 0.5 * B \dots\dots\dots(3)$$

The results of tree measurements would be used to compute several stand characteristics, including quadratic mean diameter (D), mean height (H), stand volume (V), species diversity, stand density, aboveground biomass (AGB), and carbon stock (CS). The value of stand volume was determined as the sum of tree volumes in

each sample plot, converted to hectare unit. A similar approach was also used to estimate AGB and CS at stand level. The stand volume parameter was frequently selected as an indicator for the forest ecosystem's capability for timber production (Merganič, Marušák, Merganičová, Stolariková, & Tipmann, 2013; Irauschek, Rammer, & Lexer, 2017).

To describe the degree of species diversity in the community forest, we selected three important variables, i.e. species richness, heterogeneity, and evenness. Species richness was calculated by Margalef Index (R1), while heterogeneity of species was estimated by Shannon-Wiener Index (H'). Then, species evenness was assessed using the Pielou-Evenness Index (J). The detailed equations for calculating those parameters were (Li, Su, Zhang, Zhou, Xie, Shi, & Gou, 2018):

$$R1 = S-1/\ln(N) \dots\dots\dots(4)$$

$$H' = -\sum (ni/N) (\ln ni/N) \dots\dots\dots(5)$$

$$J = H'/\ln(S) \dots\dots\dots(6)$$

where S was the number of species, N represented total tree population, and ni described the sum of trees for each species.

To estimate stand density in the community forest, we adopted Reineke's Stand Density Index (SDI) concept using a modification developed by Sadono and Umroni (2012). Referring to the concept, the value of SDI could be determined by considering the relationship between the number of trees (N) and quadratic mean diameter (D). The specific formula for calculating SDI (Sadono & Umroni, 2012) is presented below.

$$SDI = N (20/D)^{-1.153} \dots\dots\dots(7)$$

Statistical analysis was processed using

Table 2. Specific wood density and biomass expansion factor for four species in community forests

No.	Species	WD (kg m ⁻³)	BEF
1.	<i>Tectona grandis</i>	612.7	1.46
2.	<i>Swietenia macrophylla</i>	533.4	1.36
3.	<i>Acacia auriculiformis</i>	581	1.33
4.	<i>Falcataria mollucana</i>	310.6	1.34

Source: Krisnawati et al. (2012)

software R version 3.6.1 with a significance level of 5%. We selected the package agricolae to conduct data analysis. Descriptive analysis was done to identify the range of data distribution, comprising minimum, maximum, mean, standard deviation, and variation coefficient. Outlier test was detected using the box plot method. The Shapiro-Wilk test evaluated the normality of data. The Fligner-Killen test examined the homogeneity of variance among sites of community forest. Comparing stand attributes among observation sites was analyzed separately for each variable using Kruskal-Wallis, followed by Kruskal-Nemenyi (Tenzin & Hasenauer, 2016). Afterwards, the influence of stand density and species diversity on timber production and carbon stock in the community forest was assessed for every parameter using the general least square regression with the maximum likelihood method (Cai, Di, Chang, & Jin, 2016). The linear model pattern was used to evaluate the effect of stand density and species diversity on timber production and carbon stock.

III. RESULT AND DISCUSSION

A. Species Composition

Summarized results of the observation showed four species commonly planted in the study area, namely *Tectona grandis*, *Swietenia macrophylla*, *Acacia auriculiformis*, and *Falcataria mollucana* (Table 3). Among those species, it was documented that *T. grandis* became the most dominant species in every community forest site. Compared to others, this species had an abundance relative more than 80% in each site. The second position was occupied by *S. macrophylla* followed by *F. mollucana* in the third

rank. Meanwhile, *A. auriculiformis* had the lowest population. The study recorded that the number of species in the Kuwiran site was lower than in the other three sites because it only had three species..

T. grandis dominated the land cover of community forest in the study area because societies in each village have widely planted it. Besides having a high price, the market availability of this species was also accessible. The history of community forest management also supported this fact in the study area wherein *T. grandis* was the first plantation species introduced to societies since the sites were located close to the state forest, managed by Perum Perhutani (Setiahadi, 2017). However, *T. grandis* required a long growing period to obtain the yield; thus, most villagers also planted other species that had faster growth than *T. grandis*, like *S. macrophylla*, *F. mollucana*, and *A. auriculiformis*. Thereby, most community forests in the study area comprised mixed-stand, which had high variation in growth and age distribution.

B. Stand Characteristics

Stand characteristics in each site varied and demonstrated fascinating trends (Table 4). Referring to the statistical analysis outcome, there was no significant difference in quadratic mean diameter, mean height, and stand density indexes among sites of community forests ($P > 0.05$). Similar results were also documented in species diversity parameters, including richness, heterogeneity, and evenness ($P > 0.05$). In contrast, different outputs were observed in stand volume, aboveground biomass, and carbon stock, in which those parameters differed significantly among sites ($P < 0.05$).

Our study observed the highest timber

Table 3. Species composition in each site of community forest based on the relative abundance of species

No.	Species	Composition (%)			
		Kuwiran	Morang	Randualas	Kare
1.	<i>Tectona grandis</i>	88.94	80.28	83.48	83.78
2.	<i>Swietenia macrophylla</i>	8.26	16.92	14.42	13.72
3.	<i>Acacia auriculiformis</i>	2.80	0.64	0.44	0.64
4.	<i>Falcataria mollucana</i>	-	2.16	1.66	1.86

Table 4. Comparison of stand attributes in each site of community forest, covering quadratic mean diameter (D), average height (H), stand volume (V), aboveground biomass (AGB), carbon stock (CS), richness (R1), heterogeneity (H'), evenness (J), and stand density (SDI)

Observation variable	Site of community forest				p-value
	Kuwiran	Morang	Randualas	Kare	
D (cm)	13.31 ± 1.77 a	13.67 ± 1.29 a	13.57 ± 1.22 a	13.08 ± 1.71 a	0.687 ^{ns}
H (m)	13.08 ± 1.78 a	13.89 ± 0.83 a	13.88 ± 0.83 a	12.90 ± 1.61 a	0.574 ^{ns}
V (m ³ ha ⁻¹)	96.81 ± 32.54 a	171.02 ± 51.69 a	170.20 ± 51.59 a	98.87 ± 35.89 c	0.001*
AGB (Mg ha ⁻¹)	86.03 ± 13.27 a	126.70 ± 20.16 b	116.38 ± 20.12 b	73.31 ± 18.57 c	0.001*
CS (Mg ha ⁻¹)	43.23 ± 6.64 a	73.35 ± 10.08 b	69.19 ± 10.06 b	41.65 ± 9.29 c	0.001*
R1	0.28 ± 0.08 a	0.33 ± 0.12 a	0.33 ± 0.10 a	0.29 ± 0.09 a	0.987 ^{ns}
H'	0.29 ± 0.09 a	0.45 ± 0.17 a	0.49 ± 0.17 a	0.33 ± 0.12 a	0.179 ^{ns}
J	0.32 ± 0.11 a	0.58 ± 0.20 a	0.63 ± 0.18 a	0.31 ± 0.11 a	0.172 ^{ns}
SDI	416 ± 146 a	500 ± 139 a	503 ± 138 a	426 ± 144 a	0.200 ^{ns}

Remarks: *indicated a significant difference at α 5%, ^{ns} showed non-significant difference at α 5%, the similar letter in a row showed non-significant difference among sites

production and carbon stock of community forest in Morang, followed by Randualas in the second position and Kare in the third place. The lowest rank was noted in Kuwiran. The growth performance of the community forest in Morang was higher than in the other sites because its stand had greater dimensions. The bigger quadratic mean diameter, average height, and stand density, respectively, could be indicated, even though those parameters did not present significant differences. Many kinds of literature explained that greater stand dimension growth increases its timber production and carbon stock because the quantity of tree volume has increased (Gevaña, Camacho, & Camacho, 2017; Lu et al., 2018; Padilla-Martínez et al., 2020). According to the results, it was shown clearly that the degree of timber production and carbon stock in Morang was higher by approximately 43.58% and 22.43% than Kuwiran and Kare, respectively.

Compared to other sites, the existence of community forest in Randualas indicated the greatest species diversity, particularly related to heterogeneity and evenness (Table 4). Statistically, it also had an equal stand density, timber production, and carbon stock to Morang. Based on these findings, community forest capability for timber production and carbon stock in the study area could be classified into

two groups, i.e. low class (Kuwiran and Kare) and high class (Randualas and Morang).

Reviewed from the diversity of species, most community forest in the study area had low diversity based on the range value of richness, heterogeneity, and evenness (Table 4). It was caused by the low number of species and their population in each location. The majority of tree species in every site was dominated by *T. grandis* (Table 3). Although it consisted of multi-species, the community forest was principally a type of forest ecosystem commonly established by villagers. In this case, the use of silvicultural prescription was relatively limited and conducted depending on the community's preference. Interestingly, most of the communities preferred to grow trees that potentially provided financial benefit. Therefore, community forest stand attributes, especially for tree diversity, situated in a transition phase between monoculture plantation and natural forest (Filqisthi & Kaswanto, 2017).

C. Effect of Stand Density and Species Diversity on Timber Production and Carbon Stock

Stand density and species diversity significantly affected timber production and carbon stock in community forest ($P < 0.05$) (Table 5). Unfortunately, the meaningful effect

Table 5. Results of the best-fit generalized least square regression for exploring the effect of stand density and species diversity on timber production and carbon stock in community forest

Response variable	Predictor variable	R ²	Estimate	SE	t Stat	P-value
Timber production	Stand density (SDI)	0.681	0.262	0.023	11.500	<0.001*
	Richness (R1)	0.031	60.863	51.884	1.173	0.247 ^{ns}
	Heterogeneity (H')	0.268	106.861	24.428	4.374	<0.001*
	Evenness (J)	0.128	35.162	14.020	2.508	0.056 ^{ns}
Carbon storage	Stand density (SDI)	0.676	0.109	0.010	11.282	<0.001*
	Richness (R1)	0.025	22.963	21.911	1.048	0.300 ^{ns}
	Heterogeneity (H')	0.266	41.785	10.593	3.944	<0.001*
	Evenness (J)	0.104	13.334	5.983	2.229	0.051 ^{ns}

Remarks: *indicated a significant difference at α 5%, ^{ns} showed non-significant difference at α 5%

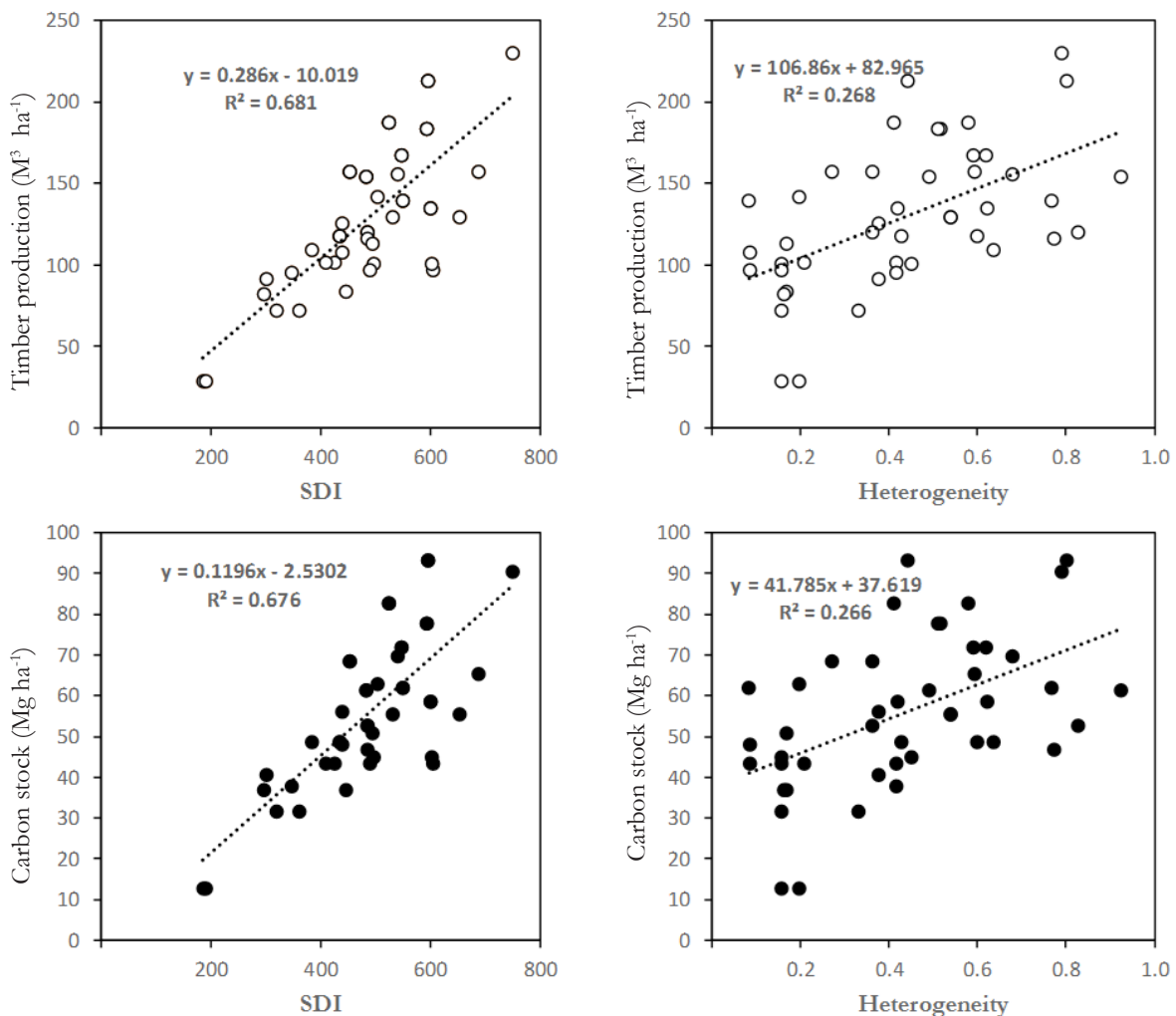


Figure 2. Relationship among stand density and species diversity with timber production and carbon stock of community forest in Madiun

of species diversity on both parameters was only demonstrated by heterogeneity ($P < 0.05$). This study shows that there was no essential influence of richness and evenness on timber production and carbon stock in community forest ($P > 0.05$). The majority of community forests had similar species composition in which *T. grandis* was the most dominant species in these areas (Table 3). These findings were considerably different from the study published by Filqisthi and Kaswanto (2017), who reported that there was no significant effect of species diversity on stand attributes of community forests in West Java, mainly related to timber production and carbon stock. The results are also different with the study conducted by Cai et al. (2016) in China, who documented a high effect of richness on carbon storage in the Korean pine forest (*P. koraensis*). Nevertheless, this study reported a similar result to an observation undertaken by McNicol et al. (2018) in South-Eastern Tanzania, who noted a substantial influence of stand density and species diversity on timber production and carbon stock in dry savannah forest. Those comparisons strongly indicated that every type of forest would demonstrate the different relationship among stand density and species diversity with timber production and carbon stock, including community forest.

Our study observed a linear relationship among stand density and species diversity with timber production and community forest carbon stock. The greater stand density and species diversity increased timber production and carbon stock (Figure 2). This was similar to a study conducted by Gevaña et al. (2017) in the Philippines, who reported a linear relationship among stand density and species diversity with stand attributes in mangroves, like timber volume and carbon stock. In addition, it was recorded wherein stand density provided a higher effect ($R^2 = 0.68$) than species diversity ($R^2 = 0.26$) on the productivity of community forest (Table 5). This trend could have occurred since stand density was one of the stand parameters that described a degree of tree

crowding per unit area (Zeide, 2001). Higher stand density indicated a greater number of trees and bigger growth dimension because this parameter was determined by considering several growth attributes, such as number of trees, spacing, mean height, quadratic mean diameter, crown projection area, and crown diameter (Lu et al., 2018).

IV. CONCLUSION

Our study concluded that stand density and species diversity significantly affect timber production and carbon stock of community forest, wherein stand density provided greater influence than species diversity on both parameters. The meaningful effect of species diversity was only demonstrated by the heterogeneity aspect while there was not an important influence of richness and evenness on timber production and carbon stock of community forest.

ACKNOWLEDGEMENT

The authors are very grateful to the village governments in every community forest site that allowed us to conduct this study in their area. We also deliver our gratitude to reviewers for their suggestions for this article.

REFERENCES

- Akossou, A. Y. J., Arzouma, S., Attakpa, E. Y., Fonton, N. H., & Kokou, K. (2013). Scaling of teak (*Tectona grandis*) logs by the xylometer technique: Accuracy of volume equations and influence of the log length. *Diversity*, 5(1), 99–113. doi://10.3390/d5010099.
- Cai, H., Di, X., Chang, S. X., & Jin, G. (2016). Stand density and species richness affect carbon storage and net primary productivity in early and late successional temperate forests differently. *Ecological Research*, 31(4), 525–533. doi://10.1007/s11284-016-1361-z.
- Chen, X. (2006). Tree diversity, carbon storage, and soil nutrient in an old-growth forest at Changbai Mountain, Northeast China. *Communications in Soil Science and Plant Analysis*,

- 37(3–4), 363–375. doi://10.1080/00103620500440210.
- Duguma, L. A., Atela, J., Ayana, A. N., Alemagi, D., Mpanda, M., Nyago, M., ... Ntamag-Ndjebet, C. N. (2018). Community forestry frameworks in sub-Saharan Africa and the impact on sustainable development. *Ecology and Society*, 23(4), 1–15. doi://10.5751/ES-10514-230421.
- Filqisthi, T. A., & Kaswanto, R. L. (2017). Carbon stock and plants biodiversity of pekarangan in Cisadane watershed West Java. *IOP Conference Series: Earth Environment Sciences*, 54, 1–9. doi://10.1088/1742-6596/755/1/011001.
- Fujiwara, T., Awang, S. A., Widayanti, W. T., Septiana, R. M., Hyakumura, K., & Sato, N. (2016). Effects of national community-based forest certification on forest management and timber marketing: a case study of Gunung Kidul, Yogyakarta, Indonesia. *International Forestry Review*, 17(4), 448–460. doi://10.1505/146554815817476422.
- Gevaña, D. T., Camacho, L. D., & Camacho, S. C. (2017). Stand density management and blue carbon stock of monospecific mangrove plantation in Bohol, Philippines. *Forestry Studies*, 66, 75–83. doi://10.1515/fsmu-2017-0008.
- Hakim, I., Dwiprabowo, H., & Effendi, R. (2009). Kajian peredaran kayu rakyat di wilayah Jawa bagian barat. *Jurnal Penelitian Sosial dan Ekonomi Kebutuhan*, 6(1), 15–37. doi://10.20886/jpsek.2009.6.1.15-37.
- Hu, Y., Su, Z., Li, W., Li, J., & Ke, X. (2015). Influence of tree species composition and community structure on carbon density in a subtropical forest. *PLoS ONE*, 10(8), 1–9. doi://10.1371/journal.pone.0136984.
- Irauschek, F., Rammer, W., & Lexer, M. J. (2017). Evaluating multifunctionality and adaptive capacity of mountain forest management alternatives under climate change in the Eastern Alps. *European Journal of Forest Research*, 136(5–6), 1051–1069. doi://10.1007/s10342-017-1051-6.
- Krisnawati, H., Imanuddin, R., & Adinugroho, W. C. (2012). Monograf allometric models for estimating tree biomass at various forest ecosystems types in Indonesia. Center for Research and Development of Conservation and Rehabilitation, Ministry of Forestry. doi://10.13140/RG.2.1.4139.2161.
- Li, S., Su, P., Zhang, H., Zhou, Z., Xie, T., Shi, R., & Gou, W. (2018). Distribution patterns of desert plant diversity and relationship to soil properties in the Heihe River Basin, China. *Ecosphere*, 9(7), 1–5. doi://10.1002/ecs2.2355.
- Li, S., Su, J., Lang, X., Liu, W., & Ou, G. (2018). Relationship between species richness and aboveground biomass across forest strata in a primary Pinus kesiya forest. *PLoS ONE*, 8(1), 1–14. doi://10.1038/s41598-018-20165-y.
- Lu, L., Zhang, B., Zhang, J., Duan, A., & Zhang, X. (2018). Application of stand density indices for Chinese fir (*Cunninghamia lanceolata* (Lamb.) Hook) plantation management. *Forestry Studies*, 68(1), 51–63. doi://10.2478/fsmu-2018-0005.
- Luintel, H., Bluffstone, R. A., & Scheller, R. M. (2018). The effects of the Nepal community forestry program on biodiversity conservation and carbon storage. *PLoS ONE*, 13(6), 1–19. doi://10.1371/journal.pone.0199526.
- Matsumoto, M., Oka, H., Mitsuda, Y., Hashimoto, S., Kayo, C., Tsunetsugu, Y., & Tonosaki, M. (2016). Potential contributions of forestry and wood use to climate change mitigation in Japan. *Journal of Forest Research*, 21(5), 211–222. doi://10.1007/s10310-016-0527-4.
- McNicol, I. M., Ryan, C. M., Dexter, K. G., Ball, S. M. J., & Williams, M. (2018). Aboveground carbon storage and its links to stand structure, tree diversity and floristic composition in South-Eastern Tanzania. *Ecosystems*, 21(4), 740–754. doi://10.1007/s10021-017-0180-6.
- Merganič, J., Marušák, R., Merganičová, K., Stolariková, R., & Tipmann, L. (2013). Relation between selected indicators of forest stand diversity and quality of timber production in young stands aged up to 40 years. *Journal of Forest Science*, 59(12), 503–513. doi://10.17221/67/2013-jfs.
- Moore, J. R., Limited, T., Cown, D. J., Mckinley, R., & Sabatia, C. O. (2015). Effects of stand density and seedlot on three wood properties of young radiata pine grown at a dry-land

- site in New Zealand. *New Zealand Journal of Forestry Science*, 45(4), 1–15. doi://10.1186/s40490-015-0035-x.
- Nunes, L. J. R., Meireles, C. I. R., Gomes, C. J. P., & Ribeiro, N. M. C. A. (2019). Forest management and climate change mitigation: A review on carbon cycle flow models for the sustainability of resources. *Sustainability*, 11(19), 1–10. doi://10.3390/su11195276.
- Padilla-Martínez, J. R., Corral-Rivas, J. J., Briseño-Reyes, J., Paul, C., López-Serrano, P. M., & Gadow, K. V. (2020). Patterns of density and production in the community forests of the sierra madre occidental, Mexico. *Forests*, 11(3), 1–14. doi://10.3390/f11030307.
- Poudyal, B. H., Maraseni, T., & Cockfield, G. (2020). Scientific forest management practice in Nepal: Critical reflections from stakeholders' perspectives. *Forests*, 11(27), 1–20. doi://10.3390/f11010027.
- Sadono, R., & Umroni, A. (2012). Penentuan Indeks Kepadatan Tegakan Sengon di Hutan Rakyat (Kecamatan Kranggan dan Pringsurat Kabupaten Temanggung). *Jurnal Ilmu Kehutanan*, 6(1), 53–60. doi://10.22146/jik.3312.
- Sakurai, T., Rayamajhi, S., Pokharel, R. K., & Otsuka, K. (2004). Efficiency of timber production in community and private forestry in Nepal. *Environment and Development Economics*, 9(4), 539–561. doi://10.1017/S1355770X04001457.
- Setiahadi, R. (2017). How significant is the existence of forest community contribution in GHG emissions reduction?. *Journal of Engineering and Applied Sciences*, 12(19), 4826–4830. doi://10.3923/jeasci.2017.4826.4830.
- Tenzin, J., & Hasenauer, H. (2016). Tree species composition and diversity in relation to anthropogenic disturbances in broad-leaved forests of Bhutan. *International Journal of Biodiversity Science, Ecosystem Services and Management*, 12(4), 274–290. doi://10.1080/21513732.2016.1206038.
- Uhl, E., Biber, P., Ulbricht, M., Heym, M., Horváth, T., Lakatos, F.,... Pretzsch, H. (2015). Analysing the effect of stand density and site conditions on structure and growth of oak species using nelder trials along an environmental gradient: Experimental design, evaluation methods, and results. *Forest Ecosystems*, 1–19. doi://10.1186/s40663-015-0041-8.
- Wegiel, A., Bembenek, M., Lacka, A., & Mederski, P. S. (2018). Relationship between stand density and value of timber assortments: A case study for Scots pine stands in north-western Poland. *New Zealand Journal of Forestry Science*, 48(12), 1–9.
- Wirabuana, P. Y. A. P., Sadono, R., & Jurniarso, S. (2019). Fertilization effects on early growth, aboveground biomass, carbon storage, and leaf characteristics of *Eucalyptus pellita* F. Muell. in South Sumatra. *Jurnal Manajemen Hutan Tropika*, 25(3), 154–163. doi://10.7226/jtfm.25.3.154.
- Zeide, B. (2001). Analysis of a concept: stand density. *Journal of Sustainable Forestry*, 14(4), 51–62. doi://10.1300/J091v14n04_05.

RAINFALL VARIABILITY IN GUNUNG SEWU KARST AREA, JAVA ISLAND, INDONESIA

Ahmad Cahyadi^{1*}, Eko Haryono², Tjahyo Nugroho Adji², Margaretha Widyastuti², Indra Agus Riyanto³, Dzakwan Taufiq Nur Muhammad¹, and Naufal Fattah Tastian¹

¹Department of Environmental Geography, Universitas Gadjah Mada,
Sekip Utara Jalan Kaliurang, Bulaksumur, Yogyakarta, 55281 Indonesia

²Karst Research Group, Universitas Gadjah Mada,
Sekip Utara, Jalan Kaliurang Bulaksumur, Yogyakarta. 55281 Indonesia

³Lentera Geosains Yogyakarta,
Jl. Tongkol V, Minomartani, Ngaglik, Sleman, Yogyakarta Indonesia

Received: 21 October 2020, Revised: 5 April 2021, Accepted: 6 April 2021

RAINFALL VARIABILITY IN GUNUNG SEWU KARST AREA, JAVA ISLAND, INDONESIA. Karst area is highly susceptible to changes to climate parameters. One of the parameters is rainfall variability. In addition to shaping the condition of water resources, rainfall in the Gunung Sewu karst area determines the nature of crop and livestock of the agriculture sectors—the local population's main economic activities, warranting the significance of the rainfall variability studies. Rainfall variability in karst areas also affects disaster conditions such as drought and floods. However, due to insufficient meteorological data in quality and quantity, there has been no rainfall variability studies conducted in this locality. The research intended to analyze rainfall variability in the Gunung Sewu karst area in 1979–2013 by utilizing rainfall predictions from satellite images that many scholars had tested in different locations and recognized as having good quality. In the analysis, mean monthly rainfall was calculated, and the trends of annual rainfall and average rainfall intensity, dry and rainy seasons, the number of rainy days, and the effect of ENSO (El Niño Southern Oscillation) on rainfall were analyzed. The research data were 35 years of daily rainfall records derived from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR). The analysis results showed that the mean rainfall, number of rainy days, and rainfall intensity had an increasing trend. Also, El Niño quantitatively influenced the rain in the Gunung Kidul karst area.

Keywords: Rainfall variability, karst, ENSO, Gunung Sewu, NCEP, CFSR

VARIABILITAS CURAH HUJAN DI KAWASAN KARST GUNUNG SEWU, PULAU JAWA, INDONESIA. Kawasan karst merupakan kawasan yang sangat sensitif terhadap perubahan parameter iklim, salah satunya adalah pada variabilitas curah hujan. Variabilitas curah hujan menjadi sangat penting dikaji di kawasan karst Gunung Sewu karena selain sangat mempengaruhi kondisi sumber daya air, curah hujan akan berpengaruh terhadap sektor pertanian dan peternakan yang menjadi sektor ekonomi utama bagi masyarakat di kawasan karst Gunung Sewu. Variabilitas curah hujan di kawasan karst juga mempengaruhi kondisi bencana seperti kekeringan dan banjir. Namun demikian, analisis variabilitas di kawasan karst Gunung Sewu belum dilakukan karena ketersediaan data meteorologis yang kurang baik dari sisi kualitas ataupun kuantitas. Penelitian ini bertujuan untuk menganalisis variabilitas curah hujan di kawasan karst Gunung Sewu pada tahun 1979–2013 dengan memanfaatkan data prediksi dari citra satelit yang telah diuji oleh banyak peneliti di lokasi lain dan memiliki kualitas yang baik. Analisis variabilitas hujan yang dilakukan dalam penelitian ini meliputi perhitungan rerata hujan bulanan, analisis trend hujan tahunan, analisis hujan musim kemarau dan penghujan, analisis jumlah hari hujan, analisis trend rata-rata intensitas hujan dan analisis pengaruh ENSO (El Niño Southern Oscillation) terhadap curah hujan di kawasan karst Gunung Sewu. Data yang digunakan dalam penelitian ini berasal dari The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR). Data yang digunakan berupa data harian selama 35 tahun. Hasil analisis menunjukkan bahwa rerata curah hujan, jumlah hari hujan dan intensitas hujan memiliki trend kenaikan. Selain itu diketahui bahwa hujan di kawasan karst Gunung Kidul secara kualitatif nampak sangat dipengaruhi oleh peristiwa EL Niño.

Kata kunci: Variabilitas hujan, karst, ENSO, Gunung Sewu, NCEP, CFSR

* Corresponding author: ahmad.cahyadi@geo.ugm.ac.id

I. INTRODUCTION

Karst landscapes are fragile and highly sensitive to environmental changes in which ecological restoration can be challenging to achieve quickly (Quine et al., 2017; Kang et al., 2020). The changes in question are those of hydrometeorological or climatic variables, which currently are prevalent issues. Dissolution as the dominant process in karst areas has led to a hydrologically dry surface because all water landing on this landscape is drained immediately into underground rivers (Cahyadi, 2014a). Here, water storage highly depends on the epikarst layer, i.e., the top layer of a karst landscape that consists of soil and the widening zone of fissures and conduits in carbonate rocks. In other words, soil thickness and the presence of loose rock grains strongly determine its capacity. However, resistance to rock disintegration has limited the formation of soils in high volume in a relatively short time of this landscape (Green et al., 2019). The epikarst layer requires a very long time to form.

Gunung Sewu is one of Indonesia's karst areas that reportedly experiences recurrent droughts (Cahyadi, Marfai, Rahmadana, & Nucifera, 2012; Fatchurohman & Cahyadi, 2013). Nevertheless, in the event of high rainfall, floods can still occur and affect the area. Gunung Sewu is highly susceptible to the variability of climatic parameters, especially rainfall. Apart from the strong influence on water resources, rainfall is also a crucial factor in crop and livestock agricultural practices, which are the main economic sectors in Gunung Sewu. Many of its inhabitants still rely on rain as a primary source of clean water throughout the rainy season, along with lakes and epikarst springs. Water availability is much dependent on rainfall. Even for merely a few months, the absence of rains can lower the water levels and dry out most of these lakes and epikarst springs. For these reasons, a study of rainfall variability is relatively important.

Gunung Sewu karst areas part of the Indonesian Maritime Continent that regulates many determinants of its rain variability, for

example, the Asia-Australia monsoon, El Niño-Southern Oscillation (ENSO), east-west circulations (Zonal/Walker circulation), north-south circulations (Meridional/Hadley Circulation) and some circulations that are heavily influenced by local factors (Hermawan, 2010; Aldrian, Gates, & Widodo, 2007). In Indonesia, the complex climate conditions are attributed to many factors, to which every part of the country shows varying responses (Gutman, Csiszar, & Romanov, 2000; Haylock & McBride, 2001; Boer, 2003; Athoillah, Sibarani, & Doloksaribu, 2017). Other studies have confirmed that southern Indonesia, including the Gunung Sewu Karst Area, is inclined to have higher rainfall variability than the northern side (Juaeni, 2006).

The climate of Java is significantly controlled by the Asian-Australian monsoon (Ramage, 1971; Aldrian, 2001). History has documented that ENSO contributes to shaping the rainfall on this island (Boer, Faqih, & Ariani 2014). Further research stated that hills, mountains, and volcanoes in the southern and central parts of the island cause the southern side to be wetter than its northern counterpart (Qian, Robertson, & Moron, 2010). In tropical studies, rainfall variability often takes precedence over other climatic parameters, given that it is the most influencing factor of plant productivity and water resources. The tropical condition may be linked to parameters other than rainfall that rarely experience similar large fluctuations (Naylor, Battisti, Vimont, Falcon, & Burke, 2007). Furthermore, comprehensive knowledge of rainfall variability helps manage water resources, understand and reduce disaster risks, assist in infrastructure work schedule, and plan the agriculture, fishery, livestock, and tourism sectors (Stefanidis & Stathis, 2018).

Rainfall variability analysis in the Gunung Sewu karst areas is vital, but long-term daily rainfall data required for the study remain insufficiently available. In total, the Gunung Kidul Regency has 13 rain gauge stations, three of which are in Gunung Sewu and since 1979 have long time-series of records with low quality as too many

data are missing: 42% of data is missing at Panggang, 46% at Tepus, and 38% at Rongkop. However, their daily rainfall availability (ratio of filled to missing) shows that the data quality is improving. At this state, rainfall analysis instead should use satellite data with relatively complete long-term records. Besides, many studies have relied on these global data, which also have easy accessibility and high accuracy (Christanto, Setiawan, Nurkholis, Sartohadi, & Hadi, 2020).

This research was intended to analyze the rainfall variability in the Gunung Sewu karst area from 1979 until 2013. A local-scale analysis is vital in that rainfall also varies depending on local factors (Hermawan, 2010; Hamada, Yamanaka, Matsumoto, Fukao, Winarso, & Sribimawati, 2002). This research is expected to contribute to climate variability at the study site to formulate the most appropriate plans to meet water needs in karst areas in the future. Furthermore, it can be used to understand rainfall characteristics, especially in temporal studies, as reference material for mitigating meteorological disasters.

II. MATERIAL AND METHOD

This report's climatological data are rainfall data obtained from the Global Weather Data for the SWAT (Soil and Water Assessment Tool) program. The data are accessible at <https://globalweather.tamu.edu>. Analyses were then conducted to produce the desired data. Daily rainfall data were generated from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR), global coverage and adequately high resolution. These data cover the years from 1979 to mid-2013 (data length= 35 years).

The spatial resolution of the CFSR data is 38 km or 0.3125 degrees. Therefore, Fuka, Walter, Macalister, Degaetano, Steenhuis, and Easton, (2014) stated that this data is very suitable for studies on an area of about 40 square km². This study only represents the Gunung Sewu karst area in the Gunung Kidul Regency, Yogyakarta. Dile and Srinivasan (2014) stated that the CFSR data's accuracy compared to the rain recording data on the ground station is high. The difference between the CFSR data and the ground station is between 5.8% and 28.57%, with an average of 16.02%. However, the studies of data utilization from Fuka, Macalister, Degaetano, Steenhuis, & Easton (2014) in the USA and Ethiopia, Dile and Srinivasan (2014) in the Blue Nile River Basin, Ethiopia and Christanto, Setiawan, Setiawan, Sartohadi, & Hadi (2020) in Serayu Watershed, Indonesia, showed an excellent performance even as an input to further hydrological models such as runoff modelling or water balance in a watershed.

Here, the rainfall variability was determined by calculating mean monthly rainfall and analyzing trends of annual rainfall and mean rainfall intensity, dry and rainy seasons, the number of rainy days, and the effect of ENSO on rains in the Gunung Sewu karst area. Rainfall trends, intensity, and the number of rainy days were analyzed using linear regression. In contrast, the effect of ENSO on rainfall variability was analyzed descriptively from the rain characteristics during the El Niño and La Niña months or years. Data on these El Niño and La Niña events were obtained from the National Oceanic and Atmospheric Administration website, US Department of Commerce, i.e., <https://noaa.gov>. In this

Table 1. El Niño and La Niña classification based on ONI values

ONI Value Range	Classification	ONI Value Range	Classification
0.5 - 1.0	Weak El Niño	-1.0 - <-0.5	Weak La Niña
>1.0 - 1.5	Moderate El Niño	-1.5 - <-1.0	Moderate La Niña
>1.5 - 2.0	Strong El Niño	-2.0 - <-1.5	Strong La Niña
>2.0	Very Strong El Niño	< -2.0	Very Strong La Niña

research, El Niño and La Niña occurrences were classified according to the Oceanic Niño Index (ONI) values, i.e., NOAA's main parameter used to determine each. ONI values were measured from sea surface temperature in the Niño 3.4 region, where $ONI > 0.5$ marks an El Niño occurrence, whereas $ONI = -0.5$ indicates La Niña. Table 1 shows the El Niño-La Niña classification details used in this research.

This research's data coverage represents the western part of the Gunung Sewu karst area, which includes Gunung Kidul Regency. Nevertheless, the study is expected to provide various related parties with a representative overview of the area as an input to their decision-making processes. This data coverage is considered adequate, given that groundwater resource and disaster management in Indonesia are currently part of provincial and local government's responsibility, respectively. Discussion on water resources in the western part of the karst areas believed to give more focused details and thoughts as a contribution to Gunung Kidul Regency's governments and the Yogyakarta Province.

III. RESULT AND DISCUSSION

The analysis of rainfall data from 1979 to 2013 revealed that the Gunung Sewu karst

area's monthly rainfall showed a monsoonal pattern. It shows the horse saddle-like shape in Figure 1. High rain lasted from January to March and November to December, whereas low rainfall occurred from May–September. April and October were transitional months between these two seasons. The highest rainfall, 258 mm/month, was found in February, and the lowest, 15 mm/month, occurred in August. These characteristics support the argument that the monsoon winds and the Intertropical Convergence Zone (ITCZ) control the wet period in November–March (Asnani, 1993). It is consistent with Aldrian (2001), who categorized the study area into the climate region A—also known as the Australian Monsoon Region—where monsoon winds strongly affect the rainfall pattern. Another corroborating opinion is that Java Island, where the Gunung Sewu karst area is located, is the center of the Australian-Asian Monsoon Region (Ramage, 1968). Because of this, the monsoon wind tends to exert a substantial effect on the climate of the study area.

The annual rainfall in the Gunung Sewu karst area was, on average, 1,831 mm/year. The highest rainfall, 3,885 mm/year, occurred in 2010, while the lowest was 909 mm/year, which appeared in 1982. Figure 2 shows an

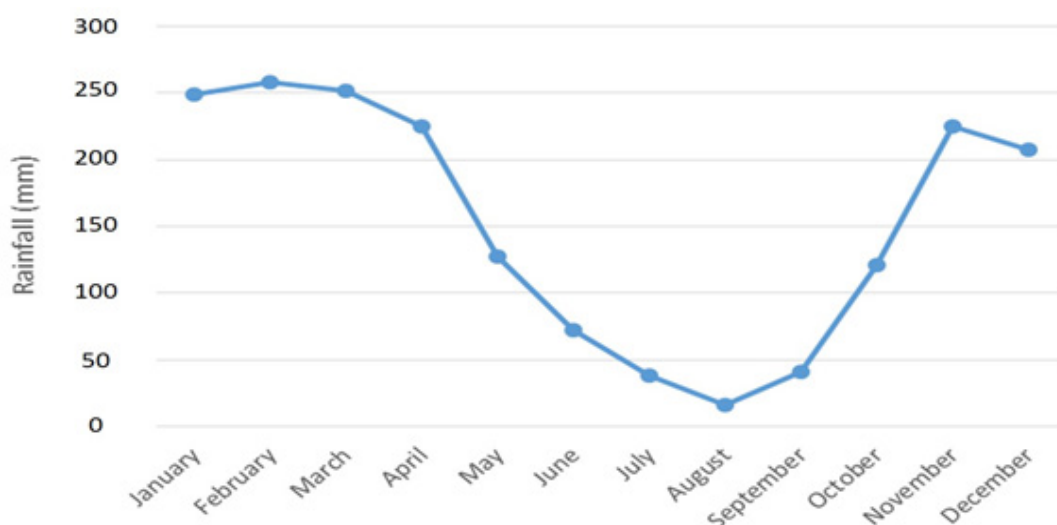


Figure 1. Mean monthly rainfall in the Gunung Sewu karst area

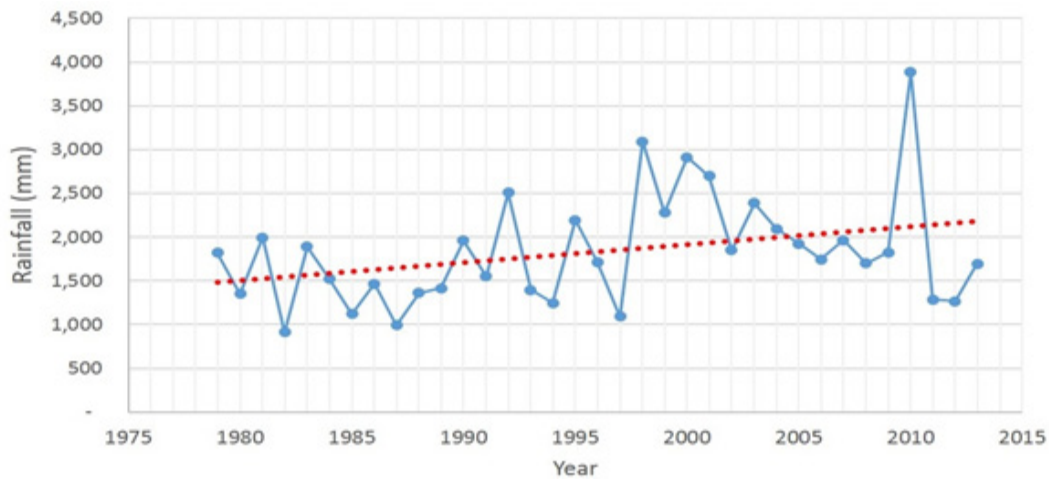


Figure 2. The trend of the annual rainfall in the Gunung Sewu karst area

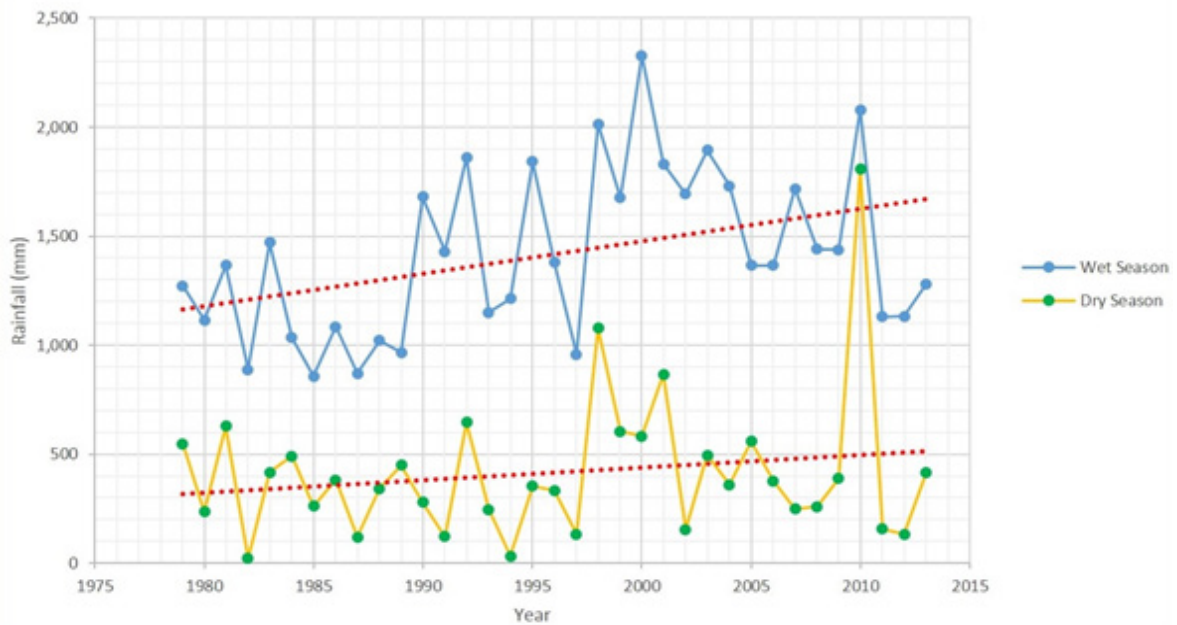


Figure 3. The trend of rainfall in rainy and dry seasons in the Gunung Sewu karst area

increasing trend of annual rainfall by ± 650 mm in 35 years. Prior scholars have also reported similar trends in neighbouring regions, Sleman Regency, Yogyakarta City, and Bantul Regency (Dipayana, Cahyadi, Mutaqin, & Nurjani, 2012a; Dipayana, Nurjani, & Adji, 2012b), and Magelang Regency that is located relatively close to the study site (Suprayogi et al., 2014). However, Figure 3 shows that rainfall in the rainy and dry seasons increased at different magnitudes (the determination of the dry and rainy seasons follows (Brunsch, Stoffel,

Ikhwan, Oberle, & Nestmann, 2011), in which the rainy season starts in November and ends in April, while the dry season lasts from May until October). Rainfall increased more significantly in the rainy season than in the dry season, as indicated by the gradient of the higher in the former than the latter.

The monsoonal pattern is observable from the amount of rainfall and the number of rainy days per month (Figure 4). From November through March, the study area had many rainy days, but this number was much fewer in

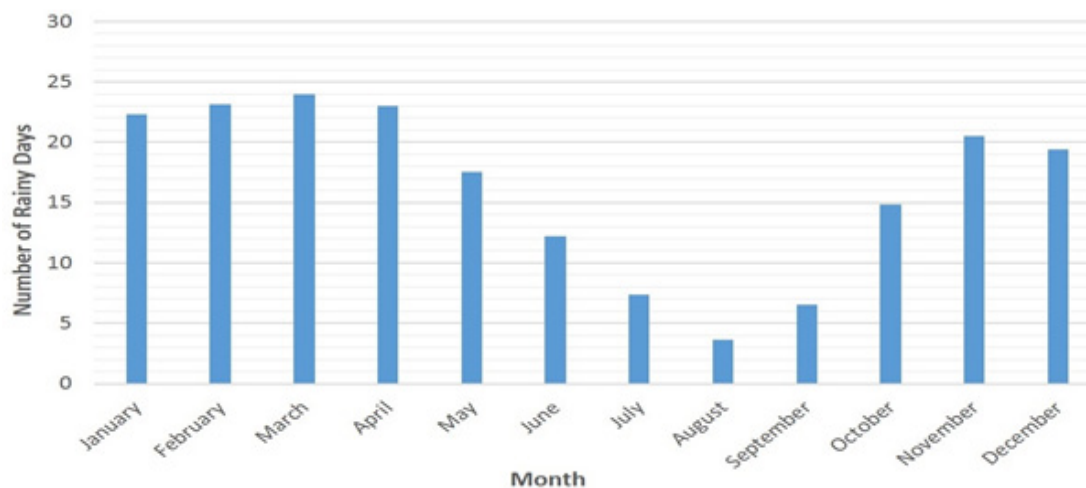


Figure 4. The number of rainy days in the Gunung Sewu karst area

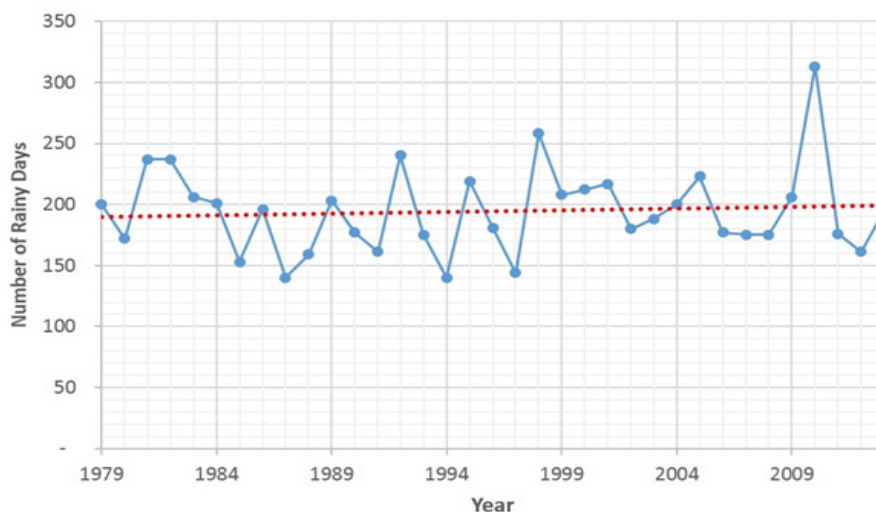


Figure 5. The trend of the number of rainy days in the Gunung Sewu karst area

May–September. Although the highest average rainfall was in February, the highest number of rainy days was in March, i.e., 24 days. August was the peak of the dry season and had the lowest number of rainy days. It also corresponds to the mean monthly rainfall, which was the least in this month. The number of rainy days is crucial in the research, especially concerning agricultural activities and flood events. Rain lasting for many days is most likely to sustain plants' lives that depend on soil moisture, such as food crops and horticulture. However, too many consecutive days of rain can oversaturate

the soil and lead to landslides and floods. Gunung Sewu karst area had 193 rainy days per year. The most extended wet condition occurred in 2019, with 313 rainy days/year, while the shortest one was in 1987 and 1984, with 140 rainy days/year. In detail, the rainy season had, on average, 132 rainy days, while throughout the dry season, rains still occurred during 61 days.

Figure 5 shows an increasing trend in the number of rainy days in the Gunung Sewu karst area. The gently sloping trendline indicates no significant change for 35 years (an increase by

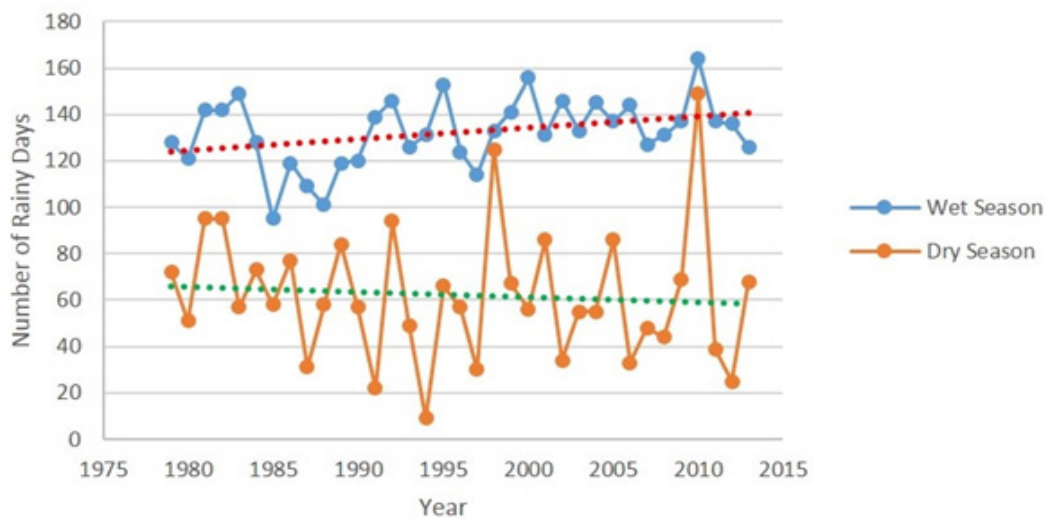


Figure 6. The trend of the number of rainy days during the rainy and dry seasons in the Gunung Sewu karst area

merely ± 10 rainy days in this period). However, after a further study of every season, it turned out that the number of rainy days increased only during the rainy season but tended to decrease in the dry season (Figure 6). The rate of increase was ± 20 rainy days per 35 years in the former, while in the latter, it was \pm ten rainy days per 35 years.

The Gunung Sewu karst area showed a steep increasing trend of rainfall but a less significant elevation in the number of rainy days (as evident from the gently sloping trendline). This condition led to an increase in the daily rainfall intensity (Figure 7). High rain in the area has been reported to cause floods, such as the 2017 flood that coincided with cyclone cempaka (Cahyadi, & Mardiatno, 2019; Haryono et al., 2020; Samodra et al., 2020) and the 2019 flood due to cyclone savannah-induced rainfall (Riyanto et al., 2020). In Gunung Sewu, some landforms are prone to this disaster, namely areas surrounding the ponor where the allogenic river enters the underground river system, springs or resurgences that are controlled by large conduit flows, and karst windows and closed basins (dolines) that have poor drainage because they are covered by sediments or have small-size sinkholes (Cahyadi & Mardiatno, 2019).

Rainfall variability in the Gunung Sewu karst areas is inseparable from the effect of ENSO. Figure 8 depicts the annual rainfall in Indonesia (blue line) and its relation to El Niño. From 1979 to 2013, there were eleven El Niño years, including two very strong events in 1982/83 and 1997/98. In the other nine El Niño events, rains were below the mean annual rainfall in the Gunung Sewu karst area (red line). In other words, El Niño strongly influenced the rainfall in the Gunung Sewu karst area, which is consistent with Boer et al. (2014), who has found a close link between 41 droughts in southern Indonesia (Java, Bali, Nusa Tenggara, South Sulawesi islands) from 1844 until 2009 due to El Niño. El Niño also affects Indonesia's agricultural sector; for example, in 1997/98, El Niño caused damages amounting to USD 2.75 billion and a total economic loss of USD 9 billion nationwide (Bappenas, 1999; Kirono & Tapper, 1999).

Low rainfall as an impact of El Niño will have a devastating effect on regions where most of the populations work in the crop and agricultural livestock sectors (Ayanlade, Radeny, Morton, & Muchaba 2018) like the Gunung Sewu karst area (Cahyadi et al., 2012; Cahyadi, 2014b). This area is mainly used for dry crop cultivations and rainfed rice farming

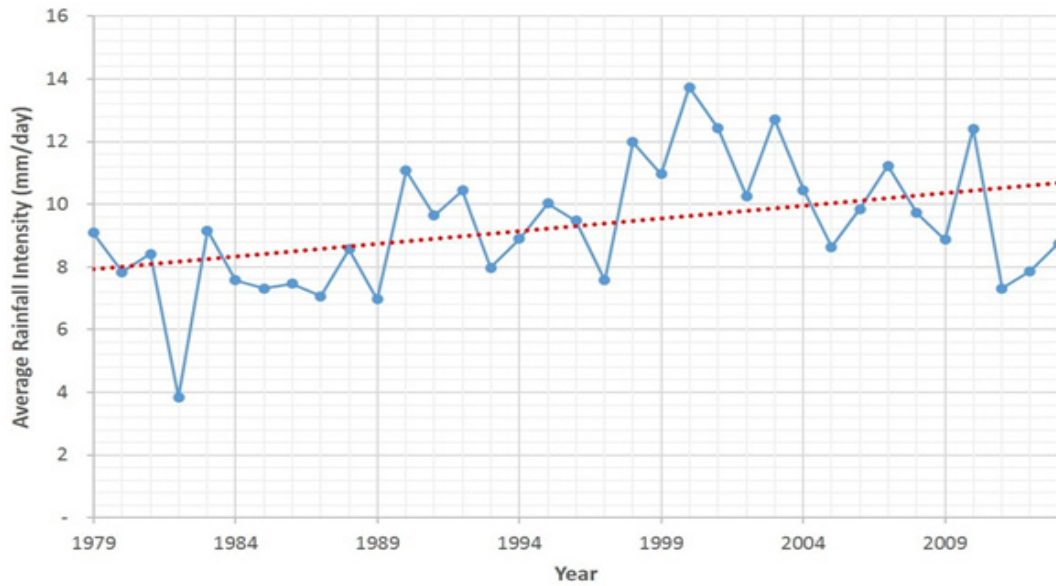


Figure 7. The Trend of daily rainfall intensity in Gunung Sewu karst area

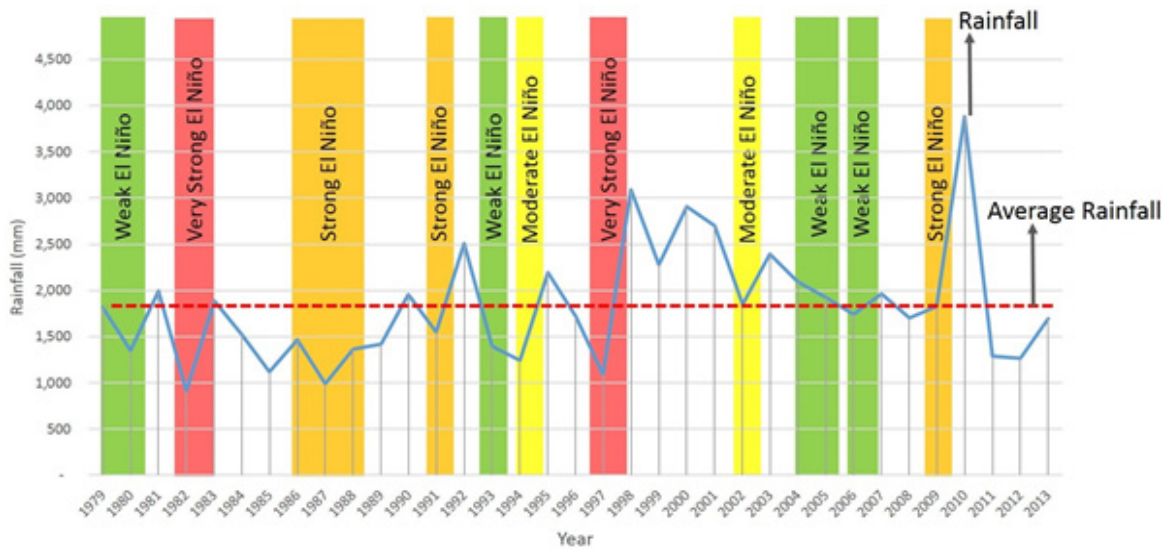


Figure 8. Rainfall data of the Gunung Sewu karst area from 1979 until 2013 with the weak, moderate, strong, and very strong El Niño years as the reference

dependent on rainwater (Naylor et al., 2007; Lestariningsih, Cahyadi, Rahmat, & Zein, 2013). Also, very low rainfall is most likely to induce secondary disasters, namely droughts, decreased agricultural production, and food shortages (Cahyadi et al., 2013; Abaje, Sawa, & Ati, 2014).

La Niña also shapes the rainfall variability in the Gunung Sewu karst area. Figure 9

shows the relationship between annual rainfall (red line) and La Niña events in Indonesia. From 1979 through 2013, La Niña happened seven times or fewer than El Niño. Figure 9 shows that during strong La Niña, the rainfall increased considerably compared to the average rainfall (yellow line). However, unlike El Niño, which has a strong influence, the weak and moderate La Niña years do not appear to be

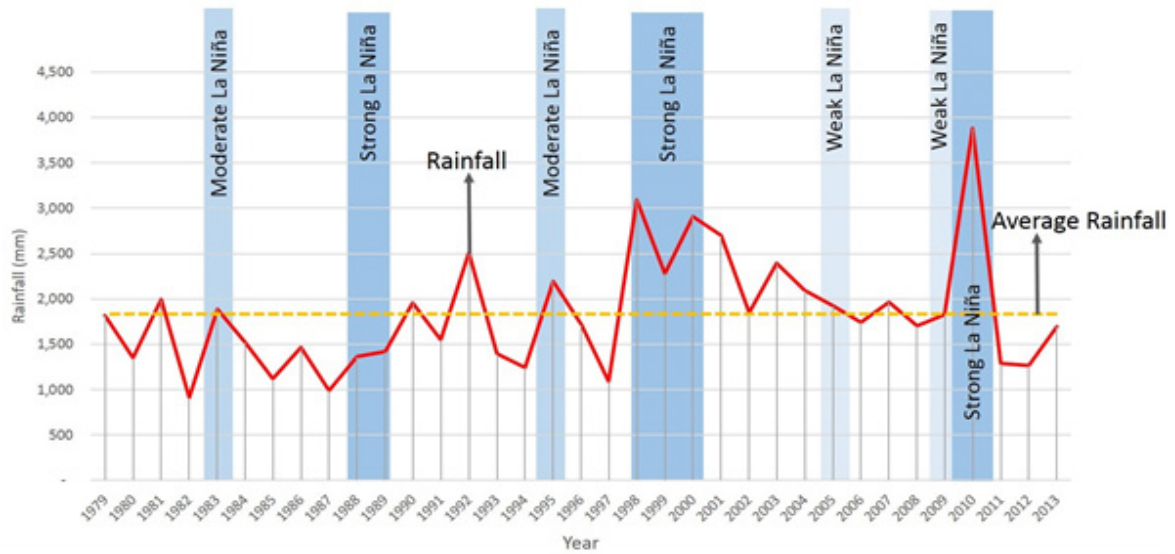


Figure 9. Rainfall data of the Gunung Sewu from 1979 until 2013 with the weak, moderate, and strong La Niña years as a reference

Table 2. Rainfall with different return periods in the Gunung Sewu karst area

Probabilities (%)	Return Periods (Year)	Rainfall (mm/day)
100	1	33
20	5	103
10	10	118
5	20	130
4	25	134
2	50	144
1	100	153
0.5	200	161

strong enough to affect the study area's annual rainfall. As evidence, the annual rainfall during these events was still below the mean yearly rainfall line. Hamada et al. (2002) and Hidayat and Ando (2014) also confirmed that El Niño is more likely to affect Indonesia's rainfall variability.

As presented in detail in Table 2, the highest rainfall in 35 years of recording in the Gunung Sewu karst area was 161 mm/day, with a return period of 200 years. The return period for 50 mm/day rainfall was five years, meaning that extreme rainfall events of this magnitude can occur every five years. Consequently, extreme events pose high hydrometeorological hazards in the area.

IV. CONCLUSION

There is generally an increase in the mean annual rainfall trend, the number of rainy days, and daily rainfall intensity based on the analysis of rainfall data in the Gunung Sewu karst area from 1979 until 2013. In more detail, the number of rainy days in the rainy season tends to increase, while that in the dry season is decreasing. It creates a challenge to the area because the possibility of drought in the dry season will be higher. The yearly rainfall is always below the annual average during the El Niño events, indicating a strong influence of El Niño on the rain. On the contrary, La Niña has less effect, which is apparent from the absence

of high rainfall following this climatological event.

Based on the analysis results, there are less rainfall and fewer rainy days in the dry season, but each rainy event occurs in higher intensity. In this state, drought and flood prevention should be the primary concern of future improvements of relevant disaster management infrastructure. Considering that rainy conditions, particularly in dry seasons, will be increasingly unreliable in the future, providing infrastructure for clean water extraction from underground rivers that caters to all residents of the Gunung Sewu karst areas, in this case, is a suggested option.

The analysis results show that for 35 years (1979–2014), there has been an increase in the mean annual rainfall of 650 mm. If this amount is properly distributed temporally, it will cause more water resources reserves in the karst area. However, this study's results also indicate that there is a trend of increasing daily rainfall intensity. This condition also means that the possibility of extreme rainfall is also getting higher. This means that the increase in the average annual rainfall that occurs does mean more water resources and the possibility of extreme rainfalls and floods that can occur more frequently.

In the future, to complement this research, it is necessary to conduct further studies related to drought susceptibilities, climate change predictions, and analyses of extreme rain events. Studies surrounding their applications, e.g., flood and drought impact analysis and food security, are also essential. They can at least contribute to long-term environmental management and disaster management.

Although satellite data meet the requirements of rainfall variability analysis, field-recorded details remain necessary. Weather satellite data are not without limitations in that information with small to medium resolution is not sufficient for large-scale analysis. Field data available in long time series will facilitate and create a better analysis. Besides, the vast area of Gunung Sewu suggests that there need to be more rain gauge stations. For an even spatial distribution, at least

one station should be added to each district, particularly at a location selected based on the sea's distance to provide distinct variations between rainfall conditions along the coast and far inland.

ACKNOWLEDGEMENT

This research is a part of the first Author's dissertation in the Geography Study Program, Faculty of Geography, Universitas Gadjah Mada. It received funding assistance from the Faculty of Geography, Universitas Gadjah Mada through the 2020 Independent Research Grant Scheme for the Faculty Lecturers (*Hibah Penelitian Mandiri Dosen Fakultas Geografi Universitas Gadjah Mada*) under the Decree of the Faculty Dean No. 1291/UN1/FGE/KPT/SETD/2020.

REFERENCES

- Abaje, I., Sawa, B., Ati, O. (2014). Climate variability and change, impacts and adaptation strategies in Dutsin-Ma Local government area of Katsina State, Nigeria. *Journal of Geography and Geology*, 6(2), 103–112.
- Aldrian, E. (2001). Pembagian iklim Indonesia berdasarkan pola curah hujan dengan metoda “double correlation.” *Jurnal Sains & Teknologi Modifikasi Cuaca*, 2(1), 11–18. doi://10.29122/jstmc.v2i1.2142.
- Aldrian, E., Gates, D., L., & Widodo, F. H. (2007). Seasonal variability of Indonesian rainfall in ECHAM4 simulations and in the reanalyses: The role of ENSO. *Theoretical and Applied Climatology*, 87(1–4), 41–59. doi://10.1007/s00704-006-0218-8.
- Asnani, G. C. (1993). *Tropical meteorology*. STD Computers.
- Athoillah, I., Sibarani, M., R., Doloksaribu, E. D.(2017). Analisis spasial el nino kuat tahun 2015 dan la nina lemah tahun 2016 (Pengaruhnya terhadap kelembapan, angin dan curah hujan di Indonesia). *Jurnal Sains & Teknologi Modifikasi Cuaca*, 18(1), 33–41. doi://10.29122/jstmc.v18i1.2140.
- Ayanlade, A., Radeny, M., Morton, J. F., & Muchaba, T. (2018). Rainfall variability and drought

- characteristics in two agro-climatic zones: An assessment of climate change challenges in Africa. *Science of the Total Environment*, 630(February), 728–737. doi://10.1016/j.scitotenv.2018.02.196.
- Bappenas. (1999). Planning for fire prevention and drought management project. Bappenas, Jakarta.
- Boer, R., Faqih, A., & Ariani, R. (2014). Relationship between Pacific and Indian Ocean sea surface temperature variability and rice production, harvesting area and yield in Indonesia. *Proceeding of the EEPSEA Conference on the Economics of Climate Change*, 330–344.
- Boer, R. (2003). Penyimpangan iklim di Indonesia. *Proceeding of the National Seminar on Soil Science*.
- Brunsch, A., Stoffel, D., Ikhwan, M., Oberle, P., & Nestmann, F. (2011). Hydrological assessment of a karst areain southern Java with respect to climate phenomena. *Asian Trans-Disciplinary Karst Conference*, January, 10.
- Cahyadi, A., Nugraha, H., & Nucifera, F. (2013). Pengaturan pola tanam meteorologis sebagai salah satu upaya optimalisasi produktivitas pertanian di kawasan karst Kabupaten Gunung Kidul. In H. Sudarmadji; Haryono, E.; Adji, T.A.; Widyastuti, M.; Harini, R.; Nurjani, E.; Cahyadi, A.; Nugraha (Ed.), *Ekologi lingkungan kawasan karst Indonesia: menjaga asa kelestarian kawasan karst Indonesia*. Deepublish. 10.31227/osf.io/k4sqe.
- Cahyadi, A. & Mardiatno, D. (2019). Mewaspada bencana hidrometeorologis di kawasan karst. *Kedaulatan Rakyat Daily Newspaper*.
- Cahyadi, A. (2014a). Keunikan hidrologi kawasan karst: Suatu tinjauan. In H. Cahyadi, A., Prabawa, B.A., Tivianton, T.A., Nugraha (Ed.), *Ekologi lingkungan kawasan karst Indonesia: menjaga asa kelestarian kawasan karst Indonesia* (2nd ed., pp. 1–13). Deepublish. doi://10.31227/osf.io/awvqs.
- Cahyadi, A. (2014b). Sumber daya lahan kawasan karst Gunungsewu. In H. Cahyadi, A., Prabawa, B.A., Tivianton, T.A., Nugraha (Eds.), *Ekologi lingkungan kawasan Karst Indonesia: menjaga asa kelestarian kawasan karst Indonesia* (2nd ed., pp. 102–113). Deepublish. doi://10.31227/osf.io/4dbr5.
- Cahyadi, A., Haryono, E., Adji, T. N., Widyastuti, M., Riyanto, I. A., Nurteisa, Y. T., Fatchurohman, H., Reinhard, H., Agniy, R. F., Nurkholis, A., Naufal, M., & Nurjani, E. (2019). Groundwater flooding due to tropical cyclone cempaka in Ngrengeng karst window, Gunung Sewu karst area, Indonesia. *E3S Web of Conferences*, 125 (2019). doi://10.1051/e3sconf/201912501020.
- Cahyadi, A., Marfai, M. A., Rahmadana, A. D. W., & Nucifera, F. (2012). Perencanaan penggunaan lahan di kawasan karst berbasis analisis kemampuan lahan dan pemetaan kawasan lindung sumberdaya air. *Proceedings of the National Seminar on Science, Engineering and Technology, December 2018*, 22–23. doi://10.31227/osf.io/6b49a.
- Cahyadi, Ahmad, Nugraha, H., Wacano, D., & Fatchurohman, H. (2012). Peran organisasi masyarakat dalam strategi adaptasi kekeringan di Dusun Turunan, Kecamatan Panggang, Kabupaten Gunung Kidul (Sebuah pembelajaran dalam adaptasi dampak perubahan iklim di masa mendatang). *Prosiding Seminar Nasional Perubahan Iklim, December*. doi://10.31227/osf.io/md957.
- Christanto, N., Setiawan, M. A., Nurkholis, A., Sartohadi, J., & Hadi, M. P. (2020). The use of global datasets in the SWAT model for tropical watershed with limited ground data: A case study in Serayu upper catchment. *Taiwan Water Conservancy*, 68(3), 18–27.
- Dile, Y. T., & Srinivasan, R. (2014). Evaluation of CFSR climate data for hydrologic prediction in data-scarce watersheds: An application in the blue Nile river basin. *Journal of the American Water Resources Association*, 50(5), 1226–1241. doi://10.1111/jawr.12182.
- Dipayana, G.A., Cahyadi, A., Mutaqin, B.W., & Nurjani, E. (2012a). Dampak perubahan iklim terhadap nilai erosivitas di DAS OPAK berdasarkan skenario perubahan iklim HadCM3 skenario A2 dan B2. *Proceedings of the Science, Engineering and Technology*. doi://10.31227/osf.io/v3f7b.
- Dipayana, G.A., Nurjani, E., Adji, T. (2012b). Estimasi distribusi spasial imbuhan airtanah menggunakan model water-budget dan Geographic Information System (GIS) di DAS Opak, DIY. *Proceedings of the Science, Engineering and Technology*, 1–7.
- Fatchurohman, H., & Cahyadi, A. (2013). Strategi

- adaptasi masyarakat terhadap bencana kekeringan di kawasan karst Kecamatan Panggang, Gunung Kidul. In H. Sudarmadji, Haryono, E., Adji, T.A., Widyastuti, M., Harini, R., Nurjani, E., Cahyadi, A., Nugraha (Ed.), *Ekologi lingkungan Kawasan Karst Indonesia: menjaga asa kelestarian Kawasan Karst Indonesia* (pp. 1–12). Deepublish. https://www.academia.edu/6261679/Strategi_adaptasi_lingkungan_masyarakat_awasan_karst.
- Fuka, D. R., Walter, M. T., Macalister, C., Degaetano, A. T., Steenhuis, T. S., & Easton, Z. M. (2014). Using the climate forecast system reanalysis as weather input data for watershed models. *Hydrological Processes*, 28(22), 5613–5623. doi://10.1002/hyp.10073.
- Green, S. M., Dungait, J. A. J., Tu, C., Buss, H. L., Sanderson, N., Hawkes, S. J., Xing, K., Yue, F., Hussey, V. L., Peng, J., Johnes, P., Barrows, T., Hartley, I. P., Song, X., Jiang, Z., Meersmans, J., Zhang, X., Tian, J., Wu, X., ... Quine, T. A. (2019). Soil functions and ecosystem services research in the Chinese karst critical zone. *Chemical Geology*, 527, [119107], doi://10.1016/j.chemgeo.2019.03.018.
- Gutman, G., Csiszar, I., & Romanov, P. (2000). Using NOAA/AVHRR products to monitor El Niño impacts: Focus on Indonesia in 1997–98. *Bulletin of the American Meteorological Society*, 81(6), 1189–1205. doi://10.1175/1520-0477(2000)081<1189:UNPTME>2.3.CO;2.
- Hamada, J. I., Yamanaka, M. D., Matsumoto, J., Fukao, S., Winarso, P. A., & Sribimawati, T. (2002). Spatial and temporal variations of the rainy season over Indonesia and their link to ENSO. *Journal of the Meteorological Society of Japan*, 80(2), 285–310. doi://10.2151/jmsj.80.285.
- Haryono, E., Cahyadi, A., Nurrohman, A.M., Adzan, G., Nasution, A. L., Diah, H., & Sari Septianingrum, R. (2020). Dinamika luweng belimbing, kawasan karst Gunung Sewu pasca siklon tropis cempaka tahun 2017. *Jurnal Geografi*, 12(01), 39–45. doi://10.24114/jg.v12i01.14769.
- Haylock, M., & McBride, J. (2001). Spatial coherence and predictability of Indonesian wet season rainfall. *Journal of Climate*, 14(18), 3882–3887. doi://10.1175/1520-0442(2001)014<3882:SCAPOI>2.0.CO;2.
- Hermawan, E. (2010). Pengelompokan pola curah hujan yang terjadi di beberapa kawasan P. Sumatera berbasis hasil analisis teknik spektral. *Jurnal Meteorologi dan Geofisika*, 11(2), 75–85. doi://10.31172/jmg.v11i2.67.
- Hidayat, R., & Ando, K. (2018). Variabilitas curah hujan Indonesia dan hubungannya dengan ENSO/IOD: Estimasi menggunakan data JRA-25/JCDAS. *Agromet*, 28(1), 1–8. doi://10.29244/j.agromet.28.1.1-8.
- Juaeni, I. (2006). Analisis variabilitas curah hujan wilayah Indonesia berdasarkan pengamatan tahun 1975–2004. *Matematika*, 9(2), 171–180.
- Kang, Z., Chen, J., Yuan, D., He, S., Li, Y., Chang, Y., Deng, Y., Chen, Y., Liu, Y., Jiang, G., Wang, X., & Zhang, Q. (2020). Promotion function of forest vegetation on the water & carbon coupling cycle in karst critical zone: Insights from karst groundwater systems in south China. *Journal of Hydrology*, 590, [125246]. doi://10.1016/j.jhydrol.2020.125246.
- Kirono, D. G. C., & Tapper, N. J. (1999). ENSO rainfall variability and impacts on crop production in Indonesia. *Physical Geography*, 20(6), 508–519. doi://10.1080/02723646.1999.10642693.
- Lestariningsih, S.P., Cahyadi, A., Rahmat, P. N., & Zein, A. G. I. (2013). Tekanan penduduk terhadap lahan di Kawasan Karst (Studi kasus di Desa Songbanyu, Kecamatan Girisubo dan Desa Jeruk Wudel Kecamatan Rongkop, Gunung Kidul). December. doi://10.31227/osf.io/kc6j6h.
- Naylor, R. L., Battisti, D. S., Vimont, D. J., Falcon, W. P., & Burke, M. B. (2007). Assessing risks of climate variability and climate change for Indonesian rice agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, 104(19), 7752–7757. doi://10.1073/pnas.0701825104.
- Qian, J. H., Robertson, A. W., & Moron, V. (2010). Interactions among ENSO, the monsoon, and diurnal cycle in rainfall variability over Java, Indonesia. *Journal of the Atmospheric Sciences*, 67(11), 3509–3524. doi://10.1175/2010JAS3348.1.
- Quine, T., Guo, D., Green, S. M., Tu, C., Hartley, I., Zhang, X., Dungait, J., Wen, X., Song, Z., Liu, H., Buss, H., Barrows, T., Evershed,

- R., Johnes, P., & Meersmans, J. (2017). Ecosystem service delivery in Karst landscapes: anthropogenic perturbation and recovery. *Acta Geochimica*, 36(3), 416–420. doi://10.1007/s11631-017-0180-4.
- Ramage, C. (1971). Monsoon meteorology. In International Geophysics Series (15th ed., pp. 365–370). Retrieved from Academic Press. <https://www.sciencedirect.com/bookseries/internationalgeophysics/vol/15/suppl/C>
- Ramage, C. . (1968). Role of a tropical marine continent in the atmospheric circulation. *Monthly Weather Review*, 96(6), 365–370.
- Riyanto, I. A., Cahyadi, A., Ramadhan, F., Naufal, M., Widyastuti, M., & Adji, T. N. (2020). Dampak siklon tropis savannah pada karst Window Kalinongko, Karst Gunung Sewu, Kabupaten Gunung Kidul, Indonesia. *Jurnal Geografi*, 17(1), 7–14. doi://10.15294/jg.v17i1.21419.
- Samodra, G., Ngadisih, N., Malawani, M. N., Mardiatno, D., Cahyadi, A., & Nugroho, F. S. (2020). Frequency–magnitude of landslides affected by the 27–29 November 2017 tropical cyclone cempaka in Pacitan, East Java. *Journal of Mountain Science*, 17(4), 773–786. doi://10.1007/s11629-019-5734-y.
- Stefanidis, S., & Stathis, D. (2018). Spatial and temporal rainfall variability over the mountainous central Pindus (Greece). *Climate*, 6(3)1-15. doi://10.3390/cli6030075.
- Suprayogi, S., Cahyadi, A., Tivianton, T.A., Riyadi, S., Fajri, A.A., Sasongko, T.R. and Arida, V. (2014). Analisis dampak perubahan iklim terhadap curah hujan tahunan menggunakan skenario iklim HadCM3 dengan skenario emisi A2 dan B2 analisis di DAS Progo Hulu. *Pekan Ilmiah Tabunan Ikatan Geograf Indonesia*. <https://10.0.68.197/OSF.IO/AY7S3>.

STAKEHOLDERS' MAPPING AND STRATEGY FOR RESTORING PEATLAND FOREST IN WEST TANJUNG JABUNG JAMBI, INDONESIA

Ignatius Adi Nugroho^{1*}, Darwo², and Dhany Yuniarti²

¹Secretariat of Research, Development, and Innovation Agency

Jl. Gunung Batu No.5 Bogor, West Java 16610, Indonesia

²Forest Research and Development Center,

Jl. Gunung Batu No.5 Bogor, West Java 16610, Indonesia

Received: 11 June 2020, Revised: 30 April 2021, Accepted: 30 April 2021

STAKEHOLDERS' MAPPING AND STRATEGY FOR RESTORING PEATLAND FOREST IN WEST TANJUNG JABUNG JAMBI, INDONESIA. Peatland forests became the centre of discussions in Indonesia because 33% of 2.4 million hectares burned in 2014. This research aims to describe the stakeholders' position and their logic in choosing a strategy for peatland forest areas. The result shows that nine stakeholders were actively involved in peatland forest restoration in West Tanjung Jabung Regency. Based on categorization, the analysis points out that all stakeholders had occupied key players' position. Further analysis using a ladder of participation criteria found two models of participation, i.e. citizen power and tokenism. However, the value of citizen power is higher than tokenism that is 56% and 44%, respectively. It means that stakeholders should develop partnership and other models in citizen power criteria to reach their targets. It also means that trust is an essential variable in the relationship among stakeholders and should be developed in peatland forest restoration. The consequence of this research is that stakeholders can improve two strategies, i.e. collaborative forest management and community-based forest management.

Keywords: Collaborative, stakeholder, peatland, participation, enabling strategy

PEMETAAN PARA PIHAK DAN STRATEGI UNTUK MERESTORASI HUTAN LAHAN GAMBUT DI TANJUNG JABUNG BARAT PROPINSI JAMBI, INDONESIA. Hutan rawa gambut yang terdapat di Indonesia menjadi isu besar setelah 33% dari 2,4 juta hektar terbakar pada tahun 2014. Tujuan penelitian ini adalah untuk memberikan gambaran mengenai posisi para pihak dan strategi logis yang dipilih oleh mereka pada kawasan hutan rawa gambut. Penelitian ini menghasilkan sembilan pihak yang terlibat secara aktif pada restorasi hutan rawa gambut di Kabupaten Tanjung Jabung Barat. Analisis kategorisasi yang digunakan dalam penelitian ini menunjukkan bahwa semua pihak yang terdapat pada area penelitian merupakan pemain kunci. Analisis lebih lanjut menggunakan kriteria tangga partisipasi menemukan bahwa ada dua model partisipasi yang digunakan oleh para pihak yaitu tokenisme dan citizen power. Nilai citizen power dibandingkan dengan tokenisme lebih tinggi yaitu 56% berbanding 44%. Hal ini berarti bahwa kemitraan dan model-model lain yang terdapat di dalam citizen power akan dikembangkan oleh para pihak untuk mencapai target mereka. Hal ini juga berarti bahwa kepercayaan merupakan variabel penting dalam relasi di antara para pihak dan harus dikembangkan dalam restorasi hutan rawa gambut. Konsekuensi dari penelitian ini bahwa para pihak dapat membangun dua strategi yaitu pengelolaan hutan kolaboratif dan pengelolaan hutan berbasis masyarakat.

Kata kunci: Kolaborasi, para pihak, rawa gambut, partisipasi, strategi pemungkin

*Corresponding author: toekang_jamoe@yahoo.co.id

I. INTRODUCTION

Peatland forest fire has occurred in Indonesia, which has been devastating for biodiversity, social welfare and economic development in seven provinces, i.e. Riau, Jambi, South Sumatera, West Kalimantan, Central Kalimantan, South Kalimantan and Papua. The fire has covered 2.4 million hectares of peatland forest and made economic losses of approximately Rp 221 Trillion; about 16.1 million USD (World Bank, 2016). Some references such as Tata and Susmianto (2016) point out that human activities are the main cause of peatland forest fires; Edwars and Heiduk (2015), Miettinen and Soo (2010) stated that people need the peatland for agriculture, concessions and plantations (Rehman, Sabiham, Sudadi, & Anwar, 2015). The fire on peatland forest also contributes to increasing greenhouse gas emissions to the atmosphere and influence to the surrounding human ecosystem and habitats (Ramdhani, Ruhimat, Wiyono, & Barnes, 2020; Edwars & Heiduk, 2015; Tata, 2019).

Human burns the peatland because they need income and peatland is the only opportunity for their agricultural activities. They construct canals on peatland to drain water, and through this, peatland can be used as farmland. Human activities have caused changes in the ecosystem and habitat level (Haapalehto, Vasander, Jauhiainen, Tahvanainen, & Kotiaho, 2010). Due to this activity, peatland will dry and

become flammable in the dry season (World Bank, 2016). Fire is a severe problem in peatland forest. In 2015, peatland forests in Indonesia had big fires due to the ENSO-El Niño Southern Oscillation effect (Edwars & Heiduk, 2015).

At the political level, President Joko Widodo was pushed by governors exposed to smoke hazards to stop the impact on their territories. Due to the evidence, the President issued Presidential Decree number 1/2016 to establish Peat Land Restoration Agency/Badan Restorasi Gambut (BRG) as a non-structural institution directly below the President's instruction. BRG has a special assignment to restore burned peatland forests in Riau, Jambi, South Sumatera, West Kalimantan, Central Kalimantan, South Kalimantan and Papua. In 2016 and 2017, BRG has declared that this institution successfully managed the target of 200 thousand hectares for restoring peatland areas each year using rewetting, replanting, and revitalization strategy.

West Tanjung Jabung Regency is in Jambi Province, which is one of the priority peatland restoration areas. Implementing the restoration activities in this regency was compiled through cooperation between BRG and Forest Research and Development Center (FRDC) Ministry of Environment and Forestry, responsible for the paludiculture pilot project. In terms of paludiculture, FRDC constructs the pilots in

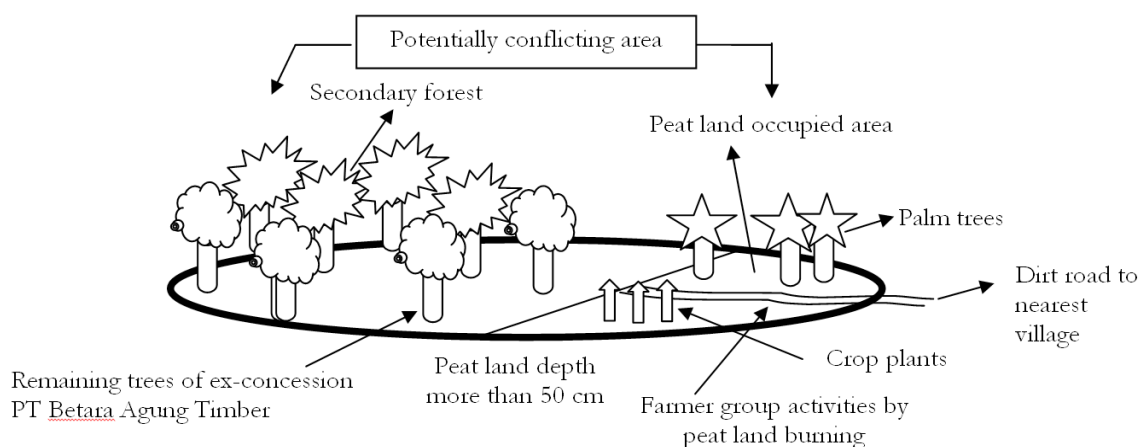


Figure 1. Current condition of Sungai Beram Hitam Forest Management Unit

a peatland conservation area, which has been occupied by humans and is at least 5 thousand to 15 thousand hectares. Sungai Beram Hitam Forest Management Unit manages the remaining secondary forest in this peatland conservation area (FMU). Occupation activities in the peatland conservation area started in 1998 when there was a change of power in Indonesia. However, Uda, Hein, and Sumarga (2017) pointed out that the conversion of peatland forests in Indonesia has occurred between 2000–2014. Other reasons, failure and cessation of concession in that area also contributed to the human occupation when the area became an open access area. It became riskier when a migrant from another island, i.e. Java and South Sulawesi, also moved in and bought land in that area. This has occurred because local villagers, commonly chief villagers, sold that area to the migrant by the *Pancung Alas* system and converted secondary forest to palm oil plantation. This disorder influenced farmers in Sungai Beram Hitam Raya village to plant palm trees on peatland conservation area since the start of the occupation.

This research aims to describe the stakeholders' position and their logic in choosing peatland forest areas. Competitiveness among stakeholders may occur and involve their

resources, i.e. money, opportunity, energy, and other social capitals; however, the stakeholders can also build cooperation. Nurrochmat, Nugroho, Hardjanto, Purwadianto, Maryudi, and Erbaugh (2017) concluded that stakeholders are ready to change their competitiveness to become cooperative when they found the same interest, e.g. in medicinal plants utilization in Meru Betiri National Park (MBNP). This manuscript used the conclusions of an overview of different locations in West Tanjung Jabung Jambi Province and tried to find similarities.

II. MATERIAL AND METHOD

A. Location and Research Period

West Tanjung Jabung Regency, Jambi Province, is about two hours travelling by car from Jambi Province capital to Kuala Tungkal as the capital of West Tanjung Jabung Regency. Figure 2 shows the research location which contains paludiculture plots. Paludiculture is how people who live near the peatland forest utilize that peatland for agriculture and rewetting and restoring its functions. Paludiculture plot is a location which is built for agriculture and plants in peatland area. This figure also shows three white colours for another use where

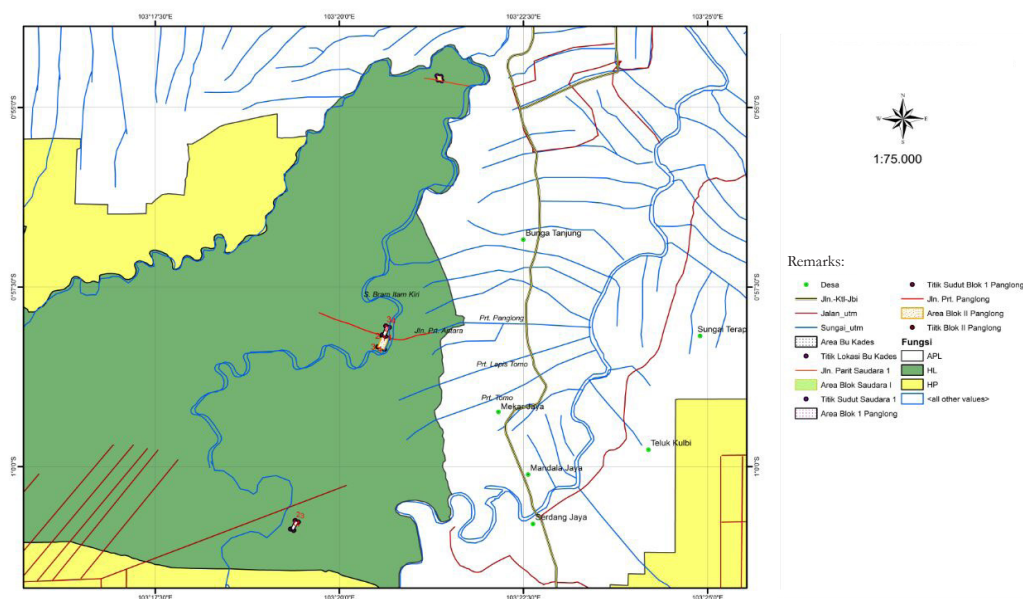


Figure 2. Location of paludiculture plots in Sungai Beram Hitam FMU



Figure 3. Peatland burning near the location of pilot paludiculture plot

the local government can use that area for any requirement, e.g. settlement, plantation, agriculture, and industry. The yellow colour is the production forest. The government can use this area only for concession and green colour is protected forest. Based on the definition, green colour is a peatland conservation forest because its position is located between Beram Hitam Kanan and Beram Hitam Kiri. Figure 1 shows that humans have built the canals (red line colour) in peatland conservation forest. This condition will worsen the peatland conservation forest, because it will degrade the water level in that area. If it occurred, peatland conservation forest would be dried and would burn easily. The consequence will be that human will occupy the peatland conservation forest and use it for agriculture. Figure 3 shows the human, near the pilot paludiculture area, uses fire to burn peatland and change it to agricultural land. This processing is used by farmers all the time because it is very efficient and effective.

This research started in June 2017 and ended in December 2017. There were three demonstration plots, and a different group owned each demonstration plot. A large amount of data have been collected, i.e. peatland soil type, forest tree species, agriculture trees, stakeholders, socio-economic, etc. However,

this study describe stakeholders because it was interesting to analyze them in peatland forest conservation.

B. Data Analysis

As mentioned above, this research is using stakeholders' approaches that are essential elements in peatland restoration. Stakeholders need to be analyzed because their interest and influence have always changed over time. This research is leaning on categorization analysis which is popularized by Reed et al. (2009) and has already been tried by other researchers (Fibriani, 2012; Nugroho, 2016; Nurrochmat et al., 2017). To describe the data processing analysis, Figure 4 provides the stage plot methodology to analyze research data.

1. Stakeholders Identification

The definition of stakeholder is the most important in this research, because it will help the researcher recognize individuals or groups with power and interest in the peatland forest. Sometimes stakeholders are also defined as parties affected by the outcome or those who can change the result of a proposed development intervention. In the simplest term, stakeholders are always related to the interested parties. Harding and Macdonald (2001) argued that individuals or groups are interested and should be engaged in the activity.

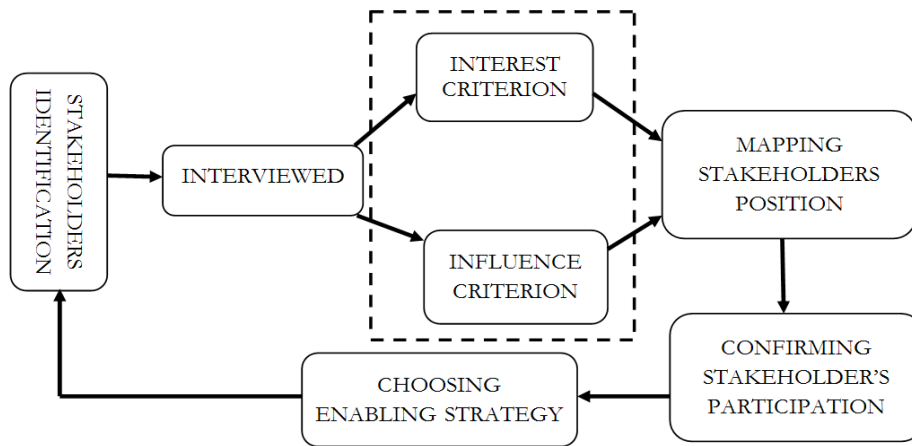


Figure 4. Data processing analysis

Sources: Modified from Reed et al. (2009); Nurrochmat, Nugroho, Hardjanto, Purwadianto, Maryudi, and Erbaugh (2017); Oktavia and Saharuddin, (2013); Azhari (2011); Collins and Ison (2006)

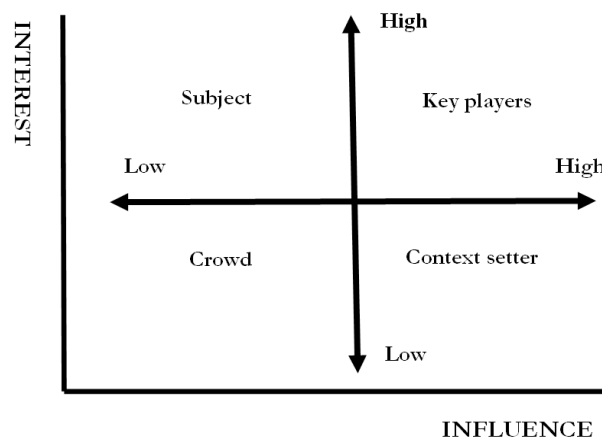


Figure 5. Matrix categorization

Source: Reed et al., (2009)

If researchers excluding them from the action, it will not make them disappear from the arena. Most literature on international development projects emphasizes the importance of those who are affected by projects to be considered key stakeholders (Mathur, Price, & Austin, 2008). Based on the information, it can conclude that the term stakeholders always involve the interests, influence, and power of individuals or groups affected (Saputra, 2019). It is also clear that stakeholders need further analysis. Reed et al. (2009) argued that stakeholder analysis had provided a diverse range of criteria that justify the involvement of other individuals and

groups.

To identify the stakeholders, stakeholder analysis was conducted accordingly (Oktavia & Saharuddin, 2013; Reed et al., 2009). The stages of stakeholder analysis will start from (a) identification of stakeholders, (b) grouping and differing among stakeholders, and (c) investigating the correlation among stakeholders (Reed et al., 2009). The stakeholders in this research will be identified and entered into the matrix categorization based on variables of interest and influence collected by interviews. The matrix categorization is provided in Figure 5.

To describe the matrix categorization, (Figure 5), Fibriani (2012) and Nurrochmat et al. (2017) agreed with these as stated by Reed et al. (2009) as follows:

"key players are individuals or groups who are belonging high interest and influence; subjects are individuals or groups who are residing high importance and low importance; context setters are individuals or groups who are belonging strong influence and little interest; and crowds are individuals or groups who are belonging low importance and low importance"

2. Interview of the Stakeholders

In this stage, stakeholders who have been identified will be interviewed. The process will start from key stakeholders Mathur, Price, and Austin (2008) as the primary component. To get more specific information regarding stakeholders' activities in peatland forest, this study attempt to extract information from key stakeholders. It is essential because a key stakeholder in this research is a person who has a role as a key informant (Fibriani, 2012; Nugroho, 2016; Nurrochmat et al., 2017). On the other hand, this research is also leaning on a qualitative approach wherein interviews of crucial stakeholders would be successful if the persons as key informants are participating.

Interview of the key informant takes place on purposive sampling. Each key informant represents an organization such as Forest Management Unit (FMU), Farmer Groups, NGO, Traders, Politicians and Village Government. Each informant obtains the questions that correlate to the variables with interest and influence that are the dotted lines in the box in Figure 4. Fibriani (2012), Nugroho (2016), and Nurrochmat et al. (2017) argued that the interest variable contains five elements, i.e. motivation, perception, needs, supporting forms, and beneficiaries. Variables of influences also have five items, i.e. participation, role and contribution to the decision, relation to another person, human resource capacity, and financial support.

To quantify those variables of the above paragraph, such as motivation, perception,

and needs, the scoring technique for each element has been developed. The scoring rank is designed from 1 to 5, wherein each number has described the informant's answer low to a high level of importance. Fauziyah and Sanudin (2017), Budiaji (2013), Brown (2011) argued that the Likert scale is useful as a tool to describe the answering level of each participant who was interviewed. Following the Likert range, the 1st means that the informant has the lowest answer score to the question element, the 2nd means low score, the 3rd means middle score, 4th means high score and 5th means the highest score. After all, respondents answered the questions; it was formulated the answers in tabular data. To confirm them in the position, scatter point was used in excel operational system to establish the matrix function of X and Y. This stage is following the categorization analysis concept (Reed et al., 2009).

3. Mapping Stakeholders Position

Recognizing the stakeholders' positions is needed because it points out their power which is the correlation between interest and influence (Reed et al., 2009). Each position will be different among stakeholders depending on their answer and power perception which they have. It will also explain that the stakeholder's location is very dynamic, and each stakeholder can influence others. Relations among stakeholders and their connectivity were also observed during the interview, helping us understand the relationship among stakeholders better. Due to these reasons, mapping stakeholder's position will help us describe who is more powerful than others (Nugroho, 2016). In another case, recognizing those positions also encourage parties to develop cooperation among them as an enabling strategy in the field, such as the utilization of medicinal plants in Meru Betiri National Park, East Java Indonesia (Nurrochmat et al., 2017) and community forestry in Sarolangun Regency, Jambi Indonesia (Fibriani, 2012). This is possible because those positions will draw the occupation of each stakeholder in the critical player, subject, context setter or

crowd. The stakeholders who are in the key player position are usually cooperative and always ready to establish cooperation among them. However, they are in a subject position against the stakeholders who are the key players. However, they should be maintaining their positions because stakeholders in a subject position always establish an alliance with others (Reed et al., 2009; 2017). In this mapping, it means that peatland restoration needs more information regarding stakeholders because this variable is influencing how human utilize that area. The stakeholders who are in key player position are recommended to be involved in peatland restoration. It is helping policymakers doing programs in that area.

Regarding this research finding, we also faced of some difficulties primarily to find stakeholder who have position in subject, context setter and crowd, even though that other position is important to mapping the stakeholder position. It's difficult because when we start this research, actors or persons who must be interviewed hard to find, remote area, and there is no public transportation at the location. Almost actors can be met at the night time after they finished work at the land field.

We realized that this research actually difficult and particularly when we should described all stakeholders to map their positions. However, all challenge is not make us give up and tried to finish this work. We know that this work is still not perfect and hope finish it at next time as long as the resources provided, particularly to fill the other position of the stakeholder (Figure 8).

4. Confirming Stakeholder's Participation

In this stage, we used the participation theory to analyze the stakeholders. Oktavia and Saharuddin (2013), Azhari (2011), Collins, Kevin, and Ison (2006) argued that participation has stages which are described as the correlation among parties where degrees of involvement dispersing from not engagement, tokenism and citizen power. This theory is defined as Arnstein's Participation Ladder (Figure 6).

Arnstein's Participation Ladder divided the degree of participation into eight ladders, i.e. manipulation and therapy (non-participation degrees), informing, consultation and placation (tokenism degrees), partnership, delegated power and citizen control (citizen power degrees). According to Oktavia and Saharuddin

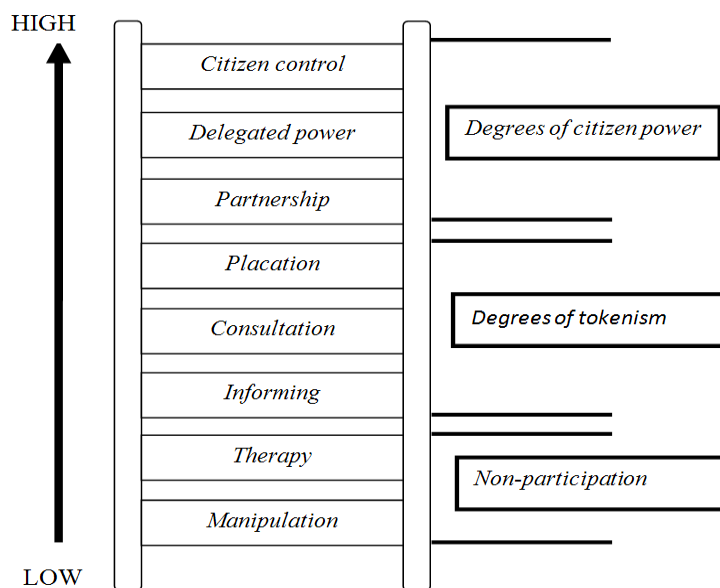


Figure 6. Ladder of participation

Sources: Oktavia and Saharuddin, (2013); Azhari (2011); Collins, Kevin, and Ison (2006)

(2013), a small group controls participation in the public community where a small group has been positioned as elite and has the power to govern the general population. Therefore, public involvement has been supported by the elite; however elite create different programs which are opposite to public programs, which can be described as therapy. Both of these conditions point out that there is no participation among stakeholders because dominant parties control the majorities and give them limited information. They were informing means that participation is directly controlling the information to the community. The consultation also means that community participation to give their opinion have been sufficient; however, opinion has not been assured to be decided by an elite. And placation means that the public community has been empowered; however, program execution depends on the program availability of the elite. These three definitions of participation describe tokenism correlation among stakeholders where the minority could influence and force the program to powerless stakeholders.

The partnership means that both public community and elite have the same perception, responsibility, and programs and then actively developed cooperation between them on condition that the public community has the power to delegate their program by representative persons to elite and both parties doing programs based on common agreement defined as delegated power. The last citizen control means the public community can control all programs that influence their livelihood. Following these definitions, the degree of power given to the community is when the government shares the power to the public community and establishes programs together. In this way, the public community will have the same potential as the government, developing a communication strategy to aid the program and increasing public participation.

5. Choosing Enabling Strategy

Since the government shares its power, the public community will increase their trust in

the government. Siisiainen (2000) has seen that trust is a special attribute of social capital in the organization. The social organization also can be drawn by the stakeholder structure that is present in the community. Each stakeholder has different attributes such as title, prosperity, political supporters, family or clan member, etc. Social capital is the total of all actual and potential resources associated with the possession of a lasting network of the more or less institutionalized relationship of knowing or respecting each other (Sylviani Suka, Surati, & Kurniasari, 2020). It is expressed and institutionalized by name or title, which shows in their attributes such as family, clan, nobility, party and so forth (Siisiainen, 2000). In terms of social capital, Birner and Wittmer (2000) suggest that social capital definition correlates with political capital in which political capital also contains two private and public perspectives. In the personal perspective, political capital consists of the resources which are actors, i.e. an individual or a group, can dispose of and use to influence the policy formation process and realize outcomes that are in the actor's perceived interest (Birner & Wittmer, 2000; Gilens & Page, 2014). This definition corresponds to political resources as necessary resources in Hick and Misra (1993) arguments, i.e. pluralist, statist, mass political conflict and social-democratic perspectives.

On the other hand, political resources also need instrumental resources and infra-resources. Instrumental resources are defined as specific resources used by specific authors to realize their perceived interests. And then infra-resources are defined as resources that broadly facilitate diverse actors pursuits of their interests by empowering their action or conditioning the effectiveness of specific instrumental resources (Hick & Misra, 1993). To explain this concept, Winkel (2012) argued that instrumental resources respond to welfare factors that are dispersed in actors interest, such as actors who are pro or anti-welfare.

These actors usually are connected with sub-governmental administrative authority

and tend to statist and develop administrative approaches. Actors connected with interest organization and electoral leverage tend to develop plural approaches, and other actors who develop disruptive leverage tend to political conflict approaches. Infra-resources is relevant for welfare spending to include such as state fiscal capacity and state internal organization (Hick & Misra, 1993; Birner & Wittmer, 2000). To develop this theory, Birner and Wittmer (2000) proposed to change the term of private perspectives into instrumental political capital. This concept was used to distinguish private term, which is often associated with the individual's position; however, in term of the actor's perspective, it is often related to the organization in the political arena concept.

Mentioning political capital, Birner and Wittmer (2000) also proposed to change the public perspective term into the structural political capital term. This concept corresponds to structural variables in the political system, which influences the possibilities of the diverse actors to accumulate instrumental political capital and condition the effectiveness of the different type of instrumental capital. The structural political capital relates to infra-resources in the political resources theory (Birner & Wittmer, 2000). Following these theories, actors can exchange their social capital

into political capital through discovering their same interest, i.e. welfare (Lunenborg, 2012). It is a needed requirement that actors understood their common purpose and also have given highest participation. Then, that participation can encourage those actors to raise trust among actors so that the political capital can be the function of their interest. Democratization is required that makes actors obtain their political positions. It has the same meaning as the citizen power concept in ladder participation theory (Collins & Ison, 2006; Azhari, 2011; Oktavia & Saharuddin, 2013).

Regarding that situation, shifting social capital into political capital in the actor's context is one condition to help actors defining their common strategy purposes. Birner and Wittmer (2000) and Nurrochmat et al. (2017) argued that actors have an option to choose their institutional strategies to manage the natural resources excellently based on the objective condition of state capacity and social capital power. It means that actors who lived in the peatland area also have the same characteristic to manage their optimum institutional strategies.

Nurrochmat, Darusman, and Ekayani (2016) divided the strategies into four areas. Firstly, state management strategy is compatible if state capacity condition is powerful and social capital condition is weak. Secondly, the opposite

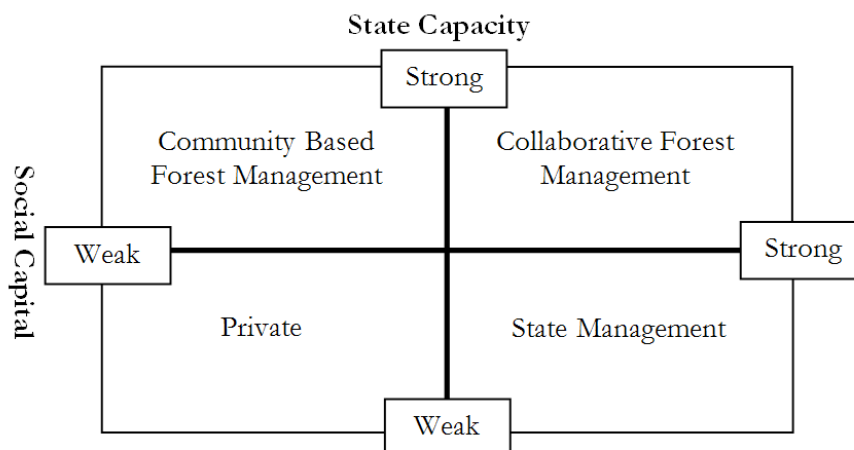


Figure 7. Strategies options related to state capacity and social capital

Sources: Nurrochmat, Darusman, and Ekayani (2016); Nurrochmat et al. (2017); Birner and Wittmer (2000)

of state management strategy is community based forest management. This condition is compatible if state capacity is weak and social capital is powerful. Thirdly, collaborative forest management is the best strategy option because state capacity and social capital have the same powerful condition. In this condition, structural political capital and instrumental political capital have the same position and both can construct the partnership. The last strategy is opposite of collaborative forest management if state capacity and social capital have the same weak condition. It is defined under private management. In this condition, the private sector can manage natural resources by contractual systems. The condition of natural resources must constantly manage and forbidding open access to the resources. The strategies option is shown in Figure 7.

III. RESULT AND DISCUSSION

This research draws on stakeholders' position and their participation by mapping them on peatland utilization. The research data is shown in Table 1 below.

A. Description of Each Stakeholder

Peatland utilization involved many stakeholders in West Tanjung Jabung. Most of them utilize peatland as farmland to earn economic-financial resources and meet their families income. Nine major stakeholders are involved in peatland management, i.e. Forest and Environment Agency Jambi Province

(FEA), Forest Management Unit (FMU) of West Tanjung Jabung, politician, Middle trader juvenile fruits of *Pinanga* sp., industry old fruits of *Pinanga* sp., NGO of WARSI, Mega Buana Farmer Group (FG), Village Government of Sungai Beram Itam Raya (VG), and Forest Farmer Group (FFG). These stakeholders have been interviewed. Minor stakeholders not yet involved in the field because of some constraints to this research, i.e. remote area, lack of a public vehicle, and very bad accessibility to the location.

1. Forest and Environment Agency Jambi Province (FEA)

FEA is a major stakeholder who is responsible for managing FMU in Jambi Province. There are two functions of FMU, i.e. protection and production entity refer to Forest Law number 41/1999. However, there are nine FMUs in Jambi Province; namely Merangin, Tebo, Sarolangun, Kerinci, Muara Bungo, Muara Jambi, West Tanjung Jabung, East Tanjung Jabung, and Batanghari. Those FMUs were under control and managed by FEA, especially after the revision of Local Government Law number 23/2014, whereby the forest agency at the district level has been terminated. The consequence is that FEA has the dominant authority to manage the forestry sector in Jambi. Then all forestry businesses and their customers have been concentrated to the province level. The forest agency at the district level has been changed to FMU.

Table1. Data stakeholder position

Stakeholders	Influence (score)	Interest (score)
Forest & Environment Agency of Jambi Province	3.4	3.4
Forest Management Unit (FMU) of West Tanjung Jabung	3.2	4.6
Politician	3.5	3.4
Middle trader of old fruits <i>Pinanga</i> sp.	4.2	4.0
The industry of juvenile fruits <i>Pinanga</i> sp.	3.6	3.8
NGO-WARSI	4.0	3.8
Mega Buana Farmer Group	3.2	4.2
Village Government of Sungai Beram Itam Raya	3.2	4.0
Forest Farmer Group (FFG)	2.8	3.0

2. FMU of West Tanjung Jabung

This FMU emphasized conservation and protection functions of the peatland area based on the Minister of Environment and Forestry decree number SK.77/Menhut-II/2010/9 November 2016 and Governor's rule of Jambi Province number 1176/2017/13/10/2017. Those policies are the legal standing for FMU operations in West Tanjung Jabung Regency and have covered 15,050 hectare peatland forest area and confined to Right Beram Itam and Left Beram Itam Rivers. One-third of this peatland forest area was occupied by the local community and used for palm tree plantations. The remaining two-third is the secondary forest in this FMU. The head of FMU, mentioned that the circumstance caused by the mismanagement of the concession.

3. Politician

Interview of the politician has been done in Kuala Tungkal City. He was an ex-parliament member and had a good relationship with Sungai Beram Hitam Raya Village. As a politician, he also supports the local community to use the peatland forest area in FMU. By that strategy, the politician hopes the community will earn economic benefits. However, the politician believes that this FMU has been an open access area, and the community can use that forest land for other function. The consequence is that local communities occupy that FMU and encourage the local institution, namely *Pancong Alas*, which contributes to trading the occurrence of peat forest land.

4. Middle Trader of Old Fruits of *Pinanga* sp.

Middle Trader (MT) of old fruits *Pinanga* sp. is a critical stakeholder in the field. This stakeholder usually becomes an intermediate trader of pinanga's fruits between farmers and industry. They create channelling because farmers need them to sell their fruits of *Pinanga* sp., and from this, farmers earn direct payment for their products. In the field, there are many MTs, and at least three or four MT in every village

collects fruits to the industry. Family relation sometimes determines the price; for example, a wife works in the industry, and a husband works as MT. The wife gives price information to the husband, including price change in the fabric, and by this provided data, a husband can influence farmers to set the pricing of pinanga fruits. Farmers planted *Pinanga* sp. because their fruits can be used as natural dye material.

5. The Industry of Juvenile Fruits of *Pinanga* sp.

This industry is also an important stakeholder which operates in the peatland field. Its existence provides many opportunities for farmers to develop the products of *Pinanga* sp. However, in some cases, farmers did not like to harvest the juvenile fruits of *Pinanga* sp., because they are worried that the fruits will be broken. The industry informed the industry that West Tanjung Jabung is a suitable area for planting *Pinanga* sp. For the industry itself, those fruits meet the raw material requirements for candy. This industry provides half-finished candy materials and delivers that to China after being packed.

6. NGO-WARSI

This stakeholder is very active because its interest in the community's livelihood, socio-economic and opportunity for the local people involved in forestry management is very high. WARSI, the abbreviation of *Warung Konservasi*, has been actively engaged in social forestry programs because WARSI has developed a bridge between government and community in peatland forest to manage the forest sustainably. Further, agricultural products planted in peatland and people in that area also need farmland to meet their livelihood requirements. Then, they used burning practice to open the area to become farmland. The impact is that it has raised the hazard caused by burning peatland and haze, which has also impacted other provinces such as Riau, Jambi and South Sumatera. The central government was supported by the local government and has

established the Peat Land Restoration Board (PLRB). The special task of this institution was to resolve and restore peatland burning area of 2.4 million hectares which have been burned in Riau, Jambi, South Sumatera, West Kalimantan, Central Kalimantan, South Kalimantan, and Papua. WARSI has responded to this situation and proposed social forestry programs as the best choice of strategy to restore peatland forest.

7. Mega Buana Farmers Group

This group has been an exceptional stakeholder because most people who joined this group obtained rights to the peatland area by the pancong alas system. Originally, before becoming a farmer, they worked in fisheries because most of them had originated from the Bugis ethnic group, which was familiar with fishery tradition. This group used the pancong alas rights to open peatland forest for palm tree plantations. There was also conflict between this group and the village government. The Mega Buana leader represents the members' group told to the village leader that their palm plantation area could not be planted because flood always covers their plantation land. However, at the same time, this leader still rejected the village government's program to normalize the river, which causes the flood in that area. There were different conditions between palm trees planted in the dry area and planted by this group. Because of the group leader's position, who has always rejected the village government's program, this group has been excluded from other government programs.

8. Village Government of Sungai Beram Itam Raya

The Village Government (VG) of Sungai Beram Itam Raya is a significant stakeholder because she/he representing the highest decision-maker at the village level. VG has a good relation to the political party actors who support VG in the head of the village election. It is very strategic for the political party actors

because they can influence the decision maker's management at the village level to achieve their aims. On the other hand, the political party actors can also develop their access to natural resources in that village. In this case, the political party actors are the counterpart to the village head to make policy on peatland utilization in Beram Itam Raya Village. The village head gives them information regarding natural resources which can be extracted, and political actors give supporting financial allocation to do the programs based on that information.

9. Forest Farmer Group (FFG)

Most members of this group are palm oil farmers. However, there is so much complaining that palm oil plants cannot grow optimally in peatland condition. Many plants can grow until ten years, and after that, palm oil plants' productivity decreases, resulting in decreasing income for farmers. This condition resulted in that part of the farmers tried to find a solution, and by cooperating with FMU, they have designed the concept of mixed crops between palm oil and forest trees. Farmers have a high perception that this combination will raise their income in the future because forest trees have a reasonably good price in that village. FMU also supports that activity and build cooperation and allow farmers to plant peatland with mixed crops under FMU jurisdiction. Further, farmers also can get coaching programs on mixed crop plantation by FMU and then get priority information on other government programs such as seed crops, funding etc.

B. Mapping Stakeholders

Mapping of stakeholders is an important step to finding out each actor's position based on a categorization analytical approach (Reed et al., 2009). It gives us information regarding stakeholders who were disposed to build cooperation with each other and have a common perception regarding utilization program in peatland forest. This method also assists analyst to formulate programs on peatland regarding

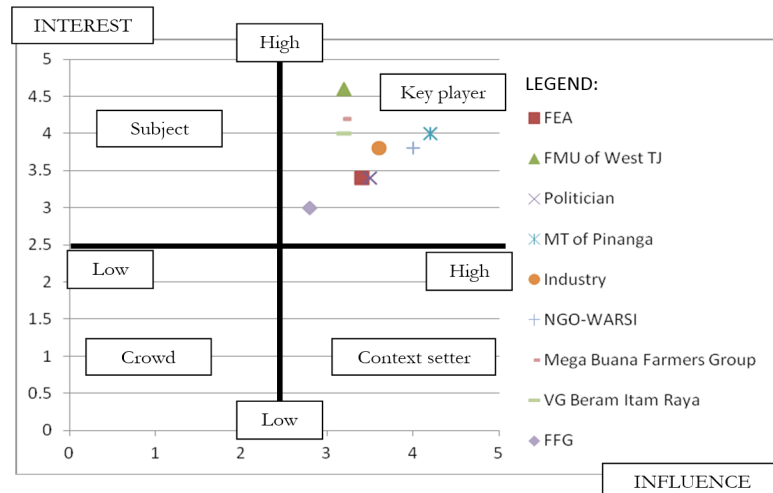


Figure 8. Mapping of stakeholders by categorization analytical method

stakeholder's interest and evaluate their level of participation in the field. Further information is shown in Figure 8.

Based on Figure 8, we know that mapping stakeholders in three other quadrant is getting empty. It's not mean that in three quadrant there is no stekaholder who contested their interest and power. In this research, authors getting difficulties to raise up the data from three quadrants because we have limitation budget, time and remote area to collect data from all stakeholder. This research is not finished and authors brave to publish the paper because there is important findings so that readers can get new perspective to the reseach. We hope other researchers disposed to fill empty quadrants.

C. Stakeholder's Participation

Interview of stakeholders regarding their participation level distributed between tokenism and citizen power. The value of tokenism is 44% and citizen power 56%. It means that citizen power was more dominant participation in which partnership and delegation of power became the key activities (Azhari, 2011; Oktavia & Saharuddin, 2013). Further information on this interview result is shown in Table 2.

D. Stakeholders Mapping

Figure 8 shows stakeholders distribution in key player positions. The analytical

categorization used in this method is not connecting completely with another stakeholder in the matrix position. It means that stakeholders positioned in key players' positions have high interest and influence on peatland forest utilization. It also gives information that stakeholders involved in that field correlate with each other with dynamic features. For example, FAE and FMU are local government agencies; however, at the same time, both institutions have a different viewpoint. FEA uses a more structural approach to solve the problems related to peatland forest, and it needs a rules framework before working and consequently tends to respond slowly.

FMU is more functional because it operates and is closer to field stakeholders, and is faster to respond. However, this stakeholder does not have enough budget to work with appropriate planning. Under the new law on local government number 23/2015, FMU management is below FEA. It caused by is financial budget for FMU activities depends on the budget available to FEA management. Debates on both institutions also occurred related to effective approaches to resolving problems such as a socio-economic and burning fire in agriculture activities. FMU is often proposing direct programs supporting farmer group needs in the field; however, FEA

Table 2. Participation degree of stakeholders

Stakeholders	Major Activities	Participation Model	Participation Degree
Forest & Environment Agency of Jambi Province	<ul style="list-style-type: none"> - Rules of law are the rationale for these stakeholders to join in peatland restoration - Partial participation 	Consultation	Tokenism
Forest Management Unit (FMU) of West Tanjung Jabung	<ul style="list-style-type: none"> - Participation of all parties is an important reason to restore peatland even they are faced with low financial access - Inviting competent parties to be involved in peatland restoration - Agroforestry programs are bridging farmers to increase their socio-economic capacity 	Partnership	Citizen power
Politician	<ul style="list-style-type: none"> - Taking side in the public interest and earn socio-economic capacity - Supporting peatland restoration based on appropriate policy 	Delegated power	Citizen power
Middle trader of old fruits of <i>Pinanga</i> sp.	<ul style="list-style-type: none"> - Trading old fruits of <i>pinanga</i> with industry for natural dye product - Price information on old pinanga raw material was obtained from family members 	Informing	Tokenism
The industry of juvenile fruits of <i>Pinanga</i> sp.	<ul style="list-style-type: none"> - Socialization on this business to local government such as raw material needs, sources and so on - The industry using these natural materials for candy 	Informing	Tokenism
NGO-WARSI	<ul style="list-style-type: none"> - Supporting farmers interest to have access to peatland forest and managing social forestry programs 	Partnership	Citizen power
Mega Buana Farmer Group	<ul style="list-style-type: none"> - Utilization of peatland forest was influenced by <i>pancong alas</i> institution - Clan members encouraged them to occupy peatland forest 	Informing	Tokenism
Village Government of Sungai Beram Itam Raya	<ul style="list-style-type: none"> - Takes side in village community's interest to utilize peatland natural resources - Develops innovation to increase village economics 	Delegated power	Citizen Power
Forest Farmer Group (FFG)	<ul style="list-style-type: none"> - Develops palm trees in peatland forest, however ready to build cooperation to other parties with the condition it can increase their economic capability - Supporting the agroforestry system to exchange palm trees 	Partnership	Citizen Power
Scoring for Tokenism and Citizen Power is 4 (44%) and 5 (56%)			

is more often focusing on the law aspects than direct programs. This condition creates a gap and needs to be resolved to restore peatland forest in West Tanjung Jabung Regency.

This figure also shows that Mega Buana Farmer Group has the opposite position to Village Government, FMU, and FFG. It occurred because Mega Buana Farmer Group believes that the peatland area they managed was their property rights under the *pancong alas* institution. They always defend that area because they have spent money to buy it through the previous village head in 1998. *Pancong alas* is an illegal institution because historically, forest land encroached by farmer group has been originally the concession of PT Betara Agung Timber based on Director General of Forestry number SK 19/kpts-1/1977 dated on 1 January 1977. The total forest land which was managed was 260.350 Ha. After the concession permit expired, this forest land has been taken by PT Wira Karya Sakti (PT WKS) based on the Minister of Forestry decree number SK 381/Menhut-II/1997 dated 4 April 1997 to avoid open access to that area. On 15th June 1999, the Government of Jambi Province determined that the forest land will become protection peatland forest based on the decree of Jambi Governor number 108/1997.

Further, this decision has been strengthened by the Minister of Forestry and Plantation decree number 421/kpts-II/1999. From 2007-2009 conflict occurred between the community and the Forest Agency of West Tanjung Jabung Regency. The community did not agree that the protection of peatland forest, which they managed, became state property land. To overcome it, the parliament of West Tanjung Jabung set up mediation between the community and Forest Agency. Both parties agreed that the peatland forest is state property land; however, the community was given access to manage that land in two planting periods. Although this conflict was over, the problems related to peatland forest encroached by farmer groups were still unfinished because the *pancong alas* system has not truly ended. Certain persons

who have power still do that system commonly in scatters by leasing to other farmers. It has become a sensitive issue, and local government's programs are always rejected in that location.

This conflict shows that open access situation has occurred in which farmer groups could encroach the peatland forest. There were ten years of a vacuum of management in that peatland forest, and this situation encouraged farmers to occupy the peatland (Okereke, 2019; Handoyo, 2015). Hackett (2001) has described open access situation as *res nullius* where there is no owner, and all people have the liberty to use that natural resource. Then, no one has the right to exclude anyone else in that peatland forest which they managed. It is the rationale that people who are nearest to the peatland forest have the opportunity to use the natural resources. Regarding that, Ribot and Peluso (2003) argued that access is not expressing the property rights such as goods and bundling of power that people can use to occupy natural resources such as market, capital, technology, labour, authority, and social identity and so on.

The community in Sungai Beram Itam Raya has known that the chief of Mega Buana Farmer Group is an opponent person. In this situation, analytical categorization should be the entrance to the chief in the subject position; however, in this research, his position changed to become a key player. It means that the opponent person on the cooperation side depends on his interest and how the proponent can develop an approach. We facilitated the opponent to be involved in the programs, such as agriculture mixed with forest planting and pasture system and used *Mangifera indica*, *Nephelium lappaceum*, *Pinanga* sp., goats, and *Shorea balangeran*, and so on which were planted in the peatland area. Their purpose is to involve Mega Buana Farmer Group to become a partner in this program because they can influence other farmers disturbing peatland forest, which FMU managed.

Another stakeholder who was analyzed is the private sector. This stakeholder was represented by the industry and middle traders interested in

juvenile and old pinanga fruits. Farmers have planted pinanga and *Coffea liberica*, which were used for saving function. It was essential for them because palm trees cannot give income continuously. Sometimes, palm trees are decreasing in productivity, and it will influence farmer's ability to support family needs such as paying tuition fee for children, hospital costs and so on. Under that condition, pinanga and *Coffea liberica* give additional income for farmers.

The existence of private sectors in that field is essential because they have acted as buyers of agriculture products. Furthermore, private sectors are also playing a balancing act between the agricultural market and supply chain of the products which can take place. Consequently, many middle traders of pinanga fruits because the industry cannot stand alone to buy the fruits directly from farmers. It would make it more costly and requires much time if the industry is attempted to absorb those products alone without cooperation with middle traders.

On the other hand, middle traders have benefits because they have established a network with farmers and developed co-partnership to sell pinanga fruits. It has created a value chain for trading pinanga fruits in the peatland area. Some cases harm industry, middle traders, and farmers; they also create a lower benefit for farmers than if they sell those products directly to the industry. Middle traders are accused of being rent-seekers for those products without counting that middle traders maintain the market's mechanism, the economic system in that area. When middle traders are removed from that system, the farmers will experience disadvantages because they lose access to cash. It was a difficult position for the farmers' group because they were in the lowest position in the value chain market. This problem should be broken, and the government should facilitate farmer groups to access the pricing of their agriculture products. It proposes the government to create an open pricing system of agriculture products by social media or internet devices.

Figure 8 shows that FMU, Mega Buana farmer

group, middle traders, and Village Government has close relation with FMU, which is the highest. Together, those stakeholders are very important because they work and represent socio-economic and ecological activities in which the government is interested in restoring the peatland forest. Without socio and economic aspects, stakeholders such as farmers group and middle traders will risk developing their products, which means that peatland forest will be extracted and agricultural land will be extended. It is difficult for the government because they should engage other stakeholders to participate in peatland forest restoration. In our opinion, it is essential using analytical categorization for mapping the positions of stakeholders and the well-known essential stakeholders who will manage the peatland restoration programs.

E. Stakeholders Participation

The stakeholder's participation is an important variable because it shows how interaction is happening among stakeholders involved in the peatland forest restoration program and how they developed cooperation, relation, and decision-making processes. Table 2 describes the two-degree stakeholders' participation model in the field, i.e. tokenism and citizen power. Citizen power has a higher degree than tokenism, with 56% and 44% values for each model. Those values indicate that citizen power has more influence for the stakeholder to participate in peatland restoration. Based on our interviews, restoration programs such as mixed crop plantation, livestock, and local forest species are very interesting for stakeholders. It gives them a new perspective that palm plantation is not the only plantation to earn income in peatland. There are other alternative forms for mixed crops to develop income while being involved in peatland restoration programs. Figure 2 also describes how stakeholders already participate in those areas. The black points show the GPS coordinates, which have been taken to mark and build mixed crop demonstration plots. There

were three demonstration plots, and different groups owned each demonstration plot.

The stakeholder's participation was an increase when restoration programs were rolled out and developed in those areas. The establishment of demonstration plots has been a marker that participation moves forward. Several ideas offered to the stakeholders got a positive response because it allows increasing their income. For example, in those plots, we have designed mixed plants among fruits, plantation, and forest species. Fruit species are used for seasons, i.e. *Nepbelium lappaceum*, *Durio zibethinus*, and *Mangifera indica*. Plantation species usually used were *Coffea liberica* and *Pinanga* sp., and the others for forest species used *Dyera costulata*, *Shorea balangeran*, and *Illex cymosa*. This condition is also similar to that people are getting incentives, they tend to be involved in the rehabilitation programs (Murniati & Suharti S, 2018; Watts, Tacconi, Hapsari, Irawan, Sloan, & Widiastono, 2019).

The positive response from stakeholders to the programs can be viewed as an opportunity to participate in peatland restoration. However, Table 2 also describes that tokenism still gives 44% of which stakeholders have chosen. It means that specific stakeholders doubt that peat swamp restoration activities will be

successful. It is marked by their perception of peat swamps products only as products that can be harvested regardless of their sustainability. This is an inhibiting factor for peat swamp restoration activities, so there is a need for a unique strategy to develop peatland restoration in the field. When we started this research, the local institution of peatland restoration was not firmly established, so the consequence was that there was no financing operation for that institution in 2017.

Figure 7 describes how stakeholders can develop a strategy concept regarding natural resources restoration. Birner and Wittmer (2000) proposed that social capital owned by stakeholders can be transformed into political capital. Such changes can determine the strategic approach that stakeholders can take. In this regard, Nurrochmat et al. (2017); Nurrochmat, Darusman, and Ekayani (2016); Santika et al. (2017); Nurrochmat (2017) and Birner and Wittmer (2000) used an approach that of links between state capacity and social capital to analyze suitable strategies that stakeholders can use in activities related to natural resources. Figure 8 and Table 2 show stakeholder's participation linked to viable strategy related to social capital and state capacity. Then, it could be concluded that peatland restoration strategy

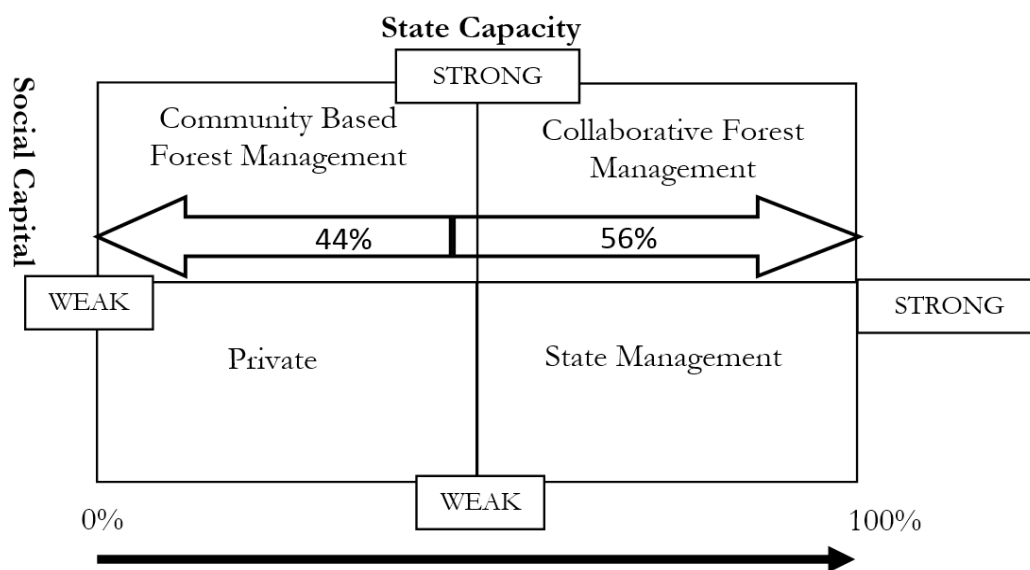


Figure 9. Strategy process from CBFM to CFM related stakeholder

at the research site is in the process leading from Community Based Forest Management (CBFM) to Collaborative Forest Management (CFM). The weakness of state capacity in peatland forest is very easily controlled or accessed by stakeholders where it also involves payments to actors who are not representing the interests of the state. This transaction cost must be decreased because it disturbs the participation process of the stakeholders in the field. The strategy process from CBFM to CFM related stakeholder participation is shown in Figure 9.

Figure 9 shows two strategy models that can be developed regarding stakeholders participation, i.e. CBFM and CFM. These two strategies take place in the field, especially CBFM, because stakeholders' acceptance of those is adequate. To encourage participation in those, strengthening government personnel is very important in the peatland restoration program in the field. Because of this training personnel, opening market and technology and capital access has been an obligation for stakeholders involved and intended to develop peatland forest restoration activities. This also argues that similar collaborative action needs attention from all stakeholders (Axelsson, Angelstam, Elbakidze, & Stryamets, 2011; Desmiwati & Christian, 2019).

To increase state capacity after the peatland burning in 2014-2016 government strengthened their powers and supported the local government. Policies related to peat land restoration has been released in 2016 and 2017 when the restoration program was launched. BRG has allocated fund in that year of approximately Rp 152 billion to restore peatland by community involvement on the site in seven provinces in Indonesia. The programs have also been announced at COP-23 in Bonn and received positive responses from the participants. Further, the document of BRG strategic planning 2016-2020 said that BRG needs Rp 10.5 Trillion budget to restore peatland in seven provinces for which the sources of the budget would come from national and/or local

government funds, donors, investors, private sectors and NGOs (Badan Restorasi Gambut, 2016). This condition can describe why stakeholder's participation tends to increase in the citizen power position (Table 2), and stakeholders have been in the position of being crucial players (Figure 8). Political changes in government and governance have encouraged participation on the site.

One of the weaknesses of this position, strategy and participation, is the government's position. Government policy indeed influenced stakeholders to participate in peatland restoration in the field. However, this condition cannot survive if the government fails to manage its capital and establish an institution regarding peatland restoration at the site. This should be clear because people tend to use fire to utilize the peatland for agriculture. Yulianto, Soekmadi, Hikmat, and Kusmana (2019) described that the existence of local institutions guarantees the local people to involve resources because there is clarity of the boundaries and legitimacy for them.

On the other hand, participation also encourages people to involve restoration if they have the opportunity by the government policy, i.e. social forestry programs (Tata & Tampubolon, 2016). People can build village forest, and in the period 2012 to 2016, this village forest area tends to expand in Sumatra and Kalimantan (Santika et al., 2017). By this argument, the participants will be completed if government policy meets people's desire who utilize the resources in the field (Muttaqin, Alviya, Lugina, Almuhayat, Hamdani & Indartik, 2019).

IV. CONCLUSION

This research concludes that stakeholders mapping could help decision-makers define a suitable strategy using the stakeholder participation approach. Identifying their interests and influence and participation can develop stakeholders' strategies to maintain the peatland forest restoration area. In this research, we provide two strategy models

that are collaborative forest management and community-based forest management. Collaborative forest management strategy is used if stakeholders have high participation and consider their opportunity to access the peatland forest area and how the government supports the stakeholders to do the peatland restoration. Another strategy, community-based forest management, is also considering access; however, the government still has scepticism to support stakeholders because there is a need for clarification regarding budgeting, institutions, and so on to restore the peatland forest.

ACKNOWLEDGEMENT

This research was conducted based on a corporation agreement between Forest Research and Development Center and Peat Land Restoration Agency (BRG), located in West Tanjung Jabung, Jambi Province. Authors are grateful to the Director-General of Peat Land Restoration Agency for their funding support and the Director-General of Research and Innovation Agency to support the researchers to be done.

Authors also say special gratitude to Professor Mark S. Reed from Scotland's Rural College for his professional review to this paper. We hope this result can be utilized by the policy makers to give the best decision on the field. Each researcher contributes to this manuscript such as researcher number one is a team member and has contributed to analyzing actor activities on research field. The researcher number two is a team leader and has contributed to steer the overall research and focused on forest culture activities. And the researcher number three has contributed to reaching socio-economic data on the field.

REFERENCES

- Axelsson R., Angelstam P., Elbakidze M., & Stryamets N.E.J.K. (2011). Sustainable development and sustainability: Landscape approach as a practical interpretation of principles and implementation concepts. *Journal of Landscape Ecology*, 4, 5–30.
- Azhari K.I. (2011). *Tingkat partisipasi masyarakat pada tahap perencanaan dalam program neighbourhood development: Studi kasus Desa Jendi Kecamatan Selogiri Kabupaten Wonogiri*. Fakultas Teknik Universitas Sebelas Maret, Surakarta.
- Badan Restorasi Gambut. (2016). Rencana strategis Badan Restorasi Gambut 2016–2020. Badan Restorasi Gambut Republik Indonesia.
- Birner R., & Wittmer H. (2000). Converting social capital into political capital: How do local communities gain political influence? A theoretical approach and empirical evidence from Thailand and Columbia. *Paper submitted to the 8th Biennial Conference of the International Association for Goettingen*.
- Brown J.D. (2011). Likert items and scales of measurement? SHIKEN: JALT testing & evaluation. *SIG Newsletter*, 15(1), 10–14.
- Budiyaji, W. (2013). Skala pengukuran dan jumlah respon skala likert. *Jurnal Ilmu Pertanian dan Perikanan*, 2(2), 127–133. Retrieved from <http://umbidharma.org/jipp> on the 1st December 2020.
- Collins K., & Ison, R. (2006). Dare we jump off Arnstein's ladder? Social learning as a new policy paradigm. In *Proceedings of PATH (Participatory Approaches in Science and Technology) Conference*. Edinburgh.
- Desmiwati, & Christian F.Y. (2019). Levelling up the collaborative forest management in Indonesia: A review. IOP Publishing.
- Edwards S.A., & Heiduk F. (2015). Hazy days: Forest fires and politics of environmental security in Indonesia. *Journal of Current Southeast Asian Affairs*, 34, 65–94.
- Fauziyah, E., & Sanudin, S. (2017). Efektifitas kelembagaan dan kebijakan hutan rakyat di Kabupaten Banjarnegara dan Banyumas. *Jurnal Wasian*, 4(2), 79–88.
- Fibriani D. (2012). *Evaluasi proses implementasi kebijakan hutan rakyat di Kabupaten Sarolangun, Jambi*. Sekolah Pasca Sarjana, IPB, Bogor.
- Gilens M., & Page, B.I. (2014). Testing theories of American politics: Elites, interest groups, and average citizens. *American Political Science Association*, 12, 564–581. doi: //10.1017/S1537592714001595.

- Haapalehto T., Vasander H., Jauhiainen S., Tahvanainen T., & Kotiaho, J.S. (2010). The effect of peatland restoration on water table depth, elemental concentration and vegetation: 10 Years of Change. *Restoration Ecology*, 19(5), 587–598.
- Hackett S.C. (2001). *Environmental and natural resources economics: Theory, policy and the sustainable society* (2nd Ed.). New York: M.E.Sharpe.
- Handoyo. (2015). Resolusi konflik TN Tesso Nilo: Tinjauan relasi pemangku kepentingan dengan power stakeholder analysis. *Jurnal Analisis Kebijakan Kehutanan*, 12(2), 89–103. doi://10.20886/jakk.2015.12..89-104.
- Harding L., & Macdonald C. (2001). Developing new approaches for stakeholder engagement in the minerals sector, mining, minerals and sustainable development project, IIEED. London.
- Hick A.J., & Misra. (1993). Political resources and the growth of welfare in affluent capitalist democracies, 1960-1982. *American Journal of Sociology*, 99(3), 668–710.
- Lunenburg, F.C. (2012). Power and leadership: An influence process. *International Journal of Management, Business and Administration*, 15, 1–8.
- Mathur V.N., Price A.D.F., & Austin, S.A. (2008). Conceptualizing stakeholder engagement in the context of sustainability and its assessment. *Construction Management and Economics*, 26(6), 601–609.
- Miettinen J., & Soo, C.L. (2010). Status of peatland degradation and development in Sumatera and Kalimantan. *AMBIO A Journal of the Human Environment*, 39, 394–401. doi://10.1007/s13280-010-0051-2.
- Murniati, & Suharti S. (2018). Toward zero burning peatland preparation: Incentives schemes and stakeholders roles. *Biodiversitas*, 19, 1396–1405.
- Muttaqin M.Z., Alviya I., Lugina, M., Almuhayat F., Hamdani U., & Indartik. (2019). Developing community-based forest ecosystem service management to reduce emission from deforestation and forest degradation. *Forest Policy and Economics*, 108, 1–9.
- Nugroho I.A. (2016). *Pemetaan para pihak dalam pemanfaatan tumbuhan obat sebagai bahan baku jamu: Studi kasus di Pulau Jawa*. Sekolah Pasca Sarjana IPB. Bogor.
- Nurrochmat D.R. (2017). *Strategi kebijakan pembangunan kebutuhan dan lingkungan berkelanjutan* (Orasi). Bogor: IPB.
- Nurrochmat D.R., Nugroho I.A., Hardjanto, Purwadianto A., Maryudi A., & Erbaugh, J.T. (2017). Shifting contestation into cooperation: Strategy to incorporate different interest of actors in medicinal plants in Meru Betiri National Park, Indonesia. *Forest Policy and Economics*, 83, 162–68.
- Nurrochmat D.R., Darusman D.R., & Ekayani M. (2016). *Kebijakan pembangunan kebutuhan dan lingkungan: Teori dan implementasi*. Bogor.: IPB Press.
- Nurrochmat, D.R., Nugroho, I.A., Hardjanto, Purwadianto, A., Maryudi, A., & Erbaugh, J.T. (2017). Shifting contestation into cooperation: Strategy to incorporate different interest of actors in medicinal plants in Meru Betiri National Park, Indonesia. *Forest Policy and Economics*, 83, 162-168. doi://10.1016/j.forpol.2017.08.005.
- Okereke, C.D.I. (2019). Palm oil, power and participation: The political ecology of social impact assessment. *Environment and Planning E: Nature and Space*, 1–21. Retrieved from <http://sro.sussex.ac.uk/id/eprint/86366/> on the 1st December 2020.
- Oktavia S., & Saharuddin. (2013). The relationship between role of the stakeholder and community participation in agropolitan program in Karacak Village, Leuwiliang Subdistrict, Bogor District. *Solidity: Jurnal Sosiologi Pedesaan*, 1(3), 231–246.
- Ramdhani M.R., Ruhimat, A., Wiyono, & Barnes, A. (2020). Imaging tropical peatland and auifer potential in South Sumatera using electrical resistivity tomography. *Indonesian Journal of Forestry Research*, 7(1), 1–14.
- Reed M.S., Grave A., Dandy N., Posthumus H., Huback K., Morris J., ... Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resources management. *Journal of Environmental Management*, 90, 1933–1949.
- Reed M.S., Vella S., Challies E., de Vente J., Frewer L., Hohenwallner-Ries D., ... van Delden, H. (2017). A theory of participation: What makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, 26(S1), 1-18. doi://10.1111/rec.12541.

- Rehman S.A.U., Sabiham S., Sudadi U., & Anwar, S. (2015). Impacts of oil palm plantations on climate change: A review of peat swamp forests' conversion in Indonesia. *International Journal of Plant and Soil Science*, 4, 1–7.
- Ribot J.S., & Peluso, N. L. (2003). Theory of access. *The Rural Sociology*, 68(2), 153–181.
- Santika T., Meijaard E., Budiharta S., Law E.A., Kusworo A., Hutabarat J.A., ... Stigner, M. (2017). Community forest management in Indonesia: Avoided deforestation in the context of anthropogenic and climate complexities. *Global Environment Change*, 46, 60–71.
- Saputra, E. (2019). Beyond fires and deforestation: Tackling land subsidence in peat land areas, A case study from Riau, Indonesia. *Land*, 8, 1–24.
- Siisiainen M. (2000). *Two concepts of social capital: Bourdieu vs. Putnam*. Finland.
- Sylviani, Suka, A.P., Surati, & Kurniasari, D. P. (2020). Social capital in managing community plantation forest: A case study at KPH Boalemo, Gorontalo Province. *Indonesian Journal of Forestry Research*, 7(1), 71–82. doi://10.20886/ijfr.2020.7.1.71-82.
- Tata H.L., & Susmianto, A. (2016). *Prospek paludikultur ekosistem gambut Indonesia*. Bogor: Forda Press.
- Tata, H.L., & Tampubolon, A. (2016). Participatory approach in the peat swamp forest management of two different forest statuses in Central Kalimantan, Indonesia. In *15th International Peat Congress 2016: Peatlands in Harmony Agriculture, Industry and Nature* (pp. 582 – 586). Kuching-Serawak, Malaysia.
- Tata, H. L. (2019). Mix farming systems on peat land in Jambi and Central Kalimantan Provinces, Indonesia: Should they be described as paludiculture? *Mires and Peat*, 25, 1–17. doi://10.19189/MaP.2018.KHR.360.
- Uda S. K., Hein L., & Sumarga, E. (2017). Toward sustainable management of Indonesia tropical peat lands. *Wetlands Ecology Management*, 25, 683–701.
- Watts J. D., Tacconi L., Hapsari N., Irawan S., Sloan S, & Widiastono, T. (2019). Incentivizing compliance: Evaluating the effectiveness of targeted village incentives for reducing burning in Indonesia. *Forest Policy and Economics*, 108, 1–15.
- Winkel, G. (2012). Foucaults in the forests-A review of the use of "Foucauldian" concepts in the forest analysis. *Forest Policy and Economics*, 16, 81–92.
- World Bank. (2016). The world bank annual report 2016. Washington DC. doi: //10.1596/978-1-4648-852-4.
- Yulianto, S. R., Hikmat A., & Kusmana, C. (2019). Crafting local institution using social-ecological system framework for sustainable rattan governance in Lore Lindu National Park. *Jurnal Manajemen Hutan Tropika*, 25, 135–145.

This page is left blank

EARLY GROWTH OF JABON (*Anthocephalus cadamba* Miq.) IN A DRAINED PEATLAND OF PELALAWAN, RIAU

Ahmad Junaedi^{1*}, Nina Mindawati², and Yanto Rochmayanto³

¹Research Institute for Fiber Technology of Forest Plant Species;

Research, Development and Innovation Agency

Jl. Raya Bangkinang - Kuok, Kec. Kuok, Kab. Kampar, Prov. Riau, Indonesia

²Forest Research and Development Center, Research, Development and Innovation Agency

Jl. Gunung Batu No.5, Bogor, West Java 16610, Indonesia

³Center for Research and Development on Social, Economy, Policy and Climate Change,

Research, Development and Innovation Agency

Jl. Gunung Batu No.5, Bogor, West Java 16610, Indonesia

Received: 21 September 2020, Revised: 11 April 2021, Accepted: 12 April 2021

EARLY GROWTH OF JABON (*Anthocephalus cadamba* Miq.) IN A DRAINED PEATLAND OF PELALAWAN, RIAU. The desirability to explore other tree species that can be used to substitute *Acacia crassiparpa* in forest plantation has increased. One of the early insights that must be known is the growth performances of tree species candidates, especially in planting conditions (site and silviculture) similar to *A. crassiparpa* plantation. This study evaluated the growth performance of jabon (*A. cadamba* Miq.) and its relationship with soil properties in a drained peatland. The research was conducted by establishing experimental plots of jabon in a drained peatland (DP) using a randomised complete block design with three spacing (2 m x 3 m, 2.5 m x 3 m, 3 m x 3 m) as treatment and three blocks as replications. The study observed survival, growth and soil chemical properties. At 24 months after planting (MaP), since the toxicity of soil micronutrients was excessive as one of the main factors; the mortality rate of jabon was high (62%), while its growth was poor (height = 259 cm and DBH = 3.74 cm) in drained peatland. However, the study observed that 7% of jabon had good growth, with a range of height growth at 24 MaP of 401–660 cm. These results indicated that though overall jabon did not show good growth in DP, however, it was found that 7% of jabon had promising growth; therefore, it was suggested that through tree improvement program and certain treatments to overcome micronutrient toxicity and weed suppression, the possibility of jabon was able to be developed in a DP for forest plantation is still.

Keywords: Growth, *Anthocephalus cadamba*, *Acacia crassiparpa*, micronutrients toxicity, tree improvement

PERTUMBUHAN AWAL JABON (*Anthocephalus cadamba* Miq.) PADA LAHAN GAMBUT YANG DIDRAINASE DI PELALAWAN, RIAU. Dorongan untuk mencari jenis pohon sebagai pengganti *A. crassiparpa* di hutan tanaman semakin meningkat. Salah satu informasi awal yang perlu diketahui adalah mengenai pertumbuhan calon pohon yang akan dipilih pada kondisi pertanaman yang sama dengan *A. crassiparpa*. Penelitian ini mengevaluasi pertumbuhan jabon (*A. cadamba*) dan hubungannya dengan sifat tanah di lahan gambut yang didrainase. Penelitian dilakukan dengan membangun plot eksperimen penanaman jabon di lahan gambut yang didrainase, menggunakan rancangan acak kelompok dengan tiga jarak tanam (2 x 2 m; 2,5 m x 3 m; 3 m x 3 m) sebagai perlakuan dan diulang sebanyak tiga blok ulangan. Parameter yang diamati meliputi kemampuan hidup, pertumbuhan dan sifat kimia tanah. Sampai umur 24 bulan setelah tanam (BST), jabon menunjukkan tingkat kematian yang tinggi (62%) dan rerata pertumbuhan yang lambat (tinggi 259 cm dan diameter 3,74 cm) di lahan gambut yang didrainase dikarenakan salah satunya oleh keracunan hara mikro berlebih. Meskipun demikian, sebanyak 7% jabon mempunyai pertumbuhan tinggi yang baik pada umur 24 BST, yakni berkisar 401–660 m. Hasil tersebut menunjukkan bahwa secara keseluruhan jabon tidak menunjukkan pertumbuhan yang baik di lahan gambut yang didrainase. Namun, adanya sebagian jabon (7%) yang menunjukkan performa yang menjanjikan; maka melalui program pemuliaan pohon dan perlakuan silvikultur untuk mengatasi permasalahan keracunan hara mikro berlebih dan tekanan gulma, nampaknya jabon masih berpeluang untuk dikembangkan di lahan gambut yang didrainase. Diharapkan jenis ini dapat dikembangkan melalui program pemuliaan pohon dan perlakuan silvikultur untuk mengatasi permasalahan keracunan hara mikro berlebih dan tekanan gulma.

Kata kunci: Pertumbuhan, *Anthocephalus cadamba*, *Acacia crassiparpa*, keracunan hara mikro, pemuliaan pohon

*Corresponding author: ajunaedi81@yahoo.co.id

I. INTRODUCTION

Indonesia is one of ten countries with the largest area of forest plantations in the world (Indufor, 2014, as cited by Barua, 2015). In total, the coverage area of forest plantations in Indonesia till 2019 reached around 5.1 million ha, and one of the most vital of that is pulpwood plantation/HTI-pulp (Ministry of Environment and Forestry, 2021). However, the productivity of HTI-pulp has decreased due to the low density of standing stock at harvest time. The survival rate of stand-in HTI-pulp at five years could reach less than 25% (Junaedi, 2018b).

The decreasing HTI-pulp productivity existed in all land types, including in the peatland of Riau Province, expressed by the low productivity of *Acacia crassicarpa* (krassikarpa). The productivity of this species in second rotations was less than 140 m³/ha (Suhartati, Aprianis, Pribadi, & Rahmayanto, 2013). Therefore, the decreasing HTI pulp productivity should be solved; due to Riau has a large area of HTI-pulp plantations (800 thousand ha), and more than 50% was in peatland (Ministry of Environment and Forestry, 2016). One way to prevent a continual decline in HTI-pulp productivity is to explore alternative species that can grow well on peatland.

Jabon (*Anthocephalus cadamba* Miq.) was selected in this study as the tree species candidate that would be further evaluated for its probability to be grown in the peatland of HTI-pulp. Jabon is a pioneer species that can grow well in acidic soil and has been categorised as fast-growing species (Bijalwan, Dobriyal, & Bhartiya, 2014b; Suhartati, Rahmayanti, & Nurrohman, 2012). Furthermore, in a term as raw material for pulp and paper, fiberwood of jabon had good quality (Aprianis, 2016; Biswas, Misbahuddin, Roy, Francis, & Bose, 2011).

In this study, the focus of the evaluation was on growth performances in the three planted spacing of the species in the conditions (site and silviculture) that were in general similar to krassikarpa plantation. A previous study of the

growth of jabon in acidic ultisol soil showed that the growth performance of jabon was influenced by soil properties (Junaedi, 2018a); thus, the current study also investigated the role of soil properties on jabon growth. Therefore, the objectives of this study to evaluate the growth performance of jabon in peatland in general term and to evaluate growth performance of jabon in peatland as the effect of variation in planted spacing, and to investigate the relationship between the growth of jabon and soil properties in peatland. Furthermore, due to the standard of site management of peatland for HTI-pulp, the area has been drained; hence the scope of evaluation was for jabon, which was grown in drained peatland.

II. MATERIAL AND METHOD

1. Site Description

The study was conducted in a peatland that has been under forest concession of PT. Riau Andalan Pulp and Paper (RAPP). The location is at Pelalawan Sector, Compartment C-047 (based on estate administration, 00°32.071' N and 102°05.469' E), Pelalawan District, Riau (Figure 1). The soil type of location is histosol with its dominant maturity of organic materials is fibric-hemic. Elevation of the location is at 8 m. Elevation of the location is at 8 m a.s.l. The climate type of the location is A, with an average annual temperature, relative humidity and rainfall of 27°C; 84%; 2,100 mm, respectively. The land was drained; the water table depth was kept more than 50 cm below the soil surface (Christianus, 2006). Previously, the land was used for the plantation forest of krassikarpa (second rotation).

2. Plot Establishment

The experimental plot was established based on the silviculture system commonly applied in RAPP for krassikarpa (Junaedi, 2018b). The targeted area was cleared using an excavator, and plots were established. There were three different spacing evaluated in this study, i.e. 2 x 2 m, 2.5 x 3 m and 3 x 3 m. The

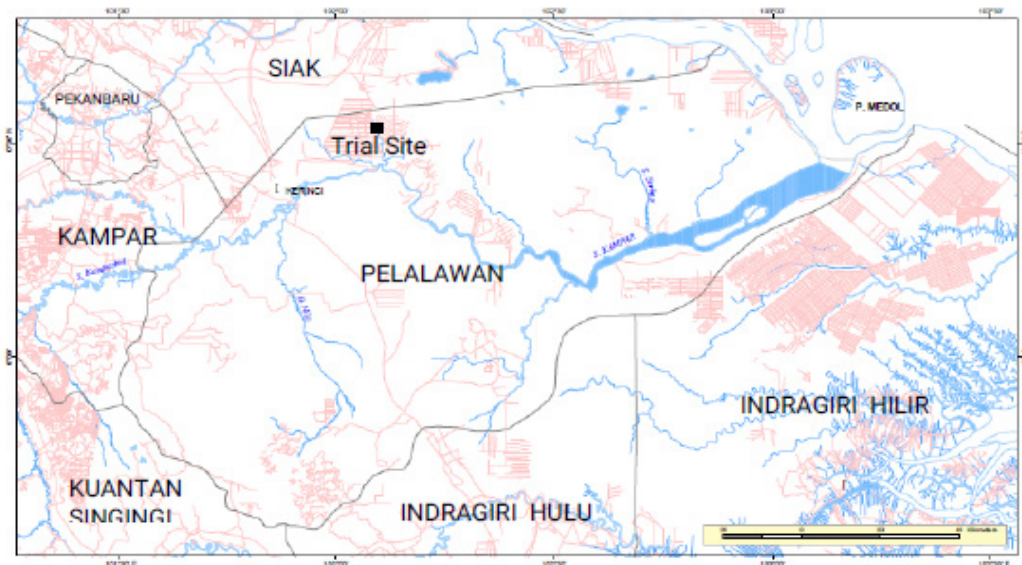


Figure 1. Location of the trial site in Pelalawan District, Riau

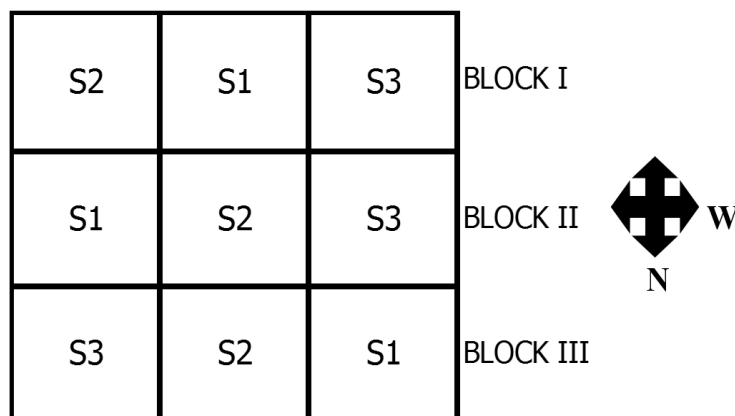


Figure 2. The design of experimental plots of jabon in a drained peatland of Pelalawan, Riau

Remarks: S1 = 2 m x 2 m, S2 = 2.5 m x 3 m and S3 = 3 m x 3 m

seedlings of jabon were planted according to a randomised complete block design (RCBD) with those spacing as single treatments and with three replications (Figure 2). The age of seedlings used for the plantation was about four months with the means of height and collar diameters of 18.5 cm and 4.38 mm, respectively. The seedling originated from generative propagation, and the seed origin was identified by standing seed sources in Dramaga, Bogor, West Java (unimproved seed).

Similar fertilisation was applied when planting for all spacing treatment. The types and dosages per seedling were 250 g rock phosphate

($\text{Ca}_3(\text{PO}_4)_2\text{CaF}$), 50 g KCl, 10 g Ertibor ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 5\text{H}_2\text{O}$) and 10 g zincop ($\text{ZnSO}_4 \cdot \text{H}_2\text{O}$ & $\text{CuSO}_4 \cdot 7\text{H}_2\text{O}$). A year after planting, jabon was intensively maintained through frequent weeding in three monthly intervals (manually with machete and hand removal) and one time pruning at six months after planting. Initially, based on the standard silviculture technique of *krassikarpa*, maintenance was not continued after one year. However, we found the weed was very dense in the plots when making the growth observation at the age of 18 months after planting (18 MaP); thus, a supplement weeding was done (once) after 18 MaP.

3. Field Measurements

The survival rates and growth of jabon were measured at the ages of 3, 6, 12, 18, and 24 months after planting (MaP). The initial planning of observation was to continue till harvest time (i.e. five years). In terms of growth evaluation for pulpwood plantation, the study decided to not continue observation at the age after 24 MaP (2 years). The survival rate was very low and tended to continue to decrease. In contrast, the growth rate tended to a standstill. The observation of all variables was undertaken based on spacing differences at 3, 6, and 12 MaP. However, this spacing difference was not followed during the observation at 18 MaP due to the high mortality of jabon in each spacing.

The number of live individuals was recorded during the time of observations. The survival rate then was quantified as the percentage/proportion of individuals remaining after 3, 6, 12, 18, and 24 months since seedling planting. The observation of growth parameters was conducted on total height (cm) and diameter breast height (DBH, cm). Total height was observed at all time of observations, while DBH was recorded at 18 MaP and 24 MaP. Height was measured by measuring stick, while DBH by the calliper.

The soil properties were identified twice to examine the relationship between growth and soil properties. The first, soil sample was collected from five points (four points at each corners of plot and one point at the center; depth = 0–30 cm) from the experiment plot and then combined to result in one composite sample. This work was done immediately after planting. Secondly, soil samples were collected at 7 MaP on two different locations based on the growth data of 6 MaP. The locations were under stunted (jabon A) and good jabon (jabon B).

Soil samples were sent to the soil laboratory of the Forestry Research and Development Division, PT. RAPP in Pangkalan Kerinci, Riau for chemical analysis. Soil samples were analysed for content of total C (colourimetric method); total N (Kjeldahl method); the availability of P

(bray II method), K, Ca and Mg (NH_4OAc (pH 7.0, 1 N) extraction method); total B, Cu, Zn, Fe, Mn (HCl 25% extraction method) and total Al ($\text{HNO}_3 + \text{HClO}_4$ extraction method) (Bray, & Kurtz, 1945; Bremner & Mulvaney, 1982; Eviati & Sulaeman, 2009; Motsara & Roy, 2008).

4. Data Analysis

One-Way ANOVA was performed to determine the effect of spacing on jabon growth at 3–12 MaP periods. However, ANOVA analysis was not run at 18 and 24 MaP to avoid bias. The possibility of bias was revealed due to high mortality caused by the massive change in current spacing compared to initial spacing treatments. Therefore, the data at 18 and 24 MaP was analysed with descriptive analyses followed with descriptions in tabular and graphical forms.

III. RESULTS AND DISCUSSION

A. The Survival Rate, Growth and Spacing Effect

The survival rate of jabon at the age of 3–12 MaP period in drained peatland (DP) was not significantly different ($p > 0.05$), based on spacing treatment. Furthermore, there was an abnormal result in the trend of survival rate at the age of 6–9 MaP period. The survival rate at 9 MaP was higher than at 6 MaP (Figure 3a). However, after 9 MaP, the survival declined till the last observation (24 MaP) and reached 38%. This abnormal survival rate may be due to the number of trees that were observed as dead plants at the age of 3 and 6 MaP, categorised by physical symptoms such as wilting, defoliating and drying; however, several of them were re-greening, and re-sprouting at 9 MaP; and thus were identified as live individuals.

Height of jabon was not significantly different ($p > 0.05$) between spacing treatments at the age of 3–12 MaP (Figure 3b). Furthermore, the increment of height and DBH showed relatively promising growth of jabon till 18 MaP (height increment=170 cm/year and DBH increment=1.72 cm/year). However, the height growth between 18–24 MaP was at

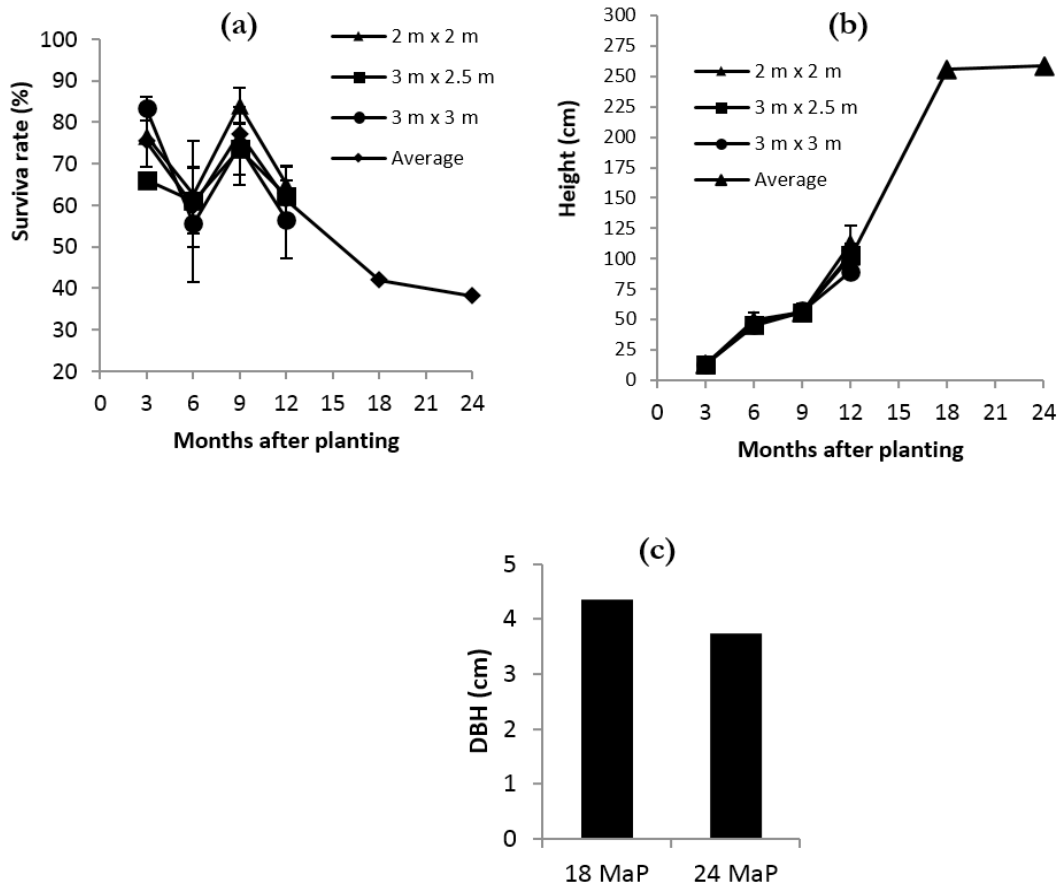


Figure 3. The survival rate (a), height growth (b) and diameter growth (c) of jabon in drained peatland

a standstill, even for the DBH, and a negative growth increment was observed (Figure 3c). At 24 MaP, the average height and DBH based on whole live individuals' data were 259 cm and 3.74 cm. The stagnant or negative increment of growth of jabon in DP probably was because several jabon did not survive after reaching 24 MaP. Therefore, the average growth tended to a standstill for height and was negative for diameter.

Spacing treatment can influence plant competition in access to water, nutrient and sunlight (Ximenes, Mayun, & Pradnyawathi, 2018; Yudianto, Fajriani, & Aini, 2015). In this study, intraspecific competition within individual trees of jabon commenced from the first establishment till 12 MaP. The competition between jabon and other species (weed) could be neglected because the weed was regularly eradicated (three monthly). However, this

intraspecific competition during the observation was not yet intensive. In this experiment, the intraspecific competition occurred at the time of early growth of jabon, when the resources (water and nutrient) requirement of the plant was relatively low. Moreover, the sunlight was unlimited for all individuals of jabon in the different spacing due to there was no canopy closure till 12 MaP. As a result, the spacing differences were not influenced yet on the difference of resources required by plants. Therefore, as previous results showed, the growth of jabon in DP during 3–12 MaP was not significantly different among spacing treatments. Similar results have been found in 2 years old *Eucalyptus spin* Brazil (Filho, Mola-yudego, & González, 2018).

The classification of the height based on the collected data from all live individuals (without being distinguished by spacing differences)

showed that most of jabon had slow growth at the age of 6, 12, and 24 MaP (Figure 4). For example, the proportion of height below 201 cm at the age of 24 MaP was 21% (Figure 4). However, a few jabon (7%) showed promising growth until 24 MaP, and height growth could reach the range of 401–660 cm (Figure 4).

The high variation in growth between individuals of jabon may be because the seed source used in this experiment came from the identified seed source in Dramaga, Bogor, East Java. Seeds originated from an identified seed source class means that seeds are not yet superior. This is because the seed source has not yet been selected from a parent tree with good growth, nor was thinning done, resulting in bad quality trees. This causes a large variation in growth and survival rate when planted in other places. The progeny test of jabon also supported this suggestion in Java, Indonesia, which showed that the difference in height and diameter of jabon was greater among families than among provenances (Sudrajat, Nurhasybi, Siregar, Siregar, Mansur, & Khumaida, 2016). Moreover, another factor that seems like the main factor in this growth variation in soil properties. However, specifically, the

explanation of the effect of soil properties would be discussed further.

Overall, the results showed that jabon in DP had a low survival rate till 24 MaP (2 years after planting). The survival rate was less than 60% (The Regulation of Forestry Ministry about a Manual for Evaluate the Successful of Forest Reclamation, 2009). Of course, this is an unexpected result, even though the observation was only made relatively young, not yet at harvest time. At a similar age, this survival rate was lower than that found in jabon in ultisol land (84%) and also than that in krassikarpa (exotic species) with a survival rate of more than 80% (Junaedi, 2018a; 2018b). Furthermore, for native tree species of tropical peat swamp forest (TPSF); the survival rate range of the pioneer (i.e. mahang (*Macaranga pruinosa*), geronggang (*Cratogeomys arborescens*), and skubung (*Macaranga gigantea*) and non-pioneer i.e. kelat (*Eugenia* sp.), kapurnaga (*Calophyllum* sp.), punak (*Tetramerista glabra*), and ramin (*Gonystylus bancanus*) species were 71–94% and 37–90% (Daryono, 2009; Junaedi, 2018b).

Jabon growth also showed an unexpected result. Overall, in point of view, as fast-growing

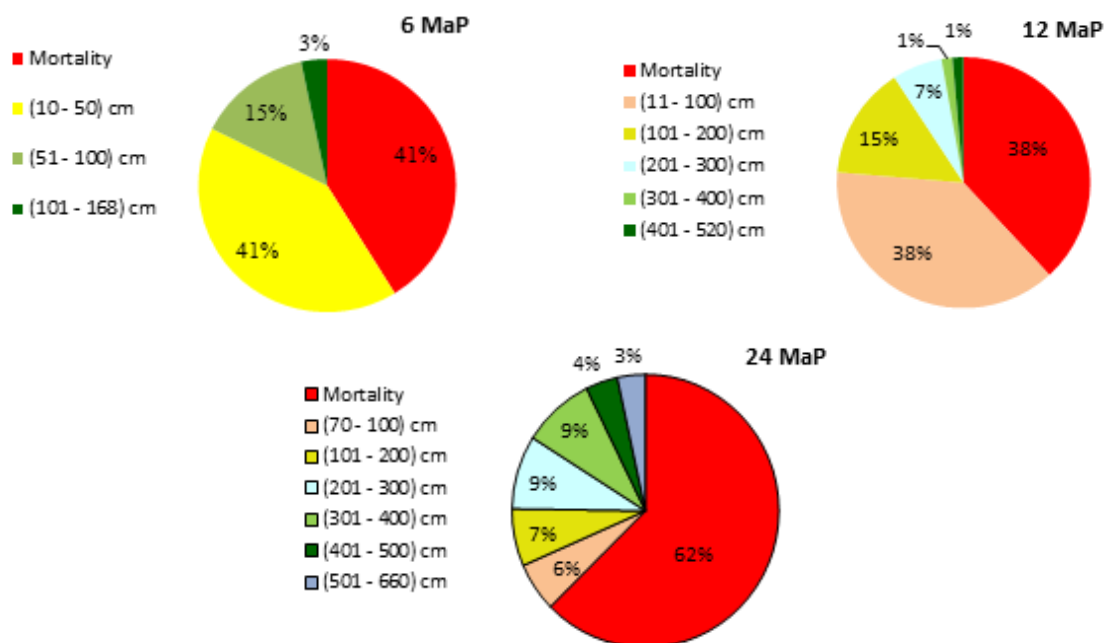


Figure 4. The distribution (%) of jabon height in some classes at 6, 12 and 24 MaP

species, the growth of jabon in DP was poor. As fast-growing species, some previous studies showed that the height and DBH increments of jabon at 2–4 years in dryland could reach 1.62–4.21 m/year and 2.03–5.25 cm/year (Abdulah, Mindawati, Kosasih, & Darwo, 2013; Bijalwan, Dobriyal, & Bhartiya, 2014a; Seo, Chun, Mansur, & Lee, 2015; Wahyudi, 2012; Zuhaidi, Hashim, Sarifah, & Norhazaedawati, 2012; Zuhaidi, 2013). It means that the height and DBH of jabon in optimal growth in DP could reach 3.24–8.42 m and 4.06–10.50 cm at the age of 24 MaP, but in this study, it was 2.59 m and 3.74 cm, respectively. The growth of jabon in DP was not better than that of jabon in marginal ultisol land with the average height and DBH, at the age of 24 MaP, of more than 3 m and 3 cm (Junaedi, 2018a).

The toxicity of soil micronutrient was suggested as the main factor that made the poor growth of jabon in DP (this study) instead of in dryland as mentioned by Wahyudi (2012) in Central Kalimantan, Ahmad Zuhaidi (2013) in Sarawak-Malaysia, Seo, Kim, Chun, Mansur, and Lee (2015) in West Java and (Junaedi, 2018a) in Baserah-Riau. Possibly, it was caused by the fact that the content of soil micronutrient in dryland was less than that in DP. For instance, the exchangeable Al content in a ultisol soil at Baserah-Riau was less than 2.5 cmol (+) kg⁻¹ (Junaedi, 2018a), while in peat soil of Kalimantan was more than 3 cmol (+) kg⁻¹

(Fahmi, Radjagukguk, Purwanto, & Hanudin, 2012). Therefore, the toxicity rate in jabon, which was grown in dryland, was less than that in DP. Furthermore, this toxicity will be explained more in detail in the sub-discussion of Effect of Soil Properties on The Growth.

Furthermore, compared with native tree species of TPSF, the growth of jabon in DP was not better than pioneer species of TPSF such as mahang, skubung and geronggang. However, compared to the growth of non-pioneer species of TPSF *Parashorea mythiessii*, the growth of jabon was better than the growth of slow-growing non-pioneer species such as kelat (*Eugenia* sp.) and ramin (*Gonyostylus bancanus*) (Daryono, 2009; Hilwan, Setiadi, & Rachman, 2013; Junaedi, 2018b; Lampela, Jauhiainen, Sarkkola, & Vasander, 2017; Subiakto, Rachmat, & Sakai, 2016). The better performances of the pioneer native species might be related to their ability to overcome soil micronutrient toxicity through mechanisms. For instance, geronggang has a root system associated with arbuscular mycorrhiza (AM) (Tawaraya et al., 2003). AM in the root gives advantage to geronggang because it can reduce the detrimental effect of soil micronutrient toxicity (Rouphael, Cardarelli, & Colla, 2015).

This study also suggested that one of the main causal factors of mortality and poor growth of jabon after 12 MaP was weed suppression. The three monthly weeding



Figure 5. The high density (crowded) of weed around jabon stand at the age of 18 MaP in drained peatland

undertaken during the age of 0–12 MaP were not continued further. Despite the impact, the study did not specifically observe some variables related to under-storey. Still, when the growth observation was made at 18 MaP, the study found dense weeds, particularly such as seedling-poles of krassikarpa and some tropical ferns (Figure 5). Moreover, the height of some of the krassikarpa pole was higher than jabon and shaded it. This evidence also showed that the supplement weeding done after 18 MaP was too late and insufficient to save the survival and growth of jabon stand due to jabon is a pioneer species that need an open area to capture optimal sunlight their life and growth. This fact was also suggested to make the better survival rate and growth of jabon in a ultisol in Baserah, Riau, where the weed control was undertaken till 24 MaP (Junaedi, 2018a).

B. Effect of Soil Properties on The Growth

The chemical soil properties at the initial condition showed that the content of primary macronutrient (N, P and K) and micronutrient (Al, Fe and Mn) were high-very high (Tabel 1). Furthermore, the soil acidity was extremely acid. The high content of total N was the common condition in peat soil due to N's source from organic matter, which is relatively abundant. However, it was surprising that the content of P and K was also high. It was presumed that the high content of P and K had a relationship with the application of rock phosphate/RP ($\text{Ca}_3(\text{PO}_4)_2\text{CaF}$) and KCl fertilisers. Before establishing a jabon trial, RP as a P and KCl as a source of K were applied in previous silviculture practices to krassikarpa. As mentioned in the method, the trial's location previously was used for the plantation of krassikarpa. Furthermore, the high acidity and micronutrient of Al, Fe and Mn content were common facts in drained peatland, as also were showed in some previous studies (Agus et al., 2020; Hikmatullah & Sukarman, 2014; Husnain, Wigena, Dariah, Marwanto, Setyanto, & Agus, 2014; Tuukkanen, Marttilla, & Klove, 2017).

The high content of soil macronutrient in

the plot was a good initial condition to support the growth of jabon. However, conversely, the existing high soil micronutrient of Al, Mn and Fe made the soil extremely acid that was very harmful to the growth of jabon. In extremely acid soil, micronutrient solubility such as Al and Fe will increase and further toxic to the plant (Soewandita, 2018). Especially for Al, the potency of this element as a toxic element for the plant was shown in several cultivated peatlands in Central Kalimantan, South Kalimantan, Riau and Jambi (Hikmatullah & Sukarman, 2014). Furthermore, based on soil sample analysis where the samples were collected from two locations in the experiment plot at 7 MaP, the soil properties tended to be different. The soil macronutrient under good jabon (jabon B) was higher than under stunted jabon (jabon A), but vice versa for micronutrients of Fe and Mn (Table 1).

Al in acidic soil ($\text{pH}<5$) demonstrated as the main toxic metal for plant (Hodson, 2012; Neenu & Karthika, 2019; Rahman, Lee, Ji, Kabir, Jones, & Lee, 2018). Based on the data of initial soil properties, the condition of the plots expressed an extremely acid state and had relatively high Al, and this suggested that the Al toxicity was the main causal factor of the massive mortality and suppressed the growth of jabon, besides the use of unimproved seed and weed factors. Despite, it could not explain the detailed mechanism of the Al toxicity in jabon in the present study yet. The data associated with the physiology of the plant was not observed. However, some previous studies in other plants such as *Vigna unguiculata*, sugar maple and soybean showed that Al toxicity could inhibit nutrient uptake in the root system and also hindering root cell division and its elongation (Neenu & Karthika, 2019; Schaberg, Tilley, Hawley, Dehayes, & Bailey, 2006; Yu, Liu, Wang, Chen, & Xu, 2011).

Based on this study, it is suggested that the role of soil micronutrient determine the growth difference between jabon A and jabon B. As reported before, the obtained micronutrient of Fe and Mn under jabon A was higher than that

Table 1. Soil properties at initial condition, under stunted jabon (jabon A) and good jabon (jabon B)

Elements	Unit	Initial condition	Jabon A	Jabon B
pH H ₂ O	-	3.30 ± 0.08 ^{EA}	3.217 ^{EA}	3.72 ^{EA}
Macronutrients :				
- C	%	45.5 ± 1.52 ^{VH}	40.17 ^{VH}	40.61 ^{VH}
- Total N	%	1.3 ± 0.13 ^{VH}	1.46 ^{VH}	1,46 ^{VH}
- Available P	me/100 g	39.55 ± 4.49 ^{VH}	32.17 ^{VH}	39.11 ^{VH}
- Available Ca	me/100 g	0.50 ± 0.08 ^{VL}	1.06 ^{VL}	5.77 ^L
- Available K	me/100 g	2.57 ± 1.07 ^{VH}	0.22 ^L	0.46 ^M
- Available Mg	me/100 g	2.27 ± 0.17 ^H	0.59 ^L	1.10 ^M
Micronutrients :				
- Available Na	me/100 g	0.11 ± 0.006 ^L	0.07 ^{VL}	0.10 ^L
- Total B	mg/kg	3.65 ± 0.84	5.82	6.11
- Total Cu	mg/kg	0.97 ± 0.51 ^S	4.5 ^S	2.7 ^S
- Total Fe	mg/kg	655.7 ± 228.5 ^{VH}	995.60 ^{VH}	723.80 ^{VH}
- Total Mn	mg/kg	10.16 ± 3.163 ^H	77.05 ^{VH}	35.36 ^{VH}
- Total Zn	mg/kg	3.31 ± 0.54	28.2	25.10
- Total Al	mg/kg	1.6 ± 94.03 ^{VH}		

Remarks : VL=very low, L=low, M=moderate, H=high, VH=very high, EA=extremely acid, S=sufficient (Eviati & Sulaeman, 2009)

under jabon B. The same as Al, the excessive presence of Fe and Mn in the soil also would be toxic for the plant. Moreover, the excessive micronutrients such as Al, Mn and Fe also negatively affected the growth of the plant through the antagonistic role on macronutrient uptake of P, K, Ca and Mg (Moosavi & Ronaghi, 2011). The possibility that the toxicity rate and antagonistic role of those micronutrients in jabon A were higher than that in jabon B, thus the growth of jabon B was better than for jabon A. This concurred with several previous studies showing that some of the metal/micronutrients such as Al, Fe and Mn were the limiting factors in the growth and productivity of some plant/crop (Choudhury & Sharma, 2014; Qadir, Schubert, & Steffens, 2013; Rehmus, Bigalke, Valarezo, Mora, & Wolfgang, 2014; Yu, Liu, Wang, Chen, & Xu, 2011).

The degradation of photosynthetic pigments expressed the toxicity of Fe and Mn, the substantial damage in the components of

root such as epidermal cells and membrane lipid and the biochemical disorder in cell (Li et al., 2012; Millaleo, Ivanov, Mora, & Alberdi, 2010; Pereira et al., 2013; Yao et al., 2012; You-qiang, Hong, Dao-ming, & Kun-zheng, 2012). As the impact, the plant's photosynthesis would be retarded and lead to the suppression of plant growth and death (Adamski, Peters, Danieloski, & Bacarin, 2011; Nagajyoti, Lee, & Sreekanth, 2010; Qadir, Schubert, & Steffens, 2013). One of the symptoms of toxicity in the individual live plant was chlorosis (Kitao, Lei, Nakamura, & Koike, 2001). The stunted jabon also showed this symptom in the present study (Figure 6a).

The difference of macronutrients (except N) under two contrasting jabon also suggested that it had a role in the difference of jabon growth. The soil under jabon B had less toxic micronutrient; it had more macronutrient than that under jabon A. This means that the supply of macronutrient required for plant growth was relatively more sufficient in the soil under jabon



Figure 6. Chlorosis symptoms on stunned (a) and good (b) jabon in drained peatland

B than jabon A. Results showed that the less the micronutrient and the more the macronutrient was in drained peatland that had a positive effect on jabon growth. However, it was suggested that this positive effect could not be sustained because the growth in all live individuals was stagnant after 18 MaP, including in jabon that had relatively good growth in the period from 6 to 12 MaP. Moreover, several of the good jabon has died at 24 MaP, and some of the remaining live individuals showed chlorosis symptoms (Figure 6b).

C. Implication

Our research has not yet proven that jabon was suitable to be grown in DP in pulpwood plantation. The research also could not evaluate the species till harvest time that commonly is used in pulpwood plantation (about five years) due to the very high mortality of jabon. However, the research obtained some relatively valuable findings from the relatively short term (till two years). It must be noticed for the development of the species as one of the candidates to be grown in DP for pulpwood plantation. The use of unimproved seedling was one factor that made unexpected growth of jabon in DP. Nevertheless, from this unimproved seedling, the research obtained 7% jabon, which had promising growth at 24 MaP, heightened by more than 400 cm (Increment of

height >2 m/year). The growth trait in 7% of jabon could be interpreted as the signal that the opportunity to obtain improved seed/seedling that will result in better growth of jabon in DP is good.

The serious weed-suppressing survival and growth in the period of 1–2 years indicated that weed control (weeding) is still needed at least two years for jabon plantation in DP. This weeding control (till two years) in rubber tree and Eucalyptus hybrid has a positive effect on the growth, thus being used in jabon plantation (Guzzo, De Carvalho, Giacotti Alves, Gonçalves, & Martins, 2014; Wirabuana, Sadono, Juniarto, & Idris, 2020). The negative effect or toxicity of the excessive Al, Fe and Mn on survival and growth rates of jabon in DP indicated that certain treatments are needed to overcome this serious problem. Some previous studies on other species showed that this toxicity could be hindered or at least alleviated through the application of soil ameliorants such as lime (CaCO_3), silicon (Si) and compost (Chatzistathis, Alifragis, & Papaioannou, 2015; Karak, Sonar, Paul, Frankowski, Boruah, Dutta, & Das, 2015; Prabagar, Hodson, & Evans, 2011; Wu, Shi, Zhu, Wang, & Gong, 2013; You-qiang, Hong, Dao-ming, & Kun-zheng, 2012). Moreover, the application of arbuscular mycorrhizal inoculation around the root system was another treatment that could be chosen

to overcome this toxicity problem (Rouphael, Cardarelli, & Colla, 2015; Turjaman et al., 2011). In practice, tree improvement is required to determine the best seed of jabon with good growth and tolerance to the DP area. It is also important to examine which individuals of jabon are resistant to toxic micronutrients.

IV. CONCLUSION

Our study was the first research that evaluated the growth performances of jabon in drained peatland for pulpwood plantation. This study provided the data of survival and growth rate of jabon in drained peatland and provided the soil properties data under jabon stand and its relationship with growth performance. These data were valuable for tree selection as the candidate for pulpwood plantation in drained peatland (DP). It showed that generally, jabon had a poor survival rate and growth in DP due to the use of unimproved seedling, the weed suppression at the age after 12 MaP and the metal/micronutrient toxicity Al, Fe and Mn. However, the study obtained that 7% of jabon in DP had promising growth at 24 MaP (height increment >2 m/year); thus, this fact is valuable to be followed up by a tree improvement program.

ACKNOWLEDGEMENT

The authors are very grateful to the Research Institute for Fiber Forest, The Ministry of Environment and Forestry of Indonesia to support our research and provide the funding. Authors are also grateful to Tateng Sasmita, Syasri Janneta, Sunarto, Arifin, Ramiduk and Minal Aminin for field assistances and Dodi Frianto for sharing valuable references and Pak Saeful Iksan for providing the map of the study site. We would also like to thank the Research and Development Division of PT. RAPP for all valuable support, assistance, accommodation in the field and the laboratory.

REFERENCES

- Abdulah, L., Mindawati, N., Kosasih, A. S., & Darwo. (2013). Early growth evaluation of *Neolamarckia cadamba* Roxb at private forest. *Jurnal Penelitian Hutan Tanaman*, 10(3), 119–128. doi://10.20886/jpht.2013.10.3.119-127.
- Adamski, J. M., Peters, J. A., Danieloski, R., & Bacarin, M. A. (2011). Excess iron-induced changes in the photosynthetic characteristics of sweet potato. *Journal of Plant Physiology*, 168(17), 2056–2062. doi://10.1016/j.jplph.2011.06.003.
- Agus, C., Ilfana, Z. R., Azmi, F. F., Rachmanadi, D., Widiyatno, Wulandari, D., ..Lestari, T. (2020). The effect of tropical peat land-use changes on plant diversity and soil properties. *International Journal of Environmental Science and Technology*, 17(3), 1703–1712. doi://10.1007/s13762-019-02579-x.
- Aprianis, Y. (2016). The possibility of alternative wood for pulp. In A. Hidayat, Sudarmalik, E. Novriyanti, H. H. Rachmat, & A. Wahyudi (Eds.), *The Proceeding of Research Finding: Opportunities and Challenges of The Development of Environment and Forestry in Riau* (pp. 1–11). Balai Litbang Teknologi Serat Tanaman Hutan.
- Barua, S. K. (2015). Plantation vision: Potentials, challenges and policy options for global industrial forest plantation development. *International Forestry Review*, 16(2), 117-127 doi://10.1505/146554814811724801.
- Bijalwan, A., Dobriyal, M. J., & Bhartiya, J. K. (2014a). A potential fast growing tree for agroforestry and carbon sequestration in a potential fast growing tree for agroforestry and carbon sequestration in India: *Anthocephalus cadamba* (Roxb.). *American Journal of Agriculture and Forestry*, 2(6), 296–301. doi://10.11648/j.ajaf.20140206.21.
- Bijalwan, A., Dobriyal, M. J. R., & Bhartiya, J. K. (2014b). A potential fast growing tree for Agroforestry and carbon sequestration in India: *Anthocephalus cadamba* (Roxb.). *American Journal of Agriculture and Forestry*, 2(6), 296–301. doi://10.11648/j.ajaf.20140206.21.
- Biswas, D., Misbahuddin, M., Roy, U., Francis, R. C., & Bose, S. K. (2011). Bioresource technology effect of additives on fiber yield improvement for kraft pulping of kadam (*Anthocephalus*

- chinensis*). *Bioresource Technology*, 102, 1284–1288. doi://10.1016/j.biortech.2010.08.059.
- Bray, R.H. & Kurtz, L. T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Sciences*, 59, 39–45.
- Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-Total, Part 2. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Method of Soil Analysis Part 2* (2nd ed., p. 595-624). American Society of Agronomy, Inc. & Soil Science Society of America, Inc.
- Chatzistathis, T., Alifragis, D., & Papaioannou, A. (2015). The influence of liming on soil chemical properties and on the alleviation of manganese and copper toxicity in *Juglans regia*, *Robinia pseudoacacia*, *Eucalyptus* sp. and *Populus* sp. plantations. *Journal of Environmental Management*, 150, 149–156. doi://10.1016/j.jenvman.2014.11.020.
- Choudhury, S., & Sharma, P. (2014). Plant physiology and biochemistry aluminum stress inhibits root growth and alters physiological and metabolic responses in chickpea (*Cicer arietinum* L.). *Plant Physiology and Biochemistry*, 85, 63–70. doi://10.1016/j.plaphy.2014.10.012.
- Christianus, S. (2006). *The experience of the establishment of industrial plantation forest in PT. RAPP, Pelalawan-Riau* (pp. 87–100). Wetlands International.
- Daryono, H. (2009). Potency, problems, policy and peatland management needed for sustainable peat swamp forest. *Jurnal Analisis Kebijakan Kebutanan*, 6(2), 71–101.
- Eviati, & Sulaeman. (2009). *Manual for chemical analysis of soil, plant and fertilise*. B. H. Prasetyo, D. Santoso, & L. Retno W (Eds.); 2nd ed.). Research Institute for Soil.
- Fahmi, A., Radjagukguk, B., Purwanto, B. H., & Hanudin, E. (2012). The influence of peat layer on hydrogen and aluminium concentration originating from the substratum sulphidic materials. *Journal of Tropical Soils*, 17(3), 197–202. doi://10.5400/jts.2012.17.3.197.
- Filho, A. C. F., Mola-yudego, B., & González-, J. R. (2018). Thinning regimes and initial spacing for Eucalyptus plantations in Brazil. *Annals of the Brazilian Academy of Sciences*, 90(1), 255–265.
- Guzzo, C. D., De Carvalho, L. B., Giancotti, P. R. F., Alves, P. L. C., Gonçalves, E. C. P., & Martins, J. V. F. (2014). Impact of the timing and duration of weed control on the establishment of a rubber tree plantation. *Anais Da Academia Brasileira de Ciencias*, 86(1), 495–504. doi://10.1590/0001-37652014119113.
- Hikmatullah, & Sukarman. (2014). Physical and chemical properties of cultivated peat soils in four trial sites of ICCTF in Kalimantan and Sumatra, Indonesia. *Journal of Tropical Soils*, 19(3), 131–141. doi://10.5400/jts.2014.19.3.131.
- Hilwan, I., Setiadi, Y., & Rachman, H. (2013). Evaluation of some Dipterocarp species in revegetation areas of PT . Kitadin, East Kalimantan. *Jurnal Silviculture Tropika*, 04(02), 108–112.
- Hodson, M. J. (2012). Metal toxicity and tolerance in plants. *Features*, 28 October. doi://10.1042/BIO03405028.
- Husnain, H., Wigena, I. G. P., Dariah, A., Marwanto, S., Setyanto, P., & Agus, F. (2014). CO₂ emissions from tropical drained peat in Sumatra, Indonesia. *Mitigation and Adaptation Strategies for Global Change*, 19(6), 845–862. doi://10.1007/s11027-014-9550-y.
- Junaedi, A. (2018a). Growth of *Anthocephalus cadamba* Miq. in marginal land ultisol in Riau. *Jurnal Pemuliaan Tanaman Hutan*, 12(1), 51–63. doi://10.20886/jpht.2018.12.1.51-63.
- Junaedi, A. (2018b). Growth performance of three native tree species for pulpwood plantation in drained peatland of Pelalawan District, Riau. *Indonesian Journal of Forestry Research*, 5(2), 119–132. doi://10.20886/ijfr.2018.5.2.119-132.
- Karak, T., Sonar, I., Paul, R. K., Frankowski, M., Boruah, R. K., Dutta, A. K., & Das, D. K. (2015). Aluminium dynamics from soil to tea plant (*Camellia sinensis* L.): Is it enhanced by municipal solid waste compost application? *Chemosphere*, 119, 917–926. doi://10.1016/j.chemosphere.2014.08.067.
- Kitao, M., Lei, T. T., Nakamura, T., & Koike, T. (2001). Manganese toxicity as indicated by visible foliar symptoms of Japanese white birch (*Betula platyphylla* var. japonica). *Environmental Pollution*, 111, 89–94.
- Lampela, M., Jauhiainen, J., Sarkkola, S., & Vasander, H. (2017). Promising native tree species for reforestation of degraded tropical peatlands. *Forest Ecology and Management*, 394, 52–63. doi://10.1016/j.foreco.2016.12.004.
- Li, X., Ma, H., Jia, P., Wang, J., Jia, L., Zhang, T., Yang,

- Y., Chen, H., & Wei, X. (2012). Responses of seedling growth and antioxidant activity to excess iron and copper in *Triticum aestivum* L. *Ecotoxicology and Environmental Safety*, 86, 47–53. doi://10.1016/j.ecoenv.2012.09.010.
- Millaleo, R., Ivanov, A. G., Mora, M. L., & Alberdi, M. (2010). Manganese as essential and toxic element for plants: transport, accumulation and resistance mechanisms. *Journal Soil Science Plant Nuts.*, 10(4), 476–494.
- Ministry of Enviroment and Forestry. (2021). The statistic of Ministry of Enviroment and Forestry 2019. The Ministry of Environment and Forestry, Jakarta.
- The Regulation of Forestry Ministry about a Manual for evaluate the succesfull of forest reclamation (2009). The Ministry of Forestry, Jakarta.
- Ministry of Environment and Forestry. (2016). The statistic of Environment and Forestry 2015. The Ministry of Environment and Forestry, Jakarta.
- Moosavi, A. A., & Ronaghi, A. (2011). Influence of foliar and soil applications of iron and manganese on soybean dry matter yieldand iron-manganese relationship in a Calcareous soil and iron-manganese relationship in a Calcareous soil. *Australian Journal of Crop Science*, 5(12), 1550–1556.
- Motsara, M. R., & Roy, R. N. (2008). Guide to laboratory establishment for plant nutrient analysis. FAO.
- Nagajyoti, P. C., Lee, K. D., & Sreekanth, T. V. M. (2010). Heavy metals , occurrence and toxicity for plants : a review. *Environmental Chemistry Lett*, 8, 199–216. doi://10.1007/s10311-010-0297-8.
- Neenu, S., & Karthika, K. S. (2019). Aluminium toxicity in soil and plants. *Harit Dbara*, 2(1), 15–19.
- Pereira, E. G., Oliva, M. A., Gusmão, E., Antonio, M., Rosado-souza, L., Camargo, G., Santos, D., Henrique, C., & Miyasaka, A. (2013). Iron excess affects rice photosynthesis through stomatal and non-stomatal limitations. *Plant Science*, 201–202(March), 81–92. doi://10.1016/j.plantsci.2012.12.003.
- Prabagar, S., Hodson, M. J., & Evans, D. E. (2011). Silicon amelioration of aluminium toxicity and cell death in suspension cultures of Norway spruce (*Picea abies* (L.) Karst.). *Environmental and Experimental Botany*, 70, 266–276. doi://10.1016/j.envexpbot.2010.10.001.
- Qadir, M., Schubert, S., & Steffens, D. (2013). Phytotoxic substances in soils. *Reference Module in Earth Systems and Environmental Sciences*, April, 1–6. doi://10.1016/B978-0-12-409548-9.05255-6.
- Rahman, A., Lee, S., Ji, H. C., Kabir, A. H., Jones, C. S., & Lee, K. (2018). Importance of mineral nutrition for mitigating aluminum toxicity in plants on acidic soils : Current status and opportunities. *International Journal of Molecular Sciences*, 19(3073), 1–28. doi: //10.3390/ijms19103073.
- Rehmus, A., Bigalke, M., Valarezo, C., Mora, J., & Wolfgang, C. (2014). Aluminum toxicity to tropical montane forest tree seedlings in southern Ecuador: response of biomass and plant morphology to elevated Al concentrations. *Plant Soil*, 382, 301–315. doi://10.1007/s11104-014-2110-0.
- Rouphael, Y., Cardarelli, M., & Colla, G. (2015). Role of arbuscular mycorrhizal fungi in alleviating the adverse effects of acidity and aluminium toxicity in zucchini squash. *Scientia Horticulturae*, 188, 97–105. doi://10.1016/j.scienta.2015.03.031.
- Schaberg, P. G., Tilley, J. W., Hawley, G. J., Dehayes, D. H., & Bailey, S. W. (2006). Associations of calcium and aluminum with the growth and health of sugar maple trees in Vermont. *Forest Ecology and Management*, 223, 159–169. doi://10.1016/j.foreco.2005.10.067.
- Seo, J., Kim, H., Chun, J.-H., Mansur, I., & Lee, C.-B. (2015). Silvicultural practice and growth of the jabon tree (*Anthocephalus cadamba* Miq.) in community forests of West Java, Indonesia. *Journal of Agriculture & Life Science*, 49(4), 81–93.
- Soewardita, H. (2018). A study of water management and palm oil productivity in peatlands (Case study : Peatlands of PT Jalin Vaneo's palm plantation in North Kayong District, West Kalimantan Province). *Jurnal Sains & Teknologi Modifikasi Cuaca*, 19(1), 41–50.
- Subiakto, A., Rachmat, H. H., & Sakai, C. (2016). Choosing native tree species for establishing man-made forest : A new perspective for sustainable forest management in changing world. *Biodiversitas*, 17(2), 620–625. doi://doi.org/10.13057/biodiv/d170233.

- Sudrajat, D. J., Nurhasybi, Siregar, I. Z., Siregar, U. J., Mansur, I., & Khumaida, N. (2016). Intraspecific variation on early growth of *Neolamarckia cadamba* Miq. in provenance-progeny tests in West Java Province, Indonesia. *Biotropia*, 23(1), 10–20. doi: //10.11598/btb.2016.2.
- Suhartati, Rahmayanti, S., & Nurrohman, E. (2012). Sebaran dan persyaratan tumbuh jenis alternatif penghasil pulp di wilayah Riau. In N. Mindawati, P. Pamoengkas, & U. Sutisna (Eds.). Kementerian Kehutanan.
- Suhartati, S., Aprianis, Y., Pribadi, A., & Rochmayanto, Y. (2013). Study of reduction cycle impact of *Acacia crassiparva* A. Cunn plantation to production value and social aspect. *Jurnal Penelitian Hutan Tanaman*, 10(2), 109–117. doi://10.20886/jpht.2013.10.2.109-117.
- Tawaraya, K., Takaya, Y., Turjaman, M., Tuah, S. J., Limin, S. H., Tamai, Y., Cha, J. Y., Wagatsuma, T., & Osaki, M. (2003). Arbuscular mycorrhizal colonisation of tree species grown in peat swamp forests of Central Kalimantan, Indonesia. *Forest Ecology and Management*, 182(1–3), 381–386. doi://10.1016/S0378-1127(03)00086-0.
- Turjaman, M., Santoso, E., Susanto, A., Gaman, S., Limin, S. H., Tamai, Y., Osaki, M., & Tawaraya, K. (2011). Ectomycorrhizal fungi promote growth of *Shorea balangeran* in degraded peat swamp forests. *Wetlands Ecology and Management*, 19(4), 331–339. doi://10.1007/s11273-011-9219-1.
- Tuukkanen, T., Marttilla, H., & Klove, B. (2017). Predicting organic matter, nitrogen, and phosphorus concentrations in runoff from peat extraction sites using partial least squares regression. *Water Resources Research*, 53, 5860–5876. doi://10.1002/2017WR020557.
- Wahyudi. (2012). Growth and yield analysis of jabon plantation (*Antbocephallus cadamba*). *Jurnal Perennial*, 8(1), 19–24.
- Wirabuana, P. Y. A. P., Sadono, R., Juniarso, S., & Idris, F. (2020). Interaction of fertilisation and weed control influences on growth, biomass, and carbon in eucalyptus hybrid (*E. pellita* × *E. brassiana*). *Jurnal Manajemen Hutan Tropika*, 26(2), 144–154. doi://10.7226/JTFM.26.2.144.
- Wu, J. W., Shi, Y., Zhu, Y. X., Wang, Y. C., & Gong, H. J. (2013). Mechanisms of enhanced heavy metal tolerance in plants by silicon: A review. *Pedosphere*, 23(6), 815–825. doi: //10.1016/S1002-0160(13)60073-9.
- Ximenes, M. P., Mayun, I. A., & Pradnyawathi, N. L. M. (2018). The combined effect of plant spacing and varieties on the growth and the corn yields (*Zea mays* L.) at Loes, Sub District of Maubara, District of Liquisa Republica Democratica De Timor Leste Plant. *E-Jurnal Agroteknologi Tropika*, 7(2), 295–303.
- Yao, A. Y., Donglin, M., Gang, X., Lutts, S., Achal, V., & Ma, J. (2012). Contrasting performance and different tolerance of chestnut rose and grape to excess manganese. *Journal Plant Growth Regulator*, 31, 416–426. doi://10.1007/s00344-011-9251-7.
- You-qiang, F. U., Hong, S., Dao-ming, W. U., & Kun-zheng, C. A. I. (2012). Silicon-mediated amelioration of Fe 2 + toxicity in rice (*Oryza sativa* L.) roots. *Pedosphere*, 22(6), 795–802. doi://10.1016/S1002-0160(12)60065-4.
- Yu, H. N., Liu, P., Wang, Z. Y., Chen, W. R., & Xu, G. D. (2011). The effect of aluminum treatments on the root growth and cell ultrastructure of two soybean genotypes. *Crop Protection*, 30(3), 323–328. doi://10.1016/j.cropro.2010.11.024.
- Yudianto, A. Y., Fajriani, S., & Aini, N. (2015). Influence of plant spacing and pilled frequency on growth and yield of arrowroot plant (*Marantba arundinaceae* L.). *Jurnal Produksi Tanaman*, 3(3), 172–181.
- Zuhaidi, Y.A., Hashim, M. N., Sarifah, K., & Norhazaedawati, B. (2012). Domestication of lesser known tropical species *Neolamarckia cadamba* among the small scale forest owners. FRIM, Malaysia.
- Zuhaidi, Y Ahmad. (2013). Crown diameter prediction model for plantation-grown *Neolamarckia cadamba*. *Journal of Tropical Forest Science*, 25(4), 446–453.

PROBIOTIC CANDIDATE PROTEOLYTIC *Bacillus* sp. COLLECTED FROM MANGROVE OF MARGASARI, LAMPUNG

Sumardi¹, Komang Rima¹, Salman Farisi¹, and Endang Linirin Widiastuti^{1,2,*}

¹Biology Department, Faculty of Mathematics and Natural Sciences, University of Lampung
Jl. Prof. Dr. Ir. Sumantri Brojonegoro, No. 1, Bandar Lampung, Lampung 35141, Indonesia

²Coastal and Marine Research Center, University of Lampung
Jl. Sumantri Brojonegoro No. 1. Bandar Lampung, Lampung 35141, Indonesia

Received: 10 June 2020, Revised: 25 March 2021, Accepted: 5 April 2021

PROBIOTIC CANDIDATE PROTEOLYTIC *Bacillus* sp. COLLECTED FROM MANGROVE OF MARGASARI, LAMPUNG. Intensive shrimp culture has encountered many problems, such as declining water quality through disease caused by pathogenic microbes, which affected mortality. This study aimed to determine any potential probiotic from *Bacillus* sp. collected from mangrove in East Lampung, which could be used to improve the cultured shrimps' proteolytic and probiotic activity. This is a descriptive research with sampling and data collection of bacteria from many samples of mangrove. Result shows 128 isolates *Bacillus* from which then it has arrived at five potential probiotic *Bacillus* sp. The study five *Bacillus* sp. has been isolated with potential properties for probiotic (KPP212, IP121, UJ131, UJ132, SB141). Each isolate has characteristics with proteolytic property, growth in a wide range of pH 4–10 and osmotic stress (0–6% NaCl), non-pathogenic, ability for glucose fermentation, non-motile, and has negative catalase activity. The five potential *Bacillus* sp. can be used as probiotics for shrimp farming.

Keywords: Characterisation, *Bacillus* sp., mangrove, probiotic

KANDIDAT PROBIOTIK PADA *Bacillus* sp. PROTEOLITIK DIKOLEKSI DARI HUTAN MANGROVE DI MARGASARI, LAMPUNG. Budidaya udang dengan cara intensif telah menyebabkan banyak masalah seperti penurunan kualitas air yang mengakibatkan munculnya mikroba patogen, sehingga mempengaruhi kematian. Tujuan dari penelitian ini adalah untuk menemukan *Bacillus* sp. yang diisolasi dari beberapa sampel di mangrove dan mengkarakterisasi mikroba terisolasi tersebut untuk penggunaan probiotik. Studi ini merupakan penelitian deskriptif dan koleksi data bakteri dari berbagai jenis sampel mangrove. Dari penelitian ditemukan lima *Bacillus* sp. yang terisolasi dan memiliki sifat potensial untuk probiotik, yaitu KPP212, IP121, UJ131, UJ132, dan SB141, dengan masing-masing isolat memiliki karakteristik bersifat proteolitik, pertumbuhan dalam rentang pH yang luas (4–10) dan tahan pada tekanan osmotik (0–6% NaCl), tidak patogen, kemampuan untuk fermentasi glukosa, tidak motil, serta tidak memiliki aktivitas katalase. Kelima bakteri *Bacillus* sp. tersebut dapat digunakan untuk probiotik pada budidaya udang.

Kata kunci: Karakterisasi, *Bacillus* sp., mangrove, probiotik

* Corresponding author: elwidi@yahoo.com

I. INTRODUCTION

Mangrove of Margasari Village in the district of Labuhan Maringgai, East Lampung Regency is in 5°51'84" South Latitude–105°64'84" East Longitude covers about 700 hectares which is 6.65% of the total mangrove in Lampung Province. Mangrove has functions ecologically and economically, such as protecting coastal abrasion, brackish water quality control, habitat for many organisms, medicines, and paper pulp. The presence of waste influences mangrove's ecological activities, decomposition by microorganisms, mineral uptaking by plants, and other biological activities to keep the equilibrium (Kementerian Kehutanan, 2014; Kariada & Andin, 2014). Furthermore, it is necessary to rehabilitate mangrove for further conservation of coastal areas.

Many researchers in various places have also isolated the bacteria potential from mangrove. The study of Deivanai, Bindusara, Prabhakaran, and Bhore (2014) isolated *Pantoea ananatis* (1MSE1) and *Bacillus amyloliquefaciens* (3MPE1) bacteria from mangrove, which is interacted positively with rice seedlings, provides significant increase in root and shoot length, fresh weight, and chlorophyll content. The study of Castro et al. (2018) proved that *Enterobacter* sp. MCR1.48 strain from mangrove endophyte effectively promotes the *Acacia polyphylla* growth and fitness. The bacteria can be used in the seedling production of the tree. Another researcher, Maulani, Rasmi, and Zulkifli (2019), has successfully isolated eighteen endophytic bacteria from mangrove *Rhizophora mucronata* from Gili Sulat, East Lombok. The 18 isolates of endophytic consist of 15 isolates: Gram-positive bacteria and 3 isolates were Gram-negative bacteria. The endophytic bacteria isolate that had antibiotic activity was *B. cereus*, *P. aeruginosa*, *S. aureus*, and *E. coli*. On the other hand, the potential fungi from mangrove were also discovered. Hamzah, Lee, Hidayat, Terhem, Hanum, and Mohamed (2018) in Malaysia isolated endophytic fungi from mangrove *Rhizophora mucronata*. The study found several

fungi, i.e. *Alternaria*, *Fusarium*, *Nigrospora*, *Pestalotiopsis*, *Phoma*, and *Xylaria*. After their culture assay for their antagonism activities with the phytopathogenic fungus, *Fusarium solani* reached 45–66%. Of the six isolates, only *Fusarium lateritium* and *Xylaria* sp. showed antibacterial activities against the pathogenic bacteria, *Bacillus subtilis*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*.

Mangrove plays an important role in the coastal waters, food web and habitat, supporting many different biotas, such as fish, crabs, shrimps, and molluscs (Scharler, 2011). Around the Margasari mangrove, there are shrimp farmings. The mangrove has many wastes, which is good nutrition for various bacterial growths. In nature, the bacteria can pass into the digestive tract of animals. Several types of bacteria found in the digestive tract of animals had an important role in improving food and fish's healthy utilisation (Sarastiti, Suminto, & Sarjito, 2020). *Bacillus* sp. can be one of the bacteria that can increase the digestibility of fish or shrimp, and it has the potential as a probiotic (Anggriani, Iskandar, & Ankiq, 2012). There was no information related to the isolation of *Bacillus* sp. from mangrove of Margasari, East Lampung, especially related to those used for probiotics.

The advantage of probiotic technology is that the process is natural and safe. Probiotics had a beneficial effect which includes interacting directly with commensal and pathogenic microorganisms. The probiotics were used for many functions, i.e. (1) to prevent and treat infections, (2) to improve the balance of microorganisms in the small intestine, (3) to produce extracellular enzymes, and (4) to produce beneficial compounds such as vitamins and short-chain fatty acids (Tensiska, 2008).

Isolation and selection of proteolytic bacteria have very good potential to be used as probiotics. The character of the bacteria is needed to increase feed efficiency. The study reported that shrimp and fish feed contained 55.51–67.68% protein (Handayani, 2011).

Other studies have also shown some other microorganisms as probiotic candidates, and they were *Bacillus subtilis*, *Bacillus licheniformis*, *Pseudomonas putida*, *Bacillus bataviensis*, and *Caulobacter* sp. (Rahmawan, Mohamad, Suminto, & Herawati, 2014; Seprianto, Feliatra, & Nugroho, 2017).

Shrimp cultures have been widely growing in Lampung Province, in which intensive shrimp culture deliberates some diseases related to its culture (Taukhid, Supriyadi, & Koesharyani, 2008). To prevent or regulate the disease, therefore, the development of probiotic is necessary. Samosir, Suryanto, and Desrita (2017) established one by developing probiotic from the surrounding ecosystem. Many isolated bacteria with potential sources of probiotic can be collected from mangrove communities, such as from mangrove plant (its root and bark), fishes like milky fish, cuttlefish, mangrove shrimps, molluscs, crabs, and other fishes, as well as from the mud, water and other abiotic factors of the mangrove ecosystem (Pratiwi, Rahayu, & Wahju, 2013; Seprianto, Feliatra, & Nugroho, 2017; Muliani, Nurbaya, Arifudin, & Muharijadi, 2017). Therefore, it is necessary to figure out any potential of the

proteolytic *Bacillus* sp. as a local probiotic is collected from the mangrove of Margasari. It could then be applied to the aquaculture digestion, and disease problems, especially in shrimp and fish cultures encountered most in Lampung Province.

II. MATERIAL AND METHOD

A. Sources of Isolated Bacteria

The sample used to isolate bacteria was collected from mangrove communities in Margasari Village, Labuhan Maringgai, East Lampung Regency. Abiotic and biotic samples were collected from water, mud, fishes, shrimps, crabs, mollusc and cuttlefish found in the mangrove ecosystem, as well as the *Rhizophora* sp. bark and roots.

B. Isolation of *Bacillus* sp.

Isolation of *Bacillus* sp. was done from different sample mass, 10 g of mud, 1 g mangrove root and skin, 1 ml of water, 1 ml intestinal suspension of shrimp, crab, mollusc, and fish (Figure 1). Sample suspension then was made by adding 90 ml physiological salt for mud and 9 ml for water, mangrove root and bark,

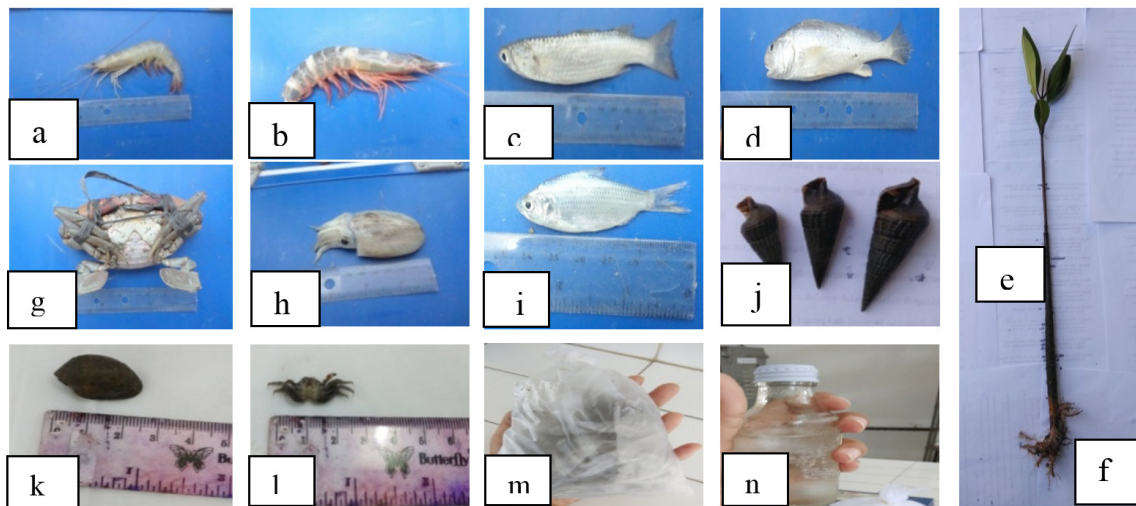


Figure 1. Collected biotic samples

Remarks: a. *Penaeus merguensis* (udang jerbung), b. *Litopenaeus vannamei* (udang kucing) c. *Mugil* sp. (ikan belanak) d. *Mallothus villosus* (ikan kepala batu) e. Epidermis of *Rhizophora* sp. (kulit bakau), f. Root of *Rhizophora* sp. (akar bakau), g. *Scylla serrata* (kepiting bakau) h. *Sepia latimanus* (sotong), i. *Tenulosa toli* (ikan pirit), j. *Telescopium telescopium* (siput bakau) k. *Nerita violacea* (keong bulat), and l. *Episesarma* sp. (kepiting pemanjat pohon) and abiotic samples, m. mud, and n. water

shrimp, mollusc, crab and fish. All samples were homogenised by using a vortex mixer at 80°C for 15 minutes. Dilution was made for each sample in series of 10-1 and 10-2. one ml of each was diluted into sample suspension and it was spread into skim milk agar media modification of Sea Water Complete (SWC), followed by incubation for 24 hours at 37°C (Hamtini, 2014). The isolate then was purified by quadrant streak into the SWC agar media.

C. Proteolytic Test

Bacillus sp. isolate was picked using a sterile ose needle and inoculated into SWC media modified with skim milk. The culture then was incubated for 24 hours at 37°C. The observation was made by determining the formed proteolytic index (Hamtini, 2014, Hapsari, Tjahjaningsih, Alamsjah, & Pramono, 2016; Sumardi, Agustrina, Ekowati, & Pasaribu, 2018).

D. Osmotic/Salinity Stress Test

Bacillus sp. isolate was picked using a sterile ose needle and inoculated into modified SWC media with NaCl concentration of 0%, 3%, and 6%. The culture then was incubated for 24 hours at 37°C. The observation was made by determining the number of growing colonies (Subagiyo, Sebastian, Triyanto, & Wilis, 2015).

E. pH-stress Test

Bacillus sp. isolate was picked using a sterile ose needle and inoculated into modified SWC media with pH 4, 7, and 10. The culture then was incubated for 24 hours at 37°C. The

observation was made by determining the measurement of growing colonies (Kepel, Widdhi, & Fatimawali, 2020).

F. Pathogenetic Test

Bacillus sp. isolate was picked using a sterile ose needle and inoculated into blood modified SWC media. The culture then was incubated for 24 hours at room temperature (Hamtini, 2014). The observation was made by determining the hemolytic ability of isolate from the change of colours (Figure 2).

G. Characteristic Test

Characterisation of isolate bacteria, presumably *Bacillus* sp. was done in 2 steps, as follows:

a. Morphological characterisation of colony and cell. Colony characterisation was done by observing the colony formed while cell morphology was made on gram smear (Yulvizar, 2013).

b. Biochemical test

Biochemical test as characterisation of the colony was conducted in different tests, such as catalase, mortality and glucose fermentation.

b.1. Catalase test

Two drops of H_2O_2 was placed in the sterile glass. Then, one ose needle picked of isolate *Bacillus* sp. was mixed into H_2O_2 in object glass (Yulvizar, 2013).

b.2. Motility test

As much as 1 ose needle isolate *Bacillus* sp. was placed into SWC agar media SWC. The culture then was incubated for 24 hours at

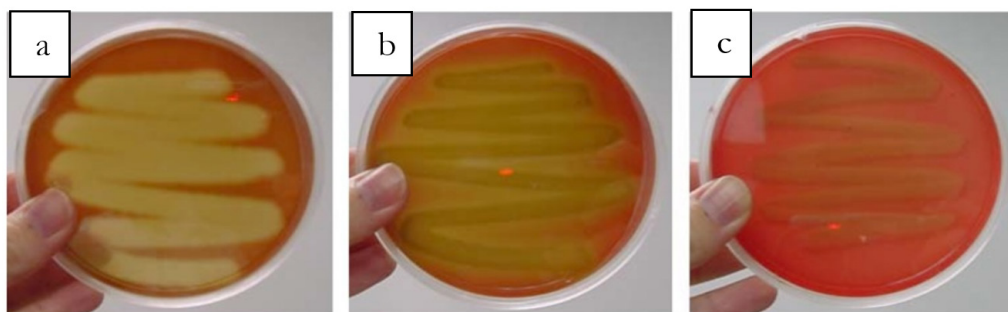


Figure 2. Hemolysis test in blood agar

Remarks: a. Beta hemolysis, b. Alpha hemolysis, c. Gamma hemolysis (Aryal, 2015)

37°C temperature (Samosir, Suryanto, & Desrita, 2017).

b.3. Glucose fermentation test

As much as 1 ose needle isolate *Bacillus* sp. was inoculated into liquid SWC agar media and added 1% sugar (glucose, lactose, mannitol, sucrose and mannose). The culture then was incubated for 24 hours at 37°C temperature (Samosir et al., 2017).

III. RESULT AND DISCUSSION

A. Margasari Mangrove

Margasari mangrove is very important for the coastal area of East Lampung. Most of the shrimp or fish cultures/ponds are found in the mangrove belt of East Lampung. It is known that mangrove can support many biotas, including fish, shrimps, molluscs (Figure 1). Margasari mangrove and other mangrove ecosystems provide food for many aquatic biotas and contribute to the biological cycle in coastal waters. With special structures of mangrove plants, such as *Rhizophora mucronata*, *Avicennia marina*, *Sonneratia alba*, and others, the mangrove's ground floor and swamp and water flow within the mangrove connecting provides shelter for many larvae of mangrove biota.

Spawning and nursery become the shelter of many biotas provided by mangrove, and it is affected by microbes activity as a decomposer. These microbes possibly believed to have beneficial uses such as probiotic, antibiotic, and bioactive products and else (Subagiyo, Muhammad, & Wilis, 2017). The recent study also indicated that some mangrove shrubs, such as *Acanthus ilicifolius* contain antioxidant (Widiastuti, Arifianti, Khairani, Christianto, Ara, & Maharani, 2019). Other studies showed that *Bacillus* sp. as probiotic bacteria had been found in Mangrove in Lampung (Sumardi, Farisi, Ekowati, & Hairisah, 2019; Sumardi, Farisi, Ekowati, Arifiyanto, & Rahmawati, 2020).

B. Isolation of *Bacillus* sp.

Five *Bacillus* sp. isolates were found from mangrove samples and predicted to be used

potentially for probiotic. They were from climbing crab intestine, fish intestine, two isolat from shrimp and one from mollusc intestine-those five isolates. *Bacillus* sp. were collected after undergoing selection tests for potential candidate for probiotic and can be seen in Table 1.

Initially, the number of isolated and purified bacteria from collected samples were 128, from which the highest isolated was from the mud (Table 1). The colour of mud was dark black, indicating it contained a high concentration of organic molecules (Suhendar, Esti, & Asep, 2019). It could be used as an indicator that some bacterial colony could be found in the mud. Another study also found seven isolated bacteria collected from mangrove mud of Wonorejo, Rungkut, Surabaya (Pratiwi, Rahayu, & Wahju, 2013). This diversity found in bacterial colonies was possible since the mangrove area was fully covered by plant debris that can be degraded and used by microorganisms as energy sources (Sinatryani, Moch, Sudarno, & Kustiawan, 2014).

Fourteen bacterial isolation was found from squids which were the highest number of bacterial isolations found among others. Some studies also indicated that four different probiotic isolation was found from carpio fish intestine (Samosir, Suryanto, & Desrita, 2017), while other studies were able to isolate 16 probiotic colonies from shrimp intestine (Febrianti, 2011). Isolation of this probiotic colony mostly was from the intestine/gut of the animal samples. Most of these variety microorganisms play an important role in the digestive system, like produced enzymes (Sarastiti, Suminto, & Sarjito, 2020). In addition, the existing variety of microorganism was also able to compete with the growth of pathogenic bacteria and presumably increased animal immunity. With the normal digestive process, growth was affected, and the animal's development was the bacterial host (Samosir et al., 2017).

While those in plant parts, such as roots and skins of mangrove plants, 5 and 6 isolated

Table 1. Number of *Bacillus* sp. from isolation and selection tests

Source	Type of Isolat	Protease Test		Osmotic Stress Test		Pathogen Test	
		Non Proteolytic	Proteolytic	No growth on pH and salinity stress tests	Growth on pH and salinity stress tests	Pathogen	Non Pathogen
Water	12	1	11	7	4	4	0
Mud	22	4	18	16	2	2	0
<i>Sepia latimanus</i>	14	9	5	4	1	1	0
<i>Episesarma</i> sp.	11	5	6	3	3	2	1
<i>Scylla serrata</i>	13	2	11	9	2	2	0
<i>Tenualosa toli</i>	8	2	6	4	2	1	1
<i>Penaeus merguensis</i>	8	2	6	3	3	1	2
<i>Telescopium telescopium</i>	7	1	6	2	4	3	1
<i>Nerita violacea</i>	7	0	7	5	2	2	0
<i>Litopenaeus vannamei</i>	5	2	3	2	1	1	0
<i>Rhizopora</i> sp. root	5	2	3	2	1	1	0
<i>Rhizopora</i> sp. bark	6	1	5	4	1	1	0
<i>Mallotus villosus</i>	7	3	4	3	1	1	0
<i>Mugil</i> sp.	3	0	3	3	0	0	0
Number	128	34	94	67	27	22	5

Table 2. Morphology of isolat *Bacillus* sp. for the probiotic candidate

Isolat	Colony				Cell Morphology	
	Form	Edges	Elevation	Colors	Gram	Form
KPP212	Circular	Raised	Entire	White	+	Basil
IPI121	Circular	Convex	Entire	White	+	Basil
UJ131	Circular	Flat	Entire	White	+	Basil
UJ132	Circular	Convex	Entire	White	+	Basil
SB141	Irregular	Raised	Lobate	White	+	Basil

bacteria were found from each, the roots and skins of the mangrove plants were used since these parts of mangrove plants had to contact with mud and water, which presumably also contained bacteria which can be isolated, and had different characteristics with other bacterial colony found from animal samples. Yet, they had potential characteristic as probiotic candidates.

C. Cell Morphology

The morphology of isolate is correct bacteria, had a similarity, yet only the isolated colony's edge had a different shape (Table 2). In contrast, the cell morphology indicated the same shape and Gram stain, bacillus and positive Gram (Table 2 and Figure 3). Positive

Gram stain was indicated by the violet colour of the bacterial cell. The crystal violet was trapped in the thick cellular wall of bacteria with one layer membrane in which bacteria underwent dehydration and shrink after exposure to 96% alcohol (Samosir, Suryanto, & Desrita, 2017).

D. Proteolytic Test

Many different tests were given to the isolated bacteria colony. This caused drastic selection among them. Before the selection was given, 128 isolated bacteria were found, then, with proteolytic selection, 94 isolates were collected. Further selection was made based on the ability to deal with salinity and pH, the *Bacillus* sp. isolates were reduced to 27 isolates.

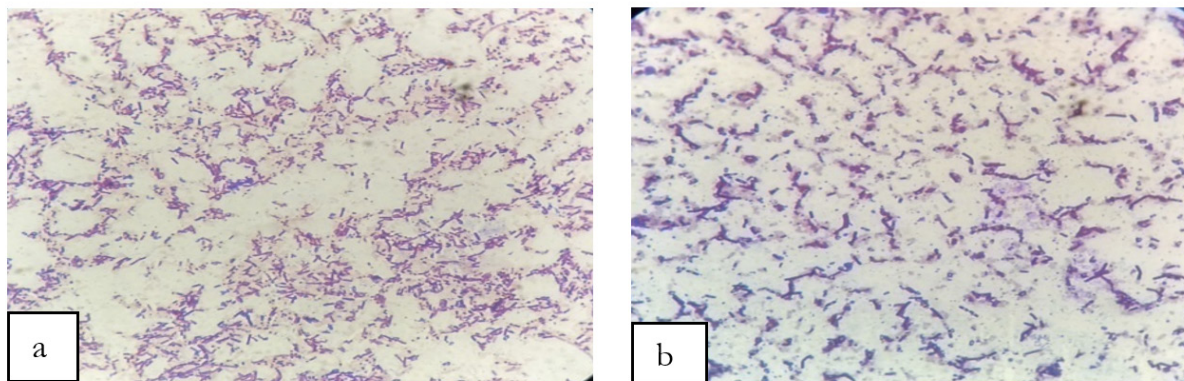


Figure 3. Cell morphology of isolat bacteria

Remarks: a. UJ132 and b. KPP212

Table 3. Proteolytic Index of isolat *Bacillus* sp.

Isolat	Area of Colony (cm ²)	Area of clear zone (cm ²)	Proteolytic Index
KPP212	0.50	1.22	2.44
IP121	0.94	2.11	2.24
UJ131	0.22	1.17	5.26
UJ132	0.56	1.67	3.00
SB141	0.72	1.94	2.69

The final selection was made for their ability to be pathogenic to ensure that the bacterial colony caused no harm if they were given probiotics. Characteristics of *Bacillus* sp. could be seen in Table 3.

The protein contained in shrimp feeds is approximately 30-40%. Therefore, proteolytic test was necessarily performed. All the isolated probiotic candidates indicated their ability to degrade casein from media, indicated by clear zone as hydrolysis process surrounding the isolated colony (Figure 3). This ability was also indicated by those colonies of probiotic candidates obtained from other studies (Samosir et al., 2017). The proteolytic ability of *Bacillus* sp. occurred since the bacteria produced protease (Hamtni, 2014). Protease, as the extra-cellular enzyme of *Bacillus* sp. can break the peptide bond of protein into oligopeptida and amino acids (Ilmiah, Nisa, & Budiasih, 2018).

A study on the potential of proteolytic bacteria from mangroves also has been observed by other researchers. Utomo et al.

(2019) succeeded in observing the protease enzyme-producing bacteria from the mangrove of Gunung Anyar, Surabaya. Two species of bacteria was obtained, namely *Yersinia enterocolotica* and *Enterobacter agglomerans*. The bacteria have been characterised as the proteolytic enzyme. Other researchers, Castro et al. (2014), isolated endophytic microorganisms from two mangrove species, *Rhizophora mangle* and *Avicennia nitida*. They found that mangrove microorganisms demonstrated a diverse range of enzymatic activities. The isolates produced enzymes of amylase, esterase, lipase, protease, and endoglucanase. In this study *Bacillus* sp. of proteolytic and non-pathogenic was observed as a potential probiotic.

All the collected isolate probiotic candidates showed different proteolytic index. The isolate bacteria with the highest proteolytic index was in code SB141, while the lowest was in code IP121. This different proteolytic index can be seen in each isolate bacteria's clear zone (Figure 4).

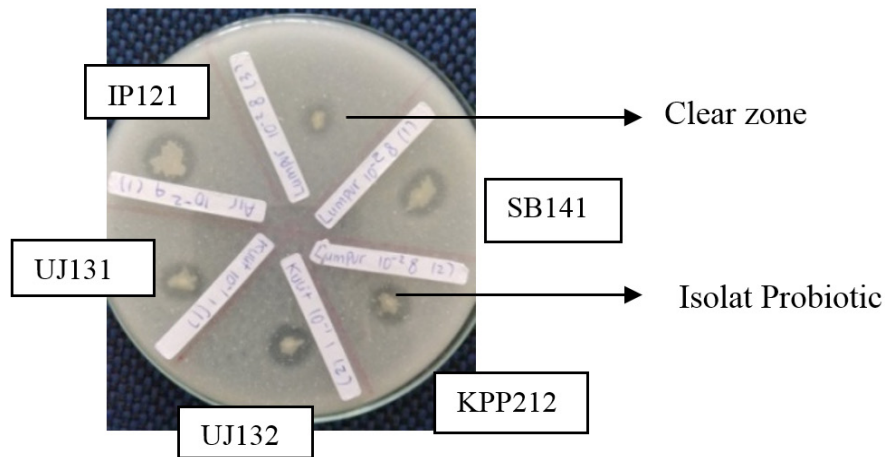


Figure 4. Illustration of the proteolytic index of *Bacillus* sp.

Remarks: Salinity and pH tests were conducted to elucidate selected isolate probiotic candidates' ability from different salinity and pH stresses of media. Isolate with codes of KPP212, IPI21, UJ131, UJ132 and SB141 survived and grew in salinity of 0%, 3%, and 6% and with pH of 4, 7, and 10

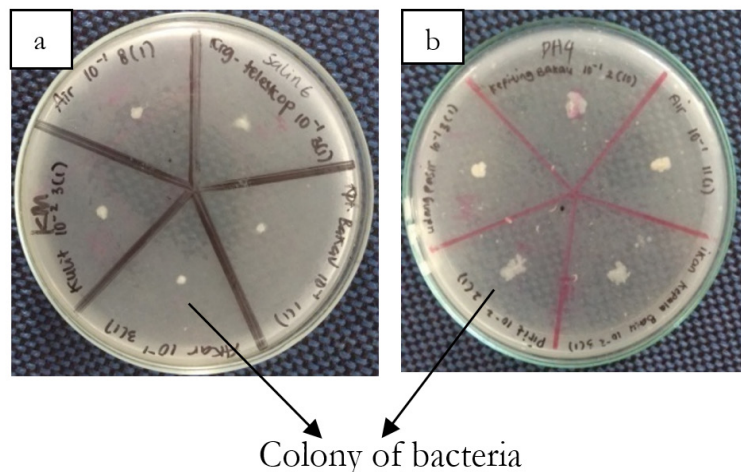


Figure 5. Colony of bacteria under saline 6% (a) and pH 4 (b)

Salinity and pH tests were conducted to elucidate selected isolate probiotic candidates' ability from different salinity and pH stresses of media. Isolate with codes of KPP212, IPI21, UJ131, UJ132, and SB141 survived and grew in salinity of 0%, 3%, and 6% and with pH of 4, 7, and 10.

E. Bacteria Characterisation

The five isolated bacteria produced protease and survived in a different range of pH (4–10) and different salinity (0–6%) (Figure 5);

meanwhile, their hemolysis activity was in gamma hemolysis or non-pathogenic activity. All the isolated ones also indicated non-motile, and only isolated with code UJ132 had positive catalase activity from biochemical tests. In contrast, in the sugar fermentation test, all isolated ones had positive results in all different types of sugar used for the test.

The ideal of probiotic is survival in many different stress conditions; therefore survival test was conducted. Isolates of KPP212, IPI21, UJ131, UJ132 and SB141 indicated that they

can survive and grew very well in pH and salinity stress (Figure 4).

This ability to survive was similar to those found by another study (Triyanto, Isnansetyo, Prijambada, Widada, & Tarmiawati, 2009) was isolated from the mangrove's mud. This bacteria colony's survival from different stress of pH and salinity presumably showed that this colony was used to environmental stress, unstable condition, which is very common in estuary ecosystem (Hutabarat, 2000).

Pathogenic or virulent isolates was determined by the degree of clear zone media produced by the isolates. All the isolates probiotic candidates had γ (Gamma) hemolysis characteristic (Table 4). Blood agar as differentiates media was used to determine bacteria's ability to lyse red blood cells (RBCs) (Hamtini, 2014). The ability of bacteria to lyse RBCs was done by extra-cellular protein produce called haemolysin (Khusnan, Dwi, & Agus, 2018). Pathogenetic in RBCs was defined into three levels, alpha hemolysis, betha hemolysis and gamma hemolysis. Alpha hemolysis occurred when RBCs and hemoglobin were partly lyzed, betha hemolysis occurred when all RBCs and hemoglobin were lyzed, causing the surrounding media to clear. Gamma hemolysis occurred when there was no

lysis for both RBCs and hemoglobin, causing no colour change in media (Hamtini, 2014).

In the sugar fermentation test, all of the isolates colony indicated positive fermentation test for sugars such as lactose, mannose, mannitol, glucose and sucrose (Table 4), indicated by the formation of yellow colour media. The change in media colour occurred since fermentation caused acidity of the media in which, by using phenol red as an indicator, it turned to yellow. Acids released in media was produced from the breaking down of sugar by bacteria. In the motility test, all isolates indicated negative results, shown by the bacteria colony's undispersed growth in their media (Damayanti, Oom, & Effendi, 2018).

A catalase test was done to determine the ability of the isolates colony to produce catalase enzyme. A positive result was shown from the UJ132 isolate, while KPP212, IP121, UJ131, and SB141 isolates indicated negative results (Table 4). A positive result was indicated by an oxygen bulb from mixing of H_2O_2 with isolate bacteria, indicating that catalase enzyme was produced by bacteria and used to break hydrogen peroxide in water and oxygen. Hydrogen peroxide was a compound that interferes with intracellular enzyme activity (Yulvizar, 2013).

Table 4. Bacteria isolated characterisation

Isolat	Pr	Stress on						Mo	K	Sugar fermentation					Pa Hemolysis		
		Stress on pH			Salinity (%)					Ms	G	S	L	Mt	α	β	γ
		4	7	10	0	3	6										
KPP212	+	+	+	+	+	+	+	-	-	+	+	+	+	+	-	-	+
IP121	+	+	+	+	+	+	+	-	-	+	+	+	+	+	-	-	+
UJ131	+	+	+	+	+	+	+	-	-	+	+	+	+	+	-	-	+
UJ132	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	-	+
SB141	+	+	+	+	+	+	+	-	-	+	+	+	+	+	-	-	+

Remarks :

- = no reaction/no growth
- + = reaction/ growth
- G = Glucose
- K = Catalase
- Mo = Motility
- Mt = Mannitol
- Pr = Protease
- α = partial hemolysis
- β = total hemolysis
- γ = no hemolysis
- L = Lactose
- Ms = Mannose
- Pa = Pathogenic test
- S = Sukrose

IV. CONCLUSION

This study found about 128 isolated *Bacillus* sp. from intestinal mangrove biota in Lampung Mangrove Center, such as shrimp, mollusc, fish, and crabs from which 94 isolated *Bacillus* sp. had proteolytic characters, and 5 of them have very good potentials as a probiotic candidate. The five probiotics were: *Bacillus* sp. KPP212 collected from climbing crab, *Bacillus* sp. IP121 collected from fish, *Bacillus* sp. SB141 collected from the mollusc, *Bacillus* sp. UJ131 and *Bacillus* sp. UJ132 collected from shrimp. Diversity of *Bacillus* sp. and biota are found in various types. Therefore, the mangrove of Margasari of Lampung is very important to conserve.

ACKNOWLEDGEMENT

This study was fully supported and funded by the Coastal and Marine Research Center of the University of Lampung.

REFERENCES

- Anggriani, R., Iskandar, & Ankiq, T. (2012). Efektivitas penambahan *Bacillus* Sp. hasil isolasi dari saluran pencernaan ikan patin pada pakan komersial terhadap kelangsungan hidup dan pertumbuhan benih ikan nila merah (*Oreochromis niloticus*). *Jurnal Perikanan dan Kelautan*, 3(3), 75-83.
- Aryal S. (2015). Haemolysis of streptococci and its types with examples. Retrieved from <https://microbiologyinfo.com/haemolysis-of-streptococci-and-its-types-with-examples>, on April 2018.
- Castro R. A., Dourado M. N., de Almeida J. R., Lacava P.T., Nave A., de Melo I. S., de Azevedo J. L., & Quecine, M. C. (2018). Mangrove endophyte promotes reforestation tree (*Acacia polyphylla*) growth. *Braz. Journal Microbiol* 49(1), 59-66 doi://10.1016/j.bjm.2017.04.002.
- Castro R. A., Quecine M. C., Lacava P. T., Batista B. D., Luvizotto D. M., Marcon J. Ferreira A., Melo I. S., & Azevedo J. L. (2014). Isolation and enzyme bioprospection of endophytic bacteria associated with plants of Brazilian mangrove ecosystem. *Springer Plus*, 3, 382 Retrieved from <http://www.springerplus.com/content/3/1/382>, on the 1st December 2020
- Damayanti, S. S., Oom, K., & Effendi, E. M. (2018). Identifikasi bakteri dari pupuk organik cair isi rumen sapi. *Ekologia: Jurnal Ilmiah Ilmu Dasar dan Lingkungan Hidup*. 18(2), 63-71.
- Deivanai S., Bindusara A. S., Prabhakaran G., & Bhore S. J. (2014). Culturable bacterial endophytes isolated from mangrove tree (*Rhizophora apiculata* Blume) enhance seedling growth in Rice. *Journal of Natural Science, Biology and Medicine*. 5(2): 437-444. doi:// 10.4103/0976-9668.136233.
- Febrianti, D. (2011). *Efektivitas probiotik asal usus udang dalam menghambat pertumbuhan vibrio harveyi pada larva udang vaname (Litopenaeus vanname)*. (Skripsi). Institut Pertanian Bogor.
- Hamtini. (2014). *Isolasi dan Karakterisasi Bacillus sp. dari ikan lele (Clarias sp.) serta potensinya sebagai probiotik*. (Tesis). Institut Pertanian Bogor.
- Hamzah T. N. T., Lee S. Y, Hidayat A., Terhem R., Hanum I. F., & Mohamed R. (2018). Diversity and characterisation of endophytic fungi isolated from the tropical mangrove species, *Rhizophora mucronata*, and identification of potential antagonists against the soil-borne fungus, *Fusarium solani*. *Frontiers in Microbiology*. 9(Article 1707).
- Handayani, H. (2011). Optimalisasi substitusi tepung azolla terfermentasi pada pakan ikan untuk meningkatkan produktivitas ikan nila gift. *Jurnal Teknik Industri*. 12(2), 177-181 doi://10.22219/JTIUMM.Vol12.No2.177-181.
- Hapsari, T., Tjahjaningsih W., Alamsjah M. A., & Pramono H. (2016). Aktivitas enzimatis bakteri proteolitik asal gastrointestinal udang vannamei (*Litopenaeus vannamei*). *Journal of Marine and Coastal Science*. 5 (3), 109-118.
- Hutabarat, S. (2000). *Produktivitas perairan dan plankton telaah terhadap ilmu perikanan dan kelautan*. Semarang: Badan Penerbit Universitas Diponegoro.
- Ilmiah, S. N., Nisa, R. M., & Budiasih, W. (2018). Characterisation of Protease from *Bacillus licheniformis* F11.1 as a bio-detergent agent. *Makara Journal of Science*, 22(3), 105-112.
- Kariada, N., & Andin, I. (2014). Peranan mangrove sebagai biofilter pencemaran air wilayah tambak bandeng tapak, Semarang. *Jurnal Manusia dan Lingkungan*, 21(2), 188-194.

- Kementrian Kehutanan. (2014). *Pengelolaan hutan mangrove dan ekosistem pantai*. sintesis hasil litbang 2010-2014. Pusat Penelitian dan Pengembangan Konservasi dan Rehabilitasi. Badan Penelitian dan Pengembangan Kehutanan.
- Kepel, B. J., Widdhi, B., & Fatimawali. (2020). Pengaruh pH dan suhu terhadap aktivitas pereduksi merkuri bakteri resisten merkuri tinggi *Bacillus cereus* yang diisolasi dari urin pasien dengan amalgam gigi. *e-GiGi*. 8 (1), 15-21.
- Khusnan, Dwi, K., & Agus, P. (2018). Deteksi hemaglutinin, hemolisin dan koagulasi secara fenotipik dan genotipik pada *Staphylococcus aureus* isolat asal broiler. *Jurnal Sains Veteriner*, 36(1), 103-114.
- Maulani B. I. G., Rasmi D. A. C., & Zulkifli L. (2019). Isolation and characterisation of endophytic bacteria from mangrove *Rhizophora mucronata* Lam. and antibacterial activity test against some pathogenic bacteria. *4th Annual Applied Science and Engineering Conference Journal of Physics: Conference Series* doi://10.1088/1742-6596/1402/3/033038.
- Muliani, M., Nurbaya, N., Arifudin, T., & Muharijadi, A. (2017). Eksplorasi bakteri filosoffer dari tanaman mangrove sebagai bakteri probiotik pada budidaya udang windu, *Penaeus monodon*. *Jurnal Penelitian Perikanan Indonesia*. 10(2), 47-57.
- Pratiwi, I., Rahayu, K., & Wahyu, T. (2013). Eksplorasi bakteri kandidat probiotik di lumpur hutan mangrove Wonorejo. *Jurnal Ilmiah Perikanan dan Kelautan*, 5(2), 187-192.
- Rahmawan, Mohamad, E. A., Suminto, & Herawati V. E. (2014). Penggunaan bakteri kandidat probiotik pada pakan buatan terhadap efisiensi pemanfaatan pakan, pertumbuhan dan kelulushidupan lele dumbo (*Clarias gariepinus*). *Journal of Aquaculture Management and Technology*, 3(4), 257-264.
- Samosir, M. F., D. Suryanto, and Desrita. (2017). Isolasi dan identifikasi bakteri potensial probiotik pada saluran pencernaan ikan mas (*Cyprinus caprio*). *Jurnal Aquacoastmarine*, 5(1), 1-14.
- Sarastiti, S., Suminto, & Sarjito. (2020). Identifikasi molekuler spesies bakteri kandidat probiotik yang diisolasi dari usus udang vaname (*Litopenaeus vannamei*) koleksi dari Kabupaten Subang, Jawa Barat. *Jurnal Pasir Laut*, 4, 1-9.
- Scharler, U. M. (2011). Whole food-web studies: Mangroves. *Treatise on Estuarine and Coastal Science*. 6, 271-286.
- Seprianto, Feliatra, & Nugroho, T. T. (2017). Isolasi dan identifikasi bakteri probiotik dari usus udang windu (*Penaeus monodon*) berdasarkan sekuens gen 16S rDNA. *Biogenesis*, 5(2), 83-92.
- Sinatryani, D., Moch, A. A., Sudarno, and Kustiawan, T. P. (2014). Kelimpahan bakteri selulolitik di muara sungai Gunung Anyar Surabaya dan Bancaran Bangkalan. *Jurnal Ilmiah Perikanan dan Kelautan*, 6 (2), 143-148.
- Subagiyo, Sebastian, M., Triyanto, & Wilis, A. S. (2015). Pengaruh pH, suhu dan salinitas terhadap pertumbuhan dan produksi asam organik bakteri asam laktat yang diisolasi dari intestinum udang penaeid. *Ilmu Kelautan*. 20 (4), 187-194.
- Subagiyo, Muhammad, S. R. D., & Wilis, A. S. (2017). Potensi ekosistem mangrove sebagai sumber bakteri untuk produksi protease, amilase, dan selulase. *Jurnal Kelautan Tropis*, 20 (2), 106-111.
- Suhendar, D., Esti, S., & Asep, S. (2019). Lumpur hitam tanah rawa hutan mangrove Karangsong (Kabupaten Indramayu): Komposisi kimia dan transformasi fasa yang dihasilkan melalui penanganan secara termal. *Jurnal Riset Geologi dan Pertambangan*, 29(2), 127-139.
- Sumardi, Farisi S., Ekowati C. N., Arifiyanto A, & Rahmawati, D. E. (2020). Halotolerant *Bacillus* sp. for mannan degradation isolated from mangrove ecosystem at Hanura Beach Lampung. *Journal of Pure and Applied Microbiology (JPAM)*, 14(2), 1237-1244.
- Sumardi, Farisi S., Ekowati C. N., & Hairisah S. F. (2019). Karakterisasi Enzim Xilanase dari isolat *Bacillus* sp. UJ131 di hutan mangrove Margasari Lampung Timur sebagai kandidat probiotik. *Oseanologi dan Limnologi di Indonesia*, 4(3), 167-174. doi://10.14203/oldi.2019.v4i3.201.
- Sumardi, Agustrina R, Ekowati C. N., & Pasaribu Y. S. (2018). Characterisation of protease from *Bacillus* sp. on medium containing FeCl₃ exposed to magnetic field 0.2 mt. *IOP Conference Series: Earth and Environmental Science*, 130. 012046 doi://10.1088/1755-1315/130/1 /012046.
- Supriyadi, T. H., and Koesharyani, I. (2008). Survey of viral diseases of pacific white shrimp,

- Litopenaeus vannamei* in indonesia. *Indonesian Aquaculture Journal*, 3(1), 59-68.
- Tensiska. (2008). Probiotik dan prebiotik sebagai pangan fungsional. Universitas Pajajaran, Bandung.
- Triyanto, A., Isnansetyo, I. D., Prijambada, Widada J., & Tarmiawati A. (2009). Isolasi, karakterisasi dan uji infeksi bakteri proteolitik dari lumpur kawasan hutan bakau. *Jurnal Perikanan*, 11(1), 13-18.
- Utomo P. B., Sudarno & Rahardja B. S.. (2019). Identification of proteolytic bacterial isolates in sediment ecosystem of Gunung Anyar Mangrove forest, Surabaya. The 1st International Conference on Fisheries and Marine Science. *IOP Conference Series: Earth and Environmental Science*. IOP Publishing doi://10.1088/1755-1315/236/1/012060.
- Widiastuti, E. L., Arifianti, R., Khairani, I.A., Christianto, Y., Ara, N. F., & Maharani, H.W. (2019). Antioxidant effect of *Clerodendrum* sp. and *Acanthus illicifolius* methanol extraction on blood profile of male mice induced by Benzo(α)pyrene. *IOP Conference Series: Earth and Environmental Science*, 305 <https://iopscience.iop.org/article/10.1088/1755-1315/305/1/012011>.
- Yulvizar, C. (2013). Isolasi dan identifikasi bakteri probiotik pada *Rastrelliger* sp. *Biospecies*, 6(2), 1-7. Retrieved from <https://online-journal.unja.ac.id/index.php/biospecies/article/view/884>, on May 18th 2020.

REVIEW ASSESSMENT OF BIODIVERSITY LOSS OF SUNDARBAN FOREST: HIGHLIGHTS ON CAUSES AND IMPACTS

Md. Shohel Khan^{1*}, Shahriar Abdullah¹ Mohammed Abdus Salam¹ Tanwee Rani Mandal²,
and Md. Rajib Hossain³

¹Department of Environmental Science and Disaster Management, Noakhali Science and Technology University, Noakhali-3814, Bangladesh

²Department of Geography and Environment, Govt. Sundarban Adarsha College, Khulna, Ministry of Education, Bangladesh

³Department of Environmental Science and Disaster Management, Bangabandhu Sheikh Mujibur Rahman Science and Technology University, Gopalganj-8100, Bangladesh

Received: 22 August 2019, Revised: 21 April 2021, Accepted: 22 April 2021

REVIEW ASSESSMENT OF BIODIVERSITY LOSS OF SUNDARBAN FOREST: HIGHLIGHTS ON CAUSES AND IMPACTS. Sundarban, the world biggest mangrove forest, was announced as a World Heritage in 1997 and Ramsar Site in 2007. Its 62% lies in Bangladesh (Khulna, Bagerhat, Satkhira, Pirojpur, and Barguna Regions) and 38% in India, that become a vanguard for coastal communities. This ecosystem's floral and faunal structure incorporates 334 floral, 300 birds, 120 fish, 35 reptiles, and 32 mammals species. It contributes 41% of the total forest income of Bangladesh. This paper is intended to recognize the significant reasons for biodiversity calamity and its related effects on lives and degradation of the environment. A total of 105 published articles and reports were identified by searching four keywords: *degradation*, *biodiversity*, *Sundarban*, and *Bangladesh*. By considering the scope, 28 articles and 17 reports were incorporated to satisfy the objectives. The study revealed that the prominent causes of biodiversity loss of Sundarban might be due to intensified shrimp cultivation, increased dependency on forest and illicit felling, changing land use pattern, oil spillage, and pollution, forest fire, improper management practices, plant diseases, tourism activities, upstream withdrawal of river water, salinity intrusion, climate change, and some natural causes. The impacts were the loss of diversity of floral and faunal species subjected to regionally extinct, critically endangered, endangered, vulnerable, near threatened, and least concern condition. Occupational change and deterioration of the quality of life of surrounding communities are identified as impacts. Finally, the study recommended the formulation of a special mangrove forest policy and proper management practices of Sundarban with several environmental protection strategies that should be adopted to conserve this unique ecosystem.

Keywords: Mangrove forest, environmental instability, environmental protection, shrimp farming

TINJAUAN PENILAIAN HILANGNYA KEANEKARAGAMAN HAYATI HUTAN SUNDARBAN: PENYEBAB DAN DAMPAK. Sundarban merupakan hutan bakau terbesar di dunia dan telah diumumkan sebagai Warisan Dunia pada tahun 1997 dan Situs Ramsar pada tahun 2007. Sebanyak 62% terletak di Bangladesh (Wilayah Khulna, Bagerhat, Satkhira, Pirojpur, dan Barguna) dan 38% di India, yang menjadi perintis bagi masyarakat pesisir. Struktur flora dan fauna ekosistem ini mencakup 334 flora, 300 burung, 120 ikan, 35 reptil, dan 32 spesies mamalia. Sundarban menyumbang 41% dari total pendapatan hutan Bangladesh. Tulisan ini bertujuan mempelajari dampak nyata berkurangnya keanekaragaman hayati dan pengaruhnya pada kehidupan dan degradasi lingkungan. Sebanyak 105 artikel dan laporan yang diterbitkan diidentifikasi berdasarkan empat kata kunci: degradasi, keanekaragaman hayati, Sundarban, dan Bangladesh. Dengan mempertimbangkan ruang lingkupnya, 28 artikel dan 17 laporan dimasukkan untuk memenuhi tujuan. Hasil penelitian mengungkapkan bahwa penyebab utama hilangnya keanekaragaman hayati di Sundarban disebabkan oleh peningkatan budidaya udang, peningkatan ketergantungan pada hutan dan penebangan liar, perubahan pola penggunaan lahan, tumpahan minyak dan polusi, kebakaran hutan, praktik pengelolaan yang tidak tepat, penyakit tanaman, kegiatan pariwisata, pengambilan air sungai di hulu, intrusi salinitas, perubahan iklim, dan beberapa penyebab alami. Dampaknya adalah hilangnya keanekaragaman jenis flora dan fauna yang terancam punah secara regional, terancam punah, hampir

*Corresponding author: sajibicb@gmail.com

punah, rentan, terancam, dan kondisi paling tidak mengkhawatirkan. Perubahan pekerjaan dan penurunan kualitas hidup masyarakat sekitar diidentifikasi sebagai dampak. Hasil studi merekomendasikan perumusan kebijakan khusus hutan bakau dan praktik pengelolaan Sundarban yang tepat dengan beberapa strategi perlindungan lingkungan yang harus diadopsi untuk melestarikan ekosistem yang unik ini.

Kata kunci: Hutan Bakau, instabilitas lingkungan, perlindungan lingkungan, tambak udang

I. INTRODUCTION

Bangladesh covers a total of 14.75 million ha (Hossain, Ahmed, Azad, & Hasan, 2020), of which approximately 13.5 million ha are land surfaces and 0.94 million ha are rivers and various inland water bodies (Islam, 2005). Sundarban is the largest and oldest systematically managed mangrove forest (Chakravorty & Ghosh, 2018) that stretches over Bangladesh and India. It covers the vicinity of 0.6 million ha (4.07% of the total area of Bangladesh) represents a unique ecosystem. It is the most economically precious and the richest natural forest in Bangladesh. Sundarban constitutes around 51% of the total reserved forest and contributes around 41% of the forest income. In 1997, the area was declared as World Heritage Site by UNESCO, and in 2007 the Sundarban was perceived as a Ramsar Wetland Site by Ramsar Convention. Around one million individuals procure their business from the forest (Khulna University, 2001; Islam & Bhuiyan, 2018).

The forest secures land on the coast against interruption by saltiness from the ocean (Iftekhara & Islam, 2004). Evidence advocate that the ecosystem is under stress and showing signs of depletion. The anthropogenic impact on mangroves has quickened unexpectedly over the last decades. Mangroves are feeling the squeeze by numerous dangers, for example, human infringement, shrimp cultivation and different kinds of aquaculture, farming, diseases, catastrophic events and regular changes in hydrology, ocean level ascent, and inadequate recovery. Furthermore, there have been impacts of mis-management and corruption because of the improvement of the two most basic ocean ports at Mongla and Chattagram (Rahman, Mohammed, Rahman, & Islam, 2010). This

paper studies the factor that causes biodiversity loss of the Sundarban, weakening of mangrove timberland, and evaluates the impacts on species and lives.

II. MATERIAL AND METHOD

A. Method

The systematic assessment coordinated evaluation of the biodiversity loss and debasement of the world biggest mangrove forest, the Sundarban in Bangladesh. The articles and reports had been identified through online search from different search engine. "Degradation", "Biodiversity", "Sundarban", and "Bangladesh" were used as keywords to find journal articles and reports. A total of 105 papers were found, but after removing duplications and irreverent articles and reports, 28 journal articles and 17 reports were incorporated for this study (Figure 1). Some secondary data were added from Bangladesh Bureau of Statistics (BBS), Food and Agriculture Organization (FAO), United Nations Environment Program (UNEP), United Nations Framework Convention on Climate Change (UNFCCC), Intergovernmental Panel on Climate Change (IPCC) and Non-governmental Organization (NGO) publications

B. Study Site

The Sundarban is shaped with several islands from freshwater commanded streams by utilizing the sediment deposition by the Ganga, Brahmaputra, and Meghna (GBM) river systems. The total area of this forest is 1,000,000 ha, of which 62% is in Bangladesh, lies between 89°00'-89°55'E longitude and 21°30'-22°30'N latitude (Figure 2), and 38% lies in India. The total Sundarban area of Bangladesh is 599.330

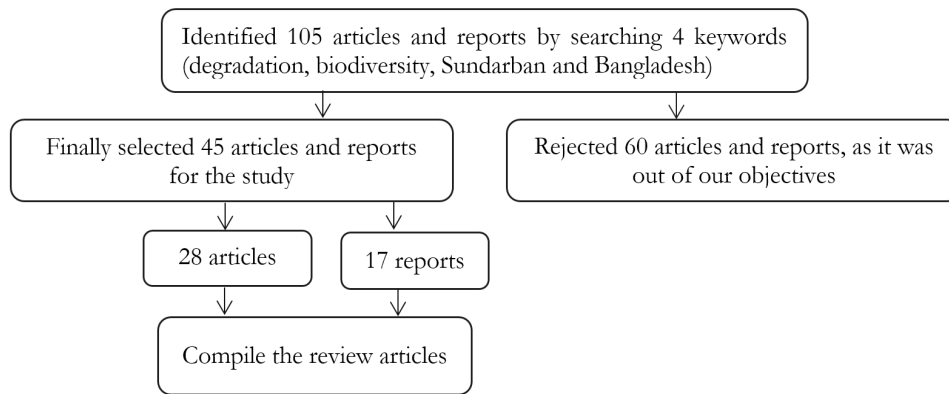


Figure 1. Review processes for this study

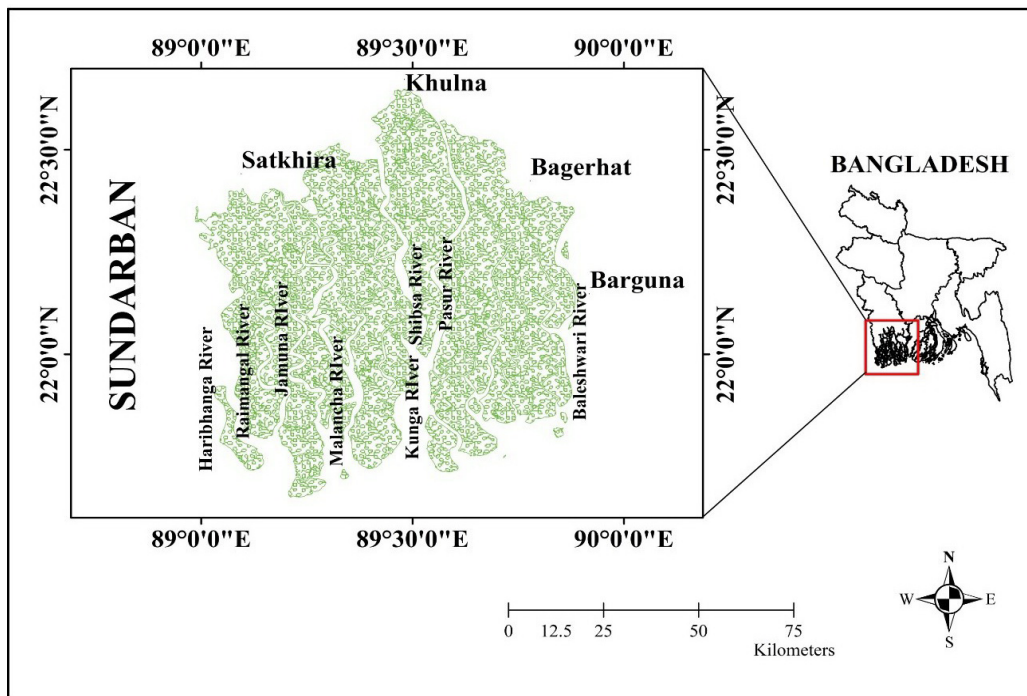


Figure 2. Map of the study area

ha consists of about 400 tidal rivers, canals and 200 islands (Banglapedia, 2010; Islam & Bhuiyan, 2018). The maximum elevation of the Sundarban is 10 m above sea level, and it has high clay, soil.

The saltiness of Sundarban increases from north to south and east to west, and the vegetation diminishes from these bearings. It was proclaimed as *Reserve Forest* in 1875-76 and placed under Forest Department (FD) for management (Rahman, 2000). The place's

climate is characterized by relatively excessive temperature and humidity at some point of the year and well-dispersed rainfall during the monsoon season. Temperature varies from a minimum of 2 to 4°C to a maximum of 32 to 43°C (Agrawala, Ota, Ahmed, Smith, & van Alst, 2003; Gopal & Chauhan, 2006). The Sundarban mangrove forest represents around 50% of the country's protected area, and around 2 million people are directly or indirectly relying upon its resources.

III. RESULT AND DISCUSSION

A. Causes of Degradation of Sundarban Mangrove Ecosystem

The forest is the most complex environment on the planet (Rahman, Mahabubur, Chongling, Islam, & Haoliang, 2009). Over the top, asset extraction and ignoring replanting were the key reasons for the reduced supply of consumer goods for the development of Sundarban forest (Ali, Kabir, & Hoque, 2006). The total area of the Sundarban forest has been reduced from 20.3 to 10.9 million ha from 1959 to 1996 (FAO, 2000). The reasons for the crumbling of the Sundarban mangrove forest biological system is depicted below.

1. Increased Shrimp Farming Practices

The swiftly increasing shrimp farming enterprise possesses the impact on deteriorating the mangrove forests in Bangladesh. Moreover, mangroves have been used for fishing, shrimp farming, crabs farming, and mainly huge *Penaeus monodo* (tiger prawn) farming (Islam & Bhuiyan, 2018). The entire vicinity under brackish water shrimp farming was increased from 51,812 to 2,17,000 ha in 1984-2008 in the coastal areas of Bangladesh (Miah et al., 2010). During shrimp cultivation, individuals utilized urea, which mixed with salty water, resulted in the degradation of the aquaculture lakes of Bangladesh that preserving the wastewater of Sundarban.

2. Increased Over-dependency of the Population and Illegal Forest Cutting

The increased population has been recognized as extra stress on the Sundarban mangrove forest environment, and it accelerates the degradation of forest resources and their production. Over-extraction of forest resources to meet the demand of growing requirements of humans being another important factor for decreasing the Sundarban. It has been over-exploited for timber, fuelwood, bark tannin, animal fodder, native medicines, and food (fish, shellfish, honey and wild animals) for decades to centuries.

3. Oil Spillage and Pollution

Oil spillage is an extreme risk for damaging aquatic species and unfavourable for sea birds in the mangrove forest region. Contamination arises from oil tanker cargo accidents because Mongla Seaport is situated just 3 km away from the Sundarban, and about 1,500-1,600 vessels and 12,000-13,000 cargo ships (Rahman et al., 2009) used the internal river routes of this forest. In 2014, an oil tanker carrying 358,000 litres of furnace oil collided with a cargo vessel and sank in the *Shalla* river, resulting in that oil spread over 2,000 ha of the Sundarban (The Daily Star, 2014). Bangladesh imported approximately 1.2 and 0.5 million heaps of crude oil and refined oil annually, which is frequently shipped by small tankers (Islam & Bhuiyan, 2018). Contamination occurred from these vessels from unintentional spillage. The oil connected to the leaf can block up stomata and have a negative impact on photosynthesis, respiration, and water metabolism of the mangrove plant life cycle (Peng & Qin, 2000). Mechanical improvement, industrial farming practice and aquaculture near the Sundarban stream bowls, expanded populace attempted to modernize privates in coastal zones, had prompted extensive amounts of waste, squander water and poisons released to the mangrove wetland (Rahman et al., 2009).

4. Fire

Fire can likewise have achieved probably the most genuine harm to the mangrove environment in recent years. On March 20, 2010, around 250 ha habitat of plants and wild lives had been wrecked through fire. In 2007-2010, 12 incidents of fires happened in the Sundarban (MoEF, 2010). The Sundarban occupies a few shrubs that produce abundant nectar and pollen, and these shrubs are utilized by honey bees (Rahman et al., 2010). To collect honey from the nest, individuals set up a fire to displace the bees, and as a result, this could create a forest fire.

5. Management Failure

Area of forest, diversified species and ecosystem characteristics has decreased, even though different forest policies, legal frameworks and plans have been enacted to guard them. The effectiveness of these policies and plans is restrained with the aid of a negative implementation ability (Iftekhhar & Islam, 2004). The lack of professionals, skilled officers; failure of institutions to effectively manipulate coastal mangrove sources; conflicting activities, negative planning, and aptitude of coastal land use; the non-execution of progress plan was the real reasons mangrove forest administration's disappointment. However, negligence and corruption amongst the personnel of authorities and forest department alongside the collaboration of neighbourhood's political leaders with the encroachers add to the administration's failure (Akhtaruzzaman, 2004; Rahman et al., 2010). However, governmental bodies tried to undertake pure conservation planning initiatives from 1960 to 2001. Although, Environmental policy, national conservation strategy and national environmental management active plan are aiming to protect mangrove ecosystems, but management strategies based totally on logical and scientific establishment have not been created until today (Islam & Wahab, 2005). At last, the national forest policy 2016 was finally prepared to protect the forest of Bangladesh.

6. Plant Diseases

Top dying, a dominant disease of *Heritiera fomes*, is one of the major causes of the deterioration of the forest. More than 5-6% of the entire *Heritiera fomes* are now suffering from top dying, and half of them have already

been affected due to salinity intrusion. Islam and Wahab (2005) showed that about 70% of *Heritiera fomes* stems were severely affected by top dying diseases.

7. Upstream Withdrawal of River Water and Salinity Intrusion

Sundarban mangrove forest acquires freshwater discharge typically from the flow of the Ganges River (Rahman et al., 2017). Stream of Ganges, Brahmaputra, and Meghna rivers were the primary wellsprings of freshwater in Bangladesh (Rahman, Islam, & Rume, 2016). India built the Farakka barrage upstream of the Ganges River in 1974. The unilateral withdrawal of water from the Ganges induced a large discount in the discharge of Ganges through Bangladesh. The average month-to-month water going through dry season used to be 2,674 cubic meters per second (cumecs) from 1935–1975, which went down to 1,871 cumecs from 1975–2004, showing about a 30% decrease at some phase in the post-dam period. After 1975, the pattern was modified due to the diversion of water at Farakka Barrage in India, simply 17 km upstream from Bangladesh (Mirza, Warrick, Ericksen, & Kenny, 1998). As a result of the regeneration of *Heritiera fomes*, the dominant timber species of Sundarban has decreased in the southwestern region (Paul, Ray, Kamila, & Jana, 2017). It affects the excessive salinity affected area (Table 1). The percentage of salinity stress concerning the number of days is in (Islam & Gnauck, 2011) and incorporated in Table 2.

8. Natural Causes

Various natural calamities like cyclone, flood, storm surges, coastal bank erosion, naturally

Table 1. Salinity rate of various areas of Sundarban

Coverage area (ha)	Coverage area (%)	Salinity (dS/m*)
4813.60	80	>2415
421.19	7	21610-32415
421.19	7	10805-21610
361.02	6	<10805

Remarks: *dS/m represents decisiemens per meter, Source: Islam and Gnauck (2011)

Table 2. Salinity stress during 2001–2002 inside the Sundarban

Duration (days)	Percentage of area (%) under different salinity (dS/m) level						Area (percent)
	>54,025 (dS/m)	43,220-54,025 (dS/m)	32,415-43,220 (dS/m)	21,610-32,415 (dS/m)	10,805-21,610 (dS/m)	<10,805 (dS/m)	
120	0	25	28	19	15	13	100
90	6	31	28	15	14	6	100
60	6	31	28	15	15	5	100
45	28	30	17	11	10	4	100
30	29	30	17	11	9	4	100
15	29	30	17	11	9	4	100

Source: Islam & Gnauck (2011)

shifting hydrology, and climate change would destroy trees and animals faster. The damage to Sundarban precipitated through the latest cyclone *Sidr* (hit on 15 November 2007) has been preliminarily assessed at \$142.9 million (Saadi, 2010). A document by UNESCO, entitled *Case Studies on Climate Change and World Heritage*, has referred to that as an anthropogenic 45 cm ascent of sea-level liable to occur with the asset of the quilt of the 21st century. Following IPCC, mixed with different sorts of anthropogenic stress on the Sundarban might also want to lead to the destruction of 75% of the forest (UNESCO, 2007). Rising seas are stated to have flooded 7,500 ha of mangroves in the Sundarban (WWF, 2007).

B. Impacts on Mangrove Forest

1. Biodiversity Loss of Sundarban Mangrove Forest

The Sundarban, the biggest chunk of swamp mangrove forest, was underneath the ocean around 4,000 years ago (Ali, 1994). Pedologically, the forest's soil is young, inadequately depleted with uncured deposits having no distinct horizon. It bolsters above 245 to 300 genera species of flora, above 120 species of fish, 35 species of reptile, more than 300 species of birds, and 32 species of mammals (IUCN, 2001). Chaffey et al. (1985) recorded around 334 plant species, which comprises 35 vegetables, 29 types of grass, 19 sedges, 18 euphorbia, and 50 mangrove plant species (Table 3). It has mentioned that

mangrove forests were the territories of 500 species of wild vascular plants. In understanding FAO gauges, the Sundarban mangrove forest is home to around 840 species of wild creatures, including Royal Bengal tigers. More than 120 species were noted to be caught by fishermen (Rahman et al., 2010).

Sundarban has an extraordinarily rich diversity of aquatic and terrestrial flora and fauna. But the quantity is reducing continuously. The preoccupation of the normal courses of waterways, development of banks, dams; extensions in the upstream; diminished buoy of freshwater in the streams brought about the expansion in the degree of saltiness; over-salting in numerous spots caused consequent adjustments in the mangrove biological community (Rahman, 2015). Both natural and anthropogenic causes are responsible for the biodiversity loss of Sundarban. Several species have been regionally extinct from Sundarban, and many more are critically endangered, endangered, vulnerable, near threatened, and least concern species from Sundarban. The details are shown in Table 4.

2. Economical Loss

Economically, Sundarban produces raw materials for privates (fuelwood, furniture, house construction, charcoal, match sticks, and newsprints) and public goods (air, natural beauty, fisheries, and navigation). Up until this point, distinctive techniques have been created for the better utilization of private

Table 3. The wildlife species of Bangladesh Sundarban

Fauna species	Number umber	Flora species	Number
Fish	177 ² , /120 ⁷	Plants	334/300 ^{8,9}
Amphibians	8 ^{4,6} /11 ²	Mangrove	50 ^{8,9}
Reptiles	50 ⁴ /53 ¹ / 35 ⁷	Legumes	35 ^{8,9}
Birds	261 ⁵ /320 ¹ /300 ^{6,7}	Grasses	29 ^{8,9}
Mammals	50 ^{5,6} /32 ⁷	Sedges	19 ^{8,9}
Shrimp	24 ⁶ /24 ³	Euphorbias	18 ^{8,9}
Crabs	7 ^{6,3}	Flowering Plants	105 ^{8,9}
Mollusca	8 ¹	Algae	150 ^{8,9}
Lobster	8 ¹	Lichens	32 ¹
Cetaceans	11 ¹²	Shrubs	25 ¹¹
Invertebrates	873 ²	Herb	10 ¹¹
Waterfowl	95 ¹⁰		
Raptors	38 ¹⁰		
Kingfisher	9 ¹⁰		
Insects	2,493 ¹⁰		
Mites	19 ¹⁰		
Echinoderms	4 ¹⁰		
Aquatic species	678 ¹²		

Sources: ¹Gopal & Chauhan (2006), ²S. Rahman (2012), ³IUCN (2003), ⁴Khan (1986), ⁵Khan et al. (2013), ⁶MoEF (2005), ⁷IUCN (2001), ⁸Chaffey (1985), ⁹Naskar & Mandal (1999), ¹⁰Rahman (2015), ¹¹Aziz & Paul (2015), ¹²MoEF (2010)

Table 4. IUCN status of different species in Sundarban

Scientific Name	Local name	Status*	Scientific name	Local name	Status*
<i>Bubalus bubalis</i>	Wild buffalo	EN	<i>Semnopithecus pileatus</i>	Capped Langur	NT
<i>Cervus duvauceli</i>	Swamp Deer	VU	<i>Lutrogale perspicillata</i>	Smooth-Coated Otter	VU
<i>Rhinoceros sondaicus</i>	Javan Rhinoceros	CR	<i>Aonyx cinerea</i>	Oriental Small-clawed Otter	VU
<i>Crocodylus palustris</i>	Marsh Crocodile	VU	<i>Viverra zibetha</i>	Great Indian Civet	LC
<i>Panthera tigris</i>	Royal Bengal Tiger	NT	<i>Aglaia cucullata</i>	Pacific maple	NT
<i>Crocodylus porosus</i>	Estuarine Crocodile	LC	<i>Cynometra ramiflora</i>	Cynometra	LC
<i>Lepidochelys olivacea</i>	Olive Ridley Turtle	VU	<i>Eretmochelys imbricate</i>	Hawks Bill Turtle	CR
<i>Batagur baska</i>	River Terrapin	EN	<i>Platanista gangetica</i>	Gangetic Dolphin	EN
<i>Chelonia mydas</i>	Green turtle	EN			

Sources: Gopal & Chauhan (2006), Khan et al. (2013), Aziz & Paul (2015), IUCN (2000)

*Note: CR, EN, VU, NT and LC represent Critically Endangered, Endangered, Vulnerable, Near Threatened and Least Concern

goods (Timberg, 1991), which more often than not empowers appointment of assets ahead of schedule as could be allowed (Ruitenbeek, 1998) as they depend on the limited future incentives from the present ones. The full value of the public goods supplied by the Sundarban mangrove ecosystem is not recognized, as many

of these items and offerings are now not traded in open markets. The Sundarban is losing its aesthetic beauty day by day. If this continues, the tourist will no longer be interested in visiting Sundarban. The traditional use of fuelwood prompts loss of biodiversity, and most of them are financially very important (Islam & Bhuiyan,

2018). Recent cyclones Sidr, Reshmi and Aila, affected Sundarban as detailed by numerous authors (Deb & Ferreira, 2017; Dutta, Das, Paul, Shama, & Dadhwal, 2015; Islam, 2013; Islam & Wahab, 2005). Saadi (2010) reported the annual loss of about \$142.9 million by cyclone Sidr that hit over Sundarban in 2007.

Sundarban is a standout amongst the most various thriving ecosystem communities on the planet (Borrell, Tomero, Bhattacharjee, & Aguilar, 2016). It went about as a protective obstruction amid the catastrophic time frame for the coastal communities (Bhowmik & Cabral, 2013; Islam, 2013) and served as various monetary, social and natural advantages. This forest also provides occupation for nearby people through fishing, nectar and wax collection, tourism, wood, and non-wood items (Table 5).

There were 45% mammals, 42% birds, 46% reptiles and 36% amphibian species found in Sundarban. In the Fiscal year 2003–2004, the evaluated wood production by the forest department was 4,33,000 ton (Uddin, van Steveninck, Stuip, & Shah, 2013). The income profits from the forest are increasing because the number of tourists and visitors are improved by nearly 25 times in 2012-2013 in contrast to 2000-2001 (Islam & Bhuiyan, 2018). The provisioning and social administrations gave by the Sundarban added to the income of the Forest Department (FD) US\$ 7,44,000 and US\$ 42,000 every year separately amid the financial years from 2001-2002 to 2009-2010 (Uddin et al., 2013). Among all items, income from timber was the most elevated one (US\$ 0.4 million), fish (US\$ 0.2 million), covering

materials, fuelwood, crab and nectar and wax (Uddin et al., 2013).

3. Sea Level Rise

Sundarban will be submerged due to the rise of sea level. Climate change induces higher evapotranspiration, and low drift in winter would increase salinity. As a result, an increase in fresh water-loving species would be impaired (World Bank, 2000). Habib (2011) affirmed the positive trend of heavy rainfall that is considerable growing during pre-monsoon (+0.00258/year) and throughout monsoon (+0.0053/year). From 1950 to 1990, excessive cyclones were merely occurring it used to be 7 (Habib, 2011), however during 20 years (1991-2010) the numbers have increased.

Basak et al. (2013) examined the variation of temperature and precipitation of 34 stations of Bangladesh over the 33 years' time frame (1976 to 2008). They observed that the average maximum temperature has been growing at a change of 0.018 C°/year. The sea degree along the Bangladesh coast is rising at about 3 mm/year, and the seafloor temperature is showing a rising trend (World Bank, 2010). This mangrove forest is the passing route of cyclones formed over the sea or down from the Himalayas. During the last 135 years, about 45 cyclones crossed the coastal belt of Bangladesh, 13 have trekked through the Sundarban (IPAC, 2012). The great impacts would be ocean level ascent, increment in the recurrence and force of the cyclonic tempest, unpredictable precipitation, saltiness interruption, etc. Sundarban will be underwater concerning developing the rise of sea level. Around 15% of the forest will go

Table 5. Uses of economically important plants of Sundarban

Uses	Species
Fuelwood	<i>Avicennia officinalis</i> , <i>Lumnitzera racemosa</i> , <i>Cynometra ramiflora</i> , <i>Ceriops decandra</i>
Furniture, bridges and house construction	<i>Xylocarpus mekongensis</i> , <i>Xylocarpus granatum</i> , <i>Phoenix paludosa</i> , <i>Bruguiera spp.</i> , <i>Sonneratia apetala</i>
Charcoal	<i>Cynometra ramiflora</i> , <i>Ceriops decandra</i>
Match sticks and newsprint	<i>Excoecaria agallocha</i>

Source: Islam & Bhuiyan (2018), Siddiqi (1998)

Table 6. Predicted ecosystem loss with sea-level rise in Sundarban

Year	Ecosystem loss (%)	Sea level rise (cm)
2020	15	10
2050	40	25
2100	100	100

Source: Karim (2012)

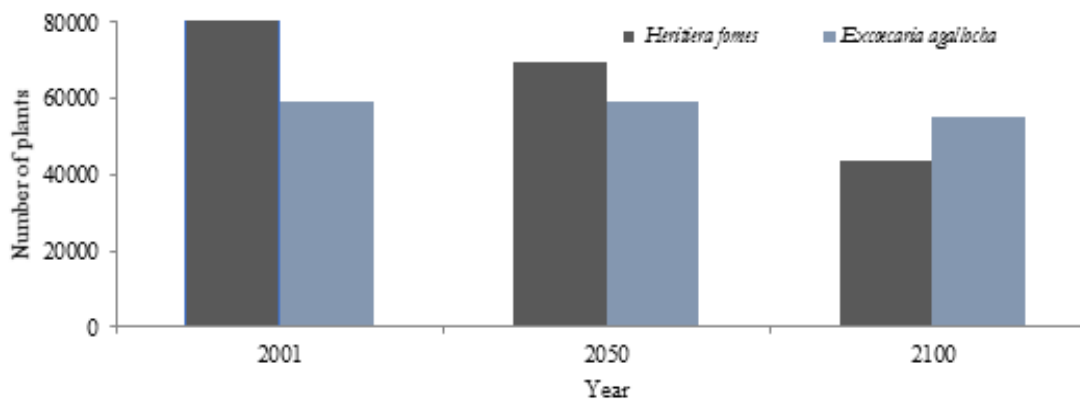


Figure 3. Projected comparison between *Heritiera fomes* and *Excoecaria agallocha* in Sundarban

Source: CEGIS (2006)

underwater as long as the sea level rises 10 cm and will be fully destroyed if the sea level rises above 100 cm (Table 6) (World Bank, 2000).

Due to the impact of climate change, species like *Heritiera fomes* (Sundari) would be replaced by less valuable species like *Ceriops* spp. (Goran.) and *Excoecaria agallocha* (Gewa) (World Bank, 2000). *Heritiera fomes* and *Excoecaria agallocha* trees will decrease by 45% and 7% respectively by 2100 (Figure 3) from the base year 2001 due to 88 cm sea-level rise (CEGIS, 2006).

4. Environmental Instability

The environmental condition of the Sundarban mangrove forest is getting unstable caused by several elements. Shrimp farming, increased salinity, accidents like oil spill and fire, pollution, climate change, and many others were the foremost reasons. In the south-eastern parts of Bangladesh, 18,200 ha of Chakaria Mangrove Sundarban had nearly been destroyed to make shrimp aquaculture (Akhtaruzzaman, 2004). The government has led different development

projects for shrimp aquaculture, founded by the Asian Development Bank and World Bank. Perhaps it would have bought tremendous destruction to the forests (Paul & Vogl, 2011). It has been determined that, at high salinity, the predominant cause of the decrease in growth is the reduction in the expansion rate of the leaf, which is caused by the high salt concentrations (Zaman, Bhattacharyya, Pramanick, Raha, Chakraborty, & Mitra, 2014). The relative leaf augmentation and net absorption diminish in mangrove species as salinity increases. Salinity influences the normal development and efficiency of mangroves. This prompts loss of biodiversity and helpful asset of Sundarban, and subsequently, the ecological condition ends up being unpredictable.

5. More Vulnerability

The Sundarban is a disaster-prone forest due to common disasters, namely flood, tropical cyclone, tornado, storm surge, salinity and coastal erosion (Shamsuzzoha & Biswas, 2010).

The degradation of the forest is accountable for the change in climatic status, and climate change is triggering natural calamities. Extreme activities impact ecological and human systems causing human suffering and monetary losses, thereby impacting human well-being. The Sundarban support a huge population in the surrounding regions, and these are currently benefiting from the coastal protection provided by the mangrove forests (Uddin et al., 2013). The Sundarban works as a barrier for various natural disasters (i.e., cyclone, storm, typhoons, coastal flooding) that first strike on the coastal sector of Bangladesh. The rate of destruction was limited till the last decade. As the safety barrier is damaging day by day, the damages are increasing all over the country.

6. Ecological Health Risk and Causes and Impacts on Unhealthy Environment

Oil spillage and water pollution degrade the environment of Sundarban, which creates several ecological health risks. Rapidly increasing variety of marine transports, oil and other chemical substances are mixing with the aquatic system. Consequently, the water is getting polluted, and the diversity of species in both water and land are facing threats. Oil from the fuel tank spread approximately 15 km downstream from the ship and influenced an impressive segment of the Sundarban mangrove region. It was responsible for the instantaneous mortality of seedlings of *Heritiera fomes* and *Excoecaria* spp. (Rawson & Munns, 1984). Stomata of the flowers are blocked by oil pollution, which is hampering the growth of plants. Because of increased salinity, *Heritiera fomes* and *Nypa fruticans* were declining quickly (Gopal & Chauhan, 2006). The essential purpose for top-dying of the species is accepted to be the expanding dimension of salinity (Zaman et al., 2014).

The people living close to the Sundarban rely upon the rivers for water. The slick oil influences the water of these streams, and their saltiness

expands; this poses dangers to the inhabitants. People, animal and vegetation, are experiencing some sicknesses, and subsequently, the number of species in Sundarban is going down day by day.

IV. CONCLUSION

Sundarban plays an imperative role for the general population of the southwestern shoreline of Bangladesh. But it is being degraded day by day. It protects from coastal disaster, assist and provide public and private goods. The study concluded that the main causes of degradation were: increased shrimp farming, oil spillage and pollution increased over-dependency of the population and illegal forest cutting, forest fire, management failure, plant diseases, upstream withdrawal of river water and salinity intrusion.

In Bangladesh, the present Forest Act does not arrange to allow participatory preservation of the forest. The government of Bangladesh has attempted to introduce some initiatives to conserve this important ecosystem. Still, the sustainability of its resources most likely never be executed because of the absence of sound procedures. A sustainable administration layout may be developed involving all beneficiaries and stakeholders and ought to be successfully applied to conserve the world's biggest mangrove ecosystem for current and future generations.

ACKNOWLEDGEMENT

The authors acknowledge the anonymous reviewers for their valuable suggestions and comments that improved the quality of this research article. We are also in-depth with our gratitude to the Department of Environmental Science and Disaster Management, Noakhali Science and Technology University, Bangladesh, to supply the necessary supports to accomplish the study.

REFERENCES

- Agrawala, S., Ota, T., Ahmed, A.U., Smith, J., & Van Aalst, M. (2003). *Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans*. OECD Paris.
- Akhtaruzzaman, A.F.M. (2004). *Mangrove forestry research in Bangladesh. Mangrove Management and Conservation: Present and Future*, 249–256.
- Ali, M., Kabir, M.A., & Hoque, A.T.M. (2006). People, policy, and perpetuity: Sustainability indicators of Bangladesh forestry. *Electronic Green Journal*, 1(24), 1-23
- Ali, S. S. (1994). Sundarbans: Its resources and ecosystem. *Proceedings of the National Seminar on Integrated Management of Ganges Flood Plains and Sundarbans Ecosystem*, 16–18.
- Anon. (2001). *Report on socio-economic baseline study on the impact zone of the Sundarbans*. Urban and rural planning discipline Khulna University, Khulna, Bangladesh.
- Aziz, A., & Paul, A.R. (2015). Bangladesh Sundarbans: Present status of the environment and biota. *Diversity*, 7(3), 242–269.
- Banglapedia. (2010). National encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka, Bangladesh.
- Basak, J.K., Titumir, R.A.M., & Dey, N.C. (2013). Climate change in Bangladesh: A historical analysis of temperature and rainfall data. *Journal of Environment*, 2(2), 41–46.
- Bhowmik, A. K., & Cabral, P. (2013). Cyclone sidr impacts on the Sundarbans floristic diversity. *Earth Science Research*, 2(2), 62.
- Borrell, A., Tornero, V., Bhattacharjee, D., & Aguilar, A. (2016). Trace element accumulation and trophic relationships in aquatic organisms of the Sundarbans mangrove ecosystem (Bangladesh). *Science of the Total Environment*, 545, 414–423.
- CEGIS. (2006). Coastal land use zoning in the South-west: Impact of sea level rise on landuse suitability and adaptation options.
- Chaffey, D.R. (1985). A forest inventory of the Sundarbans. Bangladesh. *Main Report, Project*, 41.
- Chakravorty, S., & Ghosh, D. (2018). Automatic identification of saline blanks and pattern of related mangrove species on hyperspectral imagery. *The 4th International Conference on Recent Advances in Information Technology (RAIT)*, 1–6.
- Deb, M., & Ferreira, C.M. (2017). Potential impacts of the Sunderban mangrove degradation on future coastal flooding in Bangladesh. *Journal of Hydro-Environment Research*, 17, 30–46.
- Didar-Ul Islam, S.M., Bhuiyan, M.A.H., & Ramanathan, A.L. (2015). Climate change impacts and vulnerability assessment in coastal region of Bangladesh: A case study on Shyamnagar Upazila of Satkhira District. *Journal of Climate Change*, 1(1, 2), 37–45.
- Dutta, D., Das, P.K., Paul, S., Sharma, J.R., & Dadhwal, V.K. (2015). Assessment of ecological disturbance in the mangrove forest of Sundarbans caused by cyclones using MODIS time-series data (2001–2011). *Natural Hazards*, 79(2), 775–790.
- FAO. (2000). State of world's forests 2000. Food and Agriculture Organization, Rome.
- Gopal, B., & Chauhan, M. (2006). Biodiversity and its conservation in the Sundarban mangrove ecosystem. *Aquatic Sciences*, 68(3), 338–354.
- Habib, A. (2011). Climate change: Bangladesh perspective. Retrieve from: [//www.dccc.iisc.ernet.in/22July2011-Policy/ArjumandHabib.doc](http://www.dccc.iisc.ernet.in/22July2011-Policy/ArjumandHabib.doc) on the 1st December 2020.
- Hossain, S.R., Ahmed, I., Azad, F.S., & Hasan, A.S.M.M. (2020). Empirical investigation of energy management practices in cement industries of Bangladesh. *Energy*, 212, 118741.
- Iftekhhar, M.S., & Islam, M.R. (2004). Degeneration of Bangladesh's Sundarbans mangroves: A management issue. *International Forestry Review*, 6(2), 123–135.
- IPAC. (2012). Integrated protected area co-management. State of Bangladesh's forest protected areas.
- Islam, M.S., & Wahab, M.A. (2005). A review on the present status and management of mangrove wetland habitat resources in Bangladesh with emphasis on mangrove fisheries and aquaculture. *Aquatic Biodiversity II*, 165–190.
- Islam, N. (2005). Environmental issues in Bangladesh: An overview. *Pakistan Journal of Social Science*, 3(4), 671–679.
- Islam, S.M.D.U., & Bhuiyan, M.A.H. (2018). Sundarbans mangrove forest of Bangladesh: Causes of degradation and sustainable management options. *Environmental Sustainability*, 1(2), 113–131.
- Islam, S. M. D. (2013). Evaluation of environmental and socio-economic impact due to cyclone

- Aila, present condition and adaptation practices in Shyamnagar, Satkhira of Bangladesh. (*Undergraduate Thesis*). Department of Environmental Sciences, Jahangirnagar University, Dhaka.
- Islam, S.N., & Gnauck, A. (2011). Water salinity investigation in the Sundarbans rivers in Bangladesh. *International Journal of Water*, 6(1–2), 74–91.
- IUCN. (2000). Red list of threatened animals of Bangladesh.
- IUCN. (2001). The Bangladesh Sundarbans: A photoreal sojourn.
- IUCN. (2003). Conservation monitoring of Sundarban biodiversity. In Biodiversity health status workshop proceedings.
- Karim, S. (2012). REDD+ and mangroves: A study on Sundarbans. *APCEL/NCSS Workshop on REDD+ and legal regimes of mangroves, peatlands and other wetlands: ASEAN and the World*.
- Khan, Mohammad Ali Reza, Dipu, S., & Ahmed, F. (2013). *Sundarban: Rediscovering Sundarban: the mangrove beauty of Bangladesh*. Nymphaea Publication.
- Khan, Mohammed Ali Reza. (1986). Wildlife in Bangladesh mangrove ecosystem. *Journal of the Bombay Natural History Society. Bombay*, 83(1), 32–48.
- Miah, G., Bari, N., & Rahman, A. (2010). Resource degradation and livelihood in the coastal region of Bangladesh. *Frontiers of Earth Science in China*, 4(4), 427–437.
- Mirza, M. Q., Warrick, R. A., Ericksen, N. J., & Kenny, G. J. (1998). Trends and persistence in precipitation in the Ganges, Brahmaputra and Meghna river basins. *Hydrological Sciences Journal*, 43(6), 845–858.
- MoEF. (2005). National biodiversity strategy and action plan for Bangladesh.
- MoEF. (2010). Integrated resources management plans for the Sundarbans.
- Naskar, K., & Mandal, R. (1999). *Ecology and biodiversity of Indian mangroves* (Vol. 1). Daya Books.
- Paul, A.K., Ray, R., Kamila, A., & Jana, S. (2017). Mangrove degradation in the Sundarbans. In *Coastal wetlands: alteration and remediation* (pp. 357–392). Springer.
- Paul, B.G., & Vogl, C. R. (2011). Impacts of shrimp farming in Bangladesh: Challenges and alternatives. *Ocean & Coastal Management*, 54(3), 201–211.
- Peng, L., & Qin, F. (2000). Environmental ecology and economic utilization of mangroves in China. Beijing: China Higher Education Press.
- Rahman, L.M. (2000). The Sundarbans: A unique wilderness of the world. *USDA Forest Service Proceedings RMRS-P-15-(2)*, 143–148.
- Rahman, M.R. (2015). Causes of biodiversity depletion in Bangladesh and their consequences on ecosystem services. *American Journal of Environmental Protection*, 4(5), 214–236.
- Rahman, M.T.U., Rasheduzzaman, M., Habib, M. A., Ahmed, A., Tareq, S. M., & Muniruzzaman, S. M. (2017). Assessment of fresh water security in coastal Bangladesh: An insight from salinity, community perception and adaptation. *Ocean & Coastal Management*, 137, 68–81.
- Rahman, Mohammed M., Rahman, M.M., & Islam, K.S. (2010). The causes of deterioration of Sundarban mangrove forest ecosystem of Bangladesh: Conservation and sustainable management issues. *Aquaculture, Aquarium, Conservation & Legislation*, 3(2), 77–90.
- Rahman, Mahabubur M., Chongling, Y., Islam, K. S., & Haoliang, L. (2009). A brief review on pollution and ecotoxicologic effects on Sundarbans mangrove ecosystem in Bangladesh. *International Journal of Environmental Engineering*, 1(4), 369–383.
- Rahman, S. (2012). Impacts of climate change on ecological composition & biodiversity of Sundarbans, Bangladesh. *A Conference in the Philippines*. Retrieved from: http://www.Ched.Gov.Ph/Chedwww/Index.Php/Eng/Content/Download/1792/9300/File/Impacts_CC_Sundarban_Shahriar_Rahman.Pdf. Accessed, 15. on the 1st December 2020.
- Rahman, S.H., Islam, S.M.D., & Rume, T. (2016). Seawater intrusion in coastal region of Bangladesh: Causes, impacts and adaptation. *Journal of SUB (Special Issue on Environment)*, 6(2), 44–63.
- Rawson, H.M., & Munns, R. (1984). Leaf expansion in sunflower as influenced by salinity and short-term changes in carbon fixation. *Plant, Cell & Environment*, 7(3), 207–213.
- Ruitenbeek, H. J. (1998). Research note: Economic model summary and applications for sustainable forest management. In H.J.

- Ruitenbeek (Eds.). Resource Consulting Limited, Gabriola, BC, Canada.
- Saadi, M.L.K. (2010). Hurricane sidr claims beautiful mangroves. Retrieved from <http://www.Islamonline.Net>. on the 1st December 2020.
- Shamsuzzoha, M., & Biswas, A. (2010). Sustainable biodiversity management of the Sundarban: Disaster management perspective.
- Siddiqi N. A. (1998). Enrichment planting in the Sundarbans: A review. *Bangladesh Journal of Forest Science*, 27, 103–113.
- The Daily Star. (2014). Oil spills into river as tanker sinks at Sundarbans. The Daily Star. Retrieved from <https://www.thedailystar.net/oil-spills-into-river-as-tanker-sinks-at-sundarbans-54377> on the 1st December 2020.
- Timberg, T.A. (1991). Sundarbans—goods, markets and value. The commons in South Asia: societal pressure and environmental integrity in the Sundarbans. Retrieved from <http://Www.Smartoffice.Com/Tiger/Proceedings.Html>. on the 1st December 2020.
- Uddin, M.S., van Steveninck, E. de R., Stuij, M., & Shah, M.A.R. (2013). Economic valuation of provisioning and cultural services of a protected mangrove ecosystem: A case study on Sundarbans Reserve Forest, Bangladesh. *Ecosystem Services*, 5, 88–93.
- UNESCO. (2007). The Sundarbans UNESCO World Heritage Centre.
- World Bank. (2000). Bangladesh - Climate change and sustainable development. Retrieved from <http://documents.worldbank.org/curated/en/906951468743377163/Bangladesh-Climate-change-and-sustainable-development> on the 1st December 2020.
- World Bank. (2010). Economics of adaptation to climate change: Synthesis Report. Retrieved from <https://openknowledge.worldbank.org/handle/10986/12750> on the 1st December 2020.
- WWF. (2007). Rising sea levels threaten to wash away entire nations. Retrieved from <http://www.panda.org> on the 1st December 2020.
- Zaman, S., Bhattacharyya, S.B., Pramanick, P., Raha, A.K., Chakraborty, S., & Mitra, A. (2014). Rising water salinity: A threat to mangroves of Indian Sundarbans. In *Water insecurity: A social dilemma*. Emerald Group Publishing Limited.

ANATOMICAL AND PHYSICAL CHARACTERISTICS OF *Cephalostachyum mannii* (Gamble) Stapleton – AN ENDEMIC SCRAMBLING BAMBOO OF NORTHEAST INDIA

Chaman Lal Sharma*, Madhubala Sharma, Dahunirikitre M. Lamare, Mahesh Wangkhem,
and Govinda Pangging

North Eastern Regional Institute of Science and Technology (NERIST)
Nirjuli (Itanagar), 791109 Arunachal Pradesh, India

Received: 17 August 2020, Revised: 20 April 2021, Accepted: 26 April 2021

ANATOMICAL AND PHYSICAL CHARACTERISTICS OF *Cephalostachyum mannii* (Gamble) Stapleton–AN ENDEMIC SCRAMBLING BAMBOO OF NORTHEAST INDIA. *Cephalostachyum mannii* is a tall, graceful scandent bamboo with solid culms. It is distributed in Arunachal Pradesh, Meghalaya, Mizoram, and Nagaland states of Northeast India. The present study was carried out to investigate radial and vertical variations in anatomical and physical properties in the culms of this bamboo species. The mature culms (3-4 years old) were selected from forests of Amkassar Amlarem village, West Jaintia Hills District, Meghalaya, India. The selected internodes of culms were radially divided into outer, middle and inner zones, and vertically bottom, middle and top positions. The vascular bundles were of Type II and well developed in middle zones of both bottom and middle positions. The number and size of vascular bundles increased from inner to outer zone and decreased from bottom to top. Vessel length and vessel diameter decreased both radially and vertically. Among fibre characteristics, fibre wall thickness increased, while fibre length, fibre diameter, and fibre lumen diameter decreased significantly in both radial and vertical directions. Among physical properties, density increased, and moisture content decreased in both radial and vertical directions. Radial shrinkage was higher than tangential shrinkage. Both radial and tangential shrinkage decreased significantly from bottom to top. The fibres were long, thick-walled and highly rigid, and the derived indices do not satisfy the requirement as a superior fibrous raw material for pulp and paper making. However, this bamboo species has the potential for making good quality handicrafts and basketry.

Keywords: Solid culm, fibre, density, moisture content, shrinkage, vascular bundles

KARAKTERISTIK ANATOMIS DAN FISIK Cephalostachyum mannii (Gamble) Stapleton–SEBUAH BAMBU Pengerikan ENDEMIK DARI INDIA TIMUR. Cephalostachyum mannii adalah jenis bambu tinggi, skanden lentur dengan batang yang kokoh. Jenis ini tersebar di negara bagian Arunachal Pradesh, Meghalaya, Mizoram, dan Nagaland di India Timur Laut. Penelitian ini dilakukan untuk mengetahui variasi radial dan vertikal dalam sifat anatomis dan fisik batang spesies bambu ini. Batang dewasa berumur 3-4 tahun dipilih dari hutan Desa Amkassar Amlarem, Distrik Perbukitan Jaintia Barat, Meghalaya, India. Ruas batang yang dipilih dibagi secara radial menjadi zona luar, tengah dan dalam, dan posisi bawah, tengah dan atas secara vertikal. Hasil penelitian menunjukkan bahwa batang bambu diketahui padat. Bundel vaskular tipe II dan berkembang dengan baik di zona tengah dari posisi bawah dan tengah. Jumlah dan ukuran ikatan pembuluh meningkat dari zona dalam ke zona luar dan menurun dari bawah ke atas. Panjang kapal dan diameter kapal menurun baik secara radial maupun vertikal. Di antara karakteristik serat, ketebalan dinding serat meningkat, sedangkan panjang serat, diameter serat, dan diameter lumen serat menurun secara signifikan baik pada arah radial maupun vertikal. Berat jenis meningkat, dan kadar air menurun baik secara radial maupun vertikal. Penyusutan radial lebih tinggi dari susut tangensial, dan penyusutan radial dan tangensial menurun secara nyata dari bawah ke atas. Seratnya panjang, berdinding tebal dan sangat kaku, dan indeks turunannya tidak memenuhi persyaratan sebagai bahan baku serat yang baik untuk pembuatan pulp dan kertas. Namun, jenis bambu ini berpotensi untuk dijadikan kerajinan tangan dan keranjang berkualitas baik.

Kata kunci: Batang padat, serat, kepadatan, kadar air, penyusutan, ikatan pembuluh

*Corresponding author: cls_chaman@yahoo.co.in

I. INTRODUCTION

Bamboo is one of the most important non-timber forest resources of India. It is considered a versatile material due to fast growth, easy propagation, high strength to weight ratio, and a substitute for wood in composite wood industries and other value-added products (Tan, Rahbar, Allameh, Kwofie, Dissmore, Ghavami, & Soboyejo, 2011). In India, they occur abundantly in deciduous and semi-evergreen forests of the North Eastern (NE) region and tropical moist deciduous forests of both North and South India. More than 50% of bamboo resources have been reported from NE India and West Bengal. *Bambusa cacharensis*, *Cephalostachyum mannii*, *Neomicrocalamus prainii*, and *Schizostachyum mannii* are endemic species of North East India. Meghalaya, one of the eight North-Eastern states of India, is rich in bamboo resources. It is estimated to cover an area of 0.54 million ha and ranks 3rd among northeastern states (FSI, 2019). There are 11 genera and 35 bamboo species in Meghalaya, out of which nine genera representing 32 species are sympodial type, and two genera with three species are monopodial type (Kharlyngdoh & Barik, 2008). *Dendrocalamus strictus*, *Dendrocalamus hamiltonii*, *Bambusa arundinacea*, *Bambusa pallida*, and *Bambusa tulda* are the dominant clump-forming species, whereas *Melocanna bambusoides* constitute the non-clump forming species.

Anatomical, physical, and mechanical properties are important to determine the utilization of any bamboo species for various end uses. The strength, toughness, durability and preservative absorption of bamboos are related to anatomical properties (Razak, Mohamed, Samsi, Yunus, & Mokhtar, (2006); Kelemwork, 2009) whereas, physical properties like density, moisture content and shrinkage (Razak, Mustafa, Sulaiman, Mohamed, Hassan, & Khalid, 2010) govern the suitability of bamboos for different applications and their liability to chemical treatments. The fibre morphology and their derived indices, namely Runkel's ratio, slenderness ratio, flexibility and

rigidity coefficients, are also essential to use bamboo fibrous raw material for pulp and paper making (Cao, Ma, Lin, Huang, Huang, & Chen, 2014). Like wood, both anatomical and physical properties are highly variable in bamboos and vary with species, age and height positions (Grosser & Liese, 1971; Sharma, Sharma, & Laishram, 2017; Sharma, Sharma, Tado, & Laishram, 2019).

Cephalostachyum mannii (Gamble) Stapleton syn. *Neomicrocalamus mannii* (Gamble) is a climbing bamboo species growing on hill slopes of tropical and subtropical zones of 700-1000 m.a.s.l. It is distributed in Arunachal Pradesh, Meghalaya, Mizoram, and Nagaland (Kharlyngdoh & Barik, 2008). It is a tall, graceful bamboo species with solid culms and erect, narrow acicular culm sheath. The leaves have distinct central and secondary veins with a hair-point apex (Stapleton, Li, & Xue, 1997). In NE India, only a few bamboo species are being used commercially due to a lack of basic information on the properties of other bamboo species. So far, there is no information related to the anatomical and physical properties of this wild bamboo species. Therefore, the present study attempts to obtain basic information on anatomical and physical properties and study the variations in these properties in both radial and vertical directions. The present study will assist in increasing the utilization of this species for different uses.

II. MATERIAL AND METHOD

A. Study Site

The culms of *Cephalostachyum mannii* (Gamble) Stapleton were collected from Amkassar Amlarem village, West Jaintia Hills District, Meghalaya. The geographical coordinates of the selected site were 25°17'12" N, 92°06'20" E.

B. Sample Collection

Five mature culms (3-4 years old) of bamboo were collected randomly from different clumps. The bamboo culm was cut at about 30 cm

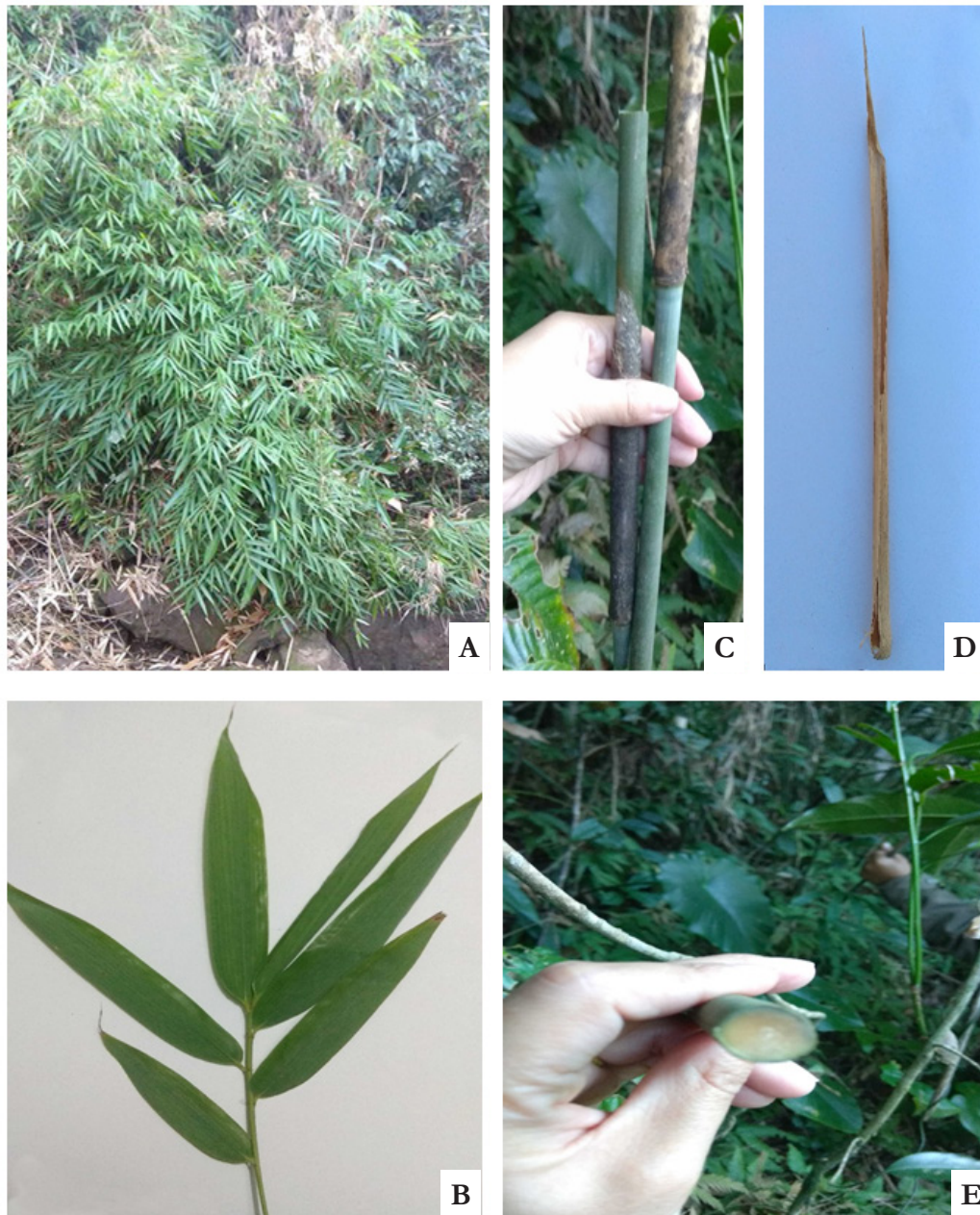


Figure 1. Morphology of *Cephalostachyum mannii*: clump (A), leaves (B), culms (C), culm sheath (D) and crosscut showing solid culm (E)

above ground level. Photographs of the whole clumps, leaves, and culm sheath were taken for identification. Then, the study measures the morphological parameters such as culm height, number of internodes, internode length, and internode diameters (Figure 1, Table 1). The unusable parts of the culms from the top were removed after harvesting. The culm age was estimated based on visual inspection

by observing the colour, culm sheaths, and growth of surface lichens. Internodes were consecutively numbered from bottom to top for each culm and divided into three sections - bottom, middle, and top. The samples were taken from the middle portion of the internodes from bottom to top for further studies. The internodes were divided into inner, middle, and outer zones across the culm radially at each

Table1: Morphological characteristics of *Cephalostachyum mannii*

Characteristics	Range (Mean \pm S.D)
Culm height (m)	4.11-5.67 (4.73 \pm 0.60)
No. of internodes	9-11 (9.4 \pm 0.89)
Internode length (cm)	Bottom 38-72 (55.44 \pm 11.07)
	Middle 19-66 (50.31 \pm 13.78)
	Top 30-64 (45.67 \pm 8.66)
Internode diameter (mm)	Bottom 6.52-13.55 (9.34 \pm 1.68)
	Middle 5.73-11.68 (8.57 \pm 1.65)
	Top 5.18-12.64 (8.26 \pm 1.79)

height positions. From each height positions, three internodes per culm were selected. A total of 45 internodes were selected for the present study.

C. Preparation of Permanent Slides and Vascular Bundle Characteristics

From the middle portion of the selected internodes, a sample of 2.5 cm length at each height position was cut and preserved in FAA solution for 24 hours and then shifted to 70% alcohol for further preservation. The cross-sections of 25-30 μ m thickness of selected internodes were cut with the help of a sliding microtome, stained following standard procedure and permanent slides were prepared (Johansen, 1940). Radial and tangential diameters of vascular bundles in inner, middle, and outer zones at each height position (bottom, middle and top) were taken at 100x magnification. For these parameters, 30 vascular bundles per zone were selected. Stem samples from ten different fields from each zone (inner, middle, outer) were selected randomly from each height position to determine the number of vascular bundles per mm². Types of vascular bundles present were classified according to Grosser and Liese (1971).

D. Measurement of Cell Dimensions

Thin bamboo splinters taken from each zone (inner, middle and outer) at each height position were treated with a mixture of glacial acetic acid and hydrogen peroxide in a ratio of 1:1 (v/v) at 60°C for 24 hours till they became soft and white. The treated material was washed

2-3 times with water and gently shaken to obtain the fluffy white mass of fibres. 2-3 drops of safranin were added, and temporary slides were prepared in 50% glycerol to measure the fibres and vessels dimensions. A total of 50 fibres and 30 vessels from each zone at each height position were selected randomly. Fibre length and vessel length were taken at 40x magnification, while other dimensions like fibre diameter, fibre wall thickness, and vessel diameter were taken at 400x magnification. Derived indices like Runkel's ratio (Runkel, 1949), flexibility ratio (Wangaard, 1962), slenderness ratio (Varghese, Subramanian, Bennet, & Jagadees, 1995), Luce's shape factor (Luce, 1970) and Rigidity co-efficient (Dutt, Upadhyaya, Tyagi, & Malik, 2004) were determined to investigate the suitability of fibres for pulp and paper making.

E. Determination of Physical Properties

The moisture content and density of bamboo strips were determined by the methods given in IS 6874 (2008). A total of 135 strips were taken separately for the determination of moisture content and density. tangential, and longitudinal shrinkage were also determined by IS 6874 (2008). A total of 75 blocks were taken for this parameter.

F. Statistical Analysis

The statistical analyses like MANOVA followed by Tukey's test were performed to compare the differences in anatomical and physical characteristics between height positions using SPSS 16 software.

III. RESULT AND DISCUSSION

The study reveals that culms of *C. mannii* were solid, unlike most of the other bamboo species. The anatomical characteristics given in Figure 2 showed that the outermost layer epidermis had radially elongated thick-walled cells with sunken stomata. The vascular bundles were scattered and arranged in 6–7 rows. The vascular bundles were incomplete, smaller in size, and thick fibrous sheath in the outer zone. The vascular bundles were well developed in the inner and middle zones. All the vascular bundles were examined as Type II (central vascular strand with larger sclerenchymatous sheath at the protoxylem than at metaxylem and phloem). The ground tissue was represented by thin-walled and rounded parenchyma cells having small intercellular spaces. The vascular bundles were also of a similar type along with the culm height. The vascular bundles in the middle zone are well developed and differentiated; therefore, the middle zone's vascular bundles are diagnostic features for identifying this species. The presence of Type II vascular bundles in this species corroborates the findings of Grosser and Liese (1971).

The number and size of vascular bundles are also characteristics of bamboo species (Latif & Tamizi, 1992; Sharma et al., 2017). The number of vascular bundles increased from inner to outer zone radially at the bottom, middle and top positions (Figure 3). The maximum number of vascular bundles in the outer zone is due to their small size and compact arrangement. The present results agree with the findings of Razak et al. (2012); Maya, Narasimhamurthy, and Pandey (2013); Kumar, Sharma, and Sharma (2015) and Sharma et al. (2017). On the other hand, there was a decrease in the number of vascular bundles from bottom to top positions. The number of vascular bundles per mm² at the bottom, middle and top positions were 10.12, 9.86, and 9.78. There was non-significant variation in the number of vascular bundles in vertical directions due to less difference in culm diameter from bottom to top.

The radial and tangential diameters ratio determines the size of vascular bundles in bamboos (Sharma et al., 2017). In *C. mannii*, radial diameter increased from inner to outer zone (radial). It decreased from bottom to top position (vertical), whereas tangential diameter decreased in radial and vertical directions (Figures 4 & 5). The vascular bundle size (R/T ratio) in *C. mannii* increased radially and was uniform vertically (Figure 6). The increase in the R/T ratio from the inner to the outer zone is due to more radial diameter of vascular bundles in the outer zone than inner and middle zones. Similar observations are reported in other bamboo species by Wang, Pu, Ding, Wan, and Lin (2011); Kumar et al. (2015) and Xing et al. (2015).

The metaxylem vessels were barrel-shaped with simple perforation and oval diameter. In the radial direction, vessel length and vessel diameter decreased significantly from the inner to the outer zone. In the vertical direction, vessel length decreased significantly from bottom to top, whereas vessel diameter increased from bottom to middle and decreased towards top positions (Table 2). The maximum diameter of metaxylem vessel in the middle zone of bottom and middle positions shows that metaxylem vessels are fully grown, and vascular bundles are well developed. The decrease in metaxylem vessel diameter in the top position may be due to a decrease in the size of vascular bundles along with the culm height. The present results agree with the findings of Londoño, Camayo, Riano, and Lopez (2002); Wang et al. (2011), Norul Hisham, Othman, Rokiah, Latif, Ani, and Tarmizi (2006); Xing, Qi, Xie, Hao, Qin, and Chen (2015) and Sharma et al. (2017).

The fibres are present in the form of isolated caps around the vascular bundles. They are elongated with pointed tips and provide mechanical support. The fibre characteristics, namely fibre length, fibre diameter, fibre lumen diameter, and fibre wall thickness, determine the raw material's suitability for pulp and paper making (Kaur & Dutt, 2013; Sharma, Sharma,

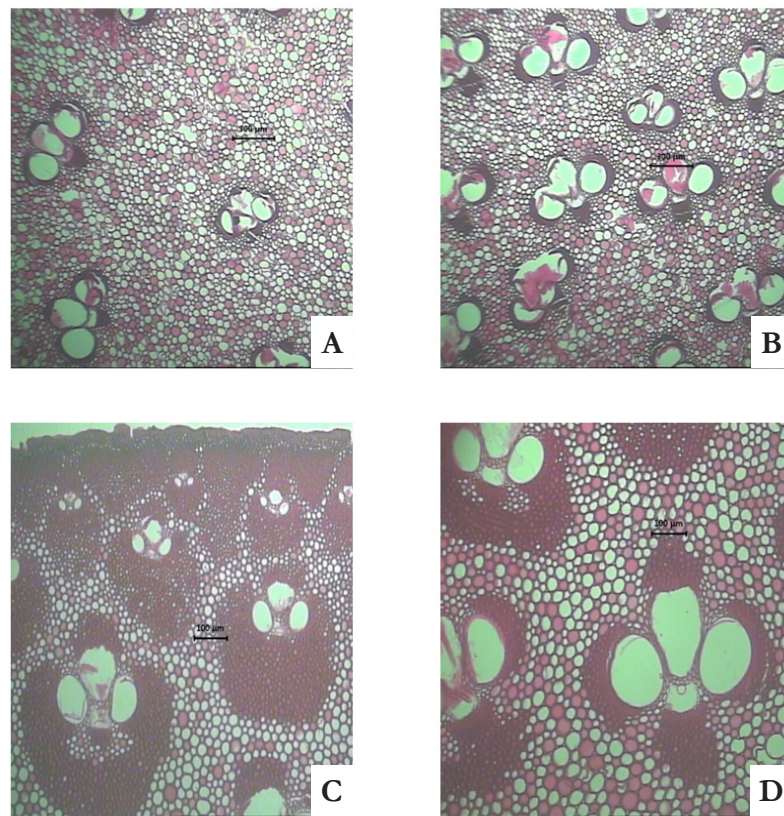


Figure 2 Cross-section of the culm of *C. mannii*: inner zone (A), middle zone (B), outer zone (C), and Type II vascular bundle (D)

Bage, Gogoi, and Pangging, 2018). The fibre length and fibre diameter increased from the inner to the middle zone and radially decreased in the outer zone. The significant variations in these parameters were observed in the bottom position only. Fibre lumen diameter non significantly decreased from inner to outer zone in the bottom position, but there was significant variation in top position. The fibre lumen diameter increased significantly from the inner to the middle zone and decreased in the outer zone. There was significant variation in fibre lumen diameter from bottom to top.

On the other hand, a significant increase in the fibre wall thickness was observed both in radial and vertical directions (Table 2). A perusal of literature reveals that fibre length varies from species to species in bamboos. They are 20–40% shorter in the inner part of the culm, and there is also a slight reduction

in fibre length along with height. It is also associated with internode length (Liese, 1998). In this study, the fibres are shorter in the inner zone and confirm the findings of Liese (1998). The decrease in fibre length, fibre diameter and fibre lumen diameter from bottom to top are in agreement with Abdullah-Siam, Uyup, Husain, Mohmod, and Awalludin (2019). The radial and vertical increases in wall thickness are related to the compact arrangement of vascular bundles in the outer zone and reduced cell wall thickness in the top position. The present results confirm the findings of other workers (Xing et al., 2015; Kumar et al., 2015; Sharma et al., 2017).

The derived indices for suitability of any fibrous raw material depend on fibre length and its various dimensions. Runkel's ratio, flexibility coefficient, slenderness ratio, Luce's shape factor and rigidity coefficient are important indices to determine the physical properties of

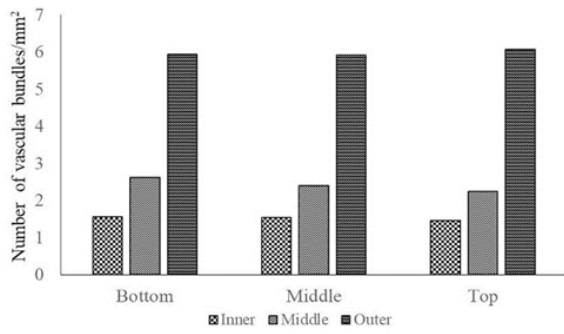


Figure 3

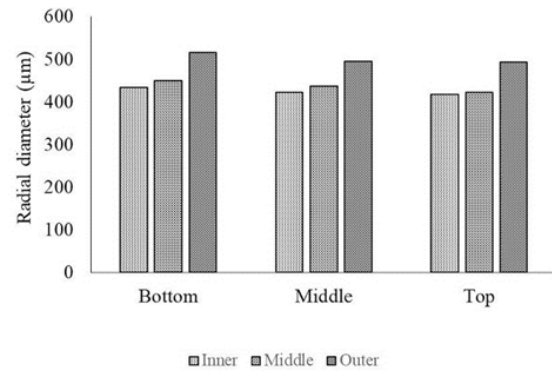


Figure 4

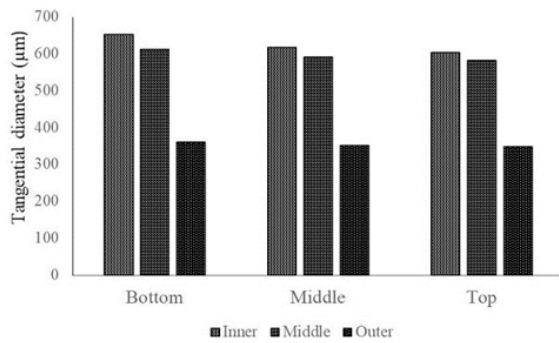


Figure 5

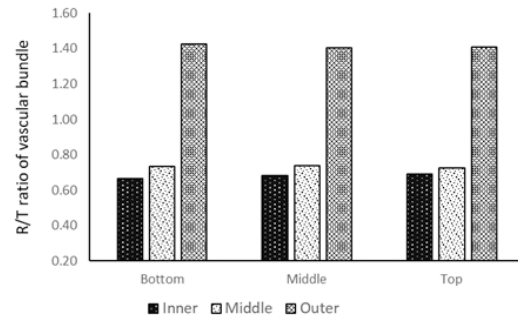


Figure 6

Figures 3-6: Histograms showing the number (Figure3), radial and tangential diameters (Figures 4 &5) and R/T ratio of vascular bundles of *C. mannii* (Figure 6)

pulp. The fibres with Runkel's ratio less than one are considered best for pulp and paper making (Sharma et al., 2018). The various derived indices presented in Table 3 showed that all derived indices of *C. mannii* varied non significantly both in radial and vertical direction and corroborates the findings of Latif and Tamizi (1992). Runkel's ratio of this species was more than one which shows that fibres were highly thick-walled. Similar observations are also reported in other bamboo species (Sharma, Dutt, Upadhyaya, & Roy, 2011, Zhan, Zhao, Li, Wang, & Wang, 2017). The flexibility coefficient determines the strength of the paper. The fibres with a flexibility coefficient of less than 30 are very rigid, and more than 75

are considered very elastic fibres (Bektas, Tutus, & Eroglu, 1999). The flexibility coefficient in this species was less than 30. Hence, the fibres are very rigid. The present results are contrary to the findings of Sadiku, Oluyeye, & Ajauji (2016). Therefore, the thick walled and rigid fibres condition did not fulfil its requirements as a superior fibrous material for pulp and paper. It may be used for making good quality handicrafts, basketry and furniture items based on the present study.

The slenderness ratio of fibres more than 70 is considered good for pulp and paper (Bektas et al., 1999). A high value of slenderness ratio is responsible for well bonded and better-formed paper (Ashori & Nourbaksh, 2009). The

Table 2. Fibre and vessel dimensions of *Cephalostachyum mannii*

Positions	Zones	Vessel Length (mean ± S.D., µm)	Vessel Diameter (mean ± S.D., µm)	Fibre Length (mean ± S.D., µm)	Fibre Diameter (mean ± S.D., µm)	Fibre Lumen Diameter (mean ± S.D., µm)	Fibre Wall Thickness (mean ± S.D., µm)
Bottom	Inner	1131.67 ± 282.90 ^{ab}	178.28 ± 41.75 ^c	1523.59 ± 250.44 ^{ab}	16.31 ± 2.69 ^b	4.02 ± 0.77 ^a	5.85 ± 0.99 ^a
	Middle	1106.79 ± 275.39 ^{ab}	178.94 ± 41.19 ^c	1546.70 ± 282.15 ^b	17.10 ± 1.82 ^b	4.02 ± 0.78 ^a	5.88 ± 1.04 ^a
	Outer	1033.20 ± 120.48 ^a	130.14 ± 39.06 ^a	1435.30 ± 156.88 ^a	15.33 ± 1.80 ^a	3.91 ± 0.68 ^a	5.99 ± 0.87 ^a
	Average	1152.50 ± 164.97 ^b	161.12 ± 43.38 ^b	1580.00 ± 104.20 ^b	17.16 ± 0.67 ^b	3.91 ± 0.51 ^a	5.96 ± 0.58 ^a
Middle	Inner	1179.00 ± 283.03 ^b	190.34 ± 39.25 ^b	1438.50 ± 234.15 ^a	15.89 ± 2.03 ^a	3.54 ± 0.48 ^{ab}	6.06 ± 0.94 ^a
	Middle	1026.17 ± 262.83 ^a	173.87 ± 25.20 ^{ab}	1539.00 ± 262.20 ^a	15.84 ± 1.16 ^a	3.68 ± 0.43 ^b	6.44 ± 0.83 ^a
	Outer	1009.00 ± 183.31 ^a	167.04 ± 42.31 ^a	1436.40 ± 200.56 ^a	15.72 ± 2.01 ^a	3.45 ± 0.40 ^a	6.22 ± 0.76 ^a
	Average	1089.28 ± 188.27 ^{ab}	179.40 ± 26.18 ^{a,b}	1490.87 ± 149.56 ^a	15.79 ± 2.09 ^a	3.59 ± 0.25 ^{ab}	6.27 ± 0.58 ^a
Top	Inner	1082.70 ± 268.92 ^b	169.61 ± 35.82 ^b	1528.50 ± 270.15 ^a	16.56 ± 1.70 ^a	3.71 ± 0.53 ^c	6.69 ± 0.80 ^b
	Middle	1075.05 ± 267.33 ^b	157.02 ± 26.67 ^{ab}	1526.00 ± 272.17 ^a	15.67 ± 2.04 ^a	3.46 ± 0.59 ^{ab}	6.43 ± 1.07 ^{ab}
	Outer	878.83 ± 210.82 ^a	149.38 ± 16.45 ^a	1447.80 ± 268.32 ^a	15.88 ± 1.82 ^a	3.26 ± 0.35 ^a	6.05 ± 0.72 ^a
	Average	1011.11 ± 252.23 ^b	165.88 ± 15.74 ^b	1519.30 ± 199.05 ^a	16.14 ± 1.20 ^a	3.65 ± 0.26 ^{bc}	6.75 ± 0.29 ^b

Remarks: Values with the same letter in the same column are not significantly different at p < 0.05

Table 3. Derived indices of *Cephalostachyum mannii*

Positions	Zones	Runkel's Ratio	Flexibility Coefficient	Slenderness Ratio	Luce's Shape Factor	Rigidity Coefficient
Bottom	Inner	3.08±0.63 ^a	26.04±4.27 ^a	100.78±16.48 ^a	0.87±0.04 ^a	0.74±0.04 ^a
	Middle	3.28±0.45 ^a	24.39±2.56 ^a	100.93±13.87 ^a	0.88±0.02 ^a	0.76±0.03 ^a
	Outer	3.17±0.41 ^a	25.08±2.52 ^a	95.41±13.02 ^a	0.88±0.02 ^a	0.75±0.03 ^a
	Average	3.18±0.35 ^a	25.17±2.47 ^a	99.04±9.02 ^a	0.88±0.02 ^a	0.75±0.02 ^a
Middle	Inner	3.50±0.51 ^a	23.06±2.75 ^a	101.86±15.73 ^a	0.90±0.02 ^a	0.77±0.03 ^a
	Middle	3.59±0.39 ^a	22.64±2.15 ^a	88.79±7.83 ^a	0.90±0.02 ^a	0.77±0.02 ^a
	Outer	3.45±0.36 ^a	23.31±1.99 ^a	92.76±8.81 ^a	0.89±0.02 ^a	0.77±0.02 ^a
	Average	3.52±0.17 ^a	23.00±0.95 ^a	94.47±9.96 ^a	0.89±0.01 ^a	0.77±0.01 ^a
Top	Inner	3.70±0.38 ^a	21.99±1.82 ^a	92.79±8.81 ^a	0.91±0.01 ^a	0.78±0.02 ^a
	Middle	3.76±0.26 ^a	21.77±1.27 ^a	94.59±9.43 ^a	0.91±0.01 ^a	0.78±0.01 ^a
	Outer	3.79±0.30 ^a	21.53±1.35 ^a	96.25±15.17 ^a	0.91±0.01 ^a	0.79±0.01 ^a
	Average	3.75±0.21 ^a	21.76±1.02 ^a	94.55±6.94 ^a	0.91±0.01 ^a	0.78±0.01 ^a

Remarks: Values with the same letter in the same column are not significantly different at $p < 0.05$

low value of Luce's shape factor and rigidity coefficient is related to better tensile, tearing, bursting strength and also folding resistance of paper (Kaur & Dutt, 2013; Sharma et al., 2011, 2018). In *C. mannii*, the slenderness ratio was more than 70, but Luce's shape factor and rigidity coefficient were higher than other bamboo species (Sharma et al., 2011; Abdullah Siam et al., 2019).

Density, moisture content and shrinkage are important physical properties. They affect the dimensional stability and strength of bamboos (Anokye et al., 2014). These properties are also related to anatomical characteristics and determine the suitability of bamboos for various uses. The results are given in Table 4 show an increase in density from inner to outer zone in the radial direction and from bottom to top in the vertical direction. On the other hand, moisture content decreased from the inner to outer zone in the radial direction. It increased from bottom to middle and then decreased towards the top. Both density and moisture content varied significantly in the radial direction but non-significantly in the vertical direction. More compactly arranged vascular bundles with a high percentage of

fibres and less parenchyma may increase density and decrease moisture content in both vertical and radial directions. The maximum moisture content in the middle position may be due to well-developed vascular bundles having a maximum diameter in the inner and middle zones. The present study corroborates the findings of other works (Yu, Jiang, Hse, & Shupe, 2008; Nordahlia, Anwar, Hamdan, Zaidon, Paridah, & Rajak, 2012; Anokye et al., 2014; Sharma et al., 2017; 2019) who reported similar results in other bamboo species.

Longitudinal shrinkage was minimal like in other bamboo species. Radial shrinkage was higher than tangential shrinkage. Both radial and tangential shrinkage decreased from bottom to top with significant variation between the bottom and middle positions (Table 5). In general, the rays are absent in bamboos like other monocotyledons which may be the probable reason for higher radial shrinkage and confirms the findings of Anokye et al. (2014). The shrinkage properties in the bamboos are also related to the anatomical structure. The alignment of microfibrils concerning the longitudinal axis in the S2 layer of fibres is responsible for this property in

Table 4. Density and moisture content of *Cephalostachyum mannii*

Position	Zone	Density (g/cc)	Moisture content (%)
Bottom	Inner	0.37±0.03 ^a	191.95±21.19 ^c
	Middle	0.43±0.05 ^b	158.73±22.81 ^b
	Outer	0.63±0.06 ^c	90.13±12.59 ^a
	Average	0.48±0.12 ^b	146.22±47.16 ^b
Middle	Inner	0.35±0.05 ^a	216.05±44.97 ^c
	Middle	0.42±0.04 ^b	168.20±19.65 ^b
	Outer	0.64±0.05 ^c	85.70±11.42 ^a
	Average	0.47±0.14 ^b	156.65±61.42 ^b
Top	Inner	0.39±0.05 ^a	194.11±37.35 ^c
	Middle	0.46±0.05 ^b	151.32±25.47 ^b
	Outer	0.71±0.07 ^c	73.67±13.45 ^a
	Average	0.52±0.02 ^b	139.54±57.20 ^b

Remarks: Values with the same letter in the same column are not significantly different at $p < 0.05$

Table 5. Shrinkage in culms of *Cephalostachyum mannii*

Position	Radial Shrinkage	Tangential Shrinkage	Longitudinal Shrinkage
Bottom	10.83 ± 1.73 ^b	8.82 ± 2.77 ^b	0.25 ± 0.32 ^a
Middle	8.45 ± 1.09 ^a	6.16 ± 2.33 ^a	0.31 ± 0.60 ^a
Top	7.74 ± 1.10 ^a	5.17 ± 2.01 ^a	0.24 ± 0.29 ^a

Remarks: Values with the same letter in the same column are not significantly different at $p < 0.05$

wood. The bamboo fibres are polylamellate in nature and have narrow lamellae with a large microfibril angle of 85-90° and broad lamellae with angle parallel to the longitudinal axis fibres (Parameswaran & Liese, 1976). The maximum shrinkage (both radial and tangential) at the bottom may be due to the presence of highly lignified fibres in the outer zone.

IV. CONCLUSION

The anatomical characteristics revealed that Type II vascular bundles are present in the culms of *Cephalostachyum mannii*. The vascular bundles were well-developed in the middle zone. Hence, the middle zone of both bottom and middle positions can be used to identify this species. Most of the anatomical characteristics varied significantly in both radial and vertical directions. In terms of fibre morphology, the fibres were long, rigid and highly thick-walled.

The slenderness ratio was desirable, but other indices did not fulfil its requirement as a superior material for pulp and paper. Among physical properties, density increased both in radial and vertical directions, whereas moisture content decreased in these directions. Radial shrinkage was more than tangential shrinkage. Both radial and tangential shrinkage decreased from bottom to top. The fibres of *C. mannii* were thick-walled and rigid. Therefore, it did not fulfil the requirements as a superior fibrous material for pulp and paper. It may be used for making good quality handicrafts, basketry and furniture items based on the present study. However, the detailed study on its mechanical properties, the ultrastructure of fibre wall and its effect on physicochemical properties need to be investigated for commercial purposes.

ACKNOWLEDGEMENT

The authors are thankful to Director, North Eastern Regional Institute of Science and Technology, Nirjuli, to provide laboratory facilities.

REFERENCES

- Abdullah-Siam, N., Uyup, M.K.A., Husain, H., Mohmod, A.L., & Awalludin, M.F. (2019). Anatomical, physical, and mechanical properties of thirteen Malaysian bamboo species. *BioResources*, 14(2), 3925-3943.
- Anokye, R., Kalong, R.M., Bakar, E.S., Ratnasingam, J., Jawaid, M., & Awang, K. (2014). Variations in moisture content affect the shrinkage of *Gigantochloa scortechinii* and *Bambusa vulgaris* at different heights of the bamboo culm. *BioResources*, 9(4), 7484-7493.
- Ashori, A., & Nourbakhsh, A. (2009). Studies on Iranian cultivated paulownia- A potential source of fibrous raw material for paper industry. *European Journal of Wood and Wood Products*, 67, 323-327.
- Bektas, I., Tutus, A., & Eroglu, H. (1999). A study of the suitability of calabrian pine (*Pinus brutia* Jen.) for pulp and paper manufacture. *Turkish Journal of Agriculture and Forestry*, 23(3), 589-597.
- Cao, S., Ma, X., Lin, L., Huang, F., Huang, L. & Chen, L. (2014). Morphological and chemical characterization of green bamboo (*Dendrocalamopsis oldhami* (Munro) Keng F.) for dissolving pulp production. *Bioresources*, 9(3), 4528-4539.
- Dutt, D., Upadhyaya, J.S., Tyagi, C.H. & Malik, R.S. (2004). Studies on pulp and paper making characteristics of some Indian non-woody fibrous raw materials: Part II. *Journal of Scientific and Industrial research* 63, 58-67.
- FSI (2019). *Indian state of forest report*. Retrieved from <http://www.fsi.nic.in>. on the 1st October 2020.
- Grosser, D., & Liese, W. (1971). On the anatomy of Asian bamboos with special reference to their vascular bundles. *Wood Science and Technology*, 5, 290-312.
- IS 6874 (2008). *Methods of test for bamboos*. Bureau of Indian Standards, New Delhi.
- Johansen, D.A. (1940). *Plant microtechnique*. New York: Mc Graw Hill Book Company.
- Kaur, H., & Dutt, D. (2013). Anatomical, morphological and chemical characterization of lignocellulosic by products of lemon and sofa grasses obtained after recuperation of essential oils by steam distillation. *Cellulose Chemistry Technology*, 47(1-2), 83-94.
- Kelemwork, S. (2009). Effects of some anatomical characteristics of Ethiopian lowland bamboo (*Oxytenanthera abyssinica*) on physical and mechanical properties. *Journal of Bamboo and Rattan*, 8, 161-174.
- Kumar, Y.B., Sharma, M., & Sharma, C.L. (2015). Anatomical and physical properties of *Bambusa mizorammeana* Naithani. *International Journal of Advanced Research*, 3(4), 479-486.
- Kharlyngdoh, E., & Barik, S. (2008). Diversity, distribution pattern and use of bamboos in Meghalaya. *Journal of Bamboo and Rattan*, 7(1 &2), 73-90.
- Latif, A.M., & Tamizi, M.M. (1992). Variation in anatomical properties of three Malaysian Bamboos from natural stand. *Journal of Tropical Forest Science*, 5(1), 90-96.
- Liese, W. (1998). The anatomy of bamboo culms. *Technical Report 18*. INBAR, Beijing.
- Londoño, X., Camayo, G.C., Riaño, N.M., & López, Y. (2002) Characterization of the anatomy of *Guadua angustifolia* (Poaceae: Bambusoideae) culms. *Bamboo Science and Culture*, 16(1), 18-31.
- Luce, G. E. (1970). The physics and chemistry of wood pulp fibres. *Tappi* 8, 278.
- Maya, C., Narasimhamurthy, & Pandey, C. N. (2013) A study on anatomical and physical properties of cultivated bamboo (*Oxytenanthera monostigama*). *International Journal Current Science*, 5, 62-66
- Nordahlia, A.S., Anwar, U.M.K., Hamdan, H., Zaidon, A., Paridah, M.T., & Rajak, A. (2012). Effects of age and height on selected properties of Malaysian bamboo (*Gigantochloa levis*). *Journal of Tropical Forest Science*, 24(1), 102-109.
- Norul-Hisham, H., Othman, S., Rokiah, H., Latif, M.A., Ani, S., & Tamizi, M.M. (2006). Characterization of bamboo *Gigantochloa scortechinic* at different ages. *Journal of Tropical Forest Science*, 18(4), 236-242.
- Parameswaran, N., & Liese, W. (1976). On the fine structure of bamboo fibres. *Wood Science and Technology*, 10, 231-246.

- Razak, W., Mohamed, A., Samsi, H.W., Yunus, A.A.M., & Moktar, J. (2006). Physical characteristics, anatomy and properties of managed *Gigantochloa scortechinii* natural bamboo stands. *Journal of Plant Sciences*, 1(2), 144–153.
- Razak, W., Mustafa, M.T., Sulaiman, O., Mohamed, A., Hassan, A., & Khalid, I. (2010). Anatomical and physical properties of cultivated two and four year old *Bambusa vulgaris*. *Sains Malaysiana*, 39(4), 571–579.
- Razak, W., Mustafa, M.T., Rahman, S., Salam, M.A., Sulaiman, O., Sudin, M., & Rasat, M.S.M. (2012). Relationship between physical, anatomical and strength properties of 3 year old cultivated tropical bamboo *Gigantochloa scortechinii*. *Journal of Agricultural and Biological Science*, 7(10), 782–791.
- Runkel, R.O.H. (1949). Über die herstellung von zellstoff aus holz der gattung eucalyptus und versuche mit zwei unterschiedlichen eucalyptussarten. *Das Papier*, 3, 476–490.
- Sadiku, N.A., Oluyeye, A.O., & Ajauji, B. (2016). Fibre dimension and chemical characterization of naturally grown *Bambusa vulgaris* for pulp and paper production. *Journal of Bamboo and Rattan*, 15(1-4), 33-43.
- Sharma, A.K., Dutt, D., Upadhyaya, J.S., & Roy, T.K. (2011). Anatomical, morphological, and chemical characterization of *Bambusa tulda*, *Dendrocalamus hamiltonii*, *Bambusa balcooa*, *Malocana baccifera*, *Bambusa arundinacea* and *Eucalyptus tereticornis*. *BioResources*, 6(4), 5062-5073.
- Sharma, M., Sharma, C.L., Tado, N. & Laishram, D. (2019). Physical properties of apatani bamboo (*Phyllostachys bambusoides* Siebold & Zucc.) in relation to age and height. *International Journal of Advances in Science Engineering and Technology*, 7(3), 76-78,
- Sharma, M., Sharma, C.L., & Laishram, D. (2017). Variation in anatomical and physical properties of some Schizostachyum species of Manipur, India. *Journal of Indian Academy of Wood Science*, 14(1), 79-90.
- Sharma, M., Sharma, C.L., Bage, M., Gagoi, B.R., & Pangging, G. (2018). Anatomical characteristics and fibre dimensions of some grass species of arunachal pradesh and their potential for pulp and paper. *Journal of Bioresources*, 5(1), 41-48.
- Stapleton, C.M.A., Li, D.Z. & Xue, J.R. (1997). A new combination in *Cephalostachyum* with notes on names in *Neomicrocalamus* (Gramineae: Bambusoideae). *Kew Bulletin*, 52(3), 699-702.
- Tan, T., Rahbar, N., Allameh, S.M., Kwofie, S., Dissmore, D., Ghavami, K., & Soboyejo, W.O. (2011). Mechanical properties of functionally graded hierarchical bamboo structures. *Acta Biomaterialica*, 7(10), 3796-3803.
- Varghese, M., Subramanian, V.K.N., Bennet, S.S.R. & Jagadees, S. (1995). Genetic effects on wood and fibre traits of *Eucalyptus grandis* provenances. In eucalyptus plantation: Improving fibre yield and quality. CRCTHF-IUFRO Conference, pp 64- 67.
- Wang, S.G., Pu, X.L., Ding, Y.L., Wan, X.C. & Lin, S.Y. (2011). Anatomical and chemical properties of *Fargesia yunnanensis*. *Journal of Tropical Forest Science*, 23(1), 73-81.
- Wangaard, F.F. (1962). Contribution of hardwood to the properties of kraft wood pulp. *Tappi* 45, 548-556.
- Xing, H.Y., Qi, J.Q., Xie, J.L., Hao, J.F., Qin, B.D., & Chen, S.M. (2015). Variation in anatomical characteristics of bamboo. *Bambusa rigida*. *Sains Malaysiana*, 44(1), 17–23.
- Yu, H.Q., Jiang, Z.H., Hse, C.Y. & Shupe, T.F. (2008). Selected physical and mechanical properties of Moso bamboo (*Phyllostachys pubescens*). *Journal of Tropical Science*, 20(4), 258-263.
- Zhan, H., Zhao, J., Li, M., Wang, C. & Wang, S. (2017). Anatomical and chemical properties of bamboo sheaths (*Dendrocalamus brandisii*) as potential raw material for paper making. *European Journal of Wood and Wood Products*, 75(5), 847-851.

WORK MEASUREMENT STUDY ON MOTOR-MANUAL PINE TAPPING OPERATION: THE APPLICATION OF THE CONCEPT OF LEAN MANUFACTURING AND ALLOWANCES

Efi Yuliati Yovi*, Diah Prasetiana, and Natasha Aquilla Nirmalasari

Department of Forest Management, Faculty of Forestry and Environment, IPB University,
Jl. Raya Dramaga, Campus IPB Dramaga Bogor, 16680 West Java, Indonesia

Received: 11 January 2021 Revised: 21 April 2021 Accepted: 22 April 2021

WORK MEASUREMENT STUDY ON MOTOR-MANUAL PINE TAPPING OPERATION: THE APPLICATION OF THE CONCEPT OF LEAN MANUFACTURING AND ALLOWANCES. Derivated products of pine resin have been recognised as competitive commodities in global trade, increasing the need to use resources more efficiently. A hand-held tapping machine with small hoe-shape cutters called “mujitek” has been widely applied in Indonesia among efforts to answer this challenge. In this study, a series of observed (actual) work time data were measured and analysed, adopting lean manufacturing to calculate the basic and standard time of the work and estimate the work produced on the tapping operation. Work elements were identified based on their contribution to change or transform the product and were categorised as value-added, non-value-added, and special allowance. Quantitative data on the work productivity in the tapping operation can be used as one fundamental data in determining a work plan to establish a continuous improvement process. The variable fatigue allowances taken into account in this study were standing posture, abnormal posture, muscular energy, atmospheric conditions, and noise. This study shows that non-value-added work elements (repairing machines, chatting, and smoking) cause inefficiency in tapping operation. Analysis of added-value work elements proved that this hand-held tapping machine offers a higher (1.7 times) work productivity than conventional hand-held tapping tools. However, since humans have limitations in the physical, physiological, and mental dimensions that limit their ability to carry out work at a certain level, the discovered work productivity level should also be validated with other thresholds, e.g., physical workload and risk perception.

Keywords: Ergonomics, pine resin, time work, standard time, work productivity

PENGUKURAN KERJA PADA OPERASI PENYADAPAN GETAH PINUS SECARA MOTOR-MANUAL: APLIKASI KONSEP LEAN MANUFACTURING DAN KELONGGARAN. Produk turunan getah pinus telah diakui sebagai komoditas yang kompetitif dalam perdagangan global, hal ini mendorong peningkatan efisiensi penggunaan sumber daya. Salah satu upaya yang dilakukan untuk menjawab tantangan tersebut adalah penggunaan secara luas mesin sadap dengan pemotong berbentuk cangkul kecil yang disebut “mujitek”. Dalam penelitian ini, serangkaian data waktu kerja yang diamati (waktu kerja aktual) diukur dan dianalisis dengan mengadopsi konsep lean manufacturing untuk menghitung waktu dasar dan waktu standar dan menentukan produktivitas kerja penyadapan. Elemen kerja diidentifikasi berdasarkan kontribusinya dalam proses mengubah atau mentransformasikan produk, dan dikategorikan sebagai elemen kerja dengan nilai tambah, non-nilai tambah, dan kelonggaran kebusus. Data kuantitatif produktivitas kerja pada operasi penyadapan dapat digunakan sebagai salah satu data dasar dalam menentukan rencana kerja untuk melangsungkan proses perbaikan yang berkelanjutan. Variabel kelonggaran kelelahan yang diperhitungkan dalam penelitian ini adalah postur berdiri, postur abnormal, energi yang dikeluarkan, kondisi atmosfer, dan kebisingan. Studi ini menunjukkan bahwa elemen pekerjaan yang tidak memiliki nilai tambah (memperbaiki mesin, mengobrol, dan merokok) menyebabkan ketidakefisienan dalam kegiatan penyadapan. Analisis terhadap elemen kerja bernilai tambah membuktikan bahwa penggunaan mesin sadap genggam menawarkan produktivitas kerja yang lebih tinggi (1,7 kali lipat) dibandingkan dengan alat sadap genggam konvensional. Namun, karena manusia memiliki keterbatasan dalam dimensi fisik, fisiologis, dan mental yang membatasi kemampuannya untuk melaksanakan pekerjaan pada tingkat tertentu, maka tingkat produktivitas kerja yang ditemukan juga harus divalidasi dengan ambang batas lainnya, antara lain beban kerja fisik dan persepsi terhadap risiko.

Kata kunci: Ergonomi, getah pinus, penelitian waktu, waktu standar, produktivitas kerja

*Corresponding author: eyyovi@apps.ipb.ac.id

I. INTRODUCTION

Pinus (*Pinus merkusii* Jungh et de Vries) is a native Indonesian species. Pine yields resin (its subsequent productions are gum turpentine and gum rosin/gum naval stores). Indonesia has managed pine on a large scale; the estimated plantation area is 1.8 million ha, 882,066.53 ha area located in Java Island (Perhutani, 2020). The national export value of this non-timber forest product was recorded at USD 84.7 million in 2019 (TrendEconomy, 2019), far greater than the economic value of pinewood obtained in the same year (BPS, 2020).

Pine tapping activity provides significant employment opportunities for local communities (Yovi & Amanda, 2019). In Indonesia, pine resin tapping is carried out under manual or motor-manual operation. Conventional tapping tool in the form of a small iron-made hoe (*kadukul*) (*Sundanese*) (*pethel*) (*Javanese*) to chop the bark away (tapping face) in Hugue or square (*koakan*) tapping technique (Yovi & Amanda, 2019) is the most common tapping practice. However, in the last decades, the use of a hand-held tapping machine, local people call it “mujitek”, has received wide attention. This tool was invented in 2012 by Muji, a pine tapper from Malang Forest District, Indonesia. He constructed mujitek from a lawnmower with a modification to the cutting head. Compared to the conventional tapping tool, this tapping machine offers convenience in completing the work, especially in the context of working speed.

In Java Island, almost all pine forests are managed by the state-owned company Perum Perhutani. The pine tapping activities are carried out by local communities who hold a “tapping contract” with a piece-rate payment system, where the wages are paid based on the volume of the tapped resin (Yovi & Amanda, 2019). This payment system is common among low-wage industries and widely adopted in developing countries (Davis, 2016). This payment system may offer higher earnings than the fixed-rate

payment system (Hart, 2016). However, this payment system may drive workers to pursue higher production (Borino, 2018) and give less attention to their occupational safety and health. The more resin collected, the greater the wages that can be received. The same thing is valid for the company; the more resin is harvested, the greater the profit.

This system leads on how to design the work to fit the tapping operation that benefits both workers and the plantation company. Among the many questions pointed out to the human-machine performance compared to motor-manual tapping, productivity is crucial. The information on work productivity will help both the tapper and the company determine a work plan to establish a continuous improvement process (Womack & Jones, 2003).

Measuring work productivity is very difficult, especially when the work involves the presence of human activity. Therefore, considering humans' limitations, it is important to measure work productivity by using work and time study techniques that accommodate humans' physical, physiological, and mental constraints. In answering these requirements, a lean manufacturing concern (Mayer, Maciel, Baggio, & Siendenberg, 2015) is apt to be applied in time study analysis (Cury & Saraiva, 2018).

Up to now, no work and time study analysis in motor-manual pine tapping operation had been carried out under the lean manufacturing concept. Therefore, this research was aimed to measure work productivity in motor-manual tapping operation, and at the same time, demonstrate how the lean manufacturing concept (that repositioning added-value and non-added-value work elements) is applied to estimate the standard time. The time study analysis described in this study would enrich the time study analysis techniques in measuring the standard work productivity, especially in examining human-work relations in the forestry sector.

II. MATERIAL AND METHOD

Tapping operation consists of wounding/refreshing and collecting. In this study, the time study analysis was carried out for wounding activities. Primary data taken includes observed time and daily temperature at the workplace. The tools used in data retrieval and processing were a video camera and a WBGT meter. The study was conducted from February to March 2020 in 3 tapping sites of *P. merkusii* Jungh et de Vries (aged 19 years). The understorey conditions at the study sites were relatively similar, with slightly thicker shrubs in some locations. The slope class is 6-15%, with an average temperature of 30°C. Work productivity is defined as the ratio between the output to the input of a production process. In this study, work productivity refers to labour productivity that describes the ratio between tapped trees to the used capacity (given in time units).

Observations were made on three respondents. In total, they tapped 405 trees per day. There were three days of observations for each respondent. For the comprehensive application of the lean manufacturing concept, one working day is considered one work cycle in this analysis. Observation time was measured by recording the tapping activities of the whole day using a video camera. Before data collection, socialisation and habituation were carried out to avoid overacting that may arise due to awkward feelings when observed using a video camera all day long.

A. Determining Work Elements

The work elements determination in this study adopts the “lean manufacturing” principle proposed by Mayer, Maciel, Baggio, and Siendenberg (2015):

“The work can be divided into work that adds value and work that does not add value. The work that does not add value can be considered a waste. On the other hand, work that adds value is the one that involves processing to change or transform the product or the assembly thereof. It should also be considered that work that does not add value can be necessary due to the machines and processes’ characteristics.” Mayer et al.

(2015) stated that one cycle of work may consist of several value-added work elements and non-value-added work elements. This opinion was later adopted by Cury and Saraiva (2018).

The value-added work elements are defined as all work elements needed for the whole cycle to take place. Value-added work elements are further classified as effective and supportive work elements. An effective work element is a work element that directly contributes to the cycle, therefore, standard work time is calculated only for this effective work element. The supportive work elements are defined as all work elements that do not directly contribute to the work cycle but are still necessary to run the whole process. This supportive work element is unintentional/unavoidable. In general, these work elements can be classified as operative and mechanical supportive work elements. These work elements needed to be minimised.

Non-value-added work elements are work elements that do not support and are not directly or indirectly related to the production process. Apart from being unrelated to the production process, this element’s main characteristic increase production costs, avoidable time delays, and unimportant. In the concept of “lean manufacturing,” this work element needs to be eliminated. Mayer et al. (2015) categorised it as “waste” - so that the standard time for these non-value-added work elements is not necessary. This “waste” is generally classified as a personal and mechanical interruption.

In a work cycle, there is another unavoidable delay that applies to work elements. This delay is categorised as a special allowance that plays a role as an enabling element. This allowance is directly added to the cumulative standard time of effective and supportive work elements in a standard time calculation. A detailed work element classification is shown in Figure 1.

B. Standard Time Measurement

Several terminologies used in this time study analysis, i.e., observed time, basic time, normal time, standard time, and allowances, are described as follows:

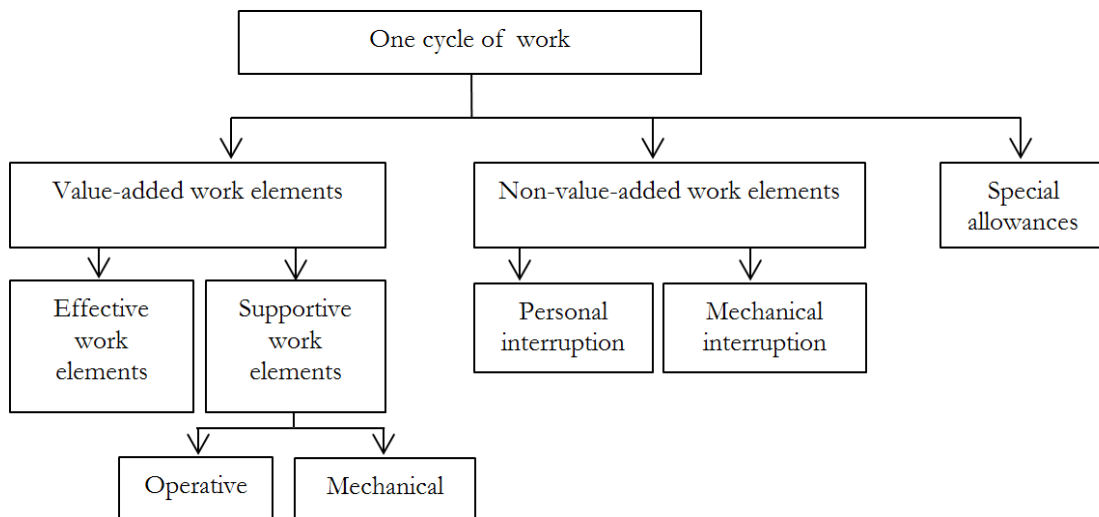


Figure 1. Work elements classification based on the lean manufacturing concept

1. Observed time

The actual work time obtained as a result of observations is referred to as “observed time.”

2. Basic time (normal time)

Basic time is obtained by multiplying the observed time to the respondent’s performance rating (known as a performance rating factor, RF) (Equation 1). RF is defined as the ratio between the operator’s actual performance to the normal performance (refers to workers with standard pace). Standard pace is defined as the effective rate of performance of a conscientious, self-paced, qualified employee when working neither fast nor slow and giving due consideration to the specific job’s physical, mental, or visual requirements (Niebel & Freivalds, 2003). RF value could be determined through preliminary observations, assessment of the co-workers, or using a predetermined value. The RF value is used as a correction factor to determine the basic time value from observation time (Equation 1).

$$BT_{we-i}^T = OT_{we-i}^T \times RF \dots\dots\dots(1)$$

Remarks:

- BT_{we-i}^T = Basic time for work element-i
- OT_{we-i}^T = Observed time for work element-i
- RF = Rating factor for work element-i

3. Allowances

Allowance is an addition to basic time, allocated and valued proportionally based on the workers’ internal and external conditions. Allowances accommodate the humans’ limitations in physical, physiological, and mental aspects. The allowance distribution in this study adopts Niebel’s method (Niebel & Freivalds, 2003). In this study, the allowance structure was categorised into constant and variable fatigue allowances.

Constant allowances consist of personal needs and basic fatigue allowances. The first constant allowance refers to all cessation in work taken to maintain the workers’ general well-being. Including in this category are personal delays for drinking water and going to the restroom. According to globally adopted consensus, a value of 5% for personal allowance and 4% for basic fatigue allowance are considered adequate (ILO, 1979).

The second allowance is defined as the delay required to compensate for the energy expended to carry out the work (Niebel & Freivalds, 2003), which may vary depending on the process, equipment, and materials. The common variable fatigue allowances are (but not limited to) standing, abnormal posture,

use of force, illumination level, visual strain, atmospheric condition, close attention, noise level, mental strain, monotony, and tediousness. In this study, the variable fatigue allowances used were only needed according to the tapping work characteristics, identified as standing, abnormal posture, use of force energy, atmospheric conditions, and noise. Constant and variable fatigue allowances applied in this

study, determined by several previous studies and widely adopted, are tabulated in Table 1.

4. Standard time

Standard time is required for a qualified worker to perform the work at a standard pace and exert average effort (Niebel & Freivald, 2003). It means that the standard time for a work element is a function of both basic time and allowance factors. Standard time is measured

Table 1. Constant and variable rest allowances applied in this study, its equation, and references

No.	Allowance	Description	Reference
1	Constant allowances		
	Personal needs	5%	ILO (1979); Niebel and Freivald (2003)
	Basic fatigue	4%	ILO (1979); Niebel and Freivald (2003)
2	Variables, fatigue allowances		
	Standing	2%	ILO (1979)
	Abnormal posture	Awkward (bending): 10% Very awkward (stretching or lying): 10%	Garg et al. (1978)
	Use of force/muscular energy	Weight lifted 25 lb: 4% Weight lifted 30 lb: 5% Weight lifted 35 lb: 7%	ILO (1979)
	Atmospheric conditions	$RA = e^{(-41.5 + 0.016w + 0.497WBGT)}$ Explanation: RA = rest allowance (%) W = energy expenditure (kcal/h) WBGT = wet-bulb globe temperature (°F)	NIOSH (1989)
Noise (using the OSHA-Permissible Noise Level), for an 8-h workday	RA = 100 (D-1) D = C1/T1 + C2/T2+ ... For intermediate noise levels: $T = \frac{32}{2^{(L-90)/5}}$ Where: RA = rest allowance (%) D = noise dose (decimal value) C = time spent at specified noise level (h) T = time permitted at specified noise level (h) (OSHA 1983) L = noise level (dBA) or 5% for intermittent-very loud/high pitched-loud for less than 8-h workday.	OSHA (1983) (1983); Niebel and Freivald (2003); ILO (1979)	

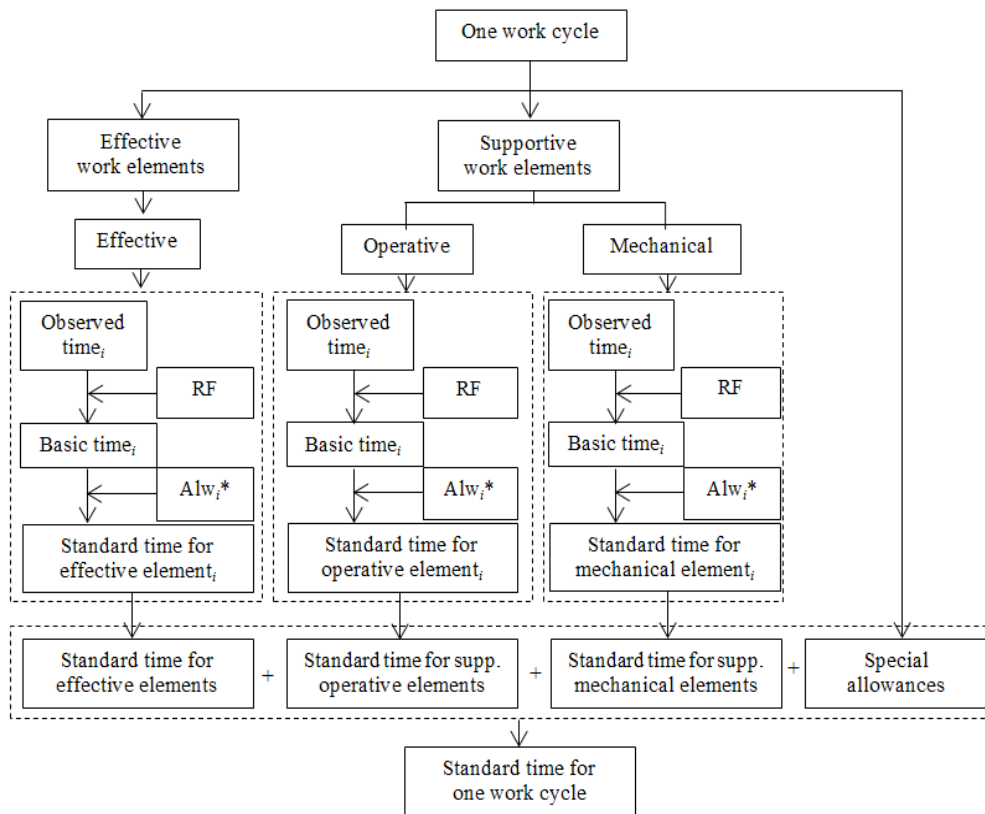


Figure 2. The workflow on standard time measurement
 Remarks: RF = Rating Factor; Alw_i = allowance for work element

only for value-added work elements. In one work cycle, the standard time is calculated as the sum of elemental’s standard time (Equation 2), in which the standard elemental time is calculated by multiplying the elemental’s basic time by (total) allowance multiplier (Equation 3). Thus, if 20% of allowances are provided on an operation, the multiplier is equal to 1.2. The flow of standard time estimation activities in one work cycle are described in Figure 2.

$$ST_{cycle} = \sum_{i=1}^n ST_{we-i} \dots\dots\dots(2)$$

Remarks:
 ST_{cycle} = Standard time for one cycle with n value-added work elements

Where:

$$ST_{we-i} = BT_{we-i} (1 + Al_{we-i}) \dots\dots\dots(3)$$

Remarks:
 ST_{we-i} = Standard time for work element-i
 BT_{we-i} = Basic time for work element-i
 Al_{we-i} = Allowance for work element-i

III. RESULT AND DISCUSSION

A. The Motor-manual Tapping Tool

In this study, the hand-held tapping machine was modified from STIHL FR 3000 weeding machine with a hand-made cutting head (12 cm diameter of gear) (Figure 2). The total weight of this machine was approximately 13 kg (average). Refreshing work in a tapping face, bark removal activity, was repeated periodically (once per three days). Three times refreshing was followed by resin collecting work (usually once per 10 days tapping period). Thus, the readers can get a broader insight into how the lean manufacturing concept should be applied in a time study analysis.

B. Special Allowances (SA)

The added-value work element in one work cycle of tapping operation consists of three effective work elements (EF: walking, cleaning

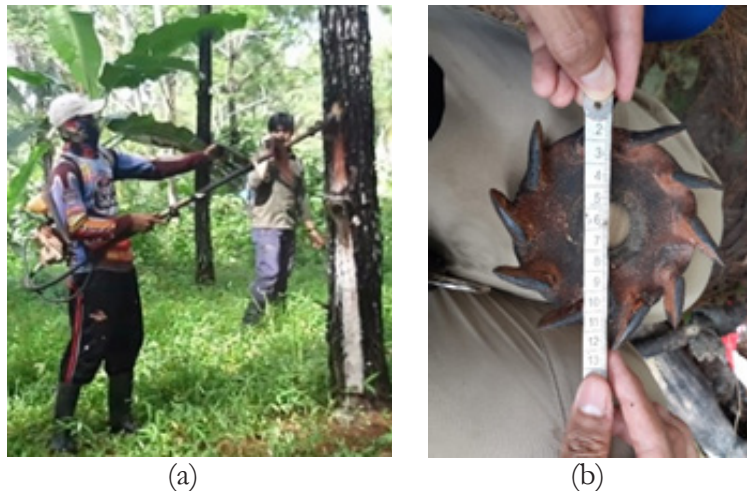


Figure 3. Tapping a pine tree: (a) hand-held tapping machine, (b) the head cutter's shape

understorey, wounding the tapping face) and two supportive operative elements (SO: reinstalling resin pot and cleaning wood chips). The identified non-value-added work elements were two personal interruption elements (PI: chatting and smoking) and the other two mechanical interruption elements (MI: machine repairing and procuring repairing tools). Further, work preparation and tidying up (after work activity) were defined as work elements that did not meet the supportive work element category. These work elements caused a delay. This delay was unavoidable but yet necessary to effort effective work elements. Tapping work will not go well, if workers do not wear personal protective equipment, starting the machine, and set the machine properly on their back before the operation. Therefore, work preparation and tidying up were categorised into special allowances (Table 2).

C. Observed time

The distribution of observed time shows that worker 1 (W1) and worker 2 (W2) spend 40% and 37% of their total work time on non-value-added work elements, namely repairing machines, chatting, and smoking (Table 3). The activity of repairing machines (caused by improper and/or regular maintenance), chatting, and smoking were intentional delays (Niebel & Freivalds, 2003), which is no way

supported the tapping operation. Thus, these activities were categorised as “waste” (Mayer, Maciel, Baggio, & Siendenberg, 2015) and were not further calculated (Cury & Saraiva, 2018). Given that apart from tapping, workers also have other activities to be carried out after tapping, waste activities must be eliminated. Conducting regular maintenance on the tapping machines, stopping or reducing smoking habits, and stopping chatting about unnecessary subjects will reduce waste elements. Regular maintenance will reduce the risk of delay in the middle of the operation. In terms of smoking, apart from time-consuming, this habit is expensive. Yovi and Yamada (2019) revealed that cigarette consumption expenditure could reach up to 17% of a household's monthly total income.

D. Basic time

Preliminary observations and field supervisors' assessment showed that worker 3 (W3, 26 years of work experience) worked normally. Thus this RF was set as 1. W1 tend to work faster than others (RF = 1.9), while W2 was slower (RF= 0.75). The observed time for the value-added work element (Table 3) was then multiplied by the RF value to obtain the basic time for each work element (Figure 4). The basic time distribution shows that the dominant work element in tapping is walking (EF1) and

Table 2 The added-value, non-added-value, and special allowances in a work cycle of tapping operation

Work elements		Descriptions
Effective work elements		
EF1	Walking	Walking from the work hut to the work area or walking among the trees.
EF2	Cleaning understory	Clearing of undergrowth.
EF3	Making refreshing wound	Any activity performed when workers make a wound on the tapping face.
Special allowance (unavoidable delays)		
SA1	Work preparation	Work preparation activities consisted of wearing PPE (mask and safety shoes), start the tapping machine, and put on the machine on their back. This preparatory activity was carried out in the work hut.
SA2	Tidying up	Turning off the engine, putting off the machine, and taking out PPE.
Supportive operation		
SO1	Reinstalling/relocating resin pot	This activity was carried out when workers find a resin pot not correctly positioned to hold resin.
SO2	Cleaning wood chips	Refreshing work caused by small pieces of wood which get stuck all over the body. The cleaning of wood chips activity was carried out when the tappers felt being disturbed by the chips.
Personal interruption		
PI1	Chatting	Chatting was defined as talking about topics with no relation (directly and indirectly) to work activities.
PI2	Smoking	Smoking was done while resting in the hut after the refreshing activity.
Mechanical interruption		
MI1	Machine repairing	Machine repair activities consisted of checking the engine's condition, spark plugs, and repairing the cutter head.
MI2	Procuring repairing tools	This element consisted of taking screwdrivers or spare spark plugs and a grind to sharpen the cutter.

Remarks : EF = effective working element; SA = special allowances; SO = supportive operative; PI = personal interruption; MI = mechanical interruption

wounding (EF3). The basic time distribution also shows that W3, the standard worker, performed cautious tapping. During tapping, he also removed the dirt and reinstalled the position of the resin pot. Proper pot installation will reduce the chance of spilling resin, saving the volume of resin being harvested.

E. Constant and Variable Allowances

In this study, allowances were calculated for each work element. The allowance type and its value follow the activity's characteristics and its specific workplace environment (Niebel & Freivalds, 2003). Tapping activities were often carried out at tapping points exceeding 2.5 m

above the forest floor, causing an exceeding shoulders flexion. The concept of natural Range of Motion (Openshaw & Taylor, 2006) has classified this shoulder movement as "extreme." Yovi, Takimoto, Ichihara, and Matsubara (2005) state that physiological workload during making refreshing wounds at breast height may burden workers with 51% VdotO2max, which could be higher in an awkward posture. Awkward postures trigger musculoskeletal stress, cause higher physical work and musculoskeletal disorders (Yovi & Andriyani, 2019). In addition, the use of a tapping machine in this work may cause unintended noise exposure that triggers psychological stress to the worker

Table 3. Observed time in motor-manual pine tapping operation

	Work elements	Work situation	Observed time (s)		
			Worker 1	Worker 2	Worker 3
Effective work elements					
EF1	Walking	Standing, carrying tapper machine, exposed by atmospheric conditions, exposed by low noise level (machine idling)	2157	1297	1999
EF2	Cleaning understorey	Standing, carrying tapper machine, exposed by atmospheric conditions, exposed by noise	105	14	96
EF3	Making refreshing wound	Standing, carrying tapper machine, exposed by atmospheric conditions, exposed by noise	2233	1357	1321
Special allowances					
SA1	Putting on PPE	Standing, not carrying tapper machine, exposed by atmospheric conditions, not exposed by noise	17	30	0
	Starting the tapper machine	Bending, not carrying tapper machine, exposed by atmospheric conditions, not exposed by noise	228	15	12
	Put the engine on the back.	Standing, carrying tapper machine, exposed by atmospheric conditions, exposed by low noise level (machine idling)	54	27	32
	Total S1		298	72	44
SA2	Set off tapper machine	Standing, not carrying tapper machine, exposed by atmospheric conditions, exposed by low noise level (machine idling)	42	13	35
	Putting off PPE	Bending, not carrying tapper machine, exposed by atmospheric conditions, not exposed by noise	20	21	0
	Total S2		62	34	35
Supportive operative					
SO1	Reinstalling/relocate the resin pot	Mostly bending, carrying tapper machine, exposed by atmospheric conditions, exposed by low noise level (machine idling)	53	18	128

Table 3 Continued

Work elements		Work situation	Observed time (s)		
			Worker 1	Worker 2	Worker 3
SO2	Cleaning body from wood chips	Standing, carrying tapper machine, exposed by atmospheric conditions, exposed by low noise level (machine idling)	84	23	14
Personal interruption					
PI1	Chatting	Sitting, not carrying tapper machine, exposed by atmospheric conditions, not exposed by noise	315	33	104
PI2	Smoking	Sitting, not carrying tapper machine, exposed by atmospheric conditions, not exposed by noise	1378	1578	0
Mechanical interruption					
MI1	Maintaining the machine	Sitting, not carrying tapper machine, exposed by atmospheric conditions, not exposed by noise	1428	18	47
MI2	Taking things from the work hut	Standing, not carrying tapper machine, exposed by atmospheric conditions, not exposed by noise	257	18	12
Total cycle time			8371	4462	3800

Remarks: EF = effective work element; SA = special allowances; SO = supportive operative; PI = personal interruption; MI = mechanical interruption

(Ising & Kruppa, 2004). Another concern that should also be addressed is the effects of excessive atmospheric heat, as has been verified by Krishnamurty, Ramalingan, Perumal, Kamalakanman, Chinnadurai, and Shanmugam (2017) and Notley, Meade, Souza, McGarr, and Kenny (2018) as this outdoor work is carried out in Indonesia.

Given that humans have limitations on physical, physiological, and psychological mechanisms (Kroemer & Grandjean, 1997), constant fatigue (personal needs and basic fatigue) allowances were added to all value-added work elements, both for effective and supportive work elements. The constant allowance was set at 9%. According to the work characteristics, the variable fatigue allowances taken into account in this study were standing, abnormal posture,

muscular energy, atmospheric conditions, and noise. In contrast, other variable relaxation allowances, i.e., illumination level, visual strain, mental strain, monotony, and repetitiveness, were excluded from the calculation (Table 4). Postural relaxation allowances for almost all elements were set at 2% because it was carried out in a standing position. Fatigue allowance for muscular energy is based on whether or not the load (machine) is carried when completing an element (ILO, 1979) (Table 1). In the case of relaxation allowances caused by atmospheric conditions, the amount of energy expenditure for each work element was calculated based on Yovi, Takimoto, Ichihara, and Matsubara (2005). For EF1, EF2, EF3, and SA13, the amount of physical workload was equivalent to 264.8 kcal/h, while the amount of energy

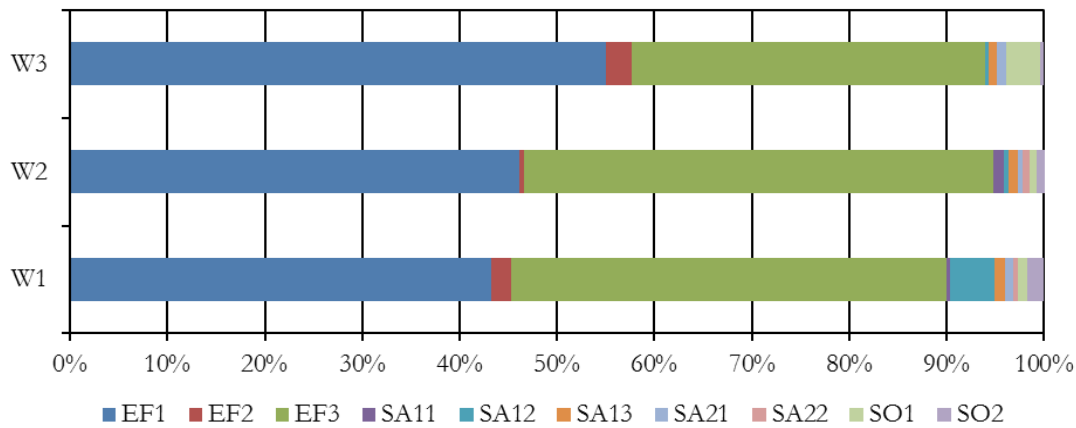


Figure 4. Basic time distribution of added-value and operative work element in motor-manual pine tapping operation

Remarks: EF1 = walking; EF2 = cleaning understorey; EF3 = making refreshing wound; SA11 = putting on PPE; SA12 = starting the tapping machine; SA13 = putting engine on the back; SA21 = putting off tapper machine; SA22 = putting off PPE; SO1 = reinstalling the resin pot; SO2 = cleaning wood chips

expenditure on the rest activities was considered to be 93.8 kcal/h. Rest allowance calculations for atmospheric conditions was 12.5% for WGBT= 86°F and W= 264.8 kcal/h, and 1% for WGBT= 86°F and W= 93.8 kcal/h. For noise factor, a high rotational speed engine can produce 94-96 dB(A) of noise, which according to OSHA-Permissible Noise Level, its permissible time is four hours. However, since the actual workday duration was less than two hours, 5% of the allowance was applied for working elements exposed by loud noise, and 0% applied for idling machines (considered as continuous-low level noise) (ILO, 1979).

F. Standard Time

Lan et al. (2009) underline the importance of work measurement in determining reasonable working time quota. Measuring standard time value is beneficial for both employers and tapping workers because pine resin harvesting is mostly considered a side economic activity (Yovi & Amanda, 2019). The standard time required to complete the tapping operation per tree was obtained by multiplying the standard time by its allowances multiplier (Table 5) (Niebel & Freivalds, 2003).

The total time required to complete tapping per tree (with two or three tapping faces) was 48-49 seconds. It means that by putting aside the house-workout travel time, tapping a 20 years pine stand with 150 trees is expected to be completed within approximately 2 hours of effective work. This verifies that hand-held machines offer far higher work productivity than conventional tapping tools. According to Yovi et al. (2005), the duration of initial observations of tapping productivity using conventional tapping tools was about 81 seconds per tree. It means that for the same number of trees, a worker needs 3.4 hours, which is 1.7 times longer. The average number of trees tapped per day by a worker who does tapping using the conventional tool only reaches 100-120 trees (or less) per day (Yovi & Amanda, 2019).

This study verified that the tapping operation, due to its uncontrollable work environment factors (Maughan, Otani, & Watson, 2012; Notley, Meade, D’Souza, McGarr, & Kenny, 2018), should be carried out in the morning. If tapping is carried out from 7 AM, the whole operation will be finished before 10 AM. This time range is the proper working duration to avoid excessive heat. This

Table 4. Basic time and allowances of added-value work elements in motor-manual pine tapping operation

WE	Basic time (s)			Allowances (%)					
	W1	W2	W3	Constant allowances		Variable fatigue allowances			
				Personal needs	Basic fatigue	Abnormal posture	Use of force/muscular energy	Atmospheric conditions	Noise
EF1	4098	973	1999	5	4	2	5	12.5	0
EF2	200	11	96	5	4	2	5	12.5	5
EF3	4243	1018	1321	5	4	2	5	12.5	5
SA11	32	23	0	5	4	2	0	1	0
SA12	433	11	12	5	4	2	0	1	0
SA13	103	20	32	5	4	2	5	12.5	0
SA21	80	10	35	5	4	2	0	1	0
SA22	38	16	0	5	4	2	0	1	0
SO1	101	14	128	5	4	2	5	1	0
SO2	160	17	14	5	4	2	5	1	0

Remarks: WE = work element; W1 = worker 1; W2 = worker 2; W3 = worker 3; EF1 = walking; EF2 = cleaning understorey; EF3 = making refreshing wound; SA11 = putting on PPE; SA12 = starting the tapping machine; SA13 = putting engine on the back; SA21 = putting off tapper machine; SA22 = putting off PPE; SO1 = reinstalled the resin pot; SO2 = cleaning wood chips

Table 5. Multiplier and standard time of added-value work elements in motor-manual pine tapping operation

Work elements	Total allowances (%)	Multiplier	Standard time (s)		
			W1	W2	W3
EF1	28.5	1.285	5266	1250	2569
EF2	33.5	1.335	256	12	123
EF3	33.5	1.335	5452	1308	1697
SA11	12	1.12	42	29	0
SA12	12	1.12	557	14	15
SA13	28.5	1.285	132	26	41
SA21	12	1.12	103	13	45
SA22	12	1.12	49	20	0
SO1	17	1.17	129	17	164
SO2	17	1.17	205	22	18
Total standard time per cycle (s)			12190	2713	4674
Total tapped trees			253	57	95
Duration per tree (s)			48	48	49

Remarks: W1 = worker 1; W2 = worker 2; W3 = worker 3; EF1 = walking; EF2 = cleaning understorey; EF3 = making refreshing wound; SA11 = putting on PPE; SA12 = starting the tapping machine; SA13 = putting engine on the back; SA21 = putting off tapper machine; SA22 = putting off PPE; SO1 = reinstalled the resin pot; SO2 = cleaning wood chips

information can also be used to organise the work shift of a workers' group who share the same machine. For plantation owners, this standard time information is useful guidance in managing tapping operation, e.g., regulate

the optimum tapping area for each worker according to management objectives (the distribution of tapping income, characteristics of local economics, or the availability of workers). Given that, globally, pine resin is

one of the potential Indonesian commodities (BPS, 2018), the use of machine tools should be considered as one promising alternative strategy in improving pine resin production.

However, operating (manuvering and controlling) this machine may require a higher physical workload as noted by the study of Hansen, Rasmussen, Kyed, Nielsen, and Andersen (2012) and vibration-noise exposure as mentioned by Ljungberg, Neely, and Lunstrom (2004), not to mention the environmental factors of the work. A well-known environmental factor that negatively influences human physiology is the heat at the workplace, as was noted by Krishnamurthy et al. (2017). Before this study, Maughen et al. (2012) noted that relative humidity is a potential environmental factor that should also be considered and may cause severe effects in human with prolonged exercise capacity. In relating to the climate change issue, Otani et al. (2016) also underline the negative effect of solar radiation on human health.

This study revealed that two major work elements dominate refreshing work: walking (while carrying the 13 kg tapping machine) and wounding a tapping face. "Walking" in this study refers to "carrying" (Table 2), a part of manual material handling because, during tapping, the machine was set on the back of the worker. Walking is one major work element; therefore, the issue on the excessive low back (L5/S1 lumbosacral disk) compression force should be further considered (Hasegawa, Katsuhira, Oka, Fujii, & Matsudaira, 2018).

This human health-work environment issue should get serious attention as humans are complex creatures with limitations in the physical, physiological, and mental dimensions that limit their ability to carry out work (Kroemer & Grandjean, 1997). Therefore, more in-depth work analysis on physiological and psychological costs (Kroemer & Grandjean, 1997) during motor-manual tapping should be carried out in the next research stage. The energy expenditure, the effect of vibration noise, postural analysis (including the psychophysical analysis), and

the risk perception (Schmidt, 2004) are other ergonomic aspects that need to be analysed. This research will provide useful, necessary information in determining the optimum tapping management for the sake of worker's well-being, which in the long run will improve the company's overall performance.

IV. CONCLUSION

The concept of lean manufacturing that considers the relationship of work elements to work productivity has offered an objective approach to work productivity calculations. In this time study analysis, the lean manufacturing concept shows that personal interruption and machine interruption are significantly time-consuming and have no contribution to effective work. Therefore, periodic machine maintenance and chatting-smoking during tapping work should be classified as non-value-added work elements. These non-value-added work elements must be reduced or fully eliminated to increase work productivity. Other work elements do not directly support tapping activities, but their existence is still required so that tapping operations can be carried out. This supportive work element needs to be categorised as value-added work elements but should be minimised. This study identifies reinstalling resin pots and cleaning wood chips as supportive work elements, while work preparation and tidying up as unavoidable delays existed in pine tapping activities. The variable fatigue allowances (that accommodates the human's limitation) that should be applied in standard time calculation of tapping operation are standing, abnormal posture, use of force/muscular energy, atmospheric conditions, and noise. The multiplier (allowances factors) for tapping operation using the hand-held tapping machine ranges from 1.12-1.34, depending on the specific work characteristics per work element. This study shows that a hand-held tapping machine offers higher work productivity (1.7 times higher) than the tapping by using conventional tools. However, there is also a need to carry out the physical workload,

postural analysis, and risk perception analysis on motor-manual tapping. A continuously improved tapping process can be formulated not only for efficient operation but also for the workers' well-being.

ACKNOWLEDGEMENT

We thank our colleagues from IPB University and Perum Perhutani for their valuable insight and expertise that greatly assisted the research.

REFERENCES

- Borino, F. (2018). Better work. Retrieved from <https://betterwork.org/portfolio/discussion-paper-28-piece-rate-pay-and-working-conditions-in-the-export-garment-sector/> on November 30, 2020.
- BPS. (2018). Beranda: Kehutanan. Retrieved from <https://www.bps.go.id/subject/60/kehutanan.html#subjekViewTab4> on September 18, 2020.
- BPS. (2020). Beranda: Kehutanan. Retrieved from <https://www.bps.go.id/subject/60/kehutanan.html#subjekViewTab4> on September 18, 2020.
- Cury, P., & Saraiva, J. (2018). Time and motion study applied to a production line of organic lenses in Manaus Industrial Hub. *Gestão da Produção, Operações e Sistemas*, 901-915. doi://dx.doi.org/10.1590/0104-530x2881-18.
- Davis, M. (2016). Pay matters: The piece rate and health in the developing world. *Annals of Global Health*, 82(5), 858-865. doi://10.1016/j.aogh.2016.05.005.
- Garg, A., Chaffin, D., & Herrin, G. (1978). Prediction of metabolic rates for manual materials handling jobs. *American Industrial Hygiene Association Journal*, 39(12), 661-674.
- Hansen, C., Rasmussen, K., Kyed, M., Nielsen, K., & Andersen, J. (2012). Physical and psychosocial work environment factors and their association with health outcomes in Danish ambulance personnel - A cross-sectional study. *BMC Public Health*, 12(1), 534. doi: 10.1186/1471-2458-12-534.
- Hart, R. (2016). *The rise and fall of piecework*. Bonn: IZA World of Labor.
- Hasegawa, T., Katsuhira, J., Oka, H., Fujii, H., & Matsudaira, K. (2018). Association of low back load with low back pain during static standing. *PLoS One*, 13(12), e0208877. doi://10.1371/journal.pone.0208877.
- ILO. (1979). *Introduction of work study*. Geneva: Impression Couleurs Weber.
- Ising, H., & Kruppa, B. (2004). Health effects caused by noise: Evidence in the literature from the past 25 years. *Noise Health*, 6(22), 5-13. Retrieved from <https://pubmed.ncbi.nlm.nih.gov/15070524/> on the 1st December 2020.
- Krishnamurty, M., Ramalingan, P., Perumal, K., Kamalakannan, L., Chinnadurai, J., & Shanmugam, R. (2017). Occupational heat stress impacts on health and productivity in steel industry in Southern India. *Safety and Health at Work*, 8(1), 99-104. doi://10.1016/j.shaw.2016.08.005.
- Kroemer, K., & Grandjean, E. (1997). *Fitting the task to the human*. 5th Edition. Bristol: Taylor & Francis.
- Lan, S., Wang, X., & Ma, L. (2009). Optimisation of assembly line based on work study. *The 16th International Conference on Industrial Engineering and Engineering Management* (pp. 813-816). Beijing: Industrial Engineering and Engineering Management. doi://10.1109/ICIEEM.2009.5344476.
- Ljungberg, J., Neely, G., & Ljunstrom, R. (2004). Cognitive performance and subjective experience during combined exposures to whole-body vibration and noise. *International Archives of Occupational and Environmental Health*, 217-221. doi://10.1007/s00420-003-0497-7.
- Maughan, R., Otani, H., & Watson, P. (2012). Influence of relative humidity on prolonged exercise capacity in a warm environment. *European Journal of Applied Physiology*, 112(6), 2313-2321. doi://10.1007/s00421-011-2206-7.
- Mayer, P., Maciel, A., Baggio, D., & Siendenberg, D. (2015). Implementation of methodology for analysing the added value in metallurgical industry of custom products. *Gestão da Produção, Operações e Sistemas*, 10(1), 177-195. doi://10.15675/gepros.v10i1.1178.
- Niebel, B., & Freivalds, A. (2003). *Methods, standards, and work design*. Boston: McGraw-Hill.

- NIOSH. (1989). *Criteria for a recommended standard for occupational exposure to hot environments*. Cincinnati: National Institute for Occupational Safety and Health.
- Notley, S., Meade, R., D'Souza, A., McGarr, G., & Kenny, G. (2018). Cumulative effects of successive workdays in the heat on thermoregulatory function in the aging worker. *Temperature*, 5(4), 293-295. doi:// 10.1080/23328940.2018.1512830.
- Openshaw, S., & Taylor, E. (2006). *Ergonomics and design - A reference guide*. Iowa: Allsteel Inc.
- OSHA. (1983). *Occupational noise exposure: Hearing conservation amendment, Federal Register 48*. Washington, DC: Occupational Safety and Health Administration.
- Otani, H., Kaya, M., Tamaki, A., Watson, P., & Maughan, R. (2016). Effects of solar radiation on endurance exercise capacity in a hot environment. *European Journal of Applied Physiology*, 116(4), 769-779. doi: 10.1007/s00421-016-3335-9.
- Perhutani. (2020). *Tentang Perhutani: Struktur organisasi*. Retrieved from Perhutani: <https://perhutani.co.id/>, on September 18, 2020.
- Schmidt, M. (2004). *Loss of agro-biodiversity in Vavilov centers, with a special focus on the risk of genetically modified organism (GMOs)*. (Doctoral dissertation). Retrieved from http://www.markusschmidt.eu/pdf/Intro_risk_perception_Schmidt.pdf. on September 18, 2020.
- TrendEconomy. (2019). Annual international trade statistics by country: Indonesia. Retrieved from https://trendeconomy.com/data/h2?commodity=3806,380690&reporter=Indonesia&trade_flow=Export,Import&partner=World&indicator=NW,TQ,TV&time_period=2019 on September 18, 2020.
- Womack, J., & Jones, D. (2003). *Lean thinking*. New York: Free Press.
- Yovi, E., & Amanda, N. (2019). Ergonomic analysis of traditional pine oleoresin tapping: Musculoskeletal disorders, cumulative fatigue, and job satisfaction. *Jurnal Sylva Lestari*, 283-296. doi:// 10.23960/jsl38283-296.
- Yovi, E., & Andriyani, L. (2019). Analisis postur kerja dalam operasi pemanenan kayu: Pemuatan log secara manual. *Jurnal Ilmiah Teknik Industri*, 18(2), 170-182. doi: 10.23917/jiti.v418i2.8727.
- Yovi, E., & Yamada, Y. (2019). Addressing occupational ergonomics issues in Indonesian forestry: laborers, operators or equivalent workers. *Croatian Journal of Forest Engineering*, 49(2), 351-363. doi: 10.5552/crojfe.2019.558.
- Yovi, E., Takimoto, Y., Ichihara, K., & Matsubara, C. (2005). Factors affecting workload and work efficiency in pine resin harvesting operation in Java's plantation forest. *Journal of the Japan Forest Engineering Society*, 20(3), 141-150

GUIDELINE FOR AUTHORS

AIM AND SCOPE

Indonesian Journal of Forestry Research is a scientific publication of the Research, Development and Innovation Agency - Ministry of Environment and Forestry, Republic of Indonesia. The journal publishes state of the art results of primary findings and synthesized articles containing significant contribution to science and its theoretical application in areas related to the scope of forestry research.

LANGUAGE: All articles should be written in clear and concise English.

FORMAT MANUSCRIPT: To prepare your manuscript, please download a template from this link: http://ejournal.forda-mof.org/ejournal-litbang/files/IJFR_Template.docx. The entire manuscript should not exceed 20 pages. An electronic file of the manuscript should be submitted to the Indonesian Journal of Forestry Research Secretariat by following the publishing rules of IJFR through www.ejournal.forda-mof.org.

TITLE: A title should be brief and informative. Title must not exceed two lines and should reflect the content of the manuscript.

AUTHORS: Authors' names should appear immediately below the title, followed by Authors' affiliation and address. For more than one authors, affiliation detail and addresses should be mentioned in the right order. Email address of every author should be placed in the footnote.

ABSTRACT: Written in Bahasa Indonesia and English. Abstract should be no longer than 250 words, giving a brief summary of the content includes brief introduction, the reason for conducting the study, objectives, methods used, result and discussion and conclusion. Do not include tables, elaborate equations or references in the abstract.

KEYWORDS: Four to six keywords should be provided for indexing and abstracting. The word or term to be written under abstract; overviewing the issues, discussed, separately written from general to specific nature.

INTRODUCTION: State the objectives of the work and provide an adequate background of the research objectives, avoiding a detailed literature survey or a summary of the results.

THEORY/CALCULATION (if any): A theory or detailed calculation should be extended, not repeated, in the introduction. The theory or calculation mentioned should lay the foundation of the work.

MATERIAL AND METHOD: Provide sufficient detail of the research work to allow method to be reproduced. Describe the time and location of the study, materials and tools used, as well as research method. Methods already published should be indicated by a reference. Specific location should include the geographical information system. Only relevant modification to the method should be described clearly.

RESULT AND DISCUSSION: Results should be presented clearly and concisely. Discussion should explore the significance of the results work to the current condition or other research result, but not repeating the result. In case of large amount of result, result and discussion may be separated into sub chapter of result and sub chapter of discussion. Current reference (five years old reference) is an advantage to support the research finding than older references.

CONCLUSION: A conclusion section is required. It contains the main points of the article. It should not replicate the abstract, but might elaborate the significant results, possible applications and extensions of the work.

TABLE: Table should be numbered. Please use comma (,) and point (.) in all figures appropriately according to the English writing rule. Most charts graphs and tables are formatted in one column wide (3 1/2 inches or 21 picas) or two-column wide (7 1/16 inches, 43 picas wide). Avoid sizing figures less than one column wide, as extreme enlargements may distort your images and result in poor reproduction. Therefore, it is better if the image is slightly larger, as a minor reduction in size should not have an adverse effect in the quality of the image.

DRAWING: Graphs and other drawing illustrations must be drawn in high contrast. Each drawing must be numbered as Figure with, titled given clear remarks. Graphic images should be formatted and saved using a suitable graphics processing program allowing creating the images as JPEG/TIFF. Image quality is important to reproduce the graphics. Poor quality graphics could not be improved.

PHOTOGRAPH: Photograph with good contrast either in coloured or black and white and related to the text, must be titled and given clear remarks in numbered Figure. All photographs should be mentioned in the text and accompany to the manuscript in separate Microsoft word file. Photographs and grayscale figures should be prepared in 300 dpi resolution and saved with no compression, 8 bits per pixel (grayscale). Color graphics should be in the following formats: TIFF, Word, PowerPoint, Excel and PDF. The resolution of a RGB color TIFF file should be 400 dpi. Please supply a high quality hard copy or PDF proof of each image. If we cannot achieve a satisfactory color match using the electronic version of your files, we will have your hard copy scanned.

ACKNOWLEDGEMENT: Acknowledgement is recommended for persons or organizations who has already helped the authors in many ways. Sponsor and financial support acknowledgements may be placed in this section. Use the singular heading even if you have many acknowledgements.

REFERENCES: At least 10 references; referring to APA style 6th edition; organized alphabetically by author name; 80% from last 5 years issues; and 80% from primary reference sources, except for specific science textbooks (mathematics, taxonomy, climate). To properly credit the information sources, please use citation tools such as Mendeley or EndNote to create a bibliography, references and in-text citations. Mendeley is a free reference manager that can be downloaded at <https://www.mendeley.com/download-mendeley-desktop>

Reference List

- American Society for Testing and Materials (ASTM). (1997). *Standard test methods for rubber products—Chemical analysis*. (ASTM-D297-93) American Society for Testing of Materials, USA.
- Ayuk, E.T., Duguma, B., Franzel, S., Kengue, J., & Zenkeng, P. (1999). Uses, management and economic potential of *Irvingia gabonensis* in the humid lowlands of Cameroon. *Forest Ecology and Management*, 113, 1-19.
- Chen, H.Q., Wei, J.H., Yang, J.L., Ziang, Z., Yang, Y., Gao, J.-H., ... Gong, B. (2012). Review : Chemical constituents of agarwood originating from the endemic genus *Aquilaria* plants. *Chemistry and Biodiversity*, 9, 236–250.
- Kementerian Kehutanan. (2009). *Keputusan Menteri Kehutanan No.SK/328/Menbut-II/2009 tentang Penetapan DAS Prioritas dalam rangka RPJM tahun 2010-2014*. Sekretariat Jenderal, Jakarta.
- Kenney, G.M., Cook, A., & Pelletier, J. (2009). Prospects for reducing uninsured rates among children: How much can premium assistance programs help. Retrieved from Urban Institute website: <http://www.urban.org/url.cfm?ID=411823>, at 1 October 2009.

- Kurinobu, S. & Rimbawanto, A. (2002). Genetic improvement of plantation species in Indonesia. In A. Rimbawanto, & M. Susanto (Eds.), *Proceeding of International Conference on advances in genetic improvement of tropical tree species*, 1-3 October 2002 (pp.1-6). Yogyakarta: Centre for Forest Biotechnology and Tree Improvement.
- Lee, S.S. (2003). Pathology of tropical hardwood plantation in South-East Asia. *New Zealand Journal of Forestry Science*, 33(3), 321-335.
- Lim, S.C. (1998). Barringtonia J.R. Forster, & J.G. Forster. In M.S.M. Sosef, L.T. Hong, & S. Prawirohatmodjo (Eds.), *Plant Resources of South-East Asia 5(3): Timber trees: Lesser-known timbers*. (pp. 98-102). Leiden: Backhuys Publishers.

In Text Citation :

Water is a necessary part of every reasons's diet and of all the nutrient a body needs to function, it requires more water each daya than any other nutrients a body needs to function, it requires more water each day than any other nutrient (Whitney & Rolfes, 2011)

Or

Whitney and Rolfes (2011) state the body requires many nutrients to function but highlight that water is of greater importance than any other nutrient.

IJFR TEMPLATE

TITLE SHOULD BE CONCISE, INFORMATIVE, AND CLEARLY REFLECT THE CONTENT OF THE MANUSCRIPT

First Author, Second Author, Third Author and Fourth Author

First, third, and fourth authors' current affiliations including current address

Second authors' current affiliations including current address

Received: Revised: Accepted: (Filled by IJFR)

TITLE SHOULD BE CONCISE, INFORMATIVE, AND CLEARLY REFLECT THE CONTENT OF THE MANUSCRIPT. The abstract should not exceed 250 words. The abstracts should be self-explanatory. It must include the reason for conducting the study, objectives, methods used, results and conclusion. Objective should briefly state the problem or issue addressed, in language accessible to a general scientific audience. Technology or Method must concisely summarize the technological innovation or method used to address the problem. Results should bring a brief summary of the results and findings. Conclusions should provide brief concluding remarks on your outcomes.

Keywords: Four to six keywords should be provided for indexing and abstracting. The word or term overviews the issues discussed, written in alphabetical order, separated by commas

JUDUL HARUS RINGKAS, INFORMATIF DAN SECARA JELAS MEREKLESIKAN ISI MANUSKRIP. Tuliskan terjemahan abstrak dalam bahasa Indonesia. Abstrak tidak lebih dari 250 kata. Abstrak menjelaskan keseluruhan isi artikel. Abstrak meliputi maksud, tujuan penelitian, metodologi yang digunakan, hasil dan kesimpulan. Maksud penelitian harus menjelaskan secara ringkas permasalahan yang diteliti menggunakan bahasa ilmiah umum yang mudah dimengerti oleh pembaca. Teknologi atau metodologi yang digunakan untuk pemecahan permasalahan penelitian harus dicantumkan secara lengkap dan ringkas dalam abstrak. Ringkasan hasil penelitian dan temuannya ditampilkan dalam ringkasan singkat. Kesimpulan harus menyatakan outcome yang dicapai dalam kegiatan penelitian.

Kata kunci: Empat sampai enam kata kunci untuk keperluan indeksasi dan abstraksi. Setiap kata mencakup isu yang dibahas dan diurutkan secara alfabet dipisahkan oleh tanda koma

Note:

- There should no nonstandard abbreviations, acknowledgements of support, references or footnotes in the abstract.
- In case of authors from one institution, footnote numbering is not necessary.

I. INTRODUCTION

State the objectives of the work and provide an adequate background of the research objectives, avoiding a detailed literature survey or summary of the results. To prepare your manuscript, a template can be downloaded from: http://ejournal.forda-mof.org/ejournal-litbang/files/IJFR_Template.docx

Do not change the font sizes or line spacing to squeeze more text into a limited number of pages. Use italics for emphasis; do not underline. To insert images in Word, position the cursor at the insertion point and either use Insert | Picture | From File or copy the image to the Windows clipboard and then Edit | Paste Special | Picture (with “float over text” unchecked). IJFR will do the final formatting of your paper.

II. THEORY/CALCULATION (if any)

This chapter of theory/calculation is noncompulsory or optional. A theory or detailed calculation should be extended, not repeated, in the introduction. The theory of calculation (if any) mentioned should lay the foundation of the work.

III. MATERIAL AND METHOD

Provide sufficient detail of the research work to allow method to be reproduced. The material and method chapter can be divided into several sub-chapters.

A. Your Study Site/Location and/or materials

Describe the time and location of the study, materials and tools used as well as research method.

B. Your Methods

Methods already published should be indicated by a reference. Specific location should include the geographical information system. Only relevant modification to the method should be described clearly.

C. Your Analysis

Write the process of inspecting, cleaning, transforming and modeling data with the goal

of discovering useful information, suggesting conclusions and supporting decision-making.

IV. RESULT AND DISCUSSION

Results should be presented clearly and concisely. Discussion should explore the significance of the results work to the current condition or other research result, but not repeating the result. References must be used to support the research findings and expected to be written at least in the last five years.

V. CONCLUSION

A brief summary of the possible clinical implications of your work is required in the conclusion section. Conclusion contains the main points of the article. It should not replicate the abstract, but might elaborate the significant results, possible applications and extensions of the work.

ACKNOWLEDGEMENT

Acknowledgement is a must for persons or organizations who that have already helped the authors in many ways. Sponsor and financial support acknowledgements may also be placed in this section. Use the singular heading even if you have many acknowledgements.

REFERENCES

At least 10 references are listed according to American Psychological Association (APA) referencing style, 6th edition. References must be listed in alphabetical order by another name. Eighty percent of references should be cited from primary sources and published in the last five years. To properly credit the information sources, please use citation tools such as Mendeley or EndNote to create a bibliography, references and in-text citations. Mendeley is a free reference manager that can be downloaded at <https://www.mendeley.com/download-mendeley-desktop/>.

REFERENCE LIST

American Society for Testing and Materials (ASTM). (1997). *Standard test methods for rubber products—Chemical analysis*. (ASTM-D297-93). American

- Society for Testing of Materials, USA.
- Ayuk, E.T., Duguma, B., Franzel, S., Kengue, J., & Zenkeng, P. (1999). Uses, management and economic potential of *Irvingia gabonensis* in the humid lowlands of Cameroon. *Forest Ecology and Management*, 113, 1-19.
- Chen, H.Q., Wei, J.H., Yang, J.L., Ziang, Z., Yang, Y., Gao, J.-H., ... Gong, B. (2012). Review : Chemical constituents of agarwood originating from the endemic genus *Aquilaria* plants. *Chemistry and Biodiversity*, 9, 236–250.
- Kementerian Kehutanan. (2009). *Keputusan Menteri Kehutanan No.SK/328/Menbut-II/2009 tentang Penetapan DAS Prioritas dalam rangka RPJM tahun 2010-2014*. Sekretariat Jenderal, Jakarta.
- Kenney, G.M., Cook, A., & Pelletier, J. (2009). Prospects for reducing uninsured rates among children: How much can premium assistance programs help. Retrieved from Urban Institute website: <http://www.urban.org/url.cfm?ID=411823>, at 1 October 2009.
- Kurinobu, S. & Rimbawanto, A. (2002). Genetic improvement of plantation species in Indonesia. In A. Rimbawanto, & M. Susanto (Eds.), *Proceeding of International Conference on advances in genetic improvement of tropical tree species*, 1-3 October 2002 (pp.1-6). Yogyakarta: Centre for Forest Biotechnology and Tree Improvement.
- Lee, S.S. (2003). Pathology of tropical hardwood plantation in South-East Asia. *New Zealand Journal of Forestry Science*, 33(3), 321-335.
- Lim, S.C. (1998). *Barringtonia* J.R. Forster, & J.G. Forster. In M.S.M. Sosef, L.T. Hong, & S. Prawirohatmodjo (Eds.), *Plant Resources of South-East Asia 5(3): Timber trees: Lesser-known timbers*. (pp. 98-102). Leiden: Backhuys Publishers.
- Matsuo, M., Yokoyama, M., Umemura, K., Sugiyama, J., Kawai, S., Gril, J., ...Imamura, M. (2011). Aging of wood: Analysis of color changes during natural aging and heat treatment. *Holzforschung*, 65, 361-368.
- Pallardy, S.G. (2008). *Physiology of woody plants* (4th ed.). London: Elsevier Inc.
- Raghavendra, A.S. (1991). *Physiology of trees*. USA: John Willey and Sons Inc.
- Salampessy, F. (2009). Strategi dan teknik pemasaran gaharu di Indonesia. Paper presented at Workshop pengembangan teknologi produksi gaharu berbasis pada pemberdayaan masyarakat di sekitar hutan, Bogor 29 October 2009.
- Thu, A.D.M. (2013). Qualitive analysis of land use change pressures, conditions, and drivers in rural-urban fringes: A case of Nairobi rural-urban fringe, Kenya. *International Journal of Innovation and Applied Studies*, 3, 820–828.
- Wezel, A., Rajot, J.L., & Herbrig, C. (2000). Influence of shrubs on soil characteristics and their function in Sahelian agro-ecosystems in semi-arid Niger. *Journal of Arid Environment*, 44, 383-398. doi:10.1006/jare.1999.0609.
- Wohl, E., Dwire, K., Sutfin, N., Polvi, L., & Bazan, R. (2012). Mechanism of carbon storage in mountainous headwater rivers. *Nature Communications*, 3, 1263. doi:10.1028/ncommc2274.



Ministry of Environment and Forestry
Research, Development and Innovation Agency
Indonesia



Indonesian Journal of Forestry Research

