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Nusirat A. Sadiku and Christiana M. Micheal

FIBRE SOURCING FOR THE NIGERIAN PULP MILLS: EVALUATION OF SUITABILITY INDICES OF SELECTED NIGERIAN RAINFOREST WOOD FIBRES

(*KESESUAIAN SUMBER SERAT PABRIK PULP DI NIGERIA: EVALUASI INDEKS KESESUAIAN SERAT KAYU TERPILIH DARI HUTAN HUJAN NIGERIA*)

Dalam upaya menemukan solusi jangka panjang serat yang sesuai untuk pembuatan pulp dan kertas di Nigeria, dilakukan evaluasi indeks kesesuaian serat dari sembilan belas spesies kayu asli zona hutan hujan Nigeria. Bahan untuk maserasi disiapkan dan diambil dari batang matang tiap spesies terpilih. Karakteristik serat kayu dilakukan mengikuti ASTM D-1030-95 dan ASTM D-1413-61. Serat yang diperoleh diamati dengan bantuan mikroskop dan dilakukan pengukuran morfologi seratnya. Minimal 25 serat diukur untuk setiap spesies untuk akurasi. Indeks morfologi serat kayu yang diperkirakan yaitu Runkel Ratio (RR), Flexibility Coefficient (FC), Slenderness Ratio (SR) dan Rigidity Coefficient (RC). Hasil penelitian menunjukkan bahwa serat kayu yang dipelajari termasuk dalam kriteria serat pendek (1,05–1,36), sedang (1,52–1,75), dan panjang (2,0 mm). Semua indeks morfologi yang diturunkan menunjukkan variasi yang signifikan dari spesies ke spesies. Semua serat tidak kaku dan menunjukkan rasio kelangsiungan (SR) yang baik dengan kekakuan sedang dan kekuatan kempa yang baik. Semua serat kayu termasuk elastis; R. heudolotii dan P. macrocarpa menunjukkan sifat elastis yang tinggi. Semua memiliki koefisien fleksibilitas (FC) ≥ 50 dan Rungkel Ratio(RR) ≤ 1, nilai yang dapat diterima untuk serat pembuatan kertas kecuali P. biglobosa dan M. excelsa. Flexibility Coefficient (FC) berada pada kisaran 0,50 dan 0,81. Semua spesies melewati SR> 33, nilai yang dapat diterima untuk serat pembuatan kertas. Spesies-spesies tersebut jika dimanfaatkan sebagai campuran serat dalam pembuatan pulp dan kertas akan membantu memecahkan masalah serat panjang yang tidak memadai untuk produksi kertas di pabrik pulp Nigeria.

Kata kunci: Panjang serat, diameter serat, ketebalan dinding sel, Runkel Ratio, serat elastis

UDC/ODC 630*907(594.42)

Vivin S. Sihombing, Endang Karlina, R. Garsetiasih, Anita Rianti and Reny Sawitri

ENVIRONMENT CARRYING CAPACITY OF ECOTOURISM IN AEK NAULI RESEARCH FOREST, SIMALUNGUN REGENCY, NORTH SUMATERA

(*DAYA DUKUNG LINGKUNGAN EKOWISATA DI HUTAN PENELITIAN AEK NAULI, KABUPATEN SIMALUNGUN, SUMATERA UTARA*)

Saat ini, ekowisata telah menjadi industri yang penting karena perkembangannya yang pesat. Banyak praktik pariwisata memiliki dampak lingkungan yang merugikan, karena komersialisasi yang semakin merusak sumber daya alam sehingga menimbulkan dampak negatif. Hutan Penelitian Aek Nauli dengan luas 1.900 hektar, merupakan salah satu tujuan wisata alam di sekitar kawasan wisata Danau Toba yang dikelola oleh Balai Penelitian Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Aek Nauli. Kawasan tersebut terletak di Kecamatan Girsang Sipangan Bolon Kabupaten Simalungun, Provinsi Sumatera Utara. Objek wisata yang dimiliki berupa panorama alam, wisata pendidikan konservasi satwa gajah, dan taman kera satwa siamang. Pengunjung yang datang ke ANRF pada hari biasa rata-rata mencapai 100-300 pengunjung/hari dan pada hari libur mencapai 300-1.700 pengunjung/hari. Peningkatan jumlah pengunjung dikhawatirkan berdampak terhadap kelestarian lingkungan. Penelitian ini bertujuan untuk mengetahui kemampuan kawasan ekowisata ANRF dalam menampung jumlah wisatawan per hari dalam waktu bersamaan. Metode yang digunakan yaitu metode daya dukung efektif oleh Cifuentes berdasarkan beberapa tahapan analisis, yaitu Daya Dukung Fisik (PCC), Daya Dukung Riil (RCC), Daya Dukung Manajemen (MC), dan Daya Dukung Efektif (ECC). Hasil analisis daya dukung lingkungan menunjukkan bahwa nilai (PCC) sebesar 26.106 pengunjung/hari, nilai RCC 3.007 pengunjung/hari, nilai MC 0,83 dan nilai ECC 2.505 pengunjung/hari. Nilai ini dapat menjadi acuan untuk pengelola supaya ada upaya pembatasan pengunjung terutama pada hari libur agar objek wisata dan kualitas kunjungan tetap terjaga.

Kata kunci: Daya dukung, lingkungan, ekowisata, Danau Toba

UDC/ODC 630*907.11(594)

Fauziah Eddyono, Dudung Darusman, Ujang Sumarwan, and Tutut Sunarminto

TOURISM COMPETITTIVENESS, TOURIST FOREIGN ARRIVAL AND NON-TAX STATE REVENUE IN NATIONAL PARKS IN INDONESIA

(*DAYA SAING PARIWISATA, KEDATANGAN WISATAWAN MANCANEGARA, DAN PENERIMAAN NEGARA BUKAN PAJAK DI TAMAN NASIONAL INDONESIA*)

Indonesia memiliki daya tarik wisata alam berupa 54 taman nasional yang tersebar di seluruh wilayah kabupaten dan kota, dengan luas mencapai 16.304.707,13 hektar, menampilkan keragaman ekosistem, pegunungan tinggi, dataran rendah, sabana hingga lahan basah dan perairan. Namun, daya tarik wisata alam tersebut, tidak serta merta memberikan kontribusi terhadap kinerja pariwisata nasional, sehingga perlu dilakukan kajian dalam mengupayakan peningkatan kunjungan wisatawan ke taman nasional, salah satunya melakukan kajian dari aspek daya saing wisata pada wilayah yang memiliki taman nasional di Indonesia. Penelitian ini bertujuan untuk membangun model manajemen daya saing pariwisata pada wilayah yang memiliki zona pemanfataan taman nasional di Indonesia. Teori yang mendasari penelitian ini adalah teori daya saing pariwisata melalui pendekatan indeks daya saing *Travel & Tourism Competitiveness Index*, *Indicators for Measuring Competitiveness in Tourism*, dan *Competitiveness Monitor*. Desain penelitian menggunakan 20 faktor daya saing, dimana teknik pengumpulan data dan memanfaatkan data yang telah tersedia pada lembaga pemerintah dan non pemerintah dan metode pengambilan data menggunakan studi kepustakaan. Data dianalisis memanfaatkan metode model dinamik. Hasil studi menunjukkan, kunjungan wisatawan mancanegara secara nyata berkorelasi simultan dengan faktor daya saing wisata di wilayah kabupaten dan kota yang memiliki taman nasional, pendapatan pariwisatan dan konservasi di zona pemanfaatan Taman Nasional. Diusulkan agar pemerintah pusat, pemerintah daerah, manajemen taman nasional dan pihak yang berkepentingan lainnya melakukan inovasi kebijakan untuk mengoptimalkan faktor-faktor daya saing wisata di wilayahnya sehingga mampu meningkatkan jumlah kunjungan wisatawan taman nasional.

Kata kunci: Daya saing, pariwisata, wisatawan, kedatangan, model

UDC/ODC 630*824:82

Adi Santoso, Ignasia M. Sulastiningsih, and Rohmah Pari

COMPATIBILITY OF SOME ADHESIVES WITH BATANG RATTAN (*Calamus zollingeri* Becc.) AS RAW MATERIAL OF RATTAN LAMINATED BOARD

(*KESESUAIAN BEBERAPA JENIS PEREKAT DENGAN ROTAN BATANG (*Calamus zollingeri *Becc.) SEBAGAI BAHAN BAKU PAPAN ROTAN LAMINASI*)

Di Indonesia, rotan secara tradisional digunakan untuk furnitur, tali pengikat, alat rumah tangga, dan barang kerajinan. Rotan yang digunakan oleh pengrajin, pada umumnya adalah rotan berdiameter kecil, sedangkan rotan berdiameter besar kurang digunakan secara optimal. Namun demikian, rotan diameter besar berpotensi untuk dikembangkan menjadi papan rotan laminasi dengan merekatkan bilah rotan menggunakan perekat yang sesuai. Akan tetapi, informasi kesesuain perekat alami untuk pembuatan papan rotan laminasi masih sangat terbatas. Papan rotan laminasi skala laboratorium dengan dimensi 60 cm x 7,5 cm x 1,5 cm dibuat dari bilah rotan batang (Calamus zollingeri Becc.). Bilah rotan direkat dengan menggunakan 6 macam perekat (4 macam perekat alami dan 2 macam perekat sintesis komersial) dan tiga macam berat labur (100, 150, dan 200 g/m^2). Tujuan penelitian ini adalah untuk mengetahui pengaruh pra-perlakuan, macam perekat, dan berat labur terhadap keteguhan rekat dan emisi formaldehida papan rotan laminasi. Hasil penelitian menunjukkan bahwa rotan batang dapat dibuat menjadi papan rotan laminasi dengan menggunakan perekat alami yang berasal dari ekstrak kulit kayu (mangium, mahoni), ekstrak serbuk gergajian kayu merbau, dan perekat sintetis komersial seperti isosianat dan poliuretan. Pra-perlakuan yang sesuai untuk membuat papan rotan laminasi sebagai bahan furnitur interior adalah perendaman rotan dalam larutan minyak tanah panas (80 minyak tanah : 20 air) dan direkat menggunakan perekat tanin dari ekstrak kulit kayu mangium dengan berat labur 200 g/m^2. Sementara itu, pra-perlakuan dengan perendaman rotan dalam larutan minyak tanah panas (80 minyak tanah : 20 air) dan direkat menggunakan perekat poliuretan (berat labur 200 g/m^2) menghasilkan papan rotan laminasi yang sangat bagus untuk mebel di luar ruangan.

Kata kunci: Calamus zollingeri Becc., keteguhan rekat, emisi formaldehida, papan rotan laminasi, perekat alami

UDC/ODC 630*432(594)

Afni. Z., Fara Merian Sari, and Prihati

THE IMPLEMENTATION OF FOREST AND LAND FIRE MANAGEMENT POLICY IN INDONESIA DURING THE COVID-19 PANDEMIC

(*IMPLEMENTASI KEBIJAKAN PENGENDALIAN KEBAKARAN HUTAN DAN LAHAN DI INDONESIA PADA MASA PANDEMI COVID-19*)

Pandemi Covid-19 menimbulkan berbagai pertanyaan terkait perubahan lingkungan, khususnya dalam pengelolaan kebakaran hutan dan lahan. Tulisan ini mempelajari penerapan kebijakan pengelolaan kebakaran hutan dan lahan di Indoesia pada masa pandemic COVID-19, khususnya pada tahun 2020. Pendekatan kualitatif dilakukan untuk menganalisa penerapan kebijakan tersebut berdasarkan teori George Edward III, dengan menekankan kepada struktur birokrasi, sumber daya, komunikasi, dan disposisi dalam kaitannya dengan operasional kerja Manggala Agni Indonesia. Hasil penelitian menunjukkan bahwa pada masa pandemi, kerja kolaboratif antara Manggala Agni dan satuan tugas kebakaran hutan dan lahan lainnya telah berhasil menekan jumlah titik api, sehingga terjadi penurunan luas kebakaran secara signifikan. Hal ini juga tidak terlepas dari faktor iklim. Selama kurun waktu tersebut tidak terjadi bencana asap, walaupun tugas pengendalian kebakaran hutan dan lahan masih menemui beberapa kendala selama masa pandemi. Hal ini disebabkan oleh adanya pelatihan, alih tekhnologi, dukungan anggaran, serta sinergisitas antar anggota satgas pengendalian kebakaran hutan dan lahan, sehingga pengurangan kebakaran lahan dan hutan di Indonesia selama tahun 2020 dapat dicapai.

Kata kunci: Pandemi Covid-19, kebakaran hutan dan lahan, Manggala Agni, titik api

UDC/ODC 630*19(540)

Manikandan Gurusamy, Vairamuthu Subramanian, and Ramasubbu Raju

DIVERSITY AND CONSERVATION STATUS OF FLORA IN PILAVAKKAL DAM FOOTHILLS OF WESTERN GHATS, TAMIL NADU, INDIAS

(*KERAGAMAN DAN STATUS KONSERVASI TUMBUHAN OBAT DI KAKI BUKIT BENDUNGAN PILAVAKKAL, GHATS BAGIAN BARAT, TAMIL NADU, INDIA*)

Studi floristik diperlukan untuk memahami keanekaragaman dan konservasi keanekaragaman hayati hutan. Telah disadari bahwa studi tentang flora lokal atau regional jauh lebih penting daripada studi di wilayah yang luas karena eksplorasi dapat dilakukan secara intensif di wilayah kecil. Memahami keanekaragaman spesies dan pola distribusi penting untuk mengevaluasi kompleksitas dan sumber daya hutan ini. Dalam penelitian ini, keanekaragaman tumbuhan obat pada kaki bukit bendungan Pilavakkal Ghats Barat terdiri dari 127 spesies yang termasuk dalam 42 famili dan 100 marga. Fabaceae, Malvaceae dan Lamiaceae merupakan famili yang dominan dengan 23 jenis, 11 jenis dan 10 jenis. Jumlah spesies meliputi 55 herba, 23 semak, 37 pohon dan 12 pemanjat. Sebanyak 127 spesies tanaman obat penting dicatat di Bendungan Pilavakkal, Lereng Kaki Ghats Barat. Dalam daftar ini Psydrax dicoccos statusnva rentan, 27 spesies statusnya kurangmendapatperhatian dan Mangifera indica statusnya Data Deficient dan 98 spesies tumbuhanlainnya belum dievaluasi oleh IUCN. Studi ini memberikan informasi mendasar tentang flora obat dan status konservasinya di Kaki Lereng Bendungan Pilavakkal Ghats Barat. Data ini akan membantu identifikasi flora dan menjadipertimbangan kebijakan konservasi dan pemanfaatan yang berkelanjutan.

Kata kunci : Ghats Barat, Fabaceae, Malvaceae, IUCN, Rentan, Psydrax dicoccos

UDC/ODC 630*906(540)

Muniyandi Balasubramanian

ECONOMIC VALUE OF WILDLIFE SANCTUARY: A CASE STUDY FROM THE WESTERN GHATS IN KARNATAKA, INDIA

(*NILAI EKONOMI SUAKA MARGASATWA: STUDI KASUS DARI GHATS BARAT DI KARNATAKA, INDIA*)

Barang dan jasa ekosistem yang disediakan oleh lingkungan alam belum dipertimbangkan dari segi nilai ekonominya. Ada sejumlah penelitian yang memperkirakan nilai ekonomi jasa ekosistem hutan di India, tetapi sangat sedikit penelitian yang memperkirakan nilai ekonomi jasa ekosistem penting lainnya. Suaka Margasatwa Kuil Biligiri Rangaswamy (BRTWLS) merupakan area unik sebagai jembatan antara Ghats Barat dan Ghats Timur di Karnataka, India. Ada 12.500 Soliga (komunitas suku) yang tinggal di daerah ini. Hasil hutan bukan kayu menyumbang lebih dari 60% pendapatan rumah tangga Soliga. Sejumlah penelitian telah dilakukan di BRTWLS. Namun, studi tentang nilai ekonomi masih kurang. Tujuan utama dari studi ini adalah untuk memperkirakan nilai jasa ekosistem yang disediakan oleh BRTWLS. Penelitian ini menggunakan metode harga pasar untuk memperkirakan nilai jasa penyediaan dan metode biaya perjalanan individu untuk memperkirakan nilai jasa rekreasi, sedangkan nilai penyerapan karbon dan pencegahan erosi tanah telah diperkirakan berdasarkan data sekunder. Studi ini memperkirakan total nilai tahunan dari jasa penyediaan, pengaturan dan budaya BRTWLS sebesar Rs 23,9 juta y-1. Temuan studi ini akan membantu pembuat kebijakan lokal untuk meningkatkan biaya masuk di BRTWLS, karena memberikan jasa ekosistem yang berharga dan menginvestasikan kembali modal alam yang sama untuk mencapai kelestarian lingkungan di tingkat lokal.

Kata kunci: : Jasa ekosistem, nilai ekonomi, suaka margasatwa, suaka margasatwa kuil biligiri rangaswamy, metode biaya perjalanan

UDC/ODC 630*944(594)

Sahara Sahara, Wildan Nur Arrasyiid Sane Pratinda, and Deden Djaenudin

THE IMPACTS OF INVESTMENT IN THE FORESTRY SECTOR ON THE INDONESIAN ECONOMY

(*DAMPAK INVESTASI DI SEKTOR KEHUTANAN TERHADAP KINERJA PEREKONOMIAN INDONESIA)*

Indonesia merupakan negara yang kaya akan sumberdaya hutan dimana luas areal kawasan hutan mencapai 120 juta hektar. Namun demikian kontribusi sektor kehutanan terhadap perekonomian nasional terus menurun. Kinerja sektor kehutanan tidak lepas dari semakin terbatasnya ketersediaan bahan baku kayu bulat dan masih belum berkembangnya kegiatan multiusaha oleh perusahaan-perusahaan yang bergerak di sektor kehutanan. Oleh karena itu, perlu dilakukan peningkatan produktivitas di sektor kehutanan melalui peningkatan investasi. Penelitian ini bertujuan untuk menganalisis dampak investasi di sektor kehutanan terhadap kinerja perekonomian Indonesia yang meliputi kinerja output, pendapatan, tenaga kerja, dan impor dengan menggunakan Model Input-Output (I-O). Hasil analisis menunjukkan bahwa investasi di sektor kehutanan akan meningkatkan output, pendapatan, dan tenaga kerja di sektor kehutanan dan sektor-sektor perekonomian lainnya. Namun seiring dengan peningkatan output, permintaan input termasuk kayu bulat juga meningkat sehingga mendorong peningkatan impor sektor kehutanan itu sendiri dan sektor-sektor lainnya. Dengan demikian, peningkatan investasi di sektor kehutanan perlu diimbangi dengan ketersediaan material kayu bulat dan input terkait lainnya di dalam negeri. Untuk penelitian selanjutnya, penting untuk memisahkan investasi ke dalam kegiatan hulu dan hilir di sepanjang rantai nilai sektor kehutanan dan memasukkan aspek regional dalam model.

Kata kunci: Keterkaitan ke belakang dan ke depan, input-output, multiplier

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SOIL EROSION OVER DIFFERENT SLOPES UNDER PINE STANDS

(*EROSI TANAH PADA BERBAGI LERENG DI BAWAH TEGAKAN PINUS*)

Hutan memiliki peran penting dalam mengendalikan erosi tanah. Tegakan pinus dianggap efektif mengendalikan erosi karena intersepsinya yang tinggi serta serasah yang tebal. Penelitian ini bertujuan untuk membandingkan tingkat erosi antara kemiringan lereng >40% dengan lereng <40%, sebagai rujukan dalam tinjauan ulang standar penetapan Kawasan hutan lindung berdasarkan kelerengan >40%. Penelitian dilakukan mulai bulan Nopember 2016 sampai Februari 2017 di bawah tegakan Pinus merkusii Hutan Pendidikan Universitas Hasanuddin di Kabupaten Maros. Pengukuran erosi dilakukan dalam plot lahan berukuran 22 m x 4 m pada lereng >40% dan <40% masing-masing 3 ulangan. Pengukuran limpasan permukaan dilakukan setiap kejadian hujan, sebanyak 39 kali hujan. Kadar suspense diperoleh dengan cara mengeringkan air limpasan dalam oven suhu 105°C. Erosi aktual (gr) dihitung dengan mengalikan total volume limpasan (m3/plot) dengan kadar suspensi (gr/m3). Hasil penelitian menunjukkan rata-rata erosi pada lereng >40% 54,94 g/plot atau 0,006 ton/ha dan 36,74 g/plot atau 0,004 ton/ha pada lereng <40%. Hasil uji beda 2 rata-rata dengan selang kepercayaan 95%, menunjukkan perbedaan rata-rata erosi pada lereng >40% dan <40%. Namun ketika terjadi peningkatan persentase penutupan tajuk, erosi menjadi lebih kecil meskipun pada lereng 40%. Penelitian ini merekomendasikan peningkatan batas atas kemiringan kawasan hutan lindung dan perlunya peninjauan kembali atas nilai batas atas yang berlaku saat ini.

Kata kunci: Erosi, intensitas hujan, lereng, tegakan pinus, penutupan

FIBRE SOURCING FOR THE NIGERIAN PULP MILLS: EVALUATION OF SUITABILITY INDICES OF SELECTED NIGERIAN RAINFOREST WOOD FIBRES

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FIBRE SOURCING FOR THE NIGERIAN PULP MILLS: EVALUATION OF SUITABILITY INDICES OF SELECTED NIGERIAN RAINFOREST WOOD FIBRES. To find a lasting solution to the problem of suitable fibre for pulp and papermaking in Nigeria, fibre suitability indices of nineteen wood species native to the rainforest zone of Nigeria were evaluated. Matured stems of the species were sourced and prepared for maceration. The fibre characteristics of the wood were carried out following ASTM D-1030-95 and ASTM D-1413-61. The fibres obtained were observed with the aid of a microscope and measurements of their morphology were done. A minimum of 25 fibres were measured for each species for accuracy. Selected morphological indices such as Runkel Ratio (RR), Flexibility Coefficient (FC), Slenderness Ratio (SR) as well as Rigidity Coefficient (RC) of the wood fibres were estimated. The results showed that the fibres lenght fall under short (1.05–1.36), medium-long (1.52–1.75), and long (2.0 mm) fibres criteria. All derived morphological indices showed significant variations from species to species. All fibres are not rigid and exhibited good SR with moderate rigidity and good felting power. They were all elastic; *R. heudolotii* and *P. macrocarpa* exhibited high elastic nature. They all have FC ≥ 50 and pass the RR ≤ 1, acceptable value for paper-making fibre except *P. biglobosa* and *M. excelsa*. The flexibility coefficients are in the range of 0.50 and 0.81. All the species pass the SR > 33 acceptable value for paper-making fibres. The species if harnessed as fibre blends in pulp and paper making furnish will help to solve the problem of inadequate long fibres for paper production in Nigerian pulp mills.

Keywords: Fibre length, fibre diameter, cell wall thickness, Runkel ratio, elastic fibre

KESESUAIAN SUMBER SERAT PABRIK PULP DI NIGERIA: EVALUASI INDEKS KESESUAIAN SERAT KAYU TERPILIH DARI HUTAN HUJAN NIGERIA. Dalam upaya menemukan solusi jangka panjang serat yang sesuai untuk pembuatan pulp dan kertas di Nigeria, dilakukan evaluasi indeks kesesuaian serat dari sembilan belas spesies kayu asli zona hutan hujan Nigeria. Bahan untuk maserasi disiapkan dan diambil dari batang matang tiap spesies terpilih. Karakteristik serat kayu dilakukan mengikuti ASTM D-1030-95 dan ASTM D-1413-61. Serat yang diperoleh diamati dengan bantuan mikroskop dan dilakukan pengukuran morfologi seratnya. Minimal 25 serat diukur untuk setiap spesies untuk akurasi. Indeks morfologi serat kayu yang diperkirakan yaitu Runkel Ratio (RR), Flexibility Coefficient (FC), Slenderness Ratio (SR) dan Rigidity Coefficient (RC). Hasil penelitian menunjukkan bahwa serat kayu yang dipelajari termasuk dalam kriteria serat pendek (1,05–1,36), sedang (1,52–1,75), dan panjang (2,0 mm). Semua indeks morfologi yang diturunkan menunjukkan variasi yang signifikan dari spesies ke spesies. Semua serat tidak kaku dan menunjukkan rasio kelangsiungan (SR) yang baik dengan kekakuan sedang dan kekuatan kempa yang baik. Semua serat kayu termasuk elastis; R. heudolotii dan P. macrocarpa menunjukkan sifat elastis yang tinggi. Semua memiliki koefisien fleksibilitas (FC) ≥ 50 dan Rungkel Ratio(RR) ≤ 1, nilai yang dapat diterima untuk serat pembuatan kertas kecuali P. biglobosa dan M. excelsa. Flexibility Coefficient (FC) berada pada kisaran 0,50 dan 0,81. Semua spesies melewati SR> 33, nilai yang dapat diterima untuk serat pembuatan kertas. Spesies-spesies tersebut jika dimanfaatkan sebagai campuran serat dalam pembuatan pulp dan kertas akan membantu memecahkan masalah serat panjang yang tidak memadai untuk produksi kertas di pabrik pulp Nigeria.

Kata kunci: Panjang serat, diameter serat, ketebalan dinding sel, runkel ratio, serat elastis

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I. INTRODUCTION

Nigeria is one of the largest wood producers in Africa and a major exporter of timber resources (Obiora, Jonah, Ikenna, & Christian, 2019; FAO, 2004). The nation's forest industry, especially the paper sub-sector seems to be the worst-performing among all the industries (Nigerian Voice, 2010). The federal government established three paper mills in the 1970s which include; Nigerian Paper Mill in Jebba, Nigerian Newsprint Manufacturing Company, Oku Iboku, and Iwopin Pulp and Paper Company. According to reports, all three mills started well but could not sustain operation and eventually closed down in 1996 (Azeez, Andrew & Sithole, 2016; Udohitinah & Oluwadare, 2011). The cause of the failed investments has been attributed majorly to the inadequate supply of long-fibre for pulp and paper production (Oluwadare, 2007) due to the absence of long fibred raw materials in Nigerian forests. This then necessitated heavy dependence on imported pulp fibres. Although several species have been suggested to be used as a feasible solution to address the inadequate long fibre problem the suggestions were never implemented until all the mills finally closed down. Efforts to develop a sustainable pulp and paper industry have proved abortive because of the high dependence on imported long-fibre pulp (Ogunwusi, 2013). As far back as the 1980's, approximately US $ 85 million was required to import 85,000 tons of long fibre pulp required by the three integrated pulp and paper mills in Nigeria (Makinde, 2004; Egbewole, & Rotowa, 2017). Thus, Nigeria currently depends on the importation of writing, duplicating, printing, and kraft papers including newsprint (Ogunwusi & Onwualu, 2013).

Nigerian forests are characterised by mixed tropical hardwood species whose fibre lengths are short. The morphology of the fibres is important index in evaluating the suitability of fibre for pulp and paper-making Dinwoodie (1965). A number of hardwood species have been studied by various researchers (Ogunwusi, 2002; Osadare, 2001; Ogunkunle & Oladele, 2008; Oluwadare, & Sotannde, 2007; Ogunjobi, Adetogun, & Omole, 2014) were reported to be suitable sources of fibre for paper making. Although the suitability rating by these authors was based only on the fibre lengths of the species. It is not that hardwoods are typically bad for paper production. Papers from hardwood pulps are generally lower in strength because of their shorter fibres than those of softwoods with longer fibres.

Long softwood fibres give essential strength, while short hardwood fibres are used in furnishes to provide good printability and stiffness to the end product. Analysis of the morphology of fibres and their derived indices are important factors in estimating the pulp quality of any fibre material (Dinwoodie, 1965). The morphology of the fibre and its derived indices correlates with most of the strength properties of pulp. Repetition A fibre with thinner cell walls will collapse more easily than a fibre with thicker cell walls. Collapsed fibres are more flexible and have a higher area available for bonding. Collapsed fibres create a network with much higher density and lower bulk. Thus, the paper will have a higher tensile strength, compression strength, burst strength, tensile stiffness, and elasticity. The flexibility of the fibres has a large influence on the tensile strength, density, porosity and light scattering of the paper. Fibre cell lumen size and cell wall thickness affect the rigidity and strength properties of the papers (Panshin & de Zeeuw 1980). Fibres with a large lumen and thin walls tend to flatten to ribbons during paper-making with enhanced inter-fibre bonding between fibres, consequently having good strength characteristics (Oluwadare, 1998; Osadare, 2001).

Suitable indices such as cell wall thickness, Runkel ratio, flexibility coefficient, slenderness ratio, and rigidity coefficient which determine the suitability of any fibrous material for pulp and paper making have not been well documented for the wood species under study. Most Nigerian woods are lacking in this aspect. To effectively use these species as raw materials in pulp and paper-making furnish, reliable

knowledge of their suitability based on the derived indices is essential. In this study, the morphological indices of 18 hardwood species were analysed to determine if they could serve as fibre blended with long softwood fibre or recycled paper pulps. This intends as to increase the raw material base for the moribund Nigerian paper mills, whose major problem is inadequate fibre raw material.

II. MATERIALS AND METHOD

A. Wood Collection and Preparation

Eighteen different wood species were collected from sawmills in Akure, Ondo State. Akure falls within the rainforest zone of Nigeria. The wood Samples were first identified by the saw millers. The literature further substantiated the local identification to obtain their corresponding scientific names. A list of the species used in the study with their local names is provided in Table 1. All of the wood samples were taken from mature wood. Special care was taken to ensure that species were accurately identified using macroscopic and microscopic anatomical features such as colour, density, and press.

B. Methods

Fibre characterisation of the wood species

Fibre characterisation of the wood samples was carried out following ASTM D-1037-12 (2020) and ASTM D-1413-61 (2007). Small slivers having radial and tangential dimensions of 2 and 5 mm, respectively, from each of the wood species were macerated with acetic acid and hydrogen peroxide (1:1) and boiled in a water bath at a temperature of 100°C for 10 minutes following a procedure adopted by Ogbonnaya, Roy-Macauley, Nwalozie & Annerose (1997). Some macerated fibres were randomly selected and mounted on slides and then observed under a Reichert Microscope. The fibre length, fibre diameter and lumen width of unbroken fibres were measured using an eyepiece micrometer after calibrating with a stage micrometer. Some derived values such as the cell wall thickness, Slenderness Ratio, Flexibility coefficient, Runkle ratio, and Rigidity coefficient were computed from the measured fibre dimensions following the method of Sadiku, Oluyege, and Ajayi (2016) as shown below. Twenty-five fibres were measured from each representative sample slides.

Table 1: Wood species: Scientific names, family and local names

No.	Wood Species	Family	Local Names
1	*Parkia biglobosa* (Jacq.) R.Br. ex G. Don	Mimosaceae	Igba
2	*Milicia excelsa* (Welw.) C.C.Berg	Moraceae	Iroko
3	*Nauclea diderrichi* (De Wild. & T. Durand) Merr.	Rubiaceae	Opepe; MTN
4	*Azadiracta indica A. Juss.*	Meliaceae	Neem, Dongorayo
5	*Daniellia oliveri* (Rolfe) Hutch. & Dalziel	Fabaceae	Ogea, Iya
6	*Terminalia superba* Engl. & Diels	Combretaceae	White Afara, Limba, fraké
7	*Vitex doniana* Sweet	Verbenaceae	Black plum, Orii
8	*Chrysophyllum albidium* G.Don_Holl	Sapotaceae	Osandan
9	*Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.	Euphorbiaceae	Rubber tree, natural rubber, Pará rubber
10	*Ricinodendron heudelotii (Baill.) Pierre ex Heckel*	Euphorbiaceae	African oil-nut tree; Arumodo
11	*Irvingia gabonensis Baill. ex Lanen*	Irvingiaceae	Bush mango, Oro
12	*Blighia sapida K.D. Koenig*	Sapindacea	Isin
13	*Pterygota macrocarpa* K. Schum.	Sterculiaceae	Oporoporo
14	*Alstonia boonei* De Wild	Apocynaceae	Ahun, cheesewood
15	*Treculia africana* Decne	Moraceae	Breadfruit, Efo
16	*Albizia zygia (DC.) Macb*	Fabaceae	Ayunre
17	*Trichilia monaldepha* (Thonn.) J.J. de Wilde	Meliaceae	Trichilia; Ako rere; Rere
18	*Pycnanthus angolensis* (Welw.) Warb	Myristicaceae	African nutmeg; Akomu, Ilomba

C. Analysis

Variations in the fibre morphology and derived values were evaluated by analysis of variance at $p \leq 0.05$. Duncan Multiple Range Test was used to compare mean values for the different species. The evaluated fibre morphology and derived values were then ranked based on the suitability of each species.

$$Cell\ Wall\ Thickness = \left(\frac{Fibre\ Diameter\ -\ Lumen\ Width}{2}\right) \quad .....(1)$$

$$Slenderness\ Ratio = \left(\frac{Fibre\ Lenght}{Fibre\ Diameter}\right) \quad .....(2)$$

$$Flexibility\ Coefficient\ = \left(\frac{Lumen\ Diameter}{Fibre\ Diameter}\right) \quad .....(3)$$

$$Runkel\ Ratio\ = 2x\left(\frac{Cell\ Wall\ Thickness}{Lumen\ Diameter}\right) \quad .....(4)$$

$$Rigidity\ Coefficient = 2x\left(\frac{Cell\ Wall\ Thickness}{Fibre\ Diameter}\right) \quad .....(5)$$

$$F\ factor = 100\ x\ \frac{Fibre\ Lenght}{Cell\ Wall\ Thickness} \quad .....(6)$$

III. RESULT AND DISCUSSION

A. Fibre Morphology

The mean values of the Fibre Length (FL), Fibre Diameter (FD), Lumen Width (LW) and Cell Wall Thickness (CWT) is presented in Table 2. The fibre length, diameter, lumen width and Cell Wall Thickness varied significantly from species to species. The fibre length varied from 1.05 mm to 2.48 mm. *N. diderichii* had the longest fibre of 2.48 mm followed closely by *R. heudollotii* (1.7 mm), while *A. indica* had the shortest fibre length (0.8 mm) and was closely followed by *P. macrocarpa* (1.05 mm). The fibre diameter varied from 15.22 μm to 51.68 μm. *R. heudolotii* had the largest (51.68 μm) fibre diameter, while *M. excelsa* had the smallest (15.22 μm) (Table 2). The wood species lumen width (LW) varied from 8.89 μm to 43.82 μm. *R. heudolotii* had the largest lumen width of 43.82 μm, while the smallest (8.89 μm) was recorded for *M. excelsa*. Cell wall thickness also varied from 2.61 μm to 6.92 μm. *P. macrocarpa* had the thinnest (2.61μm) fibre cell wall while *N. diderichii* had the thickest fibre wall of 6.48 μm based on the Duncan multiple range test (Table 3).

Generally, the influence of species was profound on the fibre properties of the wood species according to ANOVA result (Table 2). There were significant statistical variations in the fibre morphologies of the wood species (Table 2). However, the fibre length of *M. excelsa*, *A. boonei*, *T. africana* and *A. zygia* are statistically similar. *T. monaldeph* and *T. superba*; *P. angolensis* and *C. albidium* had similar fibre lengths, respectively (Table 3). The fibre diameters were statistically similar for *B. sapida*, *C. albidium*, *H. brasiliensis*, *A. indica* and *P. biglobosa*; *P. macrocarpa* and *I. gabonensis*; *A. zygia,* and *A. boonei* are statistically similar in their fibre lengths (Table 3). Lumen width were statistically similar for *P. macrocarpa*, *T. africana* and *T. monaldeph*; *P. biglobosa* and *M. excelsa*; *D. oliveri*, *A. indica*, *C. albidium* and *H. brasiliensis*; *A. zygia*, *T. superba* and *A. boonei* were statistically similar (Table 3). Cell wall thickness too were similar for *C. albidium*, *H. brasiliensis*, *A. indica* and *P. angolensis*;

Table 2. Analysis of variance for the fibre morphology and derived morphological indices

Source of variation	Property	SS	df	MS	P-values
Species	FL (mm)	20.455	19	1.077	21.600 **
	FD (μm)	13936.343	19	733.492	20.590 **
	LW (μm)	129911.823	19	683.780	20.761 **
	CWT (μm)	203.408	19	10.706	6.214 **
	SR	0.222	19	0.012	6.806 **
	FC	1.636	19	0.086	9.793 **
	RR	11.775	19	0.620	4.661 **
	RC	2.693	19	0.142	9.972 **

Note: * = Significant at ($p \leq 0.05$) probability level

P. biglobosa and *T. monaldeph*; *M. excelsa* and *T. africana*; *I. gabonensis* and *T. superba*; *A. boonei* and *A. zygia* were statistically similar in their cell wall thickness (Table 3).

The wood fibres in this study fall into short (1.05–1.36), medium-long (1.52–1.75), and long (2.0 mm) fibres (Table 3). This finding further substantiates the report of Illvessalo-Pfaffli (1995) that fibre length and width of both woody and non-woody plants vary depending on the species and the plant part from which the fibre is derived. Hurther (2001) also reported that the average length of fibres in hardwoods is about 1 mm and in coniferous wood is about 3 mm. Similar observations by Kpikpi (1992) and Uju and Ugowoke (1997) reported of less than 1.60 mm fibre lengths in some Nigerian hardwood species. All the fibre length of the species falls in the same range as those reported for Guinea savannah species except *N. diderrichi* which had 2.48 mm (Sadiku & Abdukareem, 2019). *R. heudolotii* had a larger fibre diameter, *T. monaldepha*, *R. heudolotii*, *P. angolensis*, *T. africana*, *P. macrocarpa,* and *V. doniana* had extremely wider lumen than the reported Guinea savannah woods. However, their cell wall thickness falls in the same range.

The fibre morphological properties are important quality parameters for pulp and paper properties. They are mostly correlated with the physical and mechanical properties of paper. Fibre length is one of the major factors controlling the strength properties of paper (Riki et al., 2019). The fibre length affects the tensile strength, breaking strain and fracture toughness of dry paper and is important for wet web strength (Retulainen et al., 1998). Also, fibre length has been discovered to influence paper sheet formation and its uniformity.

Fibre length is associated with a number of bonding sites available on an individual fibre. It also affects certain characteristics of pulp and paper, such as tear resistance, tensile power and folding power (Fatriani and Banjarbaru, 2017).Generally, both long and short fibres are needed for good papers. Most of the fibres of the species in this study are short except for *N. diderichii* having long fibres. A long fibred

Table 3. Effect of species on the fibre morphological characteristics of the wood species

No.	Wood species	FL (mm)	FD (μm)	LW (μm)	CWT (μm)
1.	*M. excels*	1.34^{cde}	15.22^{a}	8.89^{a}	3.81^{b}
2.	*D. oliveri*	1.64^{gh}	24.13^{bcd}	13.34^{abc}	5.40^{cdefg}
3.	*N. diderichii*	2.48^{i}	30.48^{efg}	17.53^{cf}	6.48^{h}
4.	*A. boonei*	1.35^{cde}	22.48^{bc}	14.35^{abcd}	4.07^{bc}
5.	*B. sapida*	1.21^{bcd}	19.55^{ab}	11.05^{ab}	4.26^{bcd}
6.	*V. doniana*	1.41^{def}	31.88^{g}	20.32^{ef}	5.78^{efgh}
7.	*C. albidium*	1.10^{b}	21.21^{ab}	12.19^{abc}	4.51^{bcde}
8.	*H. brasiliensis*	1.14^{bc}	21.21^{ab}	12.19^{abc}	4.51^{bcde}
9.	P. macrocarpa	1.58^{fgh}	28.19^{cdefg}	22.99^{f}	2.61^{a}
10.	*A. indica*	0.84^{a}	21.21^{ab}	12.19^{abc}	4.51^{bcde}
11.	*T. africana*	1.33^{cde}	$31\ 21^{fg}$	23.24^{f}	3.90^{b}
12.	*I. gabonensis*	1.60^{fjh}	28.07^{cdefg}	16.89^{bcde}	5.59^{defg}
13.	*P. angolensis*	1.05^{b}	29.08^{defg}	20.06^{def}	4.64^{bcde}
14.	*R. heudolotii*	1.71^{h}	51.68^{i}	43.82^{h}	3.94^{b}
15.	*A. zygia*	1.35^{cde}	22.48^{bc}	14.36^{abcd}	4.07^{bc}
16.	*P. biglobosa*	1.38^{def}	20.57^{ab}	10.41^{a}	5.08^{bcdef}
17.	*T. monaldeph*	1.47^{efg}	32.64^{g}	23.11^{f}	4.77^{bcdef}
18.	*T. superba*	1.47^{efg}	25.53^{bcdef}	14.48^{abcd}	5.53^{defg}

Note: Means with the same letter vertically are not significantly different at ($p \leq 0.05$)

material can have more fibre joints and create a stronger network than a shorter fibre (Riki et al., 2019). Although shorter fibres decrease tensile stiffness. However, the shortening of fibres will improve the formation if well beaten. Therefore, the beating of the wood species in this study will increase the fibres surface and flexibility, which will aid good paper formation.

B. Derived Fibre Morphological Indices of the Wood Species

Some indices are usually calculated to determine the suitability of any fibrous material for pulp and paper production. According to Veveris et al. (2004), the Slenderness Ratio also termed Felting Power, if less than 70 for any fibrous material is not valuable for quality pulp and paper production. Low slenderness ratio means reduced tear strength. Fibre flexibility dictates the burst and tensile strength as well as the development of the paper properties that affects printing. High elastic fibres with high flexibility can collapse easily and flatten to produce good surface area contact while elastic fibres collapsed partially to give relative contact and fibre bonding (Riki et al., 2019).

Good quality papers are produced when the Runkel Ratio is less than one. Fibres with higher Runkel Ratio are stiffer, less flexible and form bulkier paper of low bonded areas than fibres with lower Runkel Ratio (Veveris et al., 2004). The higher the Coefficient of Rigidity the lower the tensile power of the paper, conversely the lower the coefficient of rigidity the higher the tensile power of paper. The mean values of the Slenderness Ratio (SR), Flexibility Coefficient (FC), Runkel Ratio (RR) and Rigidity Coefficient (RC) are presented in Table 4. ANOVA result (Table 2) showed that there were significant variations in all the derived values among the 18 wood species (Table 4).

Generally, the most slender fibre is *R. heudolotii* while the most flexible fibre is that of *P. macrocarpa* judging from the FC value of 0.81 (Table 4). *M. excelsa* had the highest RR of 1.5 while *R. heudolotii* had the lowest RR of 0.1. However, some of the wood species showed similarities in their derived values. Generally, the most suitable wood for pulp and paper production based on Runkel Ratio is *R. heudolotii* due to the lowest RR value of 0.1 (Table 4). *R.*

Table 4. Effect of species on the derived morphological indices of the wood species

No.	Wood species	SR	FC	RR	RC	F-factor
1.	*M. excels*	0.9^{bc}	0.57^{abc}	1.51^{i}	0.51^{g}	0.35^{bc}
2.	*D. oliveri*	0.5^{d}	0.54^{ab}	0.88^{fghi}	0.46^{efg}	0.30^{b}
3.	*N. diderichii*	0.6^{d}	0.56^{abc}	0.82^{efghi}	0.44^{defg}	0.38^{bc}
4.	*A. boonei*	0.6^{abc}	0.64^{cdefg}	0.61^{bcdefg}	0.36^{bcdef}	0.33^{bc}
5.	*B. sapida*	0.7^{abc}	0.57^{abd}	0.82^{efghi}	0.43^{cdefg}	0.28^{ab}
6.	*Vitex doniana*	0.5^{ab}	0.63^{bcdef}	0.63^{cdefgh}	0.38^{bcdef}	0.24^{a}
7.	*C. albidium*	0.5^{ab}	0.58^{abcd}	0.42^{abcd}	0.70^{h}	0.24^{a}
8.	*H. brasiliensis*	0.6^{ab}	0.58^{abcd}	0.75^{cdefgh}	0.42^{cdefg}	0.25^{a}
9.	*P. macrocarpa*	0.96^{c}	0.81^{hi}	0.25^{ab}	0.19^{a}	0.61^{d}
10.	*A. indica*	0.5^{ab}	0.57^{abc}	0.79^{defghi}	0.43^{adefg}	0.19^{a}
11.	*T. africana*	0.4^{a}	0.74^{gh}	0.38^{abc}	0.26^{ab}	0.34^{bc}
12.	*I. gabonensis*	0.6^{ab}	0.60^{abcde}	0.69^{cdefgh}	0.40^{bcdefg}	0.29^{b}
13.	*P. angolensis*	0.4^{a}	0.71^{fg}	0.52^{abcdef}	0.32^{bcd}	0.23^{a}
14.	*R. heudolotii*	0.3^{a}	0.84^{i}	0.10^{a}	0.16^{a}	0.43^{c}
15.	*A. zygia*	0.6^{abc}	0.64^{cdefg}	0.61^{bcdefg}	0.36^{bcde}	0.33^{bc}
16.	*P. biglobosa*	0.7^{abc}	0.50^{a}	1.01^{hi}	0.50^{fg}	0.27^{ab}
17.	*T. monaldeph*	0.5^{ab}	0.67^{defg}	0.54^{abcdef}	0.33^{bcd}	0.31^{b}
18.	*T. superba*	0.6^{ab}	0.57^{abc}	0.81^{defghi}	0.43^{cdefg}	0.27^{ab}

Note: Means with the same letter vertically are not significantly different at ($p \leq 0.05$)

heudolotii had the least rigid fibres judging from the RC value of 0.16, while *C. albidium* was the most rigid (Table 4). The F-factor too showed significant statistical variations among the 20(? not 18?) species, with *P. macrocarpa* having the highest F-factor of 0.61 (61) while *A. indica* had the lowest of 0.19 (19). Fibre morphology, all the derived morphological indices showed significant variations from species to species.

According to Dinwoodie (1965), the basis for establishing the suitability of raw material for pulp and paper making is that the Runkel Ratio must be less than one. All the species had RR less than 1 except *M. excelsa* and *P. biglobosa*. This indicates that the two species are unsuitable for pulping considering their Runkel Ratio as they are relatively higher than the standard (Xu, Wang, Zhang, Fu & Wu, 2006) (Table 4). A higher Runkel ratio gives lower burst, tear and tensile indexes (Bektas, Tutus & Eroglu, 1999). Fibre with a high Runkel ratio value is stiff, less flexible and forms bulkier paper of low bounded area than the lower ratio fibre. Therefore, it is expected that *P. biglobosa* and *M. excelsa* produce poor paper. The RR values reported in this work are similar to other Nigeria timbers reported in previous works (Ezeibekwe, Okeke, Unamba & Ohaeri, 2009; Awaku, 1994; Ogunkunle, 2010; Oluwadare and Sotannde, 2007; Ajuziogu, Nzekwe & Chukwuma, 2010; Sadiku and Abdukareem, 2019).

The fibre flexibility (elasticity coefficient, or Istas coefficient) of the species are 0.50–0.81. Depending on the elasticity rate, fibres were grouped into four Istas followings, Heremans & Roekelboom (1954) and Bektas et al. (1999) grouping. According to this grouping, all the species are not rigid. They were all elastic with *R. heudolotii* and *P. macrocarpa* exhibiting high elastic nature. All the wood species have their flexibility/elasticity coefficient ≥ 50 and are therefore included in the elastic fibre group (Table 7). Rigid fibres do not have efficient elasticity and are not suitable for paper production except for cardboard production (Akgül and Tozluoğlu, 2009). It is expected that pulp made from all the wood species would have a greater inter-fibre bond and hence greater tensile strength, which favours those properties that affect printing (Ogunjobi et al., 2014). This range is almost similar to Brindha, Vinodhini & Alarmelumangai (2012), where 0.60 (60%) was reported as well as similar for some and higher than some Nigerian Guinea Savannah Timbers (Sadiku and Abdukareem, 2019). Considering the FC > 0.55 (55%) acceptable value for paper-making fibre (Bektas et al., 1999), all the species would be suitable. However, a flexibility ratio between 50 and 70 implies that the fibres can easily be flat and give good paper with high-strength properties (Brindha et al., 2012).

Fibre slenderness significantly influenced the pulp sheets breaking length, bursting, tearing and stretching (Ogunjobi et al., 2014). All the species had good Slenderness Ratio as they all pass the SR > 33 acceptable value for paper-making fibre according to Xu et al., (2006). However, Bektas et al. (1999) show that if Slenderness Ratio is lower than 70, it is invaluable for quality pulp and paper production (Bektas et al., 1999). But, if the Slenderness ratio is higher than 70, it can be utilized for pulp and paper production. Generally resistance to tearing increases with increasing fibre slenderness. Paper made from all the species is expected to have increased tear strength suitable for wrapping and packaging purposes (Sankia et al., 1997).

The Rigidity Coefficient (RC) of the fibres varied from 0.16 to 0.7. The RC might be associated with fibre cell wall thickness and fibre diameter used to obtain the equation for RC. These fibres are less rigid compared to those of Guinea savannah species (Sadiku & Abdukareem, 2019). This value is in the range of those reported for *Eucalyptus tereticornis* (0.63) and *Eucalyptus camadulensis* (0.53) and *Eucalyptus grandis* (0.33) (Dutt & Tyagi, 2011) which are conventional paper-making fibres as well as juvenile beech (25.85%) and black pine (13.30%) woods. As the fibre rigidity increases, the physical resistance properties of paper weaken (Akgül & Tozluoğlu, 2009). As hard wood generates thick wall fibres, their Rigidity

Coefficients are mostly higher (Hus, Tank & Goksal, 1975). The RC in this study is higher than those reported by the various researchers, which may be due to the ages of the trees from which the woods of these species were cut. Therefore, observed species shows higher RC and they may not be used conveniently for producing high quality writing and printing papers, compared with these of low RC which will be less stiff, more flexible and form lower bulk and well bonded paper. Increasing fibre rigidity results in a decrease in fibre bonding, which results in stiffer, less flexible and form bulkier paper with a lower bonded area, coarse surfaced and containing a large amount of void volume (Dutt & Tyagi, 2011).

F-factor is the fibre length ratio to the fibres cell wall thickness. According to Akgül and Tozluoğlu (2009), the higher the F-factor, the better the fibre is for paper-making. The F-factors reported in this study are extremely lower than those reported for both soft and hardwoods. 140.38 and 240.55 were reported for beech and black pine juvenile woods (Akgül & Tozluoğlu (2009); 25.92 and 206.78 for two Populus species (Kar, 2005) which are hardwood species and 606.66 and 410.34 were reported for *Pinus brutia* and *Cedrus libani* which are softwood species respectively (Erdin, 1985). The F-factor was low for all the species under study as the F-factors did not exceed 0.61 or 61%. The lower values compared to those reported for hardwoods by other researchers may be attributed to the short length of the fibres and the higher cell wall thickness of the fibres.

C. Classification of the Fibres and the Suitability Rating of the Wood Species for Pulp and Paper Production

The classification was done following Metcalfe and Chalk (1983) and Anonymous (1984). They classified fibres below 1.60 mm as short while those above 1.60 mm in length as long. Judging from the fibre morphology, we classified the fibres into four classes: <1.00mm as extremely short fibres; 1.00–1.49 mm short fibres; 1.50–1.99 mm medium long and > 2.00 mm long fibres (Table 5).

D. Classification of Suitability of the Wood Species for Pulp and Paper's Production based on their Derived Morphological Indices

The flexibility coefficient, otherwise known as elasticity coefficient, or Istas coefficient, is a function of the elasticity of the wood fibres. Depending on the elasticity rate, fibres are grouped into four following Istas et al. (1954) and Bektas et al. (1999) grouping (Table 4.17). The wood species were thus grouped following the classification as outlined in Table 7. All the wood fibres are elastic with *R. heudolotii* and *P. macrocarpa* have highly elastic fibres.

Similarly, the Runkel Ratio is the most important and primary parameter needed to find the suitability of any raw material for pulp and paper. The standard for this ratio is one (1). Any RR values greater than 1 is termed poor (does not favour pulp strength properties). Favour pulp strength properties are usually obtained when the value is below the standard value. All the wood fibres are excellent pulp and paper materials judging from their RR values. Two species; *M. excelsa* and *P. biglobosa* had RR values that were greater than 1 (Table 4.12)

F-factor shows the flexibility of fibres. The highest F-factor was observed for *P. macrocarpa* while the least was for *A. indica.* (Table 4). The high F-factor values for *P. macrocarpa* and *R. heudolotii* place these species well in the ranking at the upper limit among the selected hardwood species. The rigidity coefficient put *C. albidium* to be less suitable due to its highest rigidity (0.70) while *R. heudolotii* was most suitable considering the Rigidity Coefficient. In terms of slenderness ratio, *P. macrocarpa* had the best rating while *R. heudolotii* was the poorest considering the Slenderness Ratio.

Table 5. Fibre length classification of the wood species

No.	Wood species	Fibre length (mm)	Fibre Class
1.	*M. excelsa*	1.34^{cde}	Short
2.	*D. oliveri*	1.64^{gh}	Medium long
3.	*N. diderichii*	2.48^{i}	Long
4.	*A. boonei*	1.35^{cde}	Short
5.	*B. sapida*	1.21^{bcd}	Short
6.	*Vitex doniana*	1.41^{def}	Short
7.	*C. albidium*	1.10^{b}	Short
8.	*H. brasiliensis*	1.14^{bc}	Short
9.	*P. macrocarpa*	1.58^{fgh}	Medium long
10.	*A. indica*	0.84^{a}	Extremely short
11.	*T. africana*	1.33^{cde}	Short
12.	*I. gabonensis*	1.60^{fjh}	Medium long
13.	*P. angolensis*	1.05^{b}	Short
14.	*R. heudolotii*	1.71^{h}	Medium long
15.	*A. zygia*	1.35^{cde}	Short
16.	*P. biglobosa*	1.38^{def}	Short
17.	*T. monaldeph*	1.47^{efg}	Short
18.	*T. superba*	1.47^{efg}	Short

Note: Means with the same letter vertically are not significantly different at ($p \leq 0.05$)

Table 6. Elasticity coefficients of the wood fibres

Types of Fibres	Elasticity Coefficient
High elastic fibres	> 75
Elastic fibres	50 – 75
Rigid fibres	30 – 50
High rigid fibres	< 30

Sources: Istas et al. (1954) and Bektas et al. (1999)

Table 7: Fibre flexibility and suitability rating of the wood species

No.	Wood species	SR	FC	RR	RC	F-factor	Suitability rating
1.	*M. excels*	Slender	Elastic	Poor	Poor	Flexible	Poor
2.	*D. oliveri*	Slender	Elastic	Good	Good	Flexible	Good
3.	*N. diderichii*	Slender	Elastic	Good	Good	Flexible	Good
4.	*A. boonei*	Slender	Elastic	Good	Good	Flexible	Good
5.	*B. sapida*	Slender	Elastic	Good	Good	Flexible	Good
6.	*Vitex doniana*	Slender	Elastic	Good	Good	Flexible	Good
7.	*C. albidium*	Slender	Elastic	Good	Poor	Flexible	Good
8.	*H. brasiliensis*	Slender	Elastic	Good	Good	Flexible	Good
9.	*P. macrocarpa*	Slender	Highly elastic	Good	Good	Flexible	Good
10.	*A. indica*	Slender	Elastic	Good	Good	Flexible	Good
11.	*T. africana*	Slender	Elastic	Good	Good	Flexible	Good
12.	*I. gabonensis*	Slender	Elastic	Good	Good	Flexible	Good
13.	*P. angolensis*	Slender	Elastic	Good	Good	Flexible	Good
14.	*R. heudolotii*	Poor	Highly elastic	Good	Good	Flexible	Good

No.	Wood species	SR	FC	RR	RC	F-factor	Suitability rating
15.	*A. zygia*	Slender	Elastic	Good	Good	Flexible	Good
16.	*P. biglobosa*	Slender	Elastic	Poor	Poor	Flexible	Poor
17.	*T. monaldeph*	Slender	Elastic	Good	Good	Flexible	Good
18.	*T. superba*	Slender	Elastic	Good	Good	Flexible	Good

Note: Means with the same letter vertically are not significantly different at ($p \leq 0.05$)

IV. CONCLUSION

There were significant variations in all the measured fibre properties and derived values. Each of the 18 wood species either falls into short (1.05–1.36), medium long (1.52–1.75) or long (2.0 mm) fibre categories. All the fibres were elastic. All the wood is suitable for paper-making based on > 33 SR acceptable value for paper-making fibres. However, *P. biglobosa* and *M. excelsa* are not suitable considering their RR, which are greater than 1. *C. albidium* is unsuitable due to its highest rigidity, while *R. heudolotii* was most suitable considering its low Rigidity Coefficient. Regarding Slenderness Ratio, *P. macrocarpa* had the best rating while *R. heudolotii* had the poorest.

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ENVIRONMENT CARRYING CAPACITY OF ECOTOURISM IN AEK NAULI RESEARCH FOREST, SIMALUNGUN REGENCY, NORTH SUMATERA

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ENVIRONMENT CARRYING CAPACITY OF ECOTOURISM IN AEK NAULI RESEARCH FOREST, SIMALUNGUN REGENCY, NORTH SUMATERA. Currently, ecotourism has become an important industry because of its rapid development. Many tourism practices have adverse environmental impacts. Due to the increasingly destructive commercialization of the natural resources on which we depend, there are several negative impacts. Aek Nauli Research Forest (ANRF), with an area of 1,900 hectares, is one of the natural tourist destinations around the Lake Toba Tourism area managed by the Aek Nauli Research Institute for Environmental and Forestry Development (BP2LHK). The location of the study is in Girsang District, Sipangan Bolon, Simalungun Regency, North Sumatera Province. The tourist objects are natural panorama, elephant conservation education tour, and siamang animal ape park. On average, the number of visitors of ANRF on regular days is 100-300 visitors/day and on holidays reaches 300-1,700 visitors/day. The increase in the number of visitors is perceived to have an impact on environmental sustainability. This study aims to determine the capacity of the ANRF ecotourism area to accommodate the number of tourists per day simultaneously. The method used is the effective carrying capacity by Cifuentes method based on several stages of analysis, namely Physical Capacity (PCC), Real Capacity (RCC), Management Capacity (MC), and Effective Capacity (ECC). The environmental carrying capacity analysis results showed that the PCC, RCC, ECC were 26,106 visitors/day, 3,007 visitors/day, 2,505 visitors/day respectively while MC was 0.83. This value can be used to advise managers to limit visitors, particularly during peak season, in order to preserve objects and the quality of visits.

Keywords: Environmental, carrying capacity, ecotourism, Toba lake

DAYA DUKUNG LINGKUNGAN EKOWISATA DI HUTAN PENELITIAN AEK NAULI, KABUPATEN SIMALUNGUN, SUMATERA UTARA. Saat ini, ekowisata telah menjadi industri yang penting karena perkembangannya yang pesat. Banyak praktik pariwisata memiliki dampak lingkungan yang merugikan, karena komersialisasi yang semakin merusak sumber daya alam sehingga menimbulkan dampak negatif. Hutan Penelitian Aek Nauli dengan luas 1.900 hektar, merupakan salah satu tujuan wisata alam di sekitar kawasan wisata Danau Toba yang dikelola oleh Balai Penelitian Pengembangan Lingkungan Hidup dan Kehutanan (BP2LHK) Aek Nauli. Kawasan tersebut terletak di Kecamatan Girsang Sipangan Bolon Kabupaten Simalungun, Provinsi Sumatera Utara. Objek wisata yang dimiliki berupa panorama alam, wisata pendidikan konservasi satwa gajah, dan taman kera satwa siamang. Pengunjung yang datang ke ANRF pada hari biasa rata-rata mencapai 100-300 pengunjung/hari dan pada hari libur mencapai 300-1.700 pengunjung/hari. Peningkatan jumlah pengunjung dikhawatirkan berdampak terhadap kelestarian lingkungan. Penelitian ini bertujuan untuk mengetahui kemampuan kawasan ekowisata ANRF dalam menampung jumlah wisatawan per hari dalam waktu bersamaan. Metode yang digunakan yaitu metode daya dukung efektif oleh Cifuentes berdasarkan beberapa tahapan analisis, yaitu Daya Dukung Fisik (PCC), Daya Dukung Riil (RCC), Daya Dukung Manajemen (MC), dan Daya Dukung Efektif (ECC). Hasil analisis daya dukung lingkungan menunjukkan bahwa nilai (PCC) sebesar 26.106 pengunjung/hari, nilai RCC 3.007 pengunjung/hari, nilai MC 0,83 dan nilai ECC 2.505 pengunjung/hari. Nilai ini dapat menjadi acuan untuk pengelola supaya ada upaya pembatasan pengunjung terutama pada hari libur agar objek wisata dan kualitas kunjungan tetap terjaga.

Kata kunci: Daya dukung, lingkungan, ekowisata, Danau Toba

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I. INTRODUCTION

Popular tourist destinations such as Aek Nauli's Research Forest (ANRF) will continue to face various problems, both in terms of infrastructure, environmental carrying capacity and sociocultural issues, which may eventually lead to the degradation of the value for the tourist. If not anticipated, it will certainly impact the loss of balance (Hixon 2008, Nuzula, 2017). Meanwhile, new destinations without clear planning and following the rules of development and the character of the area will grow in an unorganized manner (Zhao, 2019). Carrying capacity is a concept that has been widely applied in tourism and recreation studies since the 1960s, although some researchers trace its emergence to the 1930s (Singh, 2006; Kennell, 2017). If you look at the history of global tourism development in recent years, several countries that have popular tourist destinations were invigorated by the issue of over-tourism. For example, China, Venice, Barcelona, Amsterdam, and other areas which later resulted in the emergence of the anti-tourist movement (Solís 2014, Shi 2015, Ye, 2016, Milano 2017).

ANRF is one of the research forests in Indonesia, which is managed by Aek Nauli's Center for Environmental Development and Forestry Research (BP2LHK). ANRF was established through the Minister of Forestry Decree No. 39 / Menhut-II / 2005, 7 February 2005 (Pratiara, 2017). The area of 1,900 hectares is mostly pine and secondary forest with various plant species, located in Girsang District, Sipangan Bolon, Simalungun Regency, North Sumatra Province. ANRF is a forest area essential for the research and development of science and technology, including education, training, religion, and culture, to expand dynamically. Biophysical potential, the expanse of pine forests and biodiversity in the ANRF area are the mainstays of tourist attractions, enhanced by elephant conservation education tourism and the siamang monkey animal park, a leading destination for visitors to come to the ANRF. The location of ANRF is strategic because it is on the main highway to the Lake Toba tourist area. It makes the ANRF area a choice as a tourist destination around the Lake Toba tourist area. The weekday visitors of ANRF are 100-300 visitors/day (BP2LHK Aek Nauli, 2019), and on major holidays or national holidays, the number of visitors reaches 300-1,700 visitors/day (BP2LHK Aek Nauli, 2019). However, the carrying capacity of the ecotourism area in the ANRF has never been studied.

Increasing the number of visitors affects the condition of ecotourism destinations (Sunaryo, 2013) and has an impact on the development of ecotourism which tends to increase the number of visitors without measuring the ability of the quality of attraction objects and facilities for ecotourism and disruption of biophysical potential (Lucyanti, 2013). Tourism development can be done with the concept of ecotourism by prioritizing aspects of nature conservation, socio-economic empowerment of the local communities, and education (Satria, 2009; Alaeddinoglu, 2013). Based on potential and existing conditions, ecotourism development is very feasible. Planning for ecotourism development in ANRF should be adjusted to the regional characteristics and ideal planning based on existing conditions and the carrying capacity of the environment (Muta'ali, 2012).

The environmental carrying capacity of ecotourism is a condition of the ability of the ecotourism area to acquire visits, visit length, visitor behavior at the same time without causing damage to the physical, economic, sociocultural environment and decreased tourist satisfaction. Ecotourism guarantees the sustainable use of environmental resources, while generating economic opportunities for the local people (Farrell & Runyan, 2001; Bhattacharya, Chowdhury, & Sarkar, 2011). The development of a tourist attraction requires good planning if the number of visitors does not exceed the carrying capacity (Cifuentes, 1992) to safe limits and allows to maintain the sustainability of ecotourism activities. According to Catanese

and Synder (1990), every natural system in an area can support a balanced population without experiencing destruction. In achieving the goals and targets of ecotourism development in an area, a management strategy for visitors is needed as an indicator of the success of an activity (Hariadi et al., 2012) the visitor management strategy should be based on the environmental carrying capacity. The maximum development based on environmental carrying capacity is the best approach to prevent environmental damage (Bhuiyan et al., 2012; Alaeddinoglu, 2013; Siswanto & Moeljadi, 2015; Chen & Teng, 2016; Sofian et al., 2019).

An environmental carrying capacity assessment for the ecotourism area in ANRFis is crucial to support the development of sustainable ecotourism as one of the conservation efforts to achieve sustainable ecotourism development (Alikodra, 2012). This research aims is to analyze the carrying capacity of the ANRF ecotourism area. The analysis of environmental carrying capacity is focused on the index of physical, real, management, and effective carrying capacity of the ANRF ecotourism area. The importance of this research is to fill the research gap on how to regulate visitor restrictions by policy makers. This research is useful for saving the environment from the degradation of destination quality. The study's results can be used as a reference so that visitors can feel comfortable and satisfied when doing tourism activities in ANRF.

II. MATERIAL AND METHODS

A. Time and location of the study

The study was conducted in the ANRF ecotourism area, Girsang Sipangan Bolon Sub-District, Simalungun Regency, North Sumatera Province, during March - October 2019, both weekdays, and weekends. The location of ANRF is shown in Figure 1.

B. Material and Devices

The devices used in the study include software Minitab, questionnaires, stationery, recorder, and digital cameras.

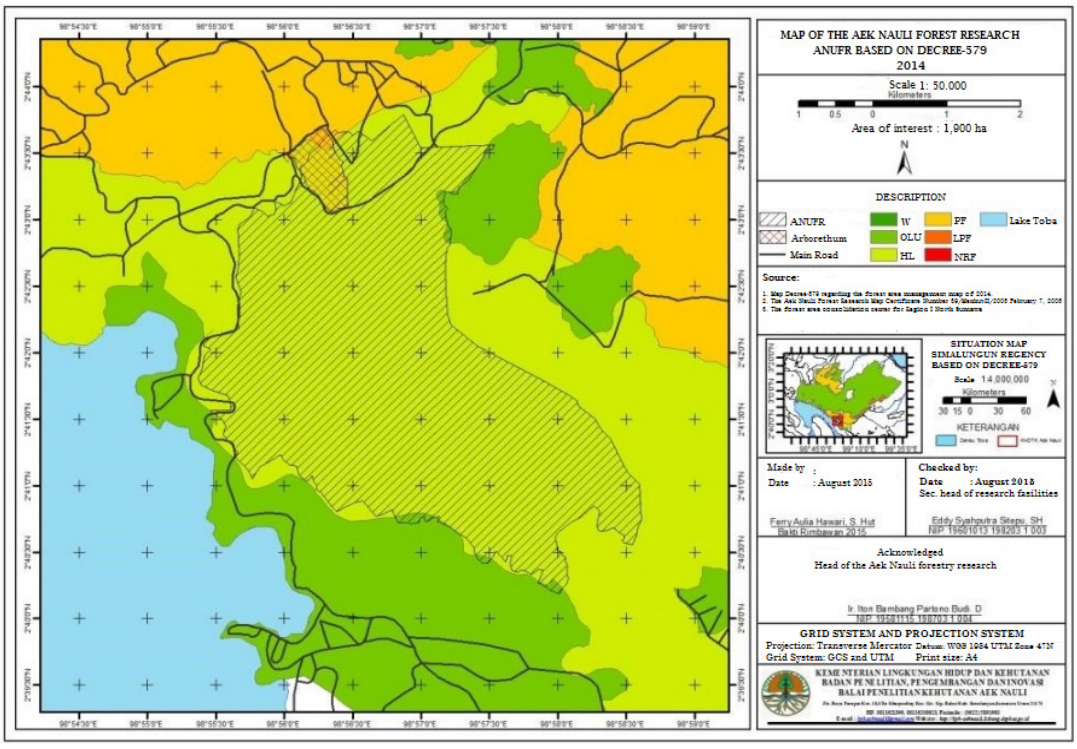

Figure 1. Map of the Aek Nauli forest research area

C. Research Method

Carrying capacity is an important tool for conserving ecological elements, rich biodiversity and rare species, and dense forests in an environment with cultural and natural experience (Arnberger, 2007; He, 2008; Chougule, 2011). A Purposive Sampling Method has been used to determine the location of the study, which reflects the criteria: a) a well-established area, b). established area, and c) less established area. The method used is the descriptive research method, and for data processing, Cifuentes method was used, by calculating the physical carrying capacity (PCC), the real carrying capacity (RCC) and the effective carrying capacity (ECC). The technique of data collection through the purposive interview is an interview conducted with respondents based on data needed. In addition to interviews, observations, and documentation were also used as data collection techniques. This study uses a mixed questionnaire, a combination of closed and open questions so that respondents answer even if they have no choice. The selection of respondents used a targeted sampling method of 107 respondents. The characteristics of the respondents were divided into 4 categories, namely: Gen Z born in 1997-2012 (42%), Gen Y born in 1981-1996 (37%), Gen X born in 1965-1980 (18%) and Baby Boomers born in 1946-1964 (3%). The N value uses the average number of visitors in 2018, which was 18,560 people per month. This data was obtained from the archives of the ticketing manager of the ANRF section. The primary data collected includes the distribution of tourist attraction items, ecotourism support facilities and infrastructure, tourists (perceptions, motives and length of visits during a tour), and correction factors (biotic and abiotic) as a basis for supporting ecotourism research. Secondary data were collected from the area manager, tourists, and the tourism office of the Simalungun Regency. As a guide for assessing carrying capacity, the collected secondary data include the general state of the study site, work charts and the number of visitors. The visitor data collection technique is the purposeful interview, a database of interviews based on the necessary data. The respondents sampled were tourists in the high and low seasons. A sample of 100 respondents was used based on (Egi et al., 2014). Based the environmental carrying capacity of the ecotourism area, data were collected on the correction factor of biotic and abiotic factors. Biotic factor includes the diversity of flora, bird species, and disturbance of the mating season of *Macaca fascicularis*, while abiotic factors includes landscape conditions, slope, soil sensitivity to erosion and climate, animals to find out the duration of visitors to the ANRF ecotourism area. Research data processing uses the carrying capacity management method Sayan and Atik (2011) where the carrying capacity of the ecotourism environment can be seen based on the biophysical characteristics of the tourist area and visitors (Figure 2). Furthermore, the collection and management of the data obtained are compiled in such a way that it can be read and interpreted (Azwar, 2012).

D. Data Analysis

Data analysis for the correction factor uses Simpson's formula to determine the diversity index of flora and bird species. The data analysis for the carrying capacity of the ecotourism environment uses (Cifuentes, 1992) formula. The justification for choosing the Cifuentes calculation method is because the synergy between tourism and nature conservation. It is necessary to consider the physical (area), ecological (environment) and managerial (effective carrying capacity) aspects. Determination and calculation of the carrying capacity and ability of the area to accommodate the number of tourists can be done using the Cifuentes approach. The Cifuentes calculation method has also been proposed by the International Union for Conservation of Nature (IUCN).

1. Vegetation and Bird Diversity Index

Tree-level vegetation is inventoried along the ANRF tourist trail. Vegetation observed was at tree level with a trunk diameter greater than 20

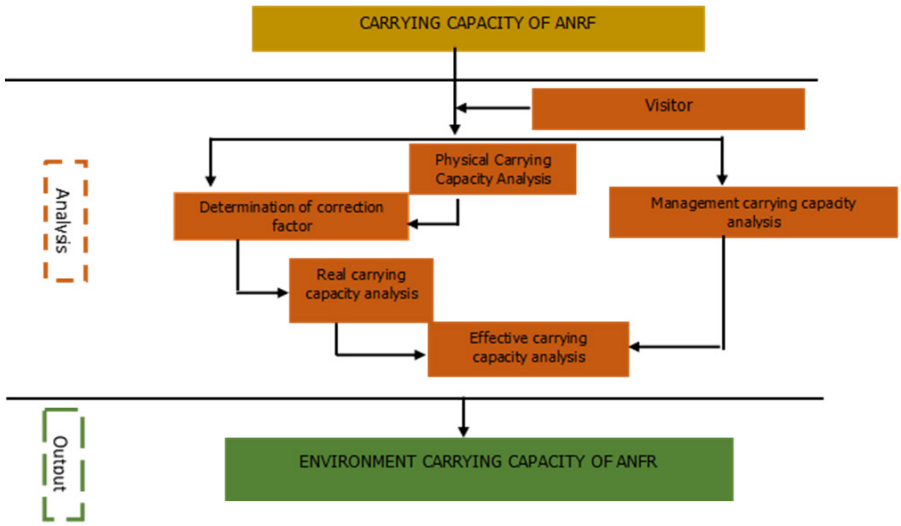

Figure 2. Framework for the flow of research data collection and processing of the environmental carrying capacity of the ANRF ecotourism area

cm measured at a hight of 130 cm from the ground surface. Inventory is done by census method on the left and right lanes with a width of 20 meters with a distance of 20 meters from the left and right lanes (Begon, 1990; Basset, 2011). Based on the vegetation observation results, the Simpson diversity index (I-DS) was calculated using the equation:

$$\mathbf{I - DS = 1 - \lambda} \quad \text{.....(1)}$$

Other correction factors are analyzed using descriptive references adjusted to the current standard values.

2. Environmental Carrying Capacity of Ecotourism Areas

a. Physical Carrying Capacity (PCC)

The Physical Carrying Capacity (PCC) is the maximum number of tourists who are physically satisfied with the space provided at a certain time (Sayan and Atik, 2011). Based on the method (Cifuentes, 1992) and the results of research modifications (Doglas, 1975) by (Fandeli & Muhamad, 2009), PCC was calculated using the formula:

$$\mathbf{PCC = A \times 1/B \times R}f \quad \text{.....(2)}$$

Where:

A = Area of ecotourism in Aek Nauli KHDTK.

B = Area required by a tourist to carry out tourist activities comfortably and obtain travel satisfaction. The need for each person to travel is 65 m² (Fandeli & Muhamad, 2009)

Rf = Rotation factor.

b. Real Carrying Capacity

The real carrying capacity is the maximum number of visitors allowed to visit the ecotourism area in ANRF with the correction factor variable (Cf), namely tree diversity, bird diversity, disturbance of the reproductive process of long-tailed Macaque, landscape, slope, soil erosion sensitivity, and Q / value climate. The formulation of real carrying capacity is based on (Cifuentes, 1992) as follows:

$$CC = PCC\ x\ \frac{100 - Cf_1}{100}\ x\ \frac{100 - Cf_2}{100}\ x\ \ldots\ldots\ \frac{100 - Cf_7}{100} \quad \text{.....(3)}$$

Where:

RCC = Real Carrying Capacity

PCC = Physical Carrying

Cf = Correction Factor

c. Management Capacity (MC)

$$MC = \frac{R_n}{R_t} x100\% \quad \text{.....(4)}$$

Where:

R_n = The number of active officers

R_t = The number of officers available

d. Effective Carrying Capacity (ECC)

Effective carrying capacity (ECC) of the ANRF ecotourism area is the optimum number

of tourists accommodated in the ecotourism area. The calculation used to assess effective carrying capacity refered to Siswanto (2013) as follows:

$$\mathbf{ECC = RCC \times MC} \quad \text{.....(5)}$$

Where:
ECC = Effective Carrying Capacity
RCC = Real Carrying Capacity
MC = Management Capacity

III. RESULT AND DISCUSSION

A. Distribution of Objects and Attractiveness of Ecotourism in KHDTK Aek Nauli

Based on the results of field studies and information obtained from the area manager, Aek Nauli KHDTK is 1,900 hectares divided into two management blocks, the 1850 hectares of KHDTK and the 50-hectare of Arboretum block. The two blocks are the entrance to the Aek Nauli ecotourism area, where visitors enjoy the attraction in the Aek Nauli KHDTK area. The developed ecotourism area is currently ± 190 hectares divided into 2 (two) ecotourism area blocks, namely the KHDTK area block of ± 165 hectares and the Arboretum block of ± 25 hectares. The distribution and extent of ecotourism objects in KHDTK Aek Nauli are as follows:

The diversity of Nature Tourist Attractions (NTA) in the KHDTK Aek Nauli region is a wealth of natural resources such as a diversity of flora and fauna, natural panorama, natural phenomena, and many products resulting from research, development, and innovation from researchers. The existence of NTA, especially elephant and camping grounds is a magnet for visitors and has become one of the choices of tourist destinations around Lake Toba tourist area.

Tourist utilise the ecotourism area is for leisure activities, sports, photography, pre-wedding picture taking, family gathering, and research objects. Based on the potential distribution of NTA and the Nauli KHDTK function, the tourism theme is focused as scientific tourism. This scientific tourism which is divided into 5 (five) themes, i.e., scientific tourism based on wildlife attractions, forest experiencing, flora and fauna, nature and environment love and tourism scientific products based on research and development and innovation (Science and Technology).

B. Facilities and infrastructure Ecoturism in Aek Nauli Research Forests

Visitor facilities need additions and improvements such as signposts, tree identification numbers/names, handrails

Table 1. Distribution and extent of ecotourism objects in the Aek Nauli KHDTK

No.	Ecotorusim Object	Acreage (ha)	Entrance/Block
1.	Pine Forest Area	30.00	KHDTK Block
2.	Elephant Attractions	11.00	KHDTK Block
3.	Jungle Tracking	4.00	KHDTK Block
4.	Water Fall	1.00	KHDTK Block
5.	Panorama Summit	5.00	KHDTK Block
6.	Monkey Park	2.20	KHDTK Block
7.	Deer Breeder	1.00	Arboretum Block
8.	Beecosystem Park	4.00	Arboretum Block
9.	Honey Galery	0.50	Arboretum Block
10.	Camping Ground	2.80	Arboretum Block
	Total Area	61.50	

in narrow-slippery tracks/paths and for the safety of visitors, shelters for visitors to rest while exploring the forest. Restroom/toilet facilities are still lacking and seriously need to be considered because the only existing toilet is near the entrance. Also, the Muslim prayer room (Mushola) is not yet available in the ANRF block.

Facilities and infrastructure to support tourism activities in the block of ANRF and Arboretum are not appropriate in terms of the quality, quantity, and aesthetic aspects of tourism activities. In the Arboretum block, facilities and infrastructure for camping grounds such as toilet, garbage dump, and prohibition-signboard are not available yet. Therefore, it may cause damage and be less secure for office facilities, employee housing in the arboretum block, and the safety and comfort of visitors. The ANRF block needs to be added and improved with interpretation boards such as entry signs, paths to tourist attractions, tree species names, and road tracking safeguards.

The placement of facilities and infrastructure needs to be reorganized and expanded corresponding to visitors needs and reconsider the aesthetic value of tourism. Placement and number of toilet facilities should be adjusted to the length of the track and placed in visitor concentration spots to comfort the visitors and increase the beauty of the tourist area. Other tourism-supporting facilities and infrastructures that need to be arranged and adjusted to visitors are vehicle parking and a food and beverages stall. A parking lot and stalls of food, and beverages have not been arranged yet and are still using office grounds with a cramped area. Such conditions will impact the inconvenience of work activities, vehicle safety, and aesthetics, especially during peak season.

There is insufficient parking space as no specific parking lot is available for the visitors buses, cars, and motorcycles. The motorcycle parking area still uses the roadside of the main road around the tourist area. Other facilities that are not yet available are places to eat and drink. For this time, visitors still bring food from outside and buy at the temporary tent on Saturdays and Sundays around the main entrance at the office of the arboretum block.

C. Duration of Tourist Visits in ANRF Ecotourism Area

According to (Anindita, 2015) tourism is a human activity carried out consciously that receives services interchangeably between people within a country itself or abroad, which includes the inhabiting of people from other regions for a while looking for diverse satisfaction variety and difference from what was experienced before. Based on a descriptive analysis of 107 respondents at ANRF, 78% of respondents stated that the tourist attraction is very attractive, especially for elephant and ape tourist objects, 12% stated attractive and the remaining 10% stated less attractive. Most visitors (89%) are is to see the elephant and ape and the remaining simply to enjoy the natural panorama and take pictures among the pine trees.

The Aek Nauli ecotourism covers 61.5 hectares or 615,000 m². Based on the categories of (Cifuentes, 1992), the need for a toured area is 65 m²/person. The opening hours of the area are 8.5 hours (7.30-16.00 Indonesia Western Time). Based on the rotation factor, the average visit of each visitor was 3.041 hours or the duration of a single visit is in three hours (Table 2).

D. The Correction Factor of the Carrying Capacity of Ecotourism in ANRF

1. Biotic Correction Factor

Carrying capacity is not a difficult concept, yet it is not simple to calculate, as a result, there are no standard calculations available. This concept is varied wildly according to time, climate, and characteristics of tourist destinations such as coastal, rural, mountain, historical, and protected areas. Douglas (1979) defined the tourism environment carrying capacity as the number of tourists using an area without bringing any change in the quality of tourism (Fandeli & Muhamad, 2009). In the calculation

Tabel 2. The average duration of a tourist visit to ANRF

Visit Duration (hours)	Category of single value (hours)	Total Visitors	Value	Average Duration (Hour)
1-2	1.5	33	49.5	
3-4	3.5	67	234.5	
5-6	5.5	7	38.5	
Total		107	322.5	3.041= 3 hours (0≤30 minute)

of the environmental carrying capacity in the ANRF ecotourism, a correction factor is taken into consideration with the effort to maintain the biophysical quality of the tourist area; as stated by (Simon et al., 2004), visitor comfort lies in the main element of the suitability of the area and its environmental factors.

Based on the field data, 37 species of flora were identified. Pine (*Pinus merkusii*) is the most common one reaching 15 of the 141 individuals (Appendix 1). In total, 60 birds were observed covering 26 species (Appendix 2). The result of the Simpson diversity index calculation for flora and bird are used as inputs to conduct an environmental carrying capacity analysis. The calculation result of the Simpson diversity index of flora is 0.967 and determined as an Mn value. An Mt value is the highest value of the flora diversity, calculation which is 1. Therefore, a correction value of 1- 0.967 = 0.03 is obtained. Similarly, since the calculation result of the Simpson diversity index of bird species is 0.959, the correction value is 1-0.959 = 0.04. Furthermore, the results of field observations and interviews with the manager of the ape tourism park in the ANRF, it is estimated that the mating season occurs throughout the year, and there is no specific mating period for long-tailed Macaque. It confirmed that the presence of visitors at ANRF does not bring disturbances to the animal in the reproduction process.

2. Abiotic correction factors

Based on the Aek Nauli KHDTK management plan document, the ecotourism area is classified in the second slope class. The slope classification is based on the Ministerial Decree of Agriculture No. 837/Kpts/UM/1/1980 regarding the criteria and procedures for determining protected forests. The second slope class means the slope of ecotourism areas in KHDTK Aek Nauli is 8-15% with a flat area so that the Mn value is 57. The Mt value for the slope correction factor is 100. Furthermore, the correction value for the slope is 1 - 0.57 = 0.43. Assessment of soil erosion sensitivity refers to the Ministerial Decree of Agriculture No. 837 of 1980 concerning the classification of soil types based on Irfan's research result (2019). The soil classification in the Aek Nauli KHDTK ecotourism area is dominated by regosol and red-yellow podsolic species. This type of soil classification has a sensitivity to sediment source rock with slow permeability and has a large erosion sensitivity property of 40%.

The correction factor for landscape potential is very important in determining the carrying capacity of ecotourism areas (Fandeli & Muhamad, 2009; Wapole, 2007) because it relates to the physical space available in determining the carrying capacity. The potential of the landscape in the development of ecotourism that exceeds the carrying capacity will disrupt the elements of the landscape in the ecotourism area. Based on the results of the landscape potential index in the ANRF area according to the Bureau of land Management in Fandelli and Muhamad (2009), the landscape potential index in the ANRF ecotourism area is 0.78% (Appendix 3).

The correction index of 0.22% showed that the ecotourism area has low and rough hills and striking peaks with erosion-prone land

formations with dominant land characteristics and an average altitude between 1,100-1,700 meters above sea level. Potential landscape conditions in the ANRF area have different types of vegetation at each altitude, such as at an altitude of 1,400–1,700 m asl dominated by salagundi species (*Vitex trifolia*), scorch (*Baccauera dulcis*), puspa (*Schima wallichii*), sulim (*Leptospermum javanicum*), and fires (*Gordonia excelsa*). The dominant species at altitudes between 1,200–1,300 meters above sea level were rasamala (*Altingia excelsa*), simartolu (*Schima wallichii*), pine (*Pinus merkusii*), tulason (*Mimusops elengi*), modang hoting (*Cinnamomum* sp.), candis (*Schcinia xanthochymus*) and tulason (*Mimusops elengi*), modang hoting (*Cinnamomum* sp.), kandis (*Garcinia xanthochymus*) and frankincense toba (*Styrax paralleloneurum*). The potential of the regional landscape provides an interesting and challenging experience to do jungle trekking toward the attractions of the waterfall and the top panorama of Lake Toba with the sound of bird species and cool air.

Rainfall of the ANRF and Lake Toba areas range from 2000 to 2600 mm/year. The highest monthly rainfall occurs during June - December reaching more than 260 mm/month, while the dry month with rainfall less than 100 mm occurs during February - March (Sihontang, et al. 2016). The monthly evaporation of Lake Toba ranges from 125.1 mm to 135.9 mm (Acreman et al., 1993). Q value index in Lake Toba and ANRF which is the ratio of the number of dry and wet months is 0.29 and included within B Climate type according to Schmidt-Ferguson, the correction factor value is 0.71. The whole correction factor consisting of biotic and abiotic can be seen in Table 3.

3. Value of Environmental Carrying Capacity of Ecotourism in ANRF - Physical Carrying Capacity (PCC)

The Aek Nauli KHDTK ecotourism used area is 61.5 hectares or 615,000 m². The average length of the tourist visits in one day is three hours (± 3 hours). Opening hours of the ecotourism area are from 7.30 to 16.00 Indonesian Western Time or about 8.5 hours. Thus, a rotation factor value of 3.014 hours is obtained or equal to three hours (Table 2).

Based on the ecotourism area and the visit duration per visit, the results of the ecotourism area's physical carrying capacity (PCC) was 26,106. This value is the maximum number of visitors physically who can visit the ecotourism area, in the sense that the ANRF ecotourism area can physically accommodate 26,106 visitors/day.

4. Real Carrying Capacity (RCC)

The real carrying capacity assessment is based on the correction factor values in the analysis. The correction factor value is obtained from the results of the previous calculation (Table 3). So the real carrying capacity is 3,007 people per day. This value indicates the capacity of tourists with the consideration of physical and biophysical aspects of the environment (correction factor)

Table 3. The correction factor value in the PCC Variable Ecotourism Area in ANRF

Factor Correction Variable	Parameter	Index Value (x100%)	Corrector Factor Value
Biotik	Tree Diversity	0.967	0.03
	Bird Diversity	0.959	0.04
	Macaca fascicularis Mating Season Disturbance	1	-
Abiotik	Landscape Potency	0.78	0.22
	Landscape Potency	0.57	0.43
	Erosion Sensitivity Potency	0.60	0.40
	Climate Potency	0.29	0.71

to visit the ANRF ecotourism area. Based on the data on the number of visitors 63,740 visitors per year (BP2-LHK Aek Nauli, 2019) that value is still below the real carrying capacity value meaning that the ecotourism area is still able to accommodate more visitors physically and biophysically.

5. Management Capacity (MC)

Based on the interview, the Aek Nauli ecotourism area has 24 staff consisted of 20 permanent employees as officers or tour guides and 4 non-permanent employees. The employees are divided based on tourist activities, namely: 9 elephant animal attractions, 4 gibbons attractions, 4 entrance staff, 7 arboretum area officers. Based on the number and status of officers in the ANRF ecotourism region the Rt is 24 and the Rn is 20, so the management carrying capacity is 0.83.

Management capacity is indicated by several variables such as legal basis, policies and regulations, equipment, officers, financing, infrastructure, and other facilities (Cifuentes., 1992). Therefore to develop a tourist attraction, it is necessary to increase the capacity of the management officer to serve the visitors better. This is to anticipate a decrease in the management capacity, especially in the peak season, when the number of visitors exceeds the carrying capacity.

6. Effective Carrying Capacity (ECC)

The effective carrying capacity (ECC) of the ANRFecotourism area is the optimum number of tourists accommodated in the ecotourism area. The calculation of the effective carrying capacity analysis obtained a value of 2.505. This value determines the effective capacity of the ANRF ecotourism area which is 3,007 tourists/day considering physical and biophysical environmental factors (correction factors). The values based on the real carrying capacity and management capacity of managers.

Based on the results of this value compared with the average number of tourist visits to the ANRF ecotourism area, which is 300 tourists per day, the value is still far below the effective carrying capacity. Thus the number of tourists expected to travel to the ANRF without disrupting to the environment and ecosystem is equal to 2,505 visitors per day at simultaneously in each ecotourism activity. So: PCC> RCC and ≥ECC = 26,776 > 3,007 ≥ 2,505. The carrying capacity of the ecotourism area can accommodate the number of visitors in the same area and time of 26,776 visitors per day physical carrying capacity and 3,007 visitors per day for real capacity. The effective capacity is 2,505 visitors/day.

ANRF's management strategy to be sustainable is to link ecological, social, and economic aspects. Recommendations for management strategies at ANRF are: first, limiting and distributing visitors who come to the location because the number has exceeded the EEC of 26,106 visitors per day. The exceeded area's carrying capacity can cause ecosystem disturbances (Milano, 2017). According to Salerno et al. (2013) limiting visitors can reduce negative effects on tourist objects and provide space for visitors to get travel satisfaction. Visitor restrictions are carried out on tourist activities that have exceeded the EEC, such as trekking and camping. When the number of visitors in the trekking zone exceeds the capacity, the visitors are distributed to other activities. It is expected that the visitors are evenly distributed among each activity and that they do not exceed the EEC. Second, to innovate and optimize existing tourism activities. Recommendations for additional zones for alternative tourism activities are the addition of a 1000–1500 m trekking route, an additional 500 m^2 collection park zone, and a 200 m^2 elephant bathing tour. This is expected to increase the capacity of the number of visitors and increase the value of tourism carrying capacity. The tourist activities at ANFR that are visitors favorites are the camping grounds and trekking with beautiful panoramas. This is because other tourist activities are not widely known by visitors and are still in the process of repair and

preparation. Tourism planning activities are expected to be completed as soon as possible to increase visitors attractiveness. The third effort is to optimize and equip facilities according to regional needs. It is necessary to add security for trekking routes, gazebos, souvenir stores, public toilets, and other facilities for photo spots. The number of these facilities is considered less than optimal because it is not proportional to the number of visitors who come. Developing of ecotourism infrastructure and facilities must be environmentally friendly but still provide comfort and satisfaction to visitors who travel.

This ecotourism activity is expected to provide education, skills, and innovation for conservation activities. Fourth, provide accommodation or transportation to the location. The unavailability of public transportation to ANRF ecotourism is an obstacle for visitors who do not have private vehicles. Visitors can use a taxi from the highway to the location, but the number of taxis is still very limited and expensive. Managers can cooperate with travel agencies or propose to the local government to procure travel and public transportation. The condition of the main road to the location is paved but needs to be maintained to provide convenience for visitors. Information and directions to tourist attractions are quite good. Fifth, organize soft skills training for the surrounding community regarding ecotourism for manufacturing of special souvenirs such as key chains, t-shirts, or regional specialities. Increasing people's income and welfare will help reduce economic problems in the area. Managers can conduct consultations or comparative studies on areas with ecotourism with other mountain landscapes that have been developed. The ecotourism development plan that will be carried out must always be coordinated with the local leaders or government so that management can be sustainable (Khaery et al. 2016, Zemla 2020). Sixth, take advantage of tourist-attracting events such as the Lake Toba Festival (LTF), which was held in early December. This event is used to attract tourists who are visiting LTF by creating an ANRF booth at the exhibition. Another effort can be made by increasing ticket prices on weekends and allowing visitors to buy t-shirts or souvenirs produced by the community. This will help the community to continue producing handicrafts. Seventh, planting and maintaining ecosystems so that they can grow well. Hopefully, with the development of ecotourism, the rehabilitation activities carried out will continue. Until now, the management is still trying to expand the tree planting area and make understorey enrichment to become elephant food gardens. Planting trees and making feed gardens does not only involve not only managers, but also NGOs, students and the community.

E. Management Implication

Ecotourism at ANRFhas started when Lake Toba became a leading tourist attraction in North Sumatra. This moment is used to develop the sector furthers a separate tourism management plan and action plan should be developed. Many people come to ANRF to see forests, wildlife, and natural beauty and to visit the surrounding tourist places.

ANRF has a good potential for eco-tourism. Management will create opportunities for creating an ecotourism-driven tourism industry based on protected areas. Ecotourism can be promoted as a conservation and sustainable development tool for wildlife and forests and from a community point of view it is expected to provide benefits that eventually increase local support for natural resource conservation. The study's result did not reveal a negative attitude towards tourism growth at ANRF, but as tourism evolves, the attitude trend of tourism may change. Further studies would therefore be needed in the future to collect comprehensive data on tourism performance in protected areas in terms of ecological, socio-economic and community conservation levels.

The management of ANRF through ecotourism has a positive impact on the villagers, the local economy and the preservation of the environment and local culture. Communities who play an active role in the management of

ANRF are increasingly aware of preserving the environment, besides that, ecotourism management of tourist areas has proven to provide new jobs. Limited facilities and infrastructure just because there is no tread design for ANRF so that the arrangement and placement of facilities for support activities on the trekking trail has not been able to finish. It is necessary to immediately design tread design and promote trekking trails related to the carrying capacity that should not be exceeded.

Furthermore, envisioned as a positive approach to sustainable development in tourism ANFR, if unplanned or poorly planned and not implemented can have a serious negative effect, offset the benefits that are designed to be given.

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

The Aek Nauli KHDTK is 61.5 hectares consisting of attractions of pine forest (30 ha), elephant animal (11 ha), jungle tracking (4 ha), waterfalls (1 ha), panorama peaks (0.5 ha), monkey park (2.20 ha), deer breeding (1 ha), ecosystem park (4 ha), honey gallery (0.50 ha), and camping ground (2.80 ha). The average tourist visit duration was three hours.The physical carrying capacity (PCC) can accommodate of 26,776 visitors per day. The maximum number of tourists in real terms (RCC) by considering two correction factors with seven parameters based on the characteristics of ANRF is 3,007 visitors per day. The value of management capacity is 0.83 and the effective number of visitors taking into account physical, ecological, and management (ECC) aspects is 2,505 visitors per day. The calculation of the environmental carrying capacity of the ecotourism area in KHDTK Aek Nauli shows PCC> RCC> ECC which is 26,776 > 3007 ≥ 2,505. The calculation results mean that the ecotourism area in ANRF can accommodate more visitors with all their activities comfortably at the same time when the actual number of visitors does not exceed the maximum limit of the RCC value.

B. Recommendation

ANRF developed areas in the spirit of local people's participation, appreciation and sensitivity. Facilities in ANSF must be improved to support ecotourism development. Different entrances and exits need to be built so that visitor management can be better monitored and organized, especially during major holidays when the number of visitors is increasing. There must be restrictions on vital and tourist zones, so that office activities and employee housing are not open to the public, allowing visitors without permission to go to the office area and employee housing.

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Apendix 1. The tree-level vegetation diversity index in Aek Nauli KHDTK

Local Name	Latin Scientific Name	ni	ni(ni-1)	n	n(n-1)	λ	IDS
Api-api	*Gordonia excelsa* Blume	6	30				
Boli-boli	*Sauraula nudiflora* Dc.	3	6				
Dori	*Syzygium cf. lineatum* (DC.) Merr.&Perr.	2	2				
Goring-goring	*Baccauera dulcis* Merr.	3	6				
hapas-hapas	*Symingtonia populnea* Steem.	4	12				
harimotting	*Rhodamnia cinerea* Jack.	8	56				
Hatinggiran	*Syzygium* sp.	3	6				
Hatuang	*Litsea velutina* Boerl.	1	-				
Hau dolok	*Syzygium sp.*	2	2				
Hau dolok baringin	*Eugenia suringariana* K.et.V.	5	20				
Horbo-horbo harangan	*Xylopia sp.*	3	6				
Horing engket-engket	*Lithocarpus daphnoideus*(Blume.) A. Carnus	4	12				
Hoting batu	*Quercus maingayi* Bakh.	2	2				
Hoting bunga merah	*Lithocarpus hystrize* (Korth.) Rehd	3	6				
Hoting bunga putih	*Castanopsis rhamifolia* (Miq.) Dc.	2	2				
Hoting merah	*Castanopsi*s sp.	5	20				
Hoting turi	*Quercus gemiflora* Blume	3	6				
Jambu-jambu	*Eugenia fastigiata* Miq.	3	6				
Kandis	*Garcinia celebica* L.	7	42				
Kemenyan	*Styrax benzoin* Dryand.	2	2				
Kemenyan durame	*Styrax sp.*	1	-				
Kemenyan toba	*Styrax sp.*	1	-				
Logan	*Dipterocarpus kunstleri King.*	2	2				
Losa	*Cinnamomum porectum (Roxb.) Kosterm*	1	-				
mayang	*Palaquium obovatum Engl., var.*	4	12				
Medang landit	*Litsea odoratissima Kosterm.*	6	30				
Meranti batu	*Shorea resinosa Sym.*	4	12				
Modang	*Litsea odorifera Valeton*	3	6				
Modang putih	*Neolitsea cassiifolia Merr.*	2	2				
Modang siak	*Cinnamomum subavenium Miq.*	4	12				
Pinus	*Pinus merkusii*	15	210				
Puspa	*Schima wallichii Korth.*	3	6				
Rasamala	*Altingea exelca*	6	30				
Salagundi	*Rhodoleria theymanii Miq*	4	12				
Sampinur bunga	*Dacricarpus sp.*	2	2				
Sanduduk bolon	*Melastoma pulcherrimum Korth.*	5	20				
Sulim	*Leptospermum javanicum*	7	42				
	Total	**141**	**642**	**141**	**19740**	**0.033**	**0.967**

Apendix 2. Bird diversity index in KHDTK Aek Nauli

Bird Species	Nama Latin	ni	ni(ni-1)	N	n(n-1)	λ	IDS
Burung madu leher	*Antherepte rhololaema Shelly*	2	**2**				
Cikrak daun	*Phylloscopus trivirgatus Strickland*	5	**20**				
Cinenen belukar	*Orthotomus atrogularis Temminck*	2	**2**				
Cinenen gunung	*Orthotomus cuculatus Temminck*	6	**30**				
Kucica kampung	*Copsychus saularis L*	3	**6**				
Kutilang	*Pycnonotus aurigaster Vieillot*	1	**-**				
Layang-layang rumah	*Delichon dasypus Bonaparte*	1	**-**				
Poksai hitam	*Garrulax lugubris Muller*	1	**-**				
Poksai jambul	*Garrulax leucolophus Hardwicke*	2	**2**				
Punai besar	*Treron capellei Temminck*	3	**6**				
Punai kecil	*Treron olax Temminck*	7	**42**				
Sikatan bubik	*Muscicapa dauurica*	1	**-**				
Srigunting bukit	*Dicrurus remifer Temminck*	1	**-**				
Srigunting kelabu	*Dicrurus leucophaeus Vieillot*	1	**-**				
Bubut besar	*Centropus sinensis Wagler*	1	**-**				
Poksai hitam	*Garrulax lugubris Muller*	3	**6**				
Punai besar	*Treron capellei Temminck*	2	**2**				
Punai kecil	*Treron olax Temminck*	4	**12**				
Kucica kampung	*Copsychus saularis L*	2	**2**				
Kutilang	*Pycnonotus aurigaster Vieillot*	3	**6**				
Layang-layang rumah	*Delichon dasypus Bonaparte*	1	**-**				
Kucica kampung	*Copsychus saularis L*	1	**-**				
Burung cabai hutan	*Dicaeum concolor Ferdon*	2	**2**				
Burung madu belukar	*Anthreptes singalensis Gmelin*	3	**6**				
Burung madu	*Antherepte rhololaema Shelly*	1	**-**				
Kacamata gunung	*Zosterops montanus Bonaparte*	1	**-**				
	Total	60	**146**	**60**	**3540**	0.041	**0,959**

Apendix 3. Landscape potential index in the Aek Nauli Ecotourism area

Lanscape element	Criteria	Score	Value
Land shape	Low and undulating hills, hill at the mountains foot or valley bottoms are not attractive features of landscaping.	1	
	Steep canyons, volcanic cones, or interesting erosion patterns or variations in land size and shape or dominant detail characteristics.	3	5
	High vertical relief with striking peaks; a spire-like summit; giant rock profile or amazing surface variations; easily eroded formations or very striking dominant features.	5	
Vegetation	Little or no difference in vegetation	1	
	Some vegetation but only 1-2 species are dominant.	3	5
	A variation of vegetation type that is indicated by attractive patterns, textures and shapes	5	
Colour	Color Subtle and contrasting color variations, generally dead.	1	
	Different types of colors, opposites of soil, rock and vegetation but not the dominant view	3	3
	A variety of color combinations or beautiful contrasts and colors of soil, rock, water vegetation and others	5	
Scenery	The nearby scenery has little/no effect on the quality of the scenery.	0	
	The nearby scenery is quite influential on the quality of the scenery.	3	3
	The nearby scenery greatly influences the quality of the scenery.	5	
Characteristic	Having an interesting background but almost the same as the general situation in an area	1	
	Distinctive though almost the same as in certain regions.	3	3
	Distinctive/different from other objects and bring impression	5	
Modification	Modifications add variety but are very contrary to nature and cause disharmony	-4	
	Modifications add little or no diversity of scenes	0	2
	The construction of facilities such as installations/ electricity, waterways, houses provides modifications that can increase visual diversity; no modification	2	
	Total	27	21
	Landscape potential Index		0.78

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TOURISM COMPETITIVENESS, TOURIST FOREIGN ARRIVAL AND NON-TAX STATE REVENUE IN NATIONAL PARKS IN INDONESIA

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TOURISM COMPETITIVENESS, TOURIST FOREIGN ARRIVAL AND NON-TAX STATE REVENUE IN NATIONAL PARKS IN INDONESIA. Indonesia has a natural tourist attraction in the form of 54 national parks spread across regencies and cities, with an area of 16,304,707.13 hectares, featuring a diversity of ecosystems, high mountains, lowlands, savannahs to wetlands, and waters. However, the appeal of natural tourism does not necessarily contribute to the performance of national tourism, hence studies need to support of increase in tourist arrivals to national parks, one of which is to study tourism competitiveness in areas that have national parks in Indonesia. This research aims to develop a model of tourism competitiveness management in areas that have national parks in Indonesia. The theory underlying this research is the theory of tourism competitiveness through the approach of the competitiveness index of the Travel & Tourism Competitiveness Index, Indicators for Measuring Competitiveness in Tourism, and Competitiveness Monitor. The research design uses 20 competitiveness factors, where data collection techniques utilize data that has been available at both government and non-government institutions and the data collection method uses library research. The data were analysed by using the dynamic model method. The results of the study found that tourist arrivals significantly correlated simultaneously with the factor of tourism competitiveness of the districts and cities that have national parks, tourist arrival, revenue tourism, and conservation in zona utility of national park in Indonesia. It is proposed that local governments, national parks management and other interested parties make policy innovations to optimize the factors of tourism competitiveness in their regions to support or increase in the number of tourist visits in national parks.

Keywords: Competitiveness, tourism, tourist arrival, model

DAYA SAING PARIWISATA, KEDATANGAN WISATAWAN MANCANEGARA, DAN PENERIMAAN NEGARA BUKAN PAJAK DI TAMAN NASIONAL INDONESIA. Indonesia memiliki daya tarik wisata alam berupa 54 taman nasional yang tersebar di seluruh wilayah kabupaten dan kota, dengan luas mencapai 16.304.707,13 hektar, menampilkan keragaman ekosistem, pegunungan tinggi, dataran rendah, sabana hingga lahan basah dan perairan. Namun, daya tarik wisata alam tersebut, tidak serta merta memberikan kontribusi terhadap kinerja pariwisata nasional, sehingga perlu dilakukan kajian dalam mengupayakan peningkatan kunjungan wisatawan ke taman nasional, salah satunya melakukan kajian dari aspek daya saing wisata pada wilayah yang memiliki taman nasional di Indonesia. Penelitian ini bertujuan untuk membangun model manajemen daya saing pariwisata pada wilayah yang memiliki zona pemanfataan taman nasional di Indonesia. Teori yang mendasari penelitian ini adalah teori daya saing pariwisata melalui pendekatan indeks daya saing Travel & Tourism Competitiveness Index, Indicators for Measuring Competitiveness in Tourism, dan Competitiveness Monitor. Desain penelitian menggunakan 20 faktor daya saing, dimana teknik pengumpulan data dan memanfaatkan data yang telah tersedia pada lembaga pemerintah dan non pemerintah dan metode pengambilan data menggunakan studi kepustakaan. Data dianalisis memanfaatkan metode model dinamik. Hasil studi menunjukkan, kunjungan wisatawan mancanegara secara nyata berkorelasi simultan dengan faktor daya saing wisata di wilayah kabupaten

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dan kota yang memiliki taman nasional, pendapatan pariwisatan dan konservasi di zona pemanfaatan Taman Nasional. Diusulkan agar pemerintah pusat, pemerintah daerah, manajemen taman nasional dan pihak yang berkepentingan lainnya melakukan inovasi kebijakan untuk mengoptimalkan faktor-faktor daya saing wisata di wilayahnya sehingga mampu meningkatkan jumlah kunjungan wisatawan taman nasional.

Kata kunci: Daya saing, pariwisata, wisatawan, kedatangan, model

I. INTRODUCTION

Indonesia has a natural tourist attraction in the form of 54 national parks spread across regencies and cities, with an area of 16,304,707.13 hectares, featuring a diversity of ecosystems, high mountains, lowlands, savannahs to wetlands, and waters. The national parks are also a center of biodiversity, and one of the best conservation areas to witness Indonesia's wildlife (Djuharsa et al., 2015). However, the superiority of mega biodiversity and tropical ecosystem which is a wealth of natural tourist attractions that is owned; apparently has not been able to contribute to the performance of national tourism. According to data published by the Indonesia Ministry of Tourism, in 2016 natural tourism only contributed to 35% of foreign tourist arrivals. If examined further, nature-based tourism ecotourism sites only contribute 45% of foreign tourist arrivals, which is about 3,150,000 foreign tourists each year. If described in more detail, the area of forest conservation including national parks only contribute 40% of ecotourism sites or brings in 1,260,000 foreign tourists each year (Kemenpar, 2017). Thus, it is necessary to carry out more in-depth studies related to factors that can be developed in an effort to bring tourist arrivals to the national parks so that the national parks are able to contribute to the performance of national tourism. One of them is related to the issue of tourism competitiveness in regencies and cities that have national parks in Indonesia.

Competitiveness is about producing more goods and services of better quality that are marketed successfully to consumers at home and abroad (Muñoz-Bullón, 2016). Competitiveness is widely regarded as an important factor in creating national prosperity (Dwyer et al., 2016). The Organization for Economic and Co-operation Development (OECD) defines competitiveness as the extent to which a country can produce goods and services that meet the needs of the international market in free and fair market conditions, while simultaneously maintaining and expanding people's real income in the long run (OECD, 2019).

Indonesia has a natural tourist attraction in the form of 54 national parks spread throughout the regency and city. However, this natural attraction does not indicate the national parks have the highest tourism product portfolio in Indonesia. According to a report published by the Ministry of Tourism, the portfolio of cultural tourism products has the largest market share of 60%, while natural tourism products only have a 35% market share, and 5% man-made tourism products (Said & Maryono, 2018). With the potential of comparative advantage possessed by national parks, the percentage of natural tourism portfolios should be optimized again if supported by the competitive value of the competitiveness of the district and city territorial areas where the national parks are located.

Currently the Government of Indonesia is establishing the tourism sector as one of the priority programs after the food, energy and maritime sectors. It has been stipulated in Presidential Regulation No. 2 of 2015 concerning the Medium Term Government Work Plan of 2015–2019. In an effort to improve the performance of the national tourism sector, supporting facilities are needed in the form of tourism competitiveness in various destinations including supporting facilities for traveling to national parks which are one of the alternative ecotourism destinations

in Indonesia. Supporting facilities are needed so that the national park can be accessed by tourists and to meet the needs of tourists during tourist activities. Therefore, the government is very serious about building infrastructure such as toll roads, airports, and seaports (Indonesian Ministry of National Development Planning, 2015)). In real implementation in supporting the tourism sector, the government has also imposed a Visit Visa Free (BVK) policy for 169 countries, even the government has also increased the Ministry of Tourism's budget for the fiscal year 2015-2019 (Kemenparekraf RI, n.d.).

Various infrastructure developments are carried out in an effort to support the tourism sector. Considering the current development of modern tourism is closely related to development. These dynamics have transformed the tourism sector into a key driver of socioeconomic progress through job creation, increased business, export revenue and infrastructure development (UNWTO, 2018). Tourism is a driving factor for economic and national development and is a major source of income from abroad through foreign tourist arrivals for a large number of developing countries because its various effects also affect other industries (Dupeyras & Maccallum, 2013). The development of modern tourism today is very closely related to development. This dynamic has transformed the tourism sector into a major driver of socioeconomic progress through job creation, business growth, export earnings, and infrastructure development (Marlina & Herawan, 2020). Tourism is a driving factor for economic and national development and is a major source of foreign income for many developing countries because of its various effects on other industries.

Based on the analysis of potential supply and demand on the aspects of nature-based tourism above, national parks in Indonesia require a tourism competitiveness model by utilizing the potential and characteristics of tourism competitiveness in its geographical area. Research related to tourism competitiveness has been widely studied in various countries and some even focus on research on the competitiveness of national park tourism.

Research related to the competitiveness of national park tourism parks has been carried out by several researchers. Like the research of Xiang (2011), this study evaluates the competitiveness of tourism competitiveness between two national parks that are close together and are in the same geographic area; namely the tourism competitiveness competition between Zhangjiajie National Park and Tianmenshan National Park. The results of the study indicate that there is a tourism competitiveness competition between the two national parks, namely tourism competitiveness competition on factors: (1) tourism resources and tourism services, (2) resource location, (3) tourism infrastructure and information services, (4) entertainment, (5) shopping, (6) smooth traffic, (7) communication networks, and (8) advocacy efforts in promoting environmental conservation.

Blanco-Cerradelo et al. (2018), designed a model for the competitiveness of protected area destinations in Spain (National Parks, Natural Parks and Biosphere Reserves). The results of the study confirm that the competitiveness of protected area tourism consists of five dimensions that are significantly positively related, namely: (1) the ability to attract visitors, (2) the social welfare of the local community and tourist sustainability related to (3) nature conservation, (4) the creation of a sense of togetherness, and (5) the economic welfare of the local community. This study also confirms that in protected areas, maximizing tourism attractiveness requires community welfare and cohesion as well as environmental sustainability.

The research of Ma et al. (2021) found the design of a national park competitiveness model that focuses on aspects of climate resources. The monitored climate utilizes time series statistical data in 11 (eleven) national parks in the United States. Analysis of times series data utilizes the Augmented Dickey-Fuller (ADF) method. The national park competitiveness

model found, shows that the climate index in the national park campsite is predicted to affect the number of national park tourist arrivals.

The research of Dos Anjos & Da Rosa (2021) evaluates the tourism competitiveness factor of National Park tourist destinations in Brazil in terms of demand. Data collected from visitors was analyzed using the structural equation modelling method. The analysis involved three steps: descriptive demographic analysis, exploratory factor analysis (EFA), confirmation factor analysis (CFA), and multiple group confirmatory factor analysis (MGCFA). The results confirm; the main competitive factors in Brazil's national parks, namely cultural attractiveness, infrastructure and support, destination management, sustainability and community quality of life are factors of tourism competitiveness.

The important point of this study is how to build a model for the competitiveness of tourism to the number of foreign tourist arrivals in national parks, especially in districts and cities that have national parks in Indonesia so that it has a value of sustainability and sustainability in the utility zone of national parks in Indonesia. Thus, this study has the main objectives; build a model tourism competitiveness management model in regencies and cities that have territorial use zones of national parks and their correlation with tourist arrivals so that they have an impact on tourism revenue and conservation in utility zones of national parks. The results of this study are expected to be used as considerations for stakeholders, especially the government in formulating policy innovation on aspects of hard infrastructure and soft infrastructure in an effort to support ecotourism-based tourism performance in national park utilization zones in Indonesia.

II. MATERIAL AND METHODS

A. Data Types and Sources

This research was carried out since July 2019, consists of collection activity, measurement, and data management. The method of data collection is carried out by the literature study method. Type and data source collected in this study, including secondary data. According to Yuan (Yuan, 2017), secondary data is data collected by other people with their own purposes and has a categorization or classification according to their needs. The method of data collection is by a literature study. According to Beins (2017) library technique is a way to collect data of various materials contained in the library, such as newspapers, books, magazines, manuscripts, documents and so on that are relevant to research. This data collection method is using statistical data and reports published by state institutions and related institutions.

This study uses the entire population, so it does not use samples. Thus, this analysis uses census techniques involving all population elements (Malhotra & Dash, 2016). The locus of this study is 54 district and city areas national parks in Indonesia. Meanwhile, the study focuses on performance tourism competitiveness in regencies/cities that have utilization zones for national parks, foreign tourist arrivals in national parks, and tourism revenue of national parks, which are the basic data used to build a dynamic system model for managing tourism competitiveness.

A series of measurement indicators is needed to create an adequate framework for evaluating tourism's competitiveness in a region. The tourism competitiveness has been measured based on measurement methods that refer to the Travel & Tourism Competitiveness Index (Calderwood & Soshkin, 2019), Competitiveness Monitor (Romão & Nijkamp, 2019) and Indicators for Measuring Competitiveness in Tourism (Gómez-Vega and Picazo-Tadeo 2019). These various measurement methods used as a measure of tourism competitiveness consisting of an index of travel competitiveness based on 20 factors (Table 1). All tourism competitiveness indicators are converted on a scale of 1 to 7, the higher the competitiveness score, the better the tourism performance and the competitiveness performance (Calderwood & Soshkin, 2019).

Table 1. Measure of the competitiveness tourism of regencies and cities that have national parks in Indonesia

No.	Factors	Indicators	Relevant literatures
1.	Security	Crime rate	Calderwood & Soshkin, 2019
2.	Health & hygiene	Physician density, access to improved drinking water, access to improved sanitation, malaria incident	Calderwood & Soshkin, 2019
3.	Overnights in all types of accommodation	Percentage growth or decline in stays in all accommodation types	Gómez-Vega & J Picazo-Tadeo, 2019
4.	Labour productivity in tourism services	Percentage growth or decline in labour productivity	Gómez-Vega & J Picazo-Tadeo, 2019
5.	Human resources	Primary education enrolment rate, secondary education enrolment rate, female labour force participation, collect enrolment rate, human development index	Calderwood & Soshkin, 2019;
6.	Purchasing power parity	Purchasing Power Parity (PPP)	Gómez-Vega & J Picazo-Tadeo, 2019
7.	Price competitiveness	Hotel price index	Calderwood & Soshkin, 2019
8.	Information communication & technology	Mobile network coverage, individuals using the internet, quality of electricity supply	Calderwood & Soshkin, 2019
9.	The travel and tourism policy and enabling conditions	Travel & tourism expenditure	Calderwood & Soshkin, 2019
10.	Air transport infrastructure	Aircraft departures	Calderwood & Soshkin, 2019; Buhalis & Amaranggana, 2015
11.	Ground infrastructure	Road density, quality of road	Calderwood & Soshkin, 2019
12.	Tourist service infrastructure	Number of hotel rooms	Calderwood & Soshkin, 2019;
13.	Openness Indicator	Ratio of the number of foreign tourists staying and total hotel guests	Romão & Nijkamp, 2019
14.	Environmental sustainability	Population density index, forest cover change	Romão & Nijkamp, 2019; Calderwood & Soshkin, 2019
15.	Cultural resources	Oral and intangible cultural heritage expressions, number of world heritage cultural sites	Calderwood & Soshkin, 2019; Gómez-Vega & J Picazo-Tadeo, 2019
16.	Social development	Average length of stay of tourists in the destination area	Romão & Nijkamp, 2019
17.	Diversity of flora species	Attractiveness of flora species assets	WTO, 2004; Eddyono, 2020
18.	Diversity of fauna species	Attractiveness of flora species assets	WTO, 2004; Eddyono, 2020
19.	Scarcity of natural phenomena	Attractiveness of flora species assets	WTO, 2004; Eddyono, 2020
20.	Accessibility to the site	Travel time to the site	WTO, 2004; Eddyono, 2020

B. Development of Dynamic Models of Tourism Competitiveness Management

Modelling of tourism competitiveness in this study utilizes a dynamic system. The dynamic system is a method of studying dynamics in complex systems (Forrester, 2007). This method focuses on the integration and modelling of feedback in the system. A dynamic model of a system is usually given in the form of a flow chart, consisting of levels, rates between them, feedback loops and additional variables, which are then translated into a system of differential equations.

Several tourism studies have focused on using the dynamic system to simulate tourist demand (Ran, 2015); (Xu & Dai, 2012) and simulate managing cultural tourism (Liu & Chen, 2015). Researchers have not found research on the use of system dynamics for modelling the competitiveness of national park tourism. The purpose of this study's dynamic system is to simulate the competitiveness model of national park tourism in Indonesia.

The development of a dynamics model for managing competitiveness tourism in this study utilizes Powersim software. The model to be built includes the existing model and the scenario model. The model is built based on the conception of the model which includes, the macro conception and the micro conception. The macro conception is the general conception of the built model. The micro concept is a more detailed conception of the interrelationships between the structures in the model. After building the macro concept, the next step is to make a causal loop diagram which is a picture of the reciprocal relationship or causal relationship of the existing structures. The next step is to make a flow chart depicting of the reciprocal relationships of existing structures in the form of stock (level), flow, auxiliary, constant and information link (Forrester, 2007). After making a flow chart, the next step is to build a simulation model (existing model and scenario model) and the last step is to validate which consists of two activities, namely structural validation (based on theory) and model validation..

1. Macro concept

The macro conception of the tourism competitiveness model (Figure 1) in areas that have national parks is based on the relationship between the performance of tourist competitiveness, tourist arrivals, tourist

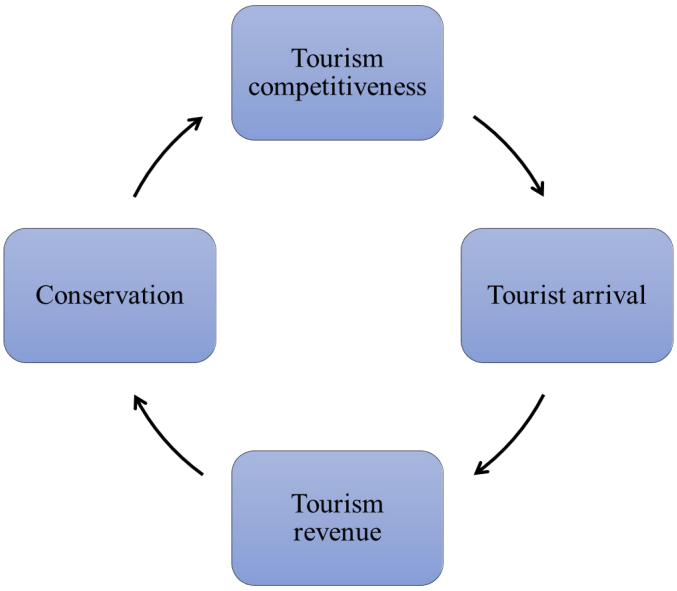


Figure 1. Macro concept of tourism competitiveness model

revenue, and conservation. The growth of tourist competitiveness performance, which is getting better every year in an area, will be correlated to tourist arrivals (Geiger & Goh, 2012; Mieczkowski, Z. & Chadee, 1987; Gunadhi & Boey, 1986; Patsouratis et al. (2005); Albalate & Bel, 2010; Eddyono, 2020; Taylor & Ortiz, 2009; Van der Merwe & Saayman, 2008) in national parks and will have an impact on tourist revenue (Dwyer et al., 2016; Murzyn-Kupisz, 2013) in the national park utilization zone. The availability of conservation funds from tourist revenue will correlate with conservation management in the national park. Meanwhile, conservation performance in the national park utilization zone will also correlate with tourist competitiveness because conservation sustainability is the main attraction for tourists in the ecotourism market niche (WTO, 2004).

2. Micro concept

The micro conception of the tourism competitiveness management model in the district/city area that has a national park, refers to a more detailed macro conception of the relationship between the structures in it. To be able to access the national park site, tourists need various factors of competitiveness of tourist destinations which are the facilitating elements that can make it easier for tourists to access and visit the national park utilization zone, as well as meet the various needs of tourists during tourist activities (Eddyono et al., 2021a). In fact, traveling to national park utilization zones and exploring conservation areas is not always easy. Most of these areas are not easily accessible because natural areas tend to be in the interior. The national park utilization zones spread throughout Indonesia are generally located in remote areas (KLHK, 2017), thus requiring various tourism supplies.

The notion of supply in tourism includes the entire range and services produced by the tourism industry group of companies as suppliers, which are offered to tourists who come directly or buy through travel agents or travel agencies as intermediaries. Included in the notion of supply are all forms of tourist attractions, accessibilities, and all forms of facilities and services available in a tourist destination area that can satisfy the needs and desires of tourists during their travels.

The supply component in the tourism industry can be sourced from natural, man-made amenities which are an attraction for tourists. The natural amenities include large forests, flora and fauna, including strange, unique and rare plants and stars. The supply components also come from "man made supply" includes, among others, historical, cultural, and religious infrastructure; means of access and transport facilities, superstructure, and people's way of life (Wahab & Cooper, 2005).

In order to provide quality, innovative tourism services that can attract potential tourists; tourism supply is stated in a competitiveness format with a standard measurement method. The standard for measuring tourism competitiveness in this study uses the Travel & Tourism Competitiveness Index (Calderwood & Soshkin, 2019), Competitiveness Monitor (Romão & Nijkamp, 2019) and Indicators for Measuring Competitiveness in Tourism (Gómez-Vega & J Picazo-Tadeo, 2019) methods. In this study, the measurement of competitiveness is stated in 20 factors of competitiveness (Table 1).

Several studies have shown that many competitiveness factors can affect tourist arrivals, including transportation accessibility, weather, economic environment, and duration of travel (Albalate & Bel, 2010); (Cho, 2003); (Taylor & Ortiz, 2009); (Van der Merwe & Saayman, 2008); (Eddyono et al., 2021a). As shown by (Cizmar & Weber, 2000), destination choice remains one of the first and most important decisions for tourists; decisions are also influenced by external factors, such as the country's image, accessibility, attractiveness, security, and others. Competitiveness tourism which is of particular concern, also focuses on creativity, tourist safety, demand conditions, historical and cultural heritage resources, organizers, and cleanliness (Pansiri, 2014).

Thus, a hypothesis can be formulated that there is a correlation between tourist competitiveness and tourist arrivals at national parks if the region has a relatively good tourism competitiveness performance.

National park tourist revenue comes from using natural tourism environmental services through entrance tickets and fees for natural tourism activities (KLHK, 2014). So the next hypothesis is a correlation between tourist arrivals and tourist revenue in the national park. Tourist revenue will be used to finance conservation to bring up the concept of mutual benefit between sustainably managed tourism and nature conservation. Conservation aims to conserve resources, especially biodiversity, and maintain the sustainable use of resources, which brings ecological experiences to tourists, preserves the ecological environment and obtains economic benefits (Fajnylber, 1988). This is in line with the opinion stated by Heal (1998), that the concept of sustainability contains two dimensions; the time dimension and the interaction dimension between the economic system the natural resource system, and the environment. Thus, ecotourism activities in national parks have significant potential to contribute to biodiversity conservation because biodiversity is an important component of the natural environment enjoyed by tourists (WTO, 2004). Thus, the next hypothesis is that there is a correlation between tourist revenue and conservation.

Based on the description of the relationship between the structures that detail the correlation between the structure of tourism competitiveness, tourist arrivals, tourism revenue, and conservation, it is possible to build a micro-conception and flow chart of the tourist competitiveness management model. The concept of a micro model of tourist competitiveness management in the utilization zone of this national park is described in Appendix 1.

C. Make Causal Loop Diagrams And Flow Diagrams

Making a diagram (causal loop) is a picture of the reciprocal relationship or cause and effect (causal relationship) of the existing structures. Meanwhile, making a flow chart (Appendix 2) is a depiction of the reciprocal relationships of existing structures in the form of stock (level), flow, auxiliary, constant and information link (Forrester, 2007).

D. Model Simulation

Simulation is a method used to study the dynamics of a phenomenon. Simulation provides an overview of the behavior of the phenomenon (system) in its development in line with increasing time (Sterman, 2002). This study, conducted simulations on each competitiveness indicator by leveraging causal lops (Appendix 1). The simulation aims to analyze whether there is a correlation between increasing tourism visit growth, tourism revenue, and increasing conservation activities if the competitiveness of tourism performance indicators are optimized.

E. Structure Validation

Structural validation is a white-box validation, where cross-checks are carried out on the models generated and reviewed by experts in related fields (Sushil, 1993), in this case in the field of competitiveness tourism. To validates the structure, validity test is carried out on the extented to which the similarity of model structure is close to the real structure, which is indicated by the extent to which the interaction of the model factors that resembles the interaction of real events. Verification of the structure is described in the following factors and in micro-conceptions (Appendix 1).

F. Factors of Tourism Competitiveness

Destination competitiveness is related to the destination's ability to provide products or services that outperform other destinations in

terms of an important tourism experience for tourists (Boes et al., 2016). Competitiveness is widely regarded as an important factor in creating national prosperity (Bhawsar & Chattopadhyay, 2015; Dwyer et al., 2016) because it increases living standards and real incomes by offering goods and services with several comparative advantages (Nguyen, 2019).

Competitiveness involves productivity, efficiency, and profitability achieve improved living standards and improve social welfare (Huggins, 2000). Competitiveness consists of national government policies and citizens' attitudes to investment in infrastructure and manufacturing capabilities (Barnes et al., 2016). The competitiveness of tourist destinations is about the ability of destinations to optimize their attractiveness to residents and non-residents. It is also to provide quality, innovative tourism services that attract consumers to gain market share in the country and global markets, while ensuring that the available resources support tourism, which is used efficiently and sustainably (Marlina et al., 2020).

Destination competitiveness is a measure of factors measured objectively such as the number of visitors, market share, tourist expenditure, employment and added value by the tourism industry, and factors measured subjectively such as cultural richness and heritage, the quality of tourist experiences, etc. (Cucculelli and Goffi, 2016). Bahar and Kozak (2017) believes the most competitive destination, in the long run, is the destination that creates prosperity for the local community.

The choice of a tourist destination remains one of the first and most important decisions made by tourists; and this decision, in turn, is largely dependent on several external factors, such as the country's image, accessibility, attractiveness, safety, etc. (Leung et al., 2017). On the other hand, destination choices also determine competition between companies such as airlines, tour operators, hotels and other tourism services (Nguyen, 2019).

Various researchers have established destination competitiveness as stated by Nguyen (2019); destination competitiveness is the ability of the destination to provide a high standard of living for the people around the destination. According to Pulido-Fernández et al. (2015) destinations can create and integrate value-added products that maintain their resources and still maintain market position relative to competitors.

The competitiveness of true destinations must be sustainable not only economically but socially, culturally, and politically (Nguyen, 2019). He explained the concept of purpose and efforts to define the factors that make destinations competitive by developing conceptual models. They developed the concept that competitive destinations must provide a high standard of living for their residents. In other words, the competitiveness of a destination is directly dependent on the level of economic, social and environmental conditions offered to the population (Nguyen, 2019). Miličević et al. (2017) stated that the ultimate goal of competitiveness is to maintain and increase people's real income (Miličević et al., 2017). In this connection, destination competitiveness is not a goal but a way to achieve goals that improve the standard of living of people in a destination under free and fair market conditions. Many researchers emphasize various determinants of tourism competitiveness, the determinants of tourism competitiveness include politics and technology-based competitiveness, infrastructure, available resources, laws, and regulations are important in achieving competitive advantage (Hanafiah et al., 2015).

The concept of competitiveness of tourist destinations as stated by; where the tourism business is not single but includes a three-dimensional concept namely markets, products, and technology to satisfy people's wants and needs. Beyond the corporate level, the concept of destination competitiveness is based on

the idea of a group of tourist attractions, infrastructure, equipment, services, and organizations that together determine what a destination has to offer to its visitors. In this context, competitiveness is not built between countries but between clusters and tourism businesses (Pike & Page, 2014).

G. Factor of Tourism Competitiveness and Tourist Arrival

The most common factor used in measuring international tourism demand is the tourist arrival from countries and regions of origin to a specific destination, followed by tourist expenditure and stay in registered accommodation in the destinations (Peng et al., 2015). Numerous studies have shown that many factors can influence tourist arrivals, including transportation accessibility, weather, economic environment, and trip duration (Albalate & Bel, 2010); (Cho, 2003); (Taylor & Ortiz, 2009); (Van der Merwe & Saayman, 2008).

Tourist arrivals usually function as dependent factors in tourism demand studies and factors that influence tourist arrivals are often considered explanatory factors (Geiger & Goh, 2012). Other studies also say almost the same thing; in the tourism demand literature, the dependent factor is the number of tourist arrivals (Mieczkowski & Chadee, 1987; Gunadhi & Boey, 1986; Patsouratis et al., 2005), per capita vacation visits (Martin & Witt, 1988) or tourist expenses (González & Moral, 1995; Tuohino & Konu, 2014; Papatheodorou, 1999; Thompson & Thompson, 2010).

H. The Factor of Tourist Arrival and Revenue Tourism

A destination can be considered competitive if it can attract and satisfy potential tourists. Not only does the competitiveness of a destination directly affect tourism revenue in terms of the number of visitors and expenses, but it also indirectly influences tourism-related businesses, such as hotels and retail industries in that destination, to some extent. For example, increasing the value of cultural heritage tourism increases the number of cultural tourists, it increases tourism revenue and the ratio of protective investment from tax revenues, thereby increasing the quantum of tourism capital with other capital investments (Murzyn-Kupisz, 2013).

Based on statutory provisions in force in the Republic of Indonesia; non-tax revenue as revenue tourism in the national park. Non-tax revenue is all central government revenue not generated from the tax. Non-tax state revenue groups, among others, are sourced from revenues from using natural resources. Although, in principle, all non-tax revenue is paid directly into the state treasury, some non-tax state revenue funds can be used for the activities of the relevant agencies. The amount of non-tax state revenue funds is determined by the Minister of Finance and government agencies can use these funds if they have received approval from the Minister of Finance (Indonesia, 2018).

I. The Factor of Revenue Tourism and Conservation

Biodiversity is the main asset of nature-based tourism. Tourism activities have significant potential to contribute to biodiversity conservation (Catibog-Sinha, 2008; De Boer et al., 2007; De Boer et al., 2007; Weaver, 2001), because biodiversity is an important component of the natural environment enjoyed by tourists in the ecotourism niche market. Tourism can be a threat to conservation, but in many cases, tourism provides benefits for conservation and economic incentives for the tourism industry, especially local communities, and the protection of biodiversity (WTO, 2004).

J. Output Validation

The simulation model that was built must be compatible, representative and logical, so that it can describe the real world. The simulation model is also a scientific model that obeys the facts because it must be validated using the recommended statistical methods (Tasrif, 2006). Validation of the output in this study

using the methods commonly used, namely Theil index and the method of measuring the error rate of RMSPE (root mean square percent error). The model is declared valid, so the error must be small and sourced from non-systemic errors (Sterman, 2002), therefore to measure the level of model accuracy, this study uses the MAPE (Mean Absolute Percentage Error) prediction accuracy measurement or the average percentage error absolute (Yamin & Shahidehpour, 2004).

III. RESULT AND DISCUSSION

Modelling simulations are carried out to obtain an overview of changes in a dynamic time scale. The results of the analysis of tourism competitiveness performance data were obtained within a four years, which were then carried out with a dynamic system simulation to obtain an overview of changes in the number of tourism visits, and conservation within that period. The dynamic simulation carried out is a simulation of the existing model (2014–2018) (Figure 2).

The simulation results of the existing model show that tourism competitiveness performance has grown linearly with time, where as within four years (2014–2018), it appears that tourism competitiveness performance has consistently increased from year to year. On the other hand, there is a picture of changes in tourism visits to national parks from 2014 to 2018 and the conservation impact caused by tourism revenue and tourism visits.

1. Test The Validity of the Output/ Performance

Validation of output/performance using data on international tourism visits at national parks for four years (Figure 3). Graphically, the model is quite good at describing the real world (Sterman, 1984). Based on the results of statistical theil test analysis, it is obtained that the correlation coefficient value (r = 0.94) and coefficient of determination (R2 = 0.89) are obtained. This value indicates that the model can explain the real condition (real world) by 89.9% or only about 10.10%, which the model cannot explain. Thus the model is said to be very good at explaining or describing the real world. The model accuracy could also be seen from the error measurement value which is depicted from the relatively small bias value (UM = 0.09). The small value of variance inequality (US = 0.77) and the covariance inequality value (UC = 0.13), which is relatively high or close to 1, indicates the systematic error of forecasting (estimation) is relatively low, then the model is relatively stable and valid (Sterman, 1984).

In addition to the Theil index test, a simple statistical test using MAPE (Mean Absolute Percentage Error) can also be used to analyse the accuracy and level of model validity. The MAPE value of 0.14% generated through evaluation (validation) as shown in Table 2 shows the ability of the simulation model as shown in the MAPE criteria to be high. Thus, the simulation model developed is considered reliable and good enough to be used as a simulation model and has high predictive accuracy (Chang et al., 2007).

2. Scenario Simulation Model for Improving The Performance of Competitiveness Tourism

Simulation scenario modeling is a modelling carried out to analyze changes in performance based on the determinant attributes. The simulation scenario model in this study was carried out using the model's controlling factors; tourism competitiveness factors. Scenarios carried out; intervene to increase the performance of competitiveness index of tourism by 1 point in an effort to improve the performance growth of competitiveness tourism so that it has an impact on the performance of tourism revenue and conservation. After the scenario simulation, the performance growth of foreign tourism visits is 2.14% per year. Whereas before the simulation scenario, the average annual growth rate of tourist arrivals was 2.11% per year.

The model simulation results, empirically show that the model built is quite good and

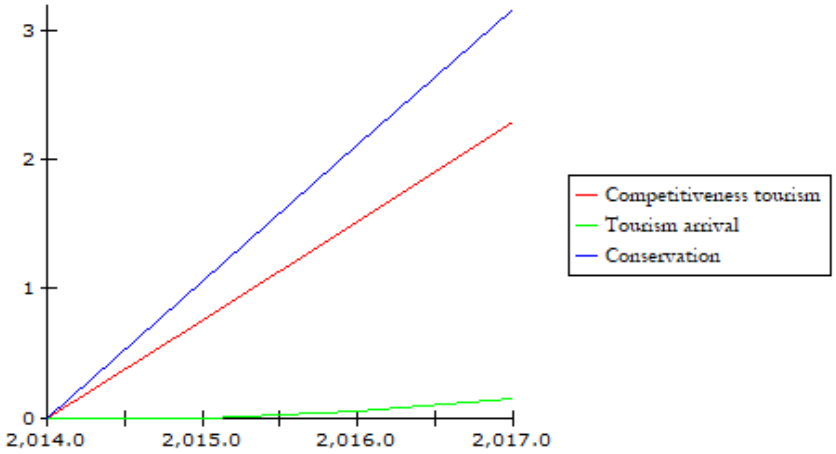


Figure 2. Simulation graphic of competitiveness tourism (2014 - 2018)

even critical in explaining or describing real conditions. Thus the simulation model built can describe the performance of tourism competitiveness in regencies and cities that have national park utilization zones is able to correlate with foreign tourist arrivals and can have an impact on revenue and conservation of national parks.

Concretely, this modelling shows that if the competitiveness performance is increased, it will be directly correlated to the increase in the growth of the number of foreign tourist arrivals. The growth of the number of foreign tourist arrivals will have a direct impact on tourism revenue growth. With the availability of funds originating from tourism revenue, there will be an increase in conservation activities in the national park. Conservation activities make the national park sustainable; the preservation of the national park is the main attraction for ecotourism tourists and this condition will have an impact on the performance of tourism competitiveness.

Adopting the concept of Mosher (1965), the conditions in tourism development can be grouped into absolute requirements and facilitating conditions. Both conditions must be met in tourism development. If the implementer only pays attention to the absolute requirements, tourism development activities can be stopped, there are only tourism activities run statically. A national park utilization zone in this study is an absolute requirement in tourism development and the facilitating element is competitiveness tourism. Facilitator requirements are needed so that national parks can be easily accessed by tourists; moreover, national parks tend to be located in remote areas, thus requiring various facilities, infrastructure and various infrastructures so that tourists, especially foreign tourists, can access the national park easily and comfortably. Optimal competitiveness of tourist destinations is a facilitating element that can make it easier for tourists to access and visit the national park utilization zone and meet the various needs of tourists during tourism activities (Eddyono et al., 2021b).

The importance of developing the facilitating element, namely tourism competitiveness, can be proven through a dynamic management model showing a correlation between competitive tourism, revenue tourism, and conservation. If the competitiveness performance is improved, it will be directly correlated to foreign tourist arrivals and directly impact tourist revenue and national park conservation. Directly to competitiveness, and so on to form a dynamic system circle. This dynamic system is a process of sustainable tourism development and development systems for districts with national parks in Indonesia. As the results of (Puri et al., 2019) research, biodiversity conservation

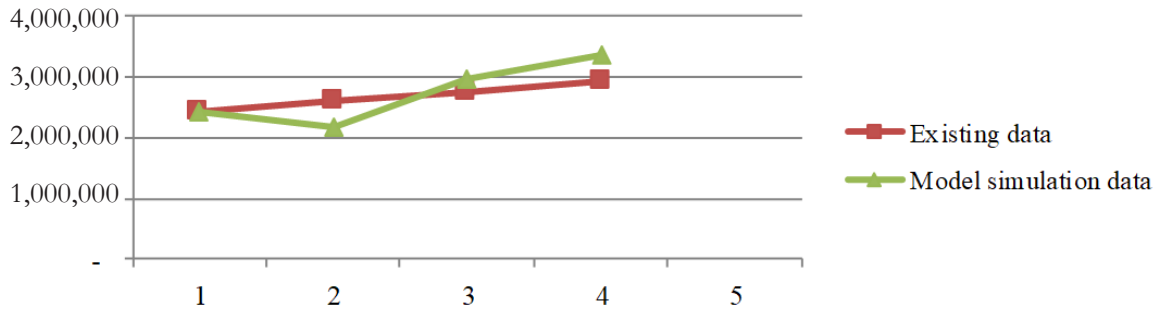


Figure 3. Accuracy of competitiveness tourism model

Table 2. Validation of performance of competitiveness tourism

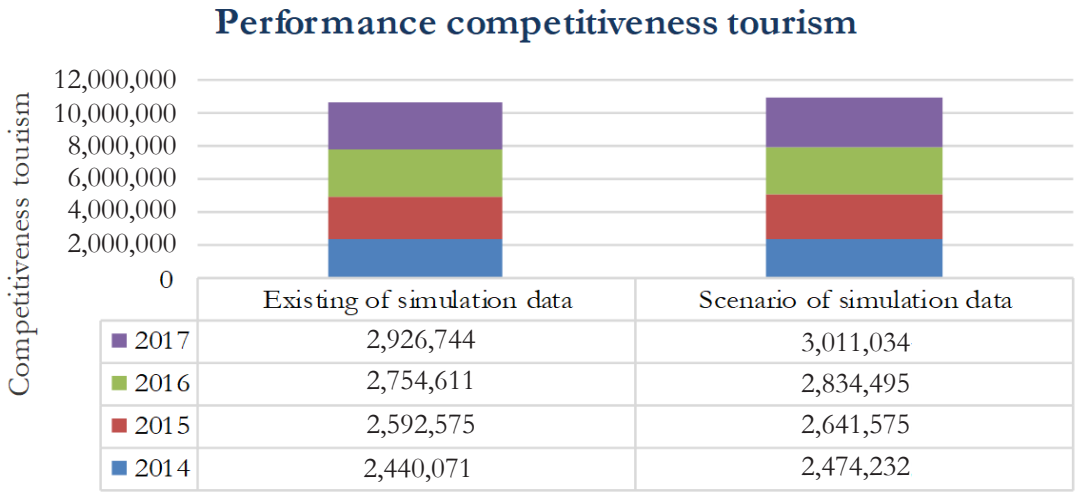
Year	Existing tourist arrival	Model of tourist arrival	Diff MAE	MAPE
2014	2,440,071	2,440,071	-	-
2015	2,168,480	2,592,575	(424,095)	(0.20)
2016	2,955,961	2,754,611	201,350	0.07
2017	3,359,617	2,926,774	432,843	0.13
			210,098	0.14%

and local socio-economic development are the main motivations for ecotourism tourists on the other hand, ecotourism is often seen as effective for promoting conservation of endangered species and habitats in developing countries (Bookbinder et al., 1998).

Efforts to improve competitiveness not only affect tourist arrivals and income caused by tourism activities. But more than that, tourism acts as a driving factor for economic and national development, it is a major source of foreign income for many developing countries due to its various effects on other industries. Thus, various researchers seek to find solutions to improve tourism competitiveness performance. Such as Pansiri's research result in 2014 informed Botswana to be able to compete globally. If improvements are made adjusted to the expectations of international tourists, it includes improving tourism competitiveness management that focuses on created resources, security, demand conditions, historical & cultural heritage resources, organized visits, and hygiene (Pansiri, 2014).

Krstic et al. (2016) research aimed to examine the effect of travel and tourism competitiveness (measured by the Travel & Tourism Competitiveness) on the national economic competitiveness of Sub-Saharan African countries (measured by the Global Competitiveness Index). Research identified important factors to increase tourist competitiveness in Sub-Saharan African countries.

According to the United Nations World Tourism Organization, tourism in many developing countries such as Indonesia it is the most viable and sustainable choice for economic development (UNWTO, 2015). It is, therefore, very important for tourist destinations of these markets to develop and strengthen competitive positions in increasingly competitive global markets. Therefore a partial analysis of destination competitiveness throughout the world is still relevant today. More specifically, the destination is destination to improve its competitiveness must be assisted with the principle of sustainability. As stated by Jibao



	Existing of simulation data	Scenario of simulation data
2017	2,926,744	3,011,034
2016	2,754,611	2,834,495
2015	2,592,575	2,641,575
2014	2,440,071	2,474,232

Figure 4. Accuracy of competitiveness tourism model

and Prichard (Jibao and Prichard, 2015), to be competitive, the development of destinations for tourism must be economically, ecologically, socially, culturally and politically sustainable.

It should be noted that the opinion expressed by Pulido-Fernández et al., 2015, the competitiveness of tourism destinations hasve been identified as the ability of destinations to create and integrate value-added products to maintain their resources, while maintaining market position relative to competitors, to pay great attention to the factors that influence tourist destination competitiveness. Specifically, Leung et al. (2017) argues strategies to improve the competitiveness of tourist destination could affect the choice of tourist destination and have an impact on the number of visitors. Therefore, the competitiveness of tourism destinations is closely related to the strategies used by managers of tourism destinations to foster such competitiveness. However, the OECD Tourism Committee also regulates destination competitiveness as the ability to increase the attractiveness of citizens and non-residents, to provide quality, innovative, and attractive tourism services for consumers and to gain market access in domestic and global markets, meanwhile ensure that available resources support being used and are efficiently maintained.

Pike and Page (2014) believed that government efforts should be focused on two areas: the strategic planning of the country's tourism business, which is a guide to the development of the public and private sectors. The involvement of parties involved in this business to buildi a competitive environment, which must be the foundation of tourism policy.

IV. CONCLUSION

Regencies and cities that have territorial zones for national park tourism tend to have optimal tourism competitiveness to make it easier for tourists to access and visit national park utilization zones, as well as meet the various needs of tourists during tourist activities. For this reason, policy innovations from tourism stakeholders are needed in an effort to optimize the performance of tourism competitiveness in the region. Optimizing all tourism competitiveness factors in regencies and cities that have national parks is a necessity because tourism competitiveness tends to contribute to the acceleration of growth in the number of foreign tourist arrivals and has an impact on tourism revenue performance and the preservation of national park utilization zones.

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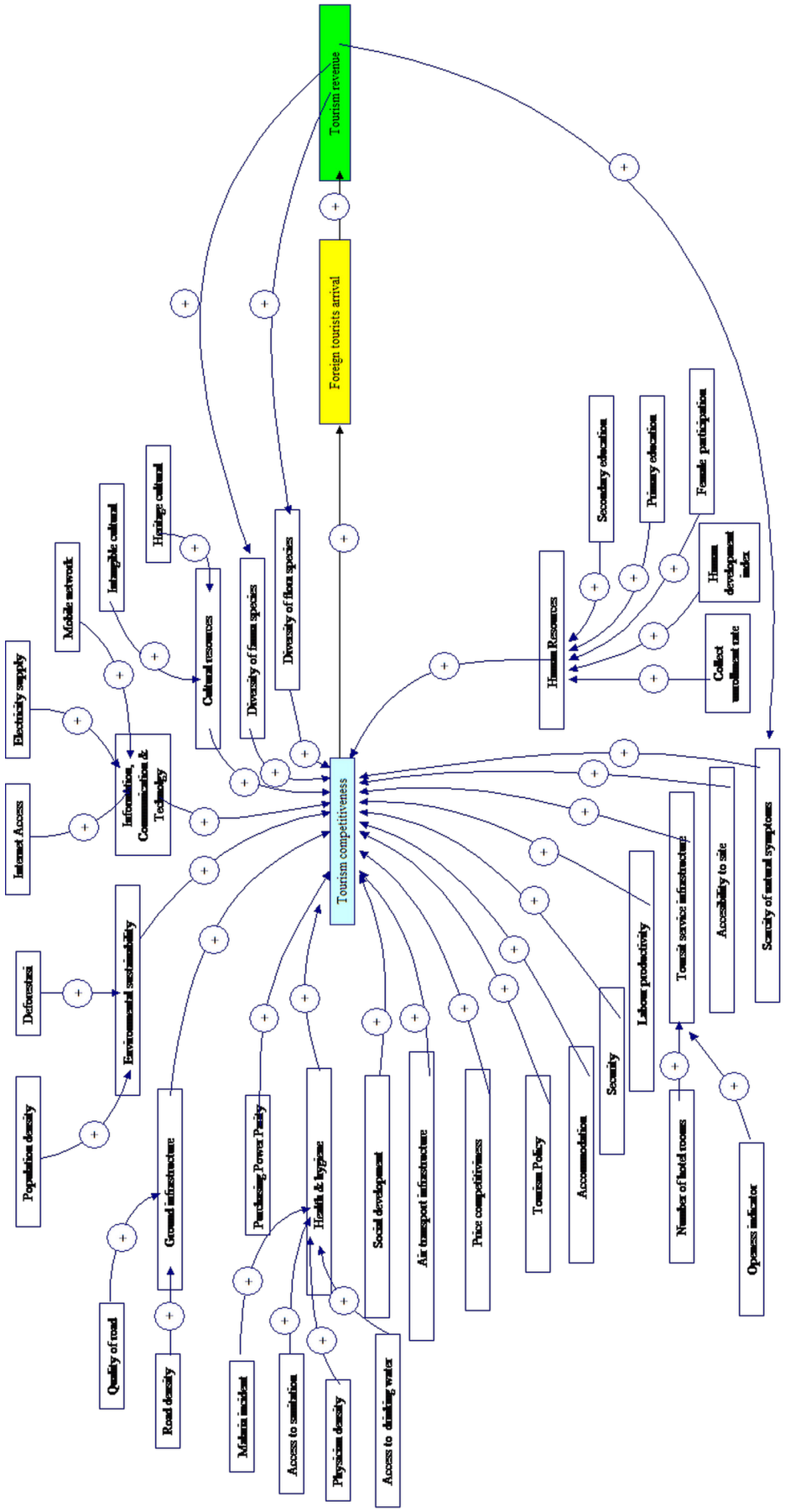
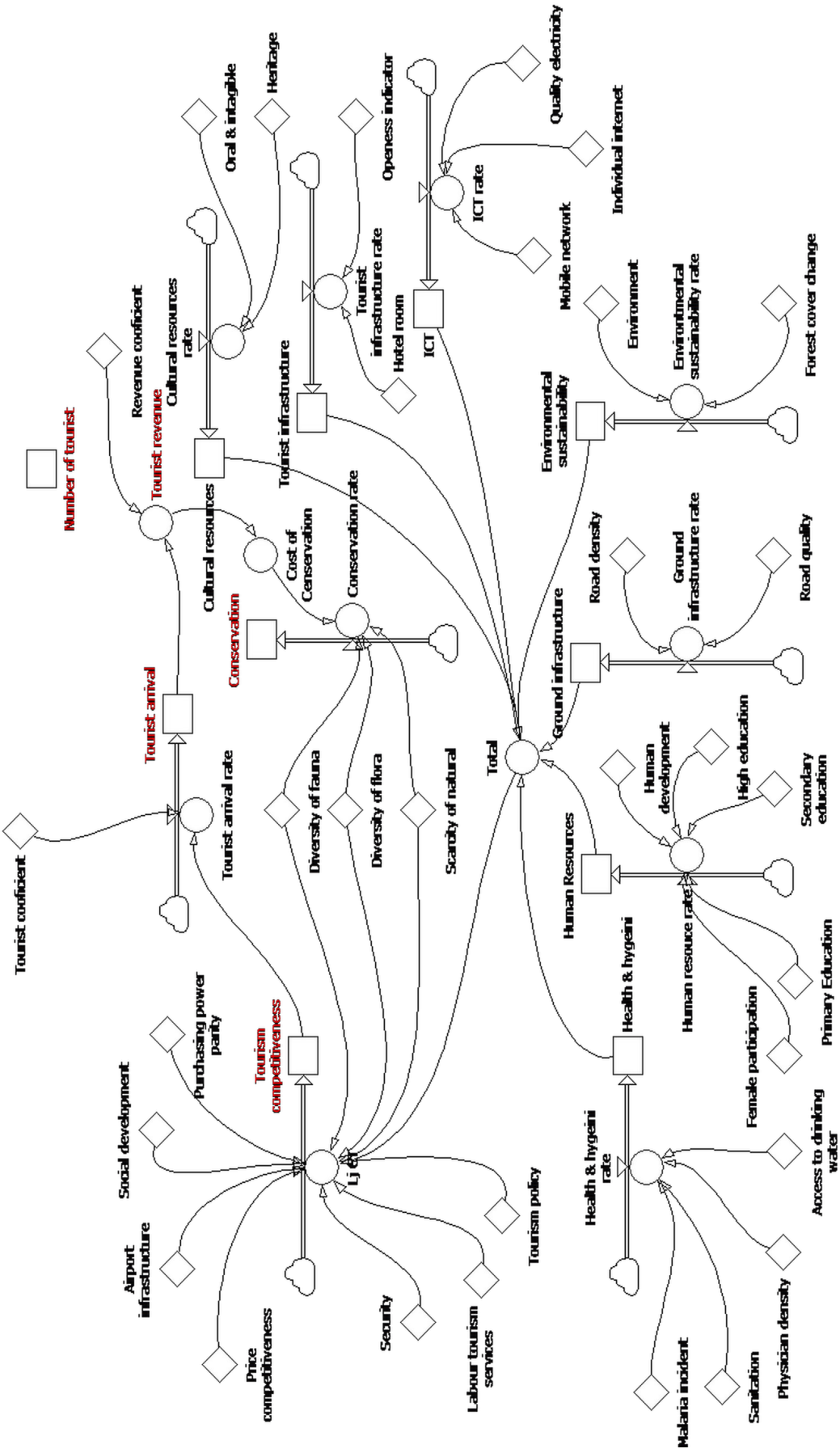


Apendix 1. Micro concept of tourism competitiveness model



Apendix 2. Flowchart of the competitiveness tourism management model

COMPATIBILITY OF SOME ADHESIVES WITH BATANG RATTAN (*Calamus zollingeri* Becc.) AS RAW MATERIAL OF RATTAN LAMINATED BOARD

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COMPATIBILITY OF SOME ADHESIVES WITH BATANG RATTAN (*Calamus zollingeri* Becc.) AS RAW MATERIAL OF RATTAN LAMINATED BOARD. Rattan in Indonesia is traditionally utilized for furniture, binding materials, household appliances, and handicraft items. Small diameter rattans are commonly used by craftsmen, while large diameter rattans are not optimally utilized. Large diameter rattan, however, has potential to be developed into rattan laminated board (RLB) by gluing rattan strips using appropriate adhesive. Nevertheless, the information of the suitable natural adhesive for RLB production is still limited. Laboratory scale of RLBs with the dimensions of 60 cm x 7.5 cm x 1.5 cm were manufactured using batang rattan strips (*Calamus zollingeri* Becc.). The strips were glued with six types of adhesives (4 types of natural adhesives and 2 types of commercial synthetic adhesives) and three glue spread rates of (100, 150, and 200 g/m^2) were used. The study objective was to determine the effect of rattan pre-treatments, adhesive types and glue spread rates on the bonding quality and formaldehyde emission of RLBs. The results showed that batang rattan can be processed into RLBs by using natural adhesives originating from wood bark extract (mangium, mahogany), merbau wood powder, as well as commercial synthetic adhesives such as isocyanate and polyurethane. The appropriate pre-treatment in producing RLBs for interior furniture was by applying oil heat treatment with kerosene solution (80 kerosene : 20 water) and glued with tannin adhesive of mangium bark extract with glue spread of 200 g/m^2. Similarly, rattan strips treated with heated oil (80 kerosene : 20 water) and glued with polyurethane adhesive (glue spread of 200 g/m^2) produced excellent RLBs for exterior furniture.

Keywords: *Calamus zollingeri* Becc., bonding strength, formaldehyde emission, rattan laminated board, natural adhesives

*KESESUAIAN BEBERAPA JENIS PEREKAT DENGAN ROTAN BATANG (*Calamus zollingeri *Becc.) SEBAGAI BAHAN BAKU PAPAN ROTAN LAMINASI. Di Indonesia, rotan secara tradisional digunakan untuk furnitur, tali pengikat, alat rumah tangga, dan barang kerajinan. Rotan yang digunakan oleh pengrajin, pada umumnya adalah rotan berdiameter kecil, sedangkan rotan berdiameter besar kurang digunakan secara optimal. Namun demikian, rotan diameter besar berpotensi untuk dikembangkan menjadi papan rotan laminasi dengan merekatkan bilah rotan menggunakan perekat yang sesuai. Akan tetapi, informasi kesesuain perekat alami untuk pembuatan papan rotan laminasi masih sangat terbatas. Papan rotan laminasi skala laboratorium dengan dimensi 60 cm x 7,5 cm x 1,5 cm dibuat dari bilah rotan batang (*Calamus zollingeri *Becc.). Bilah rotan direkat dengan menggunakan 6 macam perekat (4 macam perekat alami dan 2 macam perekat sintesis komersial) dan tiga macam berat labur (100, 150, dan 200 g/m^2). Tujuan penelitian ini adalah untuk mengetahui pengaruh pra-perlakuan, macam perekat, dan berat labur terhadap keteguhan rekat dan emisi formaldehida papan rotan laminasi. Hasil penelitian menunjukkan bahwa rotan batang dapat dibuat menjadi papan rotan laminasi dengan menggunakan perekat alami yang berasal dari ekstrak kulit kayu (mangium, mahoni), ekstrak serbuk gergajian kayu merbau, dan perekat sintetis komersial seperti isosianat dan poliuretan. Pra-perlakuan yang sesuai untuk membuat papan rotan laminasi sebagai bahan furnitur interior adalah perendaman rotan dalam larutan minyak tanah panas (80 minyak tanah : 20 air) dan direkat menggunakan perekat tanin dari ekstrak kulit kayu mangium dengan berat labur 200 g/m^2. Sementara itu, pra-perlakuan dengan perendaman rotan dalam larutan minyak tanah panas (80 minyak tanah : 20 air) dan direkat menggunakan perekat poliuretan (berat labur 200 g/m^2) menghasilkan papan rotan laminasi yang sangat bagus untuk mebel di luar ruangan.*

Kata kunci: Calamus zollingeri Becc., keteguhan rekat, emisi formaldehida, papan rotan laminasi, perekat alami

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I. INTRODUCTION

Rattan is a multipurpose monocotyledonous plant with a long, hard slender stem, commonly found in tropical rain forests (Akpenpuun, Adeniran, & Okanlawon, 2017). It is considered an important forest product after wood and bamboo. It is widely used as an excellent natural material for furniture, ropes, decorative items, housing, handicraft products, and also as an innovative bone implant material (Adefisan, 2011; Eichenseer et al., 2010; Olorunnisola & Adefisan, 2002). Rattan is one of the original biological natural resources from Indonesia which has very significant economic value for the country's income, because Indonesia supply 80% of all the world's rattan needs, with producing areas spread across various islands, especially in Kalimantan, Sulawesi and Sumatera. Data from the Ministry of Industry showed that in 2019 the value of national furniture exports reached US$1.69 billion (Rp. 23.66 trillion) (Ministry of Industry, 2019).

Rattan has elastic and flexible properties to be processed into several furniture products and has several advantages compared to wood such as light weight, strong, and cheap (Pujiati, 2017). Moreover, Ahmad et al. (2019) mentioned that rattan's great versatility, such as its durability, elasticity, light-weight, shiny and flexibility can be used in furniture industries, construction materials, household articles, tool handles, and lifting heavy items and bridge construction. Furthermore rattan as natural fibers can be used as an advanced polymer composite material for various applications (Sahoo et al., 2019), and the strength properties are related to cellulose and lignin content (Munshi et al., 2020). Rattan chemical composition consists of holocellulose (71-76%), cellulose (39-60%), lignin (18-48%), silica (0.54-8.0%), and starch (14-29%) (Rachman & Jasni, 2013). Rattan can also be used as cement-bonded rattan composites (Olorunnisola & Agrawal, 2015, 2018; Olorunnisola & Asimiyu, 2016).

Rattan utilization in Indonesia is traditionally for furniture, furniture frame from round rattan, binding materials for traditional house components, household appliances, and handicraft items. The raw materials used by craftsmen are commonly rattan with a small diameter of < 20 mm, while rattan with large diameter of >20 mm are not optimally utilized, resulting in an increasing amount of waste in the form of discarded rattan poles. Nevertheless rattan with large diameter can further developed into composite products in the form of Rattan Laminated Board (RLB) with the desired dimensions from rattan strips with the aid of appropriate adhesives. Studies on the manufacture of rattan laminated boards have been done by using water based polymer-isocyanate (WBPI) adhesive (Sulastiningsih, Trisatya, & Sukadaryati, 2019) and by using tannin-based adhesive (Pari, Abdurachman, & Santoso, 2019; Santoso & Pari, 2020). Studies on the pre-treatment of raw materials for the application of rattan laminate boards have not been widely carried out.

The round-shaped rattan has must be converted into strips and glued with a suitable adhesive to be fabricated as rattan laminated board (RLB). Constraints faced in the manufacturing of good quality rattan laminated board, among others is that there is not enough information regarding the type of natural adhesive suitable for the production of RLB. Therefore a research was carried out with the objective to determine the compatibility of six types of adhesives (4 types of natural adhesives (tannin-based adhesive) and 2 types of commercial synthetic adhesives with rattan batang strips as raw material for rattan laminated board. The evaluation was conducted by testing the bonding strength and formaldehyde emission of RLBs.

II. MATERIAL AND METHOD

A. Materials

The batang rattans (*Calamus zollingeri* Becc.) used in this study were 2 meters in length with diameters ranging from 27.91 to 34.53 mm with

an average of 29.47 mm, densities ranging from 0.49 to 0.58 g/cm^3 with an average of 0.55 g/cm^3 collected from Ampibabo Subdistrict of Prigi Moutong Regency (Central Sulawesi). Other materials used in this study were preservatives, tannin formaldehyde, tannins from bark extract and sawdust powder and commercial synthetic adhesives.

B. Methods

1. Chemical Component Analysis of Rattan Cane

The chemical components of rattan cane were measured using pyrolysis gas chromatography mass spectrometry (py-GCMS-QPXP-2010; Shimadzu). The analysis was carried out on a fused silica capillary column (HP-SMS column, 60 m by 0.25 mm with a film thickness of 0.25 μm; Agilent). About 1μg of rattan cane powder was inserted without any further preparation into the bore of the pyrolysis solids injector and than placed with the plunger on quartz wool in the quartz tube of the furnace pyrolyzer Pyrojector II (S.G.E., Melbourne, Australia) with a constant temperature of 400°C and a total run time of 50 minutes. The pressure of the helium carrier gas at the inlet to the furnace was 101 kPa. The pyrolyzer was connected to a 7890A gas chromatograph with series 5975C quadropole mass spectrometer operated in electron impact ionization mode.

2. Adhesive Preparation

The procedure for preparing the tannin resorcinol formaldehyde (TRF) adhesive made of tannin from mangium and mahogany bark extract refers to Santoso, Hadi and Malik (2012), and Lestari et al. (2015). A similar procedure was applied to the TRF adhesive made of merbau sawdust extract (Hendrik et al., 2019; Malik et al., 2016; Santoso et al., 2016a; Santoso et al., 2012). While the procedure of preparing tannin formaldehyde (TF) adhesive refers to Hendrik et al. (2018). A phenolic compound in tannin was activated by resorcinol addition. This study used two types of commercial adhesives were used, namely isocyanate and polyurethane as a comparison.

3. Preparation and Manufacture of Rattan Laminated Boards

Rattan canes were pre-treated by immersing in 2 different heated kerosene solutions (A1 solution in which 80 parts of kerosene was mixed with 20 parts of water and A2 solution in which 70 parts of kerosene was mixed with 30 part of water). Immersion was done for approximately 20 minutes. The purpose of pre-treatment was to remove dirt and resin from the surface of rattan skin, thus speeding up the drying process. Rattan canes were then sun-dried to about 15% moisture content and the cane's outer layer removed. The rattan cores were then manually fed into the rattan splitter machine to produce rattan strips with the dimension of 1.5 cm x 1.5 cm x 200 cm. The rattan strips were immersed in 7% w/v boron solution at room temperature for 2 hours and then sun-dried to about 12% moisture content. The rattan strips were sorted for straight and uniform dimensions and then were cross-cut to 60 cm in length and were used to produce rattan laminated boards.

Laboratory scale of rattan laminated boards (RLBs) with the dimension of 60 cm x 7.5 cm x 1.5 cm were manufactured by assembling 5 rattan strips, which were horizontally arranged side-by-side and glued with six types of adhesives (Mb (C1) = tannin resorcinol formaldehyde (TRF) adhesive made of tannin from merbau wood extract, Ac (C2) = TRF adhesive made of tannin from mangium bark extract, Mh (C3) = TRF adhesive made of tannin from mahogany bark extract, TF (C4) = tannin formaldehyde adhesive made of tannin from mangium bark extract without resorcinol, ICN (C5) = isocyanate adhesive, PU (C6) = polyurethane adhesive) and in combination with three various glue spreads of 100 g/m^2 (B1), 150 g/m^2 (B2), and 200 g/m^2 (B3). The rattan strips assemblies were cold pressed using wooden clamps for three hours. Four replications for each treatment combination were prepared. The RLBs produced were conditioned at room temperature for one week before testing.

4. Evaluation of Rattan Laminated Boards

The characteristics evaluation of each type of adhesive was carried out regarding JIS K 6833-1994 (JIS, 1994) and SNI (1998), consisting of organoleptic test, pH, viscosity, specific gravity, solid content, and free formaldehyde. The imported phenol resorcinol formaldehyde (PRF) was used as a comparison (Akzonobel, 2001). The properties of rattan laminated boards comprised of moisture content, density, formaldehyde emission and bonding strength were tested according with Japanese standards (JAS, 2003), and Indonesian standards (SNI, 2005). The bonding strength of RLB samples from the National Rattan Innovation Center (PIRNAS) was also tested as a comparison.

A. Data Analysis

A completely randomized design with factorial experiment was used in which the treatment factor A as the pre-treatment process (using oil and water mixture with a volume ratio of 80:20 and 70:30), various glue spread as the treatment factor B (100, 150 and 200 g/m^2 on the surface), and six types of adhesives as the treatment factor C (4 types of tannin adhesives, 2 types of synthetic adhesives). Four replications were prepared for each treatment combination.

III.RESULT AND DISCUSSION

A. Chemical Components of Rattan Cane

The results of the analysis with py-GCMS (Figure 1) show that the chemical components in rattan cane are dominated by phenolic group compounds (37.86%), such as Guaiacol, 2-Methoxy-4-methyl phenol; class of sugar (15.75%), such as alpha-L-Galactopyranoside; amine groups (6.67%) such as cis-1,3-Dideuterio-1,3-cyclohexan diamine, N-Hydroxy Acetaminophen, 2,6-Dimethoxyphenol; carboxylic acid groups (4.92%), such as Stearic acid, 9,12-Octadecadienoic acid, Oleic acid, and Elcosa-5,8,11,14-Tetraynoic acid; group of ketones (4.79), such as 4,7-Methano-1H-indene-1,8-dione, Ethanone, 6,7-Dihydro-3-nitro-5H-Cyclo-penta [B] Pyrin-2 (1H)-one.

The presence of sugar groups and carboxylic acids in rattan stems, which are hygroscopic and easily hydrolyzed in water (both cold and hot), will dissolve the adhesive that is applied to the surface of the rattan so that the adhesive is diluted, it will also result in thinner adhesive lines and the glued products will be delaminated during immersion test in cold water (interior test) or boiling water (exterior test). As a result, the bonding strength value of laminated rattan products will be very low, even delaminated.

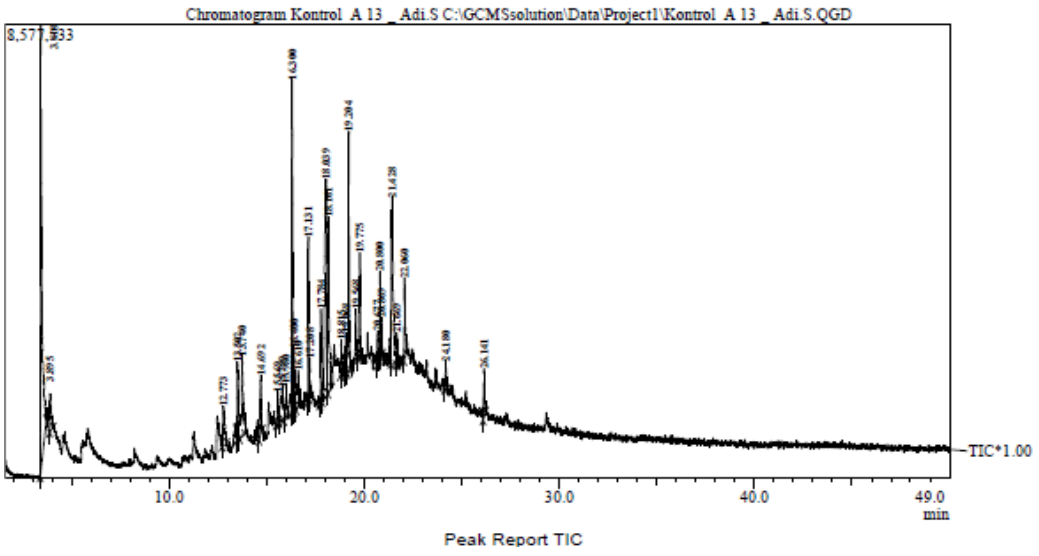

Figure 1. Chromatograph of chemical component of rattan *Calamus zollingeri* Becc.

On the other hand, the results of extractive substances analysis (Figure 2) in rattan cane showed that non-polar compounds of alkane groups (24.41%), such as n-Tridecane, n-Pentadecane, n-Hexadecane, n-Heptadecane; polar bit ketone compound (23.21%), such as 2-Hepta-decanone, Palmitone; polar group carboxylic acid compounds (40.65%), such as Methyl palmitate, Palmitic acid, Methyl stearate, 9-Hexa-decenoic acid, Stearic acid. The existence of extractive substances especially from the nonpolar group will inhibit the interaction of adhesive with adherend, so the chemical bond between the two materials is not maximum, consequently the bonding strength of the rattan laminated product will be low (Pizzi, 1983).

B. Characterization of the Physical-Chemical Properties of Adhesives

The characteristics of each type of adhesive used to produce rattan laminated boards (RLBs) are presented in Table 1.

Characteristics of phenolic group adhesives synthesized from biological raw materials such as merbau, mangium, and mahogany bark extracts have relatively similar properties to each other. Still, they are different from imported commercial synthesis (isocyanate and polyurethane) adhesives commonly used in the wood processing industry. The difference is very obvious especially in solid content and gelatinous time. In practice, adhesives that have high solid content will have high adhesive properties, while the shorter gelatinous time will be detrimental in terms of application of the adhesive because it will have a short pot life, so the material has been spread by adhesive if not immediately assembled will overheat and dry too quickly, as a result of the adhesive penetration into the adherend material is minimal, so the bonding quality of the product will be low.

According to Maloney (1977), a high density resin with a corresponding viscosity will enable it to penetrate the wood pores properly and form an optimum bond, resulting in a satisfactory adhesion. One of the fundamental properties of the adhesive in bond formation is viscosity. The higher the viscosity the shorter the pot life of the adhesive. It will harden faster than the low viscosity, so the quality of the adhesive is relatively low. According to Pizzi (1983), the minimum recommended pot life of adhesive ± 88 minutes. On the other hand, Vick (1999) suggested that the maximum adhesive bonds can be achieved if the adhesive soaks all the adherent surfaces so that contact between the adhesive molecule and the wood molecule occurs, thereby intermolecular attraction between the wood and the adhesive can be

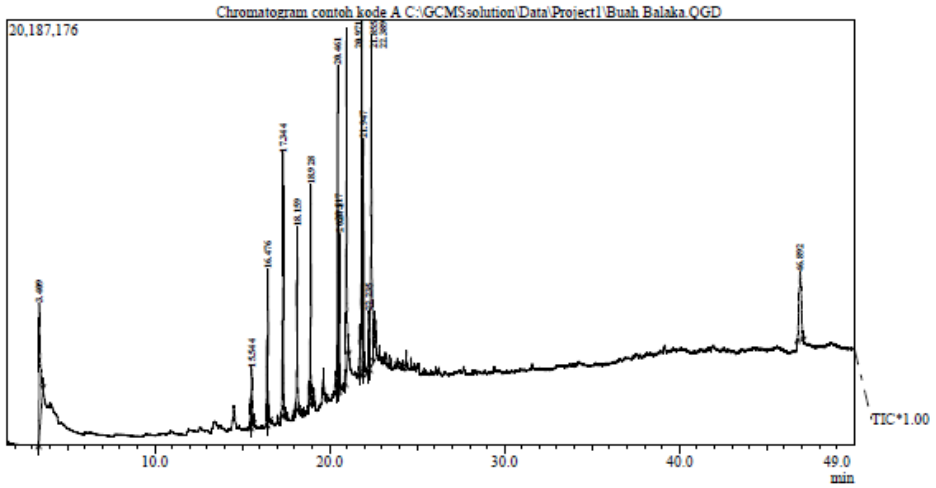

Figure 2. Chromatograph of the extractives of the chemical component of rattan *Calamus zollingeri* Becc.

Table 1. Characteristics of the adhesive types used for the manufacture of RLBs*)

Properties	Adhesive types					
	Mb (C1)	Ac (C2)	Mh (C3)	TF (C4) **	ICN (C5)	PU (C6)
Visual test: • Phase • Color • Odor	Liquid Dark red Phenol	Liquid Dark red Phenol	Liquid Dark red Phenol	Liquid Dark red Phenol	Liquid Dark red Phenol	Liquid Dark red Phenol
pH	10.50	9.99	10.00	10.50	-	-
Viscosity, cp	8.67	7.16	11.35	12.34	-	-
Specific gravity	1.06	1.06	1.07	1.02	-	1.14
Solid content, %	11.94	12.92	13.05	8.63	73.52	91.46
Free formaldehyde, %	0.004	0.003	0.004	0.054	-	-
Gelatinous time, minutes	110	180	160	300	15	30

Remarks: *) = Means of 3 replicates, Mb = tannin resorcinol formaldehyde (TRF) adhesive made of tannin from merbau wood extract, Ac = TRF adhesive made of tannin from mangium bark extract, Mh = TRF adhesive made of tannin from mahogany bark extract, TF = tannin formaldehyde adhesive made of tannin from mangium bark extract without resorcinol, ICN = isocyanate adhesive, PU = polyurethane adhesive, (-) = no data, **) Santoso & Pari (2020)

more fully bonded. Thus, the increase in solid resin content tends to improve the quality of the adhesive.

Free formaldehyde levels describe the presence of a formaldehyde excess in the formation of a polymer (SNI, 1998). This determination is undertaken to know the excess amount of unreacted formaldehyde in the adhesive formation, and the possible emission levels as a result of the formaldehyde being released. The test results show that the free formaldehyde of the adhesive used is entirely within safe limits for less than 3% as required for adhesives containing formaldehyde (SNI, 1998).

C. Evaluation of the Quality of Rattan Laminated Boards

The engineered rattan product made in this study was in the form of a 3-inch rattan laminated board measuring 60 cm x 7.5 cm x 1.5 cm in length, width, and thickness, respectively, using 4 types of synthesized adhesive types of natural resources and 2 types of commercial synthetic adhesives, while on a pilot scale at PIRNAS the rattan laminated panel has the dimension measuring 400 cm x 60 cm x 6 cm, and produced using a commercial synthetic adhesive type from the resorcinol group commonly used in the wood processing industry (Pari et al., 2019). In this research we applied 3 kinds of glue spread rates on the surface, namely 150, 200, and 250 g/m^2. The test of bonding strength of adhesive by means of compressive shear strength was performed to determine the performance of the adhesive in the resulting rattan laminated boards (RLBs). The quality of the RLBs tested in the laboratory are presented in Table 2, which includes moisture content, density, bonding strength, and formaldehyde emissions.

The physical properties of RLBs, as one of the lignocellulosic-based products, are closely related to the nature of its strength. Yap (1984) stated that moisture content affects the strength and adhesion of lamina products. The rattan laminated boards produced in this study have an equivalent density (0.26–0.38 g/cm^3) to the density of glued laminated timber made from sengon (*Falcataria moluccana* Miq.) and jabon

(*Anthocephalus cadamba* Roxb.) (0.25–0.37 g/cm^3) glued with mahogany tannin based adhesive (Lestari et al. , 2018). The moisture content of RLB ranged from 9.46% to 10.63% which meets the JAS 234-2003 standard requirement since the moisture content of RLBs were less than 15%.

The results of the bonding strength in the wet condition of RLBs that were glued with natural adhesive has delamination of 100% so it could not be tested for its bonding strength, bonding strength of RLBs produced using commercial adhesives ranged from 2.28 kg/cm^2 to 26.33 kg/cm^2 (Table 2). The average bonding

Table 2. The average value of physical-mechanical properties and formaldehyde emission of RLBs

Pre-treatment method (A)	Adhesive type (C)	Glue spread (g/m^2 surface) (B)	Parameters				
			Moisture content (%)	Density (g/cm^3)	Bonding strength (kg/cm^2)		Formaldehyde emissions (mg/L)
					Dry test	Wet test	
Mixture of kerosene with water 80:20 (A1)	TRF Mb (C1)	100	9.46	0.35	36.66	0.00	0.035
		150	10.03	0.37	41.49	0.00	0.044
		200	10.28	0.36	37.19	0.00	0.066
	TRF Ac (C2)	100	9.74	0.27	31.30	0.00	0.027
		150	10.11	0.33	44.39	0.00	0.034
		200	10.32	0.32	33.68	0.00	0.046
	TRF Mh (C3)	100	10.10	0.26	27.81	0.00	0.022
		150	10.21	0.29	35.61	0.00	0.023
		200	10.63	0.30	22.58	0.00	0.045
	TF Ac (C4)	100	10.33	0.30	39.47	0.00	0.545
		150	10.33	0.32	46.16	0.00	0.781
		200	10.34	0.33	34.77	0.00	1.212
	ICN (C5)	100	9.69	0.35	30.65	9.52	0.000
		150	10.17	0.37	37.64	9.79	0.000
		200	10.19	0.37	41.46	4. 42	0.000
	PU (C6)	100	9.87	0.36	27.72	17.71	0.000
		150	10.04	0.37	33.52	25.66	0.000
		200	10.13	0.37	37.69	20.56	0.000
Mixture of kerosene with water 70:30 (A2)	TRF Mb (C1)	100	9.89	0.27	29.53	0.00	0.044
		150	10.04	0.29	32.56	0.00	0.057
		200	10.16	0.30	24.59	0.00	0.064
	TRF Ac (C2)	100	10.12	0.30	34.70	0.00	0.247
		150	10.15	0.32	45.38	0.00	0.277
		200	10.15	0.31	28.90	0.00	0.327
	TRF Mh (C3)	100	10.31	0.26	25.39	0.00	0.034
		150	10.33	0.29	37.50	0.00	0.038
		200	10.33	0.30	24.52	0.00	0.074
	TF AC (C4)	100	10.23	0.31	38.64	0.00	0.775
		150	10.31	0.33	41.55	0.00	2.042
		200	10.32	0.33	41.28	0.00	3.216
	ICN (C5)	100	9.29	0.35	29.66	18.67	0.000
		150	10.12	0.36	31.72	4.33	0.000
		200	10.16	0.38	41.58	2.28	0.000
	PU (C6)	100	9.89	0.36	44.71	20.60	0.000
		150	10.20	0.38	42.60	26.33	0.000
		200	10.23	0.38	37.70	20.52	0.000

Remarks**:** A1 = a mixture of kerosene with water 80:20, A2 = a mixture of kerosene with water 70:30, TRF Mb = tannin resorcinol formaldehyde (TRF) adhesive made of tannin from merbau wood extract, TRF Ac = TRF adhesive made of tannin from mangium bark extract, TRF Mh = TRF adhesive made of tannin from mahogany bark extract, TF = tannin formaldehyde adhesive made of tannin from mangium bark extract without resorcinol, ICN = isocyanate adhesive, PU = polyurethane adhesive.

strength of the RLBs made in the pilot scale at PIRNAS was 8.70 kg/cm^2. The low value of RLBs bonding strength which is tested in wet condition (for exterior condition) is likely caused by high levels of polar chemical components contained in rattan material, which is easily hydrolyzed in both hot and cold water, such as sugar compounds, amine and carboxylic acid (Figure 1), in which the degree of crystallinity reaches 27.34%. While the extractive substance that inhibits gluing is dominated by non-polar chemical compounds of alkyne and ketone, which reaches 47.63% (Figure 2).

The existence of sugar and organic acids compounds, as well as non-polar compounds of the alkyne as an extractive substance in the lignocellulosic material, will inhibit the adhesive reaction with cellulose so that the bonding of adhesive molecules with rattan molecules is not maximal. These results in RLBs, which are easily delaminated when immersed in boiling water. Only RLBs using a synthetic commercial isocyanate adhesive with a glue spread of 100 g/cm^2 and polyurethane adhesive with a glue spread of 150–200 g/cm^2 have relatively high bonding strength (20.52–26.33 kg/cm^2). The quality of the rattan laminated board is equivalent to the andong (*Gigantochloa pseudoarundinacea*), mayan (*Gigantochloa robusta*) and betung (*Dendrocalamus asper*) bamboo laminated boards, which used tannin adhesive from the merbau wood powder extract (11.87–18.67 kg/cm^2) (Santoso et al., 2016a).

The average bonding strength of RLBs glued with various adhesive types and tested in dry condition ranged from 24.52 kg/cm^2 to 46.16 kg/cm^2 (Table 2), while RLBs made at pilot scale in PIRNAS-Palu used commercial adhesives (resorcinol) had averaged bonding strength of 35.49 kg/cm^2 (Santoso et al., 2016b). Based on the data in Table 2, it can be seen that about 52.78% of treatment combinations (19 of 36 combinations) have equal or higher bonding strength value compared to PIRNAS product. The value of RLBs bonding strength are higher than that of glued laminated timber made of sengon wood (18.99 kg/cm^2) which uses commercial isocyanate adhesives (Muthmainnah, 2011). However RLBs bonding strength values are similar to the bonding strength of laminated bamboo boards (21.46–33.52 kg/cm^2) made from three bamboo species (andong, mayan and betung) glued with natural adhesives from merbau powder extract (Santoso et al., 2016a).

The data on bonding strength was subjected to analysis of variance (Table 3) and the results showed that pre-treatment, glue spread, and adhesive type have significant effect on the bonding strength. The RLBs made from rattan strips which were pre-treated by immersing it in heated kerosene solution (80 kerosene : 20 water) with 150 g/m^2 glue spread and used tannin based adhesives (particularly TF) have higher bonding strength than commercial adhesive (Table 2). In general, the highest

Table 3. Analysis of variances of bonding strength and formaldehyde emission

Source of variation	df	F-calculation	
		Bonding strength	Formaldehyde emission
Pretreatment, A	1	31.57 ^{hs}	133.22 ^{hs}
Glue spread, B	2	2988.16 ^{hs}	58.61 ^{hs}
Types of adhesive, C	5	1980.43 ^{hs}	468.04 ^{hs}
A * B	2	178.15 ^{hs}	18.02 ^{hs}
A * C	5	1137.89 ^{hs}	77.57 ^{hs}
B * C	10	775.26 ^{hs}	48.95^{hs}
A * B * C	10	288.20 ^{hs}	16.38^{hs}

Remarks): hs = *Highly significant*, *df* = *degree of freedom*

bonding strength value of RLBs in almost all types of adhesives was reached by applying 200 g/m^2 glue spread.

In this study, RLBs that use natural adhesives synthesized by incorporating formaldehyde have to be tested regarding formaldehyde emission. The average formaldehyde emissions of RLBs which used natural adhesive ranges from 0.022 mg/L to 3.216 mg/L (Table 2), which is classified as a low-emission product classification (F * – F * * * *). The result of ANOVA in Table 3 shows that pre-treatment, glue spread and adhesive types have significant ly affect on formaldehyde emission of RLBs. The best treatment combination in producing RLBs were pre-treatment with kerosene solution (70 kerosene : 30 water) and 150 g/m^2 glue spread of TRF mangium which resulted in the value of 0.28 mg/L formaldehyde emission and pre-treatment with kerosene solution (80 kerosene : 20 water) and 150 g/m^2 TF mangium which resulted in the value of 0.78 mg/L formaldehyde emission. Nevertheless, when we consider the formaldehyde emission requirement, the safest treatment combination to produce RLBs for interior purposes was pre-treatment with kerosene solution (80 kerosene : 20 water) glued with TRF mahogany and glue spread of 100 g/m^2 (0.022 mg/L) and 150 g/m^2 (0.023 mg/L).

IV. CONCLUSION

Batang rattan (*Calamus zollingeri* Becc.) can be processed into rattan laminated board by using a natural adhesive such as wood bark extract (mangium, mahogany), merbau wood powder, and commercial synthetic adhesives such as isocyanate and polyurethane. The appropriate pre-treatment in producing RLBs for interior furniture was pre-treatment by applying oil heat treatment with kerosene solution (80 kerosene : 20 water) and glued with tannin adhesive of mangium bark extract with glue spread of 200 g/m^2. Similarly, rattan strips treated with heated oil (80 kerosene : 20 water) and glued with polyurethane adhesive (glue spread of 200 g/m^2) produced excellent RLBs for exterior furniture.

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AUTHOR'S CONTRIBUTION

The three authors (AS, IMS and RP) of this article were the main contributors in which the ideas, designs, and experimental designs were carried out by the three authors. Material preparation, experimental and test treatments, and data collection and analysis by AS and RP; manuscript writing by AS, IMS and RP; the revision and finalization of the manuscript was carried out by AS, IMS and RP.

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THE IMPLEMENTATION OF FOREST AND LAND FIRE MANAGEMENT POLICY IN INDONESIA DURING THE COVID-19 PANDEMIC

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THE IMPLEMENTATION OF FOREST AND LAND FIRE MANAGEMENT POLICY IN INDONESIA DURING THE COVID-19 PANDEMIC. The coronavirus outbreak (COVID-19) has raised questions about changes in subsequent environmental effects, mainly forest and land fires. This paper evaluates the implementation of land and forest fire management policies in Indonesia during the COVID-19 pandemic, particularly in 2020. A qualitative approach was conducted in policy implementation analysis based on George Edward III's theory by looking at bureaucratic structure, resources, communication, and disposition factors. The research focused on the operational work of the Forest and Land Fire Brigade, known as Manggala Agni, in Indonesia. The results showed that the collaborative work of Manggala Agni and the other forest and land fire task forces successfully reduced the hotspots; hence there was a significant decrease in the burned area. It is also inseparable from climatic factors. During this period there was no haze disaster although the task of controlling forest and land fires still encountered several obstacles during the pandemic. This is because of training, technology transfer, budget support, and synergy between stakeholders and Manggala Agni's team members, so a significant reduction in forest and land fires during 2020 can be achieved.

Keywords: Covid-19 Pandemic, forest and land fire, Manggala Agni, hotspot

IMPLEMENTASI KEBIJAKAN PENGENDALIAN KEBAKARAN HUTAN DAN LAHAN DI INDONESIA PADA MASA PANDEMI COVID-19. Pandemi Covid-19 menimbulkan berbagai pertanyaan terkait perubahan lingkungan, khususnya dalam pengelolaan kebakaran hutan dan lahan. Tulisan ini mempelajari penerapan kebijakan pengelolaan kebakaran hutan dan lahan di Indoesia pada masa pandemic COVID-19, khususnya pada tahun 2020. Pendekatan kualitatif dilakukan untuk menganalisa penerapan kebijakan tersebut berdasarkan teori George Edward III, dengan menekankan kepada struktur birokrasi, sumber daya, komunikasi, dan disposisi dalam kaitannya dengan operasional kerja Manggala Agni Indonesia. Hasil penelitian menunjukkan bahwa pada masa pandemi, kerja kolaboratif antara Manggala Agni dan satuan tugas kebakaran hutan dan lahan lainnya telah berhasil menekan jumlah titik api, sehingga terjadi penurunan luas kebakaran secara signifikan. Hal ini juga tidak terlepas dari faktor iklim. Selama kurun waktu tersebut tidak terjadi bencana asap, walaupun tugas pengendalian kebakaran hutan dan lahan masih menemui beberapa kendala selama masa pandemi. Hal ini disebabkan oleh adanya pelatihan, alih tekhnologi, dukungan anggaran, serta sinergisitas antar anggota satgas pengendalian kebakaran hutan dan lahan, sehingga pengurangan kebakaran lahan dan hutan di Indonesia selama tahun 2020 dapat dicapai.

Kata kunci: Pandemi Covid-19, kebakaran hutan dan lahan, Manggala Agni, titik api

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I. INTRODUCTION

The coronavirus outbreak (COVID-19) has raised questions about changes in subsequent environmental effects in many countries including Indonesia, especially on the incidence of forest and land fires. Since March 17, 2020, the Government of Indonesia has imposed a Covid-19 emergency response status, and the Indonesian President Joko Widodo announced the Covid-19 Corona pandemic as a national disaster through Presidential Decree number 12 of 2020. The pandemic has changed people's lives in almost all aspects, including social life. In a pandemic situation, the government policies focus on the principal matters (i.e., the spread of COVID-19) and most importantly to suppress the spread of the virus and ensure the system optimally agrees to deliver policies from top to bottom at the site level (Aram Dani & Yogi, 2020).

During the pandemic, essential issues recur as natural phenomena in Indonesia, such as forest and land fires (Purnomo et al., 2017). One of the factors causing forest and land fires to continue is the expansion of oil palm plantations areas which is increasingly putting pressure on the environment and having an impact on the local and national economy (Purnomo et al., 2018). The national forest and land fire disasters affected material and immaterial losses (Ayu et al., 2020). Efforts to control forest and land fires have been set as one of the work priorities of the Indonesian Government during the pandemic to prevent multiple disasters of forest and land fires as well as corona diseases simultaneously (Humas KLHK, 2020). Forest fires are also still a threat due to the impact of extreme climate change (Harrison et al., 2020).

The Ministry of Environment and Forestry (MOEF), Republic of Indonesia, was mandated to combat forest and land fires, including efforts to prevent, suppress, and handle post-forest fires. For the implementation of fieldwork, MOEF formed the forest and land fire brigade known as MA in 2003 to prevent and suppress forest and land fires. This task force has significant challenges in conducting its duties (Yungan & Saharjo, 2014). Furthermore, in 2020, the MA still faces many obstacles to controlling forest and land fires. For example, the lockdown policy during Covid-19 impacts the activities in forestry. Therefore, the Government's priority shifts between overcoming the pandemic and preventing forest and land fires (Amador et al., 2020).

On January 28, 2020, President Joko Widodo signed Presidential Instruction No. 3/2020 concerning Forest and Land Fire Management, addressed to 28 leaders of Ministries/ Institutions, including governors, regents, and mayors. This policy has strengthened the fieldwork operations regulated by the Minister of Environment and Forestry Regulation No. 32 of 2016 on Forest and Land Fire Control. Efforts made under this policy include planning, prevention, mitigation, law enforcement, preparedness, and handling of post-fire activities.

Indonesia has had many policies to control forest and land fires over the last three decades (Zulkifli et al., 2021). During the pandemic, MoEF has prepared several procedures to implement MA's tasks in combating forest and land fires. The Ministry issued Circular Letter No. 6 of 2020 concerning Safety for Covid-19 Prevention. The Letter is a binding material that becomes the instruments of policy and information from the Minister containing both regeling and beschikking, and the legal standing of the letter could be equated with discretion.

In Article 1 Paragraph 9 of Law Number 30 of 2014 concerning Government Administration, discretion is defined as decisions and actions that are determined or carried out by government officials to overcome incomplete or unclear problems in statutory regulations. Meanwhile, it is stated that public policy responds to any political action taken by the Government at all levels in addressing a problem in its political context or environment. One of the inputs that play a significant role in public administration is

the implementation of public policies to solve complex environmental issues such as forest and land fire control finding the most effective policy implementation (Carmenta et al., 2017). The purpose of this paper is to evaluate: first, the implementation of forest and land fire control policies during the covid-19 pandemic, and second, the supporting and inhibiting factors for implementing forest and land fire control policies during the covid-19 pandemic, especially in Indonesia's MA operating areas (central, regional, and operational area).

II. MATERIAL AND METHOD

A. Research Area

The Indonesian government has prioritized forest and land fire control during the Covid-19 pandemic. Forest and land wildfires could become worse during the pandemic. Several vulnerable areas in Sumatera and Kalimantan are the major concern as most of the area is peat ecosystem, which is very difficult to stop when burning. The work of controlling forest and land fires has been regulated in Presidential Instruction Number 3 of 2020 concerning Forest and Land Fires Management and the Ministry of Environment and Forestry Regulation Number 32 of 2016 concerning Forest and Land Fires Control. Therefore, it is necessary to conduct a critical review in this article that refers to the issuance of Circular Letter No. 6/Menlhk-Setjen/Roum/Set.1/4/2020 concerning the Continuity of Efforts to Prevent the Spread of COVID-19 in the internal work within the MOEF.

B. Participants

Data for this study were collected from various correspondents which have mandate in land and fire control at the national, regional and operational levels. These included the Director of Forest and Land Fire Control of the MOEF, the Head of the Climate Change Control and Forest and Land Fire for Sumatera, Kalimantan, and Sulawesi regions, as well as all the Heads of Manggala Agni operational area in Indonesia, 34 members.

C. Data Collection Procedure

The in-depth online interviews were conducted with all correspondents to get primary data during the pandemic. The online interview is an accurate and valid method for obtaining data in social research (Sidauruk, 2013). Apart from the interview, the observation and documentation were collected to support the analysis (Nugroho, 2014).

D. Data Analysis Process

Miles and Huberman (1984) in Sugiyono (2015) suggested that qualitative data analysis were conducted interactively and it should be continued to completion until the data is saturated. Data analysis includes summary key findings, data display, short description, conclusion, and recommendation of the forest and land fire implementation policies during the pandemic. This study deploys a qualitative approach to examine the implementation of forest and land fire control policies during the Covid-19 pandemic, with the scope of work of the ranks of the Manggala Agni organization, where Manggala Agni has been under the Ministry of Environment and Forestry, with the Directorate of Forest and Land Fire Control, Directorate General of Climate Change Control since 2015.

Further, the analysis of public policy implementation refers to the theory of George C. Edward III. According to Edward (1980), the factors that influence the success or failure of policy implementation include bureaucratic structure, resources, communication, and disposition (Nugroho, 2009). In this case, Minister of Environment and Forestry Regulation No. P.32/MenLHK/Setjen/Kum.1/3/2016 concerning Forest and Land Fire Control was examined by applying Edward III's parameters to validate its sufficiency.

III. RESULTS AND DISCUSSION

A. The Indonesian Policies on Forest and Land Fires Control

Large-scale forest and land fires have occurred since the Indonesian industrialization era 1982/1983. (Saharjo, 2016) reported that human actions caused the most forest and land fires. This condition is inseparable from population growth that demands massive land clearing and the widespread behaviour of people who use fires in land clearing. Since 2015, the Indonesian Government has focussed on every occurrence of forest and land fires. This is a moment of changing the paradigm to control the fires seriously. The policies implemented include the protection of the Peat Hydrological Unit (PHU), strengthening the supervision of concession areas, law enforcement, work integration between the central government and local governments, and strengthening the role of leaders in each government organization and stakeholders so that forest and land fires are no longer run independently (Table 1). Various corrective actions regarding regulations or rules (corrective policy) for forest and land fire control in Indonesia have shown results with the controlled number of hotspots and burned areas (Zulkifli et al., 2019).

B. Indonesian Forest and Land Fire During Pandemic

World Health Organization (WHO) announced the Covid-19 pandemic on March 11, 2020; it was first officially announced by President Joko Widodo as a National disaster on March 2, 2020. At the peak of the hot summer in 2020, the President reiterated that anticipating forest and land fires must remain a priority during a pandemic. Moreover, 99 % of the causes of forest and land fires are human-made (Saharjo, 2016). Since the beginning of the year, the control of forest and land fires has been strengthened with Presidential Instruction No 3 of 2020. After issuing Presidential Decree No.12 of 2020 concerning the Determination of the Non-Natural Disaster of the Corona Virus Disease 2019 (Covid-19) as a national disaster.

Table 1. Corrective policies of forest and land fire control in Indonesia

Regulation	Implication Policy
President Instruction Number 3/2020 concerning forest and land fires management, in lieu of President Instruction Number 11/2015 concerning in increasing forest and land fire control. Revision of Government Regulation No. 71/2014 to Government Regulation No. 57/2016 on protection and management of peat ecosystems. Derivative policy: P.14/2017 concerning procedures for Inventory and Determination of Function of the Peat (Scale 1: 50,000) P.15/2017 concerning procedures for measuring the groundwater level at the point of structuring the peat ecosystem. P.16/2017 concerning technical guidelines for restoring the function of the peat ecosystem. P.17/2017 amendments to P.12/2015 concerning the development of industrial forests plantation. SK. 129/2017 concerning the establishment of a map of the national peat hydrological unit. SK. 130/2017 concerning the establishment of the national peat ecosystem function map. P.10/2019 concerning the designation, establishment and management of peat dome peak based on peat hydrological unit.	Strengthening efforts to prevent, extinguish, and programmes post forest and land fires. This President Instruction mandates 28 Ministries/Agencies including Governors, Regents, and Mayors.

Table 1. Continued

Regulation	Implication Policy
Revision of Government Regulation No. 71/2014 to Government Regulation No. 57/2016 on protection and management of peat ecosystem.	All parties, especially concession holders, are obliged to maintain the Peat Hydrological Unit.
Derivative policy: P.14/2017 concerning procedures for inventory and determination of the function of the peat (Scale 1: 50,000) P.15/2017 concerning procedures for measuring the groundwater level at the point of structuring the peat ecosystem. P.16/2017 concerning technical guidelines for restoring the function of the peat ecosystem.	It contains six Ps, namely *perencanaan* (planning), *pemanfaatan* (utilization), *pengendalian* (control), pemeliharaan (maintenance), *pengawasan* (supervision), and *penegakan hukum* (law enforcement).
P.17/2017 on Industrial Plantation Forest Development amendments to P.12/2015 concerning the Development of Industrial Plantation Forests. Ministerial Decree No 129/2017 – Determination of National Peat Hydrological Units Map	The concession permits holders is obliged to protect the KHG, which will be seen in the Business Work Plan (RKU). For concessions that do not prepare an RKU in accordance with the KHG protection provisions, the permit will be evaluated.
Ministerial Decree No. 130/MENLHK/SETJEN/PKL.0/2/2017 about the Establishment of the National Peatland Ecosystem Function Map.	Permit holders must obey the use of their area by protecting the peat dome tops and are obliged to protect their area from the threat of forest and land fires. If they are not guarded, they will be subject to administrative, civil and criminal sanctions. This sort of thing had never been arranged beforehand.
Minister of Environment and Forestry No. P.32/MenLHK/Setjen/Kum.1/3/2016 about Forest and Land Fire Control.	Regulating the forest and land fires control operation includes planning prevention, post-fire prevention, work coordination, and alert status. This policy provides the paradigm shift on forest and land fire control in which from suppression to prevention of the forest and land fire.

Source: modified from various sources

Indonesian President then issued Presidential Decree No. 3/2020 on the forest and land fires managements a working guideline for Ministries/ Institutions and Local Governments for quick, precise, focused, integrated, and synergistic steps in dealing with the spread of the virus. The main implication of this policy is that the forest and land fire task force consists of the central and local governments and must share their concentrations for handling the spread of the Covid-19 virus. The implementation of forest and land fire control work during 2020 was carried out while still implementing the Covid-19 health protocol.

The highest number of hotspots is still dominated by forest and land fire-prone provinces such as West Kalimantan, East Kalimantan, and Riau. Several provinces need attention for potential forest and land fires during the pandemic, including Aceh, East Nusa Tenggara, and South Sulawesi. Compared with the number of hotspots in Indonesia in 2019 and 2020, the work of the forest and land fires task force is relatively successful in forcing down the hotspots during the pandemic. More specifically, the decline of the hotspots was also supported by La Nina climatic factors across the continent and restriction policies caused

by the Covid-19 pandemic (Gonzalves et al., 2020), which provided limited access for illegal immigrants logging.

However, it should be noticed that the fire challenges in 2020 are very tough. Since it could be one of the hottest years in history, the global warming trend is taking place dramatically (NASA, 2021). Therefore, it is understandable that if there is no policy and field intervention like Manggala Agni and the task force team, the threat of forest and land fires would be even more significant. Consequently, in 2020, when several other countries experienced fire disasters, Indonesia avoided meeting forest and land disasters during the Covid-19 pandemic. Based on the Terra/Aqua (NASA) satellite with a confident level of ≥80% from January 1 to December 17, the number of hotspots in 2019 (before pandemic) was 29,306 hotspots. Meanwhile, in 2020 (during the pandemic), there were 2,545 hotspots. In this circumstance, it means that during the Covid-19 pandemic, Indonesia succeeded in reducing the number of hotspots by 26,761 points or 91.32% (Table 2).

In 2019, the total forest and land fires area was 1,649,258 ha , while the total area of forest and land fires in 2020 decreased to 296,942 ha (Table 3). Overall, there was a significant decrease of 1,352,316 ha during the Covid-19 pandemic. However, there was a greater forest and land fires area at seven provinces as recorded in 2020. Seven provinces includes Aceh, Bengkulu, Central Java, Riau Islands, West Papua, North Sumatera, and Yogyakarta. The other 27 provinces remain lower during the pandemic in 2020. Significant forest and land fires reduction was recorded in the Provinces of Banga Belitung, Gorontalo, Jambi, West Kalimantan, South Kalimantan, Central Kalimantan, East Kalimantan, North Kalimantan, Lampung, Riau, South Sulawesi, South Sumatera, and other provinces as shown in Table 3.

Meanwhile, Table 4 indicates mineral lands that still dominate the total area of forest and land fires. The largest peatland burned in 2020 occurred in Riau Province, covering about 11,587 ha. The forest and land fires in 2020 is lesser than those of burnt area in 2019, which was about 90,550 ha. Moreover, the figure is less than those of 2015, about 183,808.59 ha. The specific illustration of each area can be seen in Table 4.

Table 2. Indonesian hotspots from 1 January 2019 to 17 December 2020

Province	Hotspot Terra/Aqua (NASA) Confidence Level >80 %	
	2019	2020
North Sumatera	49	44
Riau	2,915	327
Jambi	3,701	10
South Sulawesi	3,872	19
West Kalimantan	4,028	251
Central Kalimantan	7,469	122
South Kalimantan	906	31
East Kalimantan	970	91
North Kalimantan	177	44
Papua	683	237
Total of potential provinces	24,770	1,176
Total of Indonesia	29,306	2,545

Source: Directorate of PKHL MOEF, 2020

Table 3. Recapitulation of forest and land fires area (ha) by provinces in Indonesia 2015-2020

No	Provinces	2015	2016	2017	2018	2019	2020
1.	Aceh	913.27	9,158.45	3,865.16	1,284.70	730	1,078
2.	Bali	373.46	-	370.80	1,013.76	373	29
3.	Bangka Belitung	19,770.81	-	-	2,055.67	4,778	576
4.	Banten	250.02	-	-	-	9	2
5.	Bengkulu	931.76	100,39	131.04	8.82	11	221
6.	Jakarta	-	-	-	-	-	-
7.	Gorontalo	5,225.89	737.91	-	158.65	1,909	80
8.	Jambi	115,634.34	8,281.25	109.17	1,577.75	56,593	1,002
9.	West Java	2,886.03	-	648.11	4,104.51	9,552	2,344
10.	Central Java	2,471.70	-	6,028.48	331.67	4,782	7,516
11.	East Java	7,966.79	-	5,116.43	8,886.39	23,655	19,148
12.	West Kalimantan	93,515.80	9,174.19	7,467.33	68,422.03	151,919	7,646
13.	South Kalimantan	196,516.77	2,331.96	8,290.34	98,637.99	137,848	4,017
14.	Central Kalimantan	583,833.44	6,148.42	1,743.82	47,432.57	317,749	7,681
15.	East Kalimantan	69,352.96	43,136.78	676.38	27,893.20	68,524	5,221
16.	North Kalimantan	14,506.2	2,107.21	82.22	627.71	8,559	1,721
17.	Riau islands	-	67.36	19.61	320.96	6,134	8,805
18	Lampung	71,326.49	3,201.24	6,177.79	15,156.22	35,546	1,358
19.	Maluku	43,281.45	7,834.54	3,918.12	14,906.44	27,211	20,270
20.	North Maluku	13,261.10	103.11	31.10	69.54	2,781	59
21.	West Nusa Tenggara	2,565.71	706.07	33,120.81	14.461.38	60,234	29,157
22.	East Nusa Tenggara	85,430.89	8,968.09	38,326.09	57,428.79	136,920	114,719
23.	Papua	350,005.30	186,571.60	28,767.38	88,626.84	108,110	28,277
24.	West Papua	7,964.41	542.09	1,156.03	509.50	1,533	5,716
25.	Riau	183,808.59	85,219.51	6,866.09	37,236.27	90,550	15,442
26.	West Sulawesi	4,989.38	4,133.98	188.13	978.38	3,029	569
27.	South Sulawesi	10,074.32	438.40	1,035.51	1,741.27	15,697	1,902
28.	Central Sulawesi	31,679.88	11,744.40	1,310.19	4,147.28	11,551	2,555
29.	Southeast Sulawesi	31,763.54	72.42	3,313.69	8,594.67	16,929	3,206
30.	North Sulawesi	4,861.31	2,240.47	103.04	326.39	4,574	177
31.	West Sumatera	3.940.14	2,629.82	2,227.43	2,421.90	2,133	1,573
32.	South Sumatera	646,298.80	8,784.91	3,625.66	16,226.60	336,798	950
33.	North Sumatera	6,010.92	33,028.62	767.98	3,678.79	2,514	3,744
34.	Yogyakarta	-	-	-	-	23	181
Total		2,611,411.44	438,363.19	165,483.92	529,266.64	1,649,258	296,942

Remarks: Forest and land fires coverage was determined based on Citra description Satellite 8 OLI/TIRS analysis, which had been overlayed with hotspots distribution and hotspot ground-check report as well as extinguished fires by Manggala Agni. Source: Sipongi.menlhk.go.id

Table 4. Comparison of burnt area in Indonesia of 2019 and 2020

No.	Provinces	Recapitulations in 2019 (ha)	Forest and Land fire coverage (ha) 2020		Remarks	
			Mineral lands	Peatlands	Amount	
1.	Aceh	730	885	193	1,078	Up
2.	Bengkulu	11	193	-	193	Up
3.	Jambi	56,593	943	7	950	Down
4.	Bangka Belitung	4,778	350	226	576	Down
5.	Riau islands	6,134	8,798	7	8,805	Up
6.	Lampung	35,546	1,024	-	1.024	Down
7.	Riau	90,550	3,855	11,587	15,442	Down
8.	West Sumatera	2,133	925	473	1,398	Down
9.	South Sumatera	336,798	433	517	950	Down
10.	North Sumatera	2,514	2,827	897	3,724	Up
11.	Banten	9	2	-	2	Down
12.	West Jawa	9,552	2,344	-	2,344	Down
13.	Central Jawa	4,782	7,516	-	7,516	Up
14.	East Jawa	23,655	19,148	-	19,148	Down
15.	Yogyakarta	23	181	-	181	Up
16.	Bali	373	29	-	29	Down
17.	West Nusa Tenggara	60,234	29,069	-	29,069	Down
18.	East Nusa Tenggara	136,920	114,701	-	114,701	Down
19.	West Kalimantan	151,919	5,735	1,360	7,095	Down
20.	South Kalimantan	137,848	3,972	39	4,011	Down
21.	Central Kalimantan	317,749	4,475	1,520	5,995	Down
22.	East Kalimantan	68,524	5,084	137	5,221	Down
23.	North Kalimantan	8,559	1,721	-	1,721	Down
24.	Gorontalo	1,909	80	-	80	Down
25.	West Sulawesi	3,029	568	-	568	Down
26.	South Sulawesi	15,697	1,839	-	1,839	Down
27.	Central Sulawesi	11,551	2,394	-	2,394	Down
28.	Southeast Sulawesi	16,929	2,959	-	2,959	Down
29.	North Sulawesi	4,574	177	-	177	Down
30.	Molluca	27,211	19,709	-	19,709	Down
31.	North Molluca	2,781	59	-	59	Down
32.	Papua	108,110	27,853	398	28,251	Down
33.	West Papua	1,533	3,182	2,534	5,716	Up
34.	DKI Jakarta	-	-	-	-	-
Total		**1,649,258**	**273,028**	**19,894**	**292,922**	

Source: Dit PKHL KLHK, 2020

C. Implementation of Forest and Land Fire Control Policies During the Pandemic

The implementation of the forest and land fire control policy at the Ministry of Environment and Forestry is conducted with reference to the Presidential Instruction 3/2020 concerning forest and land fires and Forestry and Environment Minister Regulation No. 32/2016 on forest and land fire control. During the Covid-19 pandemic, the implementation of fieldwork for the Manggala Agni Brigade refers to Circular Letter (SE) No. 6/Menlhk-Setjen/Roum/Set.1/4/2020 concerning the continuity efforts to prevent the spread of COVID-19 internally within the Ministry of Environment and Forestry. Manggala Agni and the forest and forestry task forces team continue to conduct integrated and independent patrols for preventive purposes. In 2020, the integrated team was assigned to patrol 267 fire posts which are considerably prone to forest and land fires in Sumatera, Kalimantan, and

Table 5. Integrated forest and land fire patrols team in 2020

Province	Fire posts	Village coverage
North Sumatera	25	74
Riau	34	64
Jambi	29	158
South Sumatera	50	149
West Kalimantan	31	128
Central Kalimantan	27	81
South Kalimantan	21	100
East Kalimantan	14	32
North Sulawesi	3	3
South Sulawesi	15	15
Central Sulawesi	2	2
Southeast Sulawesi	14	14

Source: Dit PKHL KLHK, 2020

Sulawesi, covering up 822 villages. Meanwhile, independent patrols were also conducted in 776 villages categorized as the prone area to forest and land fires in Indonesia (Table 5).

The Ministry of Environment and Forestry applies some strategies to strengthen the prevention policies, including implementing early Weather Modification Technology (TMC) by involving cross-agency cooperation, including the Indonesian Air Force, Agency for the Assessment and Application of Technology (BPPT), National Disaster Management Agency (BNPB), and the private sector. TMC is intended to wet peat, canals, and reservoirs, so that forest and land fires will not broadly spread during the pandemic. TMC is implemented in the three most vulnerable provinces and based on the recommendation of the Agency for Meteorological, Climatological and Geophysics (BMKG), namely in Riau, South Sumatera, and Jambi. TMC was conducted in 176 sorties, with the total salt sown reaching 168,250 kg.

In addition to TMC, ground and air blackouts, some efforts to control forest and land fires during a pandemic are also carried out by monitoring hotspots, conducting hotspot ground checks, and following up the hotspot information system satellites, as well as following-up information reported by communities. All information was extracted from sipongi.menlhk.go.id website. Meanwhile, post-forest and land fire activities are conducted by law enforcement and post-forest and land fire restoration activities. To control forest and land fires during the pandemic, the Fire Care Community or MPA-Paralegal's legal awareness activities are part of the permanent solution to controlling forest and land fires. Activities have been carried out in 12 provinces in Indonesia from August to November 2020 (Table 6). In general, throughout 2020, it was well known that all areas carrying out MPA-Paralegal activities did not experience forest and land fires or were known as 'zero hotspots'.

MPA-Paralegal is a collaborative work between people with legal awareness and the forest and land fire task force consisting of *Manggala Agni* of MOEF, BNPB, Army, Police, Local Government, and other parties to prevent forest and land fires. There are two main activities, namely preparation and field operational activities. Preparatory activities in the form of debriefing for MPA-Paralegal personnel were carried out using the e-learning method funded by MOEF (BP2SDM, Directorate of PKHL, and PPIKHL office). Meanwhile, field operations are funded from the BNPB Ready-to-Use Fund (DSP). The MPA-Paralegal activities include forming groups, providing field activities through e-learning (material on forest and land fire policies and law enforcement, atmosphere development,

Table 6. Target locations to support the Fire Care Community (MPA) - Paralegal support for permanent solutions to forest and land fire control

No.	Province	Districts	Sub-districts	Villages
1.	Riau	Pelalawan	Ukui	Lubuk Kembang Bunga
2.	Riau	Indragiri Hulu	Kuala Cenaku	Pulau Gelang
3.	Riau	Siak	Pusako	Dosan
4.	Riau	Bengkalis	Rupat	Tanjung Medang
5.	Riau	Bengkalis	Rupat	Pergam
6.	Jambi	Tanjung Jabung Timur	Dendang	Catur Rahayu
7.	Jambi	Muaro Jambi	Berbak	Rantau Rasau
8.	South Sumatera	Musi Banyuasin	Banyuasin II	Tanah Pilih
9.	South Sumatera	OKI	Pangkalan Lampam	Riding
10.	West Kalimantan	Kubu Raya	Rasau Jaya	Rasau Jaya Umum
11.	Central Kalimantan	Pulang Pisau	Jabiren Raya	Tumbang Nusa
12.	West Java	Majalengka	Argapura	Bantaragung

Source: Ditjen PPI KLHK, 2020

disaster management, and evacuation, legal understanding, forest and land fire control, conservation partnership assistance), and field operations. Efforts to extinguish forest and land fires during the pandemic were also assisted by air blackout activities or water booming carried out in the five most vulnerable provinces, namely Riau, South Sumatra, West Kalimantan, South Kalimantan, and Central Kalimantan. The total water spilled during water bombing for blackout activities is around 164,077,000 liters.

1. Bureaucracy Structure

The bureaucracy structure includes two aspects: the structure of the bureaucracy itself and its mechanism. In this case, the former relates to the organization of the Forest and Land Fire Control institution, and the latter refers to the working operational system of Forest and Fire Control. More specifically, the organizational structure of Forest and Land Fire Control during the pandemic has not been changed, either at the primary level or in the Technical Implementation Unit within the MOEF. In this case, acting as the supervisor of MA is under the Directorate General of Climate Change Control. At the same time, the highest leadership of MA Center is held by the Director of Forest and Land Fire Control. Both sections are responsible for the operation conducted by the Regional of MA. However, The Director-General of Climate Change Control will give reports on the results of operational work in this bureaucratic structure to the Minister as the highest leader of the Ministry.

Because the Land and Forest Fire Control working areas include all the regions of Indonesia, there are five MA Regional working areas under sub-ordinate, namely the Sumatera Regional PPIKHL Center, the Java, Bali and Nusa Tenggara PPIKHL Centers, the Kalimantan PPIKHL Office, the Sulawesi Regional PPIKHL Center, and the Maluku Papua Regional PPIKHL Office. Thirty-four Heads of Operation manage those regional working areas (henceforth: *Kadaops*) throughout Indonesia, and they are in charge of facilitating regional capacity building in preventing and overcoming forest and land fires in the working areas. At the same time, some of the *Kadaops* are appointed as Provincial Coordinators of MA, whose responsibility is to coordinate all *Kadaops*. In addition, they supervised MA Operational Areas (Daops), led by operational leaders as their representatives in the field, and took the lead of the team members of MA Operation Areas.

Implementing tasks following the division of authority and work responsibilities for forest and land fire control during the Covid-19 pandemic impacts the distribution of the focus

of attention of all task force members, but this does not reduce the implementation of Land Fire Control. Cooperation and coordination between task forces have been strengthened with the MPA Paralegal and TMC programs in vulnerable provinces, recognized as one of Forest & Land Fire Control's solutions at the site level that were effective during the Covid 19 pandemic.

The Standard Operating Procedure for controlling forest and land fires during the pandemic also applies to MA by implementing health protocols including washing hands with soap, using masks, maintaining distance, avoiding crowds, and limiting mobility and interaction. Consequently, during the pandemic at the regional level bureaucratic structure, the crowd level, and the picket squad were reduced.

At the Daops Level, the MA teams that usually picket the office were two teams with 30 people before the pandemic. The outbreaking time is significantly reduced to one squad of 15 people. Similarly, the situation is also valid for MA at the Pondok Kerja as the lowest level, in which the member of the team decreased simultaneously. Initially, the number of office pick-up teams was a sub-team consisting of 7-8 people, but it was reduced to one sub-team with only 3-4 members. The pandemic also influences the field work stations activities, in which the health protocols become a priority for the MA. For example, in condition of emergency alert and forest fire response, members of the MA Daops and Workhouses, who do not have office duty should be ready to be summoned for gathering and carrying out their responsibilities and functions both in the office and in the field by applying the health protocols. Indeed, the team's structure must follow the health protocol of COVID-19. In line with this, the information given by participants indicates that most of them (88.3%) are capable of adapting to this working situation, followed by 8.8 % of participants declaring that it is fair to it.

Regarding workability according to the organizational structure of the forest and land fire control during the pandemic, from 34 *Kadaops* MA throughout Indonesia, 15 people (44%) said they were pretty capable, 12 people (35.5%) said they were good, three people (8.8%) said it was perfect, three people (8.8%) said it was not enough. One person (2.9%) said it was not there.

2. Resources

According to Edward III (Budiningsih, 2017), resources are related to all sources that can be used to support the successful implementation of policies, including human resources, budget, and facilities. Although budgeting shift occurs as a result of the pandemic, the implementation of forest and land fire control policies remains one of the budget priorities sourced from MOEF State Budget and supported by the National Disaster Management Agency' Ready-to-Use Fund source. To control forest and land fires effectively and efficiently during the pandemic, optimizing the source of funds is conducted by carrying out forest and land fire control activities on the site levels. Table 7 indicates the specific steps regarding the policy.

The total number of Manggala Agni resources under the Directorate General of Climate Change is 34 Daops with 125 squads and 1,875 personnel. Meanwhile, the total human resources of Manggala Agni in seven prone provinces are 27 Daops and 1,515 personnel (Table 8).

Forest and land fire control activities are also assisted by Brigdalkarhut, who control forest fires, especially in conservation areas. There are 37 units of the brigade, scattered in the UPT Balai KSDA and Balai National Park, under the Directorate General of KSDAE. Since the 2015-2019 period, KLHK has also facilitated the formation of Brigdalkarhut in KPHP/ KPHL, the Regional Government UPT, totaling 61 units Brigdalkarhut KPHP/KPHL. Infrastructure is prioritized in areas prone to forest and land fires, such as Riau, Jambi, South Sumatra and all regions of Kalimantan (Table 9).

The thirty-four heads of the Indonesian MA operational area (*Kadaops*)

Table 7. Forest and land fire control activities in Indonesia during the Covid-19 Pandemic

No.	Activity
1.	Implementing independent patrols and integrating patrols applies health protocols following established village targets
2.	Improving pre-emptive and preventive efforts among parties in forest and land fires control who care about fire and people with legal awareness
3.	Utilizing weather modification technology to reduce the risk of drought on peatlands
4.	Altering forest and land fire control task force command post
5.	Campaigning/raising awareness of forest and land fires prevention more intensively through various information media
6.	Implementing ground/air extinguishing of forest and land fires as early as possible
7.	Conducting activities to increase the capacity and competence of human resources as well as to fulfil the need of forest and land fire control infrastructure

Source: modified from various sources

Table 8. Data on the distribution of personnel for 34 units of the Manggala Agni Daops in Indonesia

No.	Province	Operational area (Daops)	Team number	Personnel (PNPN)
A	North Sumatera	Sumatera I (Sibolangit)	4	60
		Sumatera II (Pematang Siantar)	4	60
		Sumatera III (Labuhan Batu)	4	60
B	Riau and Riau Islands	Sumatera IV (Pekanbaru)	2	30
		Sumatera V (Dumai)	4	60
		Sumatera VI (Siak)	4	60
		Sumatera VII (Rengat)	4	60
		Sumatera VIII (Batam)	2	30
C	Jambi	Sumatera IX (Kota Jambi)	4	60
		Sumatera X (Muara Bulian)	2	30
		Sumatera XI (Bukit Tempurung)	3	45
		Sumatera XII (Muara Tebo)	4	60
		Sumatera XIII (Sarolangun)	4	60
D	South Sumatera	Sumatera XIV (Banyuasin)	4	60
		Sumatera XV (Musi Banyuasin)	4	60
		Sumatera XVI (Lahat)	4	60
		Sumatera XVII (OKI)	4	60
E	Central Kalimantan	Kalimantan I (Palangkaraya)	5	75
		Kalimantan II (Kapuas)	3	45
		Kalimantan III (Pangkalan Bun)	4	60
		Kalimantan IV (Muara Teweh)	3	45
F	South Kalimantan	Kalimantan V (Banjar)	4	60
		Kalimantan VI (Tanah Laut)	4	60
		Kalimantan VII (Tanah Bumbu)	4	60

Table 8. Continued

No.	Province	Operational area (Daops)	Team number	Personnel (PNPN)
G	West Kalimantan	Kalimantan VIII (Pontianak)	4	60
		Kalimantan IX (Singkawang)	4	60
		Kalimantan X (Ketapang)	4	60
		Kalimantan XI (Sintang)	6	90
H	East Kalimantan	Kalimantan XII (Pasel)	4	60
		Kalimantan XIII (Sangkima)	3	45
I	South Sulawesi	Sulawesi I (Goa)	4	60
		Sulawesi II (Malili)	4	60
J	South east Sulawesi	Sulawesi III (Tinanggea)	2	30
K	Nort Sulawesi	Sulawesi IV (Bitung)	2	30
Total			125	1,875

Source: Ditjen Climate Change Control MOEF, 2020

Table 9. Control Infrastructure in Seven Provinces Prone to Karhutla

No.	Type of equipment	Numbers (Unit)
1.	Filed operation vehicle	27
2.	Equipment vehicle	69
3.	Water tank vehicle	28
4.	Slip-on vehicle	57
5.	Monilog	53
6.	Motor cycle	627
7.	Back pump	1,392
8.	Extinguisher pump	308
9.	Drone	30
10.	Peatland injection	64
11.	GPS	112
12.	CCTV thermal camera	13

Source: Ditjen Climate Change Control MOEF, 2020

perceptions on the forest and land fire control infrastructure indicate that the resources' availability during COVID-19 is preferable (19 people). More specifically, the perception of infrastructures from all participants can be summarized as follows: 19 people (55.9%) said they were good, two people (5.9%) said they were perfect, ten people (29.4%) said it was enough, and only three people (8.8%) said it was not enough. The ability of MA implementers or members to respond to forest and land fire control policies during a pandemic is quite adaptive, where MA members could adjust their method of carrying out their duties and functions with the forest and land fire control policy in a new habit era.

Some improvements in the quality of human resources in controlling forest and land fires during the pandemic were carried out using virtual training on CCTV Thermal Camera operations, virtual training on drone operations and application use, virtual training on occupational health and safety, and webinars on land and forest fire control during the Covid-19 pandemic. There is still a combination of field practice with limited participants and

adherence to health protocols for those who have difficulties participating in the virtual training. Initially, MA members found it difficult to adapt new habits to protect themselves from Covid 19 transmission while on duty. This condition is more strictly applied as they meet people in court and public areas; for example, in handling the case, the Supreme Court, who are later detected positive for Covid, made them go for healing treatment.

In terms of training during the pandemic, there are various opinions. Sixteen members (47.1%) declared that they still need more forest and land fires training, particularly during the pandemic. However, eight members (23.5%) mentioned that the training was unnecessary concerning the COVID-19 situation, and 17.6% said the training was good. One person (2.9%) stated that they were excellent, while two members (5.9%) noted that the training was inferior, and the other two members (5.9%) indicated that they had not had received training.

3. Communication

In general, policy communication delivers policy information from policymakers to policy implementers (Mardika et al., 2018). During the pandemic, forest and land fire prevention are socialization is conducted using traditional methods like informing door to door (to community huts in rice fields/fields/gardens) to avoid activities with more groups. Socialization is also carried out by utilizing various social media platforms, such as the Kalimantan PPIKHL Balai PPIKHL youtube channel and holding a zoom meeting by the Sulawesi Regional PPIKHL Office. At the PPIKHL Sumatera Regional Hall, communication on forest and land fire control is conducted by creating group Whatsapp from field posts, postal command posts, Balai posts, PKHL Directorate posts, and KLHK posts. The fire complaint channel also uses the contact center at the Daops level. Whatsapp groups were also formed to accelerate operations and reporting in the task force. Even sub-task force groups to expedite the command line and implementation of field strategies. The leadership role for work coordination is very important to ensure good communication between divisions in the field, so that the potential for a small fire can be controlled (Zulkifli, 2021).

When implementing the door-to-door method, the MA Daops/Work Lodge members included the TNI, POLRI, local BPBD, and other related Satker (generally agricultural extension). Community leaders are still implementing strict health protocols. The Government established the socialization to prevent forest and land fires and an invitation for the public to comply with the health protocols to prevent the spread of the Covid-19 virus. In this case, most participants (55.9%) stated that the socialization of forest and land fire control policies during the pandemic was significantly good. Three members (8.8%) said it was terrific, eight members (23.5%) said it was enough, five members (14.7%) said it was not enough, and only one member (2.9%) said it was very lacking. Regarding the stakeholder understanding of forest and land fire control policies during the pandemic, four members (11.8%) said they were excellent. Twenty-three members (67.6%) said they were good, six members (17.6%)) stated it was sufficient, and a member (2.9%) stated that it was not enough.

4. Disposition

As for the disposition, MA members obey the forest and land fire control policy to implement health protocols during their duties and implement SWAB Antibody/PCR Rapid Test for members. The routine test is conducted by the Regional PPIKHL Balai or the Regency/City Covid-19 Task Force. For reporting work mechanisms, every level of the land and forest fire control organization must prepare a report on implementing land and forest fire control activities in stages. In this case, the reports refer to monitoring early detection data, early detection field checks, field conditions, forest and land fire control activities, and other activities. Other Task Force

agencies also support controlling forest and land fires during the pandemic, which is shown by maintaining an exceptional commitment to controlling forest and land fires in an integrated manner.

Regarding the work team, the forest and land fire-control task force during the pandemic mentioned that the cohesiveness of the task force team is going well (20 members, 58.9%). Eight members (23.5%) stated that the task force cohesiveness is very good, five members (14.7%) said it was enough, and a member (2.9%) said it was not enough. Community involvement in controlling forest and land fires during the pandemic is expressed as follows: fourteen members (41.2%) stated that community participation was going well, a member (2.9%) said it was perfect, fifteen members (44.1%) said it was enough, and four members (11.8%) said it was not enough.

Supervision of forest and land fire control policies during the pandemic period are conducted in stages hierarchy, starting from management by the Head of the team, the Head of MA at the Daops Level, the Provincial MA Coordinator, the Head of the Forest and Land Fire Section, to the Head of the Regional Office. There is still assistance, monitoring, and evaluation at the site level to ensure that fieldwork is administratively correct. The command structure and organization are still conducted according to the prevailing regulations. Monitoring policy implementation is still completed directly by paying attention to health protocols and online reports and documentation from members of MA. All supervision is conducted periodically at the Balai and Daops levels and external coordination with related parties through correspondence mechanisms or limited direct visits. For the management of forest and land fire control tasks during the pandemic, 20 members (58.9%) stated that the supervisory work was going well, five-member (14.7%) said it was perfect, eight-member (23.5%) said it was enough. Only one person (2.9%) said it was not enough.

D. Supporting and Inhibiting Factors for Implementing Forest and Land Fire Control Policies During a Pandemic

1. Supporting factors

The implementation of forest and land fire control during the pandemic is supported by a more conducive climate factor, vigilance, cooperation, cohesiveness, solidity, and synergy between MA and the parties (Provincial/Regency/City Task Force). The Heads of the Regional Office also appreciate the MA members and all forest and land fire stakeholders in implementing forest and land fire control and is supported by policies and strategies to control forest and land fires during the pandemic period. Especially for the Sumatera region (Riau, South Sumatera, and Jambi), control of forest and land fires during the pandemic was supported by the efforts of TMC in collaboration with KLHK, BNPB, TNI AU, BMKG, private sector, and BPPT, which support the availability of rain at critical times. There are good synergies at the provincial level, starting from early detection through air and ground patrols rapid response to blackout from an integrated team on the ground supported by air-extinguishing operations in burnt areas where water is unavailable or difficult to access by ground troops. This cooperation is needed because fires are caused by many factors such as fuel, climatic factors, social economy, ecology, culture, technology, institutional systems and forest and land management (Akbar, 2011).

Apart from that, other supporting factors are online socialization, social media, the use of technology, and the existence of a legal awareness community program or MPA-Paralegal, which is proven to prevent forest and land fires in prone areas. This effort complements other corrective measures such as a permit moratorium, peat governance, and law enforcement. The collaboration between the members of the land and forest fire control Task Force that went well, 34 the heads of MA's operational areas throughout Indonesia claimed

that other supporting factors for the success of work at the site level were due to the availability of Personal Protective Equipment (PPE), thus providing a sense of comfort and safety for MA members in working during the pandemic. The *Kadaops* also found a reduction in the activities carried out by the community during the pandemic period due to fears of exposure to the virus, which had an impact on decreasing land clearing activities employing burning. Another factor is the increasing awareness of the community to open land without burning it.

2. Obstacle factor

During the Covid-19 pandemic, the task force for handling forest and land fire disasters focused on the region's local area (micro). Operationally, the movement of the forest and land fire control team, especially MA, which operates in the red zone, is limited. The stamina of the officers is expected to be excellent in conducting their duties amid the Covid 19 pandemic by implementing health protocols. The difficulty of supervising MA members to follow health protocols occurs in its environment. The existence of a budget refocusing policy, among others, also impacts supporting operational activities and meeting the need for facilities and infrastructure for forest and land fire control to be less than optimal. The awareness campaign, especially among communities around the area, sometimes did not work well since the concerns of both parties, both from the district and from the MA side of the Task Force team. Meanwhile, efforts to conduct online training encountered obstacles because not all people were friendly to e-learning and distance training. In addition, the threat of damage to biodiversity still occurs because of forests, logging products, forest fires due to inappropriate land use (Khan et al., 2021). Communication is still the main obstacle in the socialization of prevention work because not all areas prone to forest and land fires in Indonesia can be reached by technology

IV. CONCLUSION AND RECOMMENDATION

A. Conclusion

Forest and land fires are still a threat amid the Covid-19 pandemic situation in Indonesia. *Manggala Agni* together other Forest & Land Fire Control Task Force teams, implemented forest and land fire control policies during the Covid-19 pandemic went well, where all operational implementation of forest and land fire control went well was carried out by implementing strict health protocols. During the Covid-19 pandemic in 2020, Indonesia's forest and land fire significantly reduced in the number of hotspots (down to 91.32%) and the burned area (down to 81.7%). Despite, there are still obstacles in controlling hotspots, especially in areas designated as the Covid-19 red zone, generally, there will be no forest and land fires disaster in Indonesia in 2020. The decrease of hotspots was supported by more favorable La Nina climatic factors across the continent and policies due to the Covid-19 pandemic prevention policy. However, the fire challenges in 2020 are very tough, as it will be one of the hottest years in history which is the global warming trend is taking place dramatically. Therefore, if there is no policy and field intervention like MA and the task force team did, the threat of forest and land fires will probably be even more significant. Additionally, when several other countries (i.e., USA, Australia, and Brazil) experienced fire disasters in 2020, Indonesia successfully avoided forest and land disasters during the Covid-19 pandemic. These achievements are achieved from various supporting factors such as natural conditions, the solidarity of the MA team and the Land and Forest Task Force, and prevention efforts by Indonesia's weather modification technology and the voluntary participation of local communities such as Fire Concerned Community and Land and Forest Fire Care Community.

B. Recommendation

Consistency in implementing forest and land fire control work is necessary because the threat of the Covid-19 pandemic is not over yet. Members of *Manggala Agni* and the forest and land fire control task force must strengthen synergies and create innovations to control forest and land fires in a new normal period. For this reason, training and budget support are still needed and synergy among members of the Forest and Land Fire task force, especially during the pandemic. In addition, further research is needed to see the implementation of forest and land fire control policies, with a broader focus and object of study, so fire control policies can run better even during a pandemic situation. This is very important to prevent two disasters, namely fire disasters and COVID-19 disasters.

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DIVERSITY AND CONSERVATION STATUS OF FLORA IN PILAVAKKAL DAM FOOTHILLS OF WESTERN GHATS, TAMIL NADU, INDIA

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DIVERSITY AND CONSERVATION STATUS OF FLORA IN PILAVAKKAL DAM FOOTHILLS OF WESTERN GHATS, TAMIL NADU, INDIA. The floristic study is necessary to understand the present diversity status and conservation of forest biodiversity. It has been realized that the study of local or regional flora is of much more significance than those covering big areas because explorations can be carried out intensively in small areas with damaging consequences. Understanding species diversity and distribution patterns are important to evaluate the complexity and resources of these forests. In the present study, the medicinal floristic diversity of Pilavakkal dam Foothills of the Western Ghats comprised of 127 species belonging to 42 families and 100 genera. Fabaceae, Malvaceae and Lamiaceae were dominant families with 23, 11 and 10 species, respectively. The total number of species includes 55 herbs, 23 shrubs, 37 trees and 12 climbers. Totally 127 important medicinal plant species are recorded in Pilavakkal dam Foot Slopes of Western Ghats. Psydrax dicoccos is vulnerable in this list, 27 plants species are Least Concern and Mangifera indica comes under the Data Deficient and 98 plants species evaluated are not categorized by IUCN. This study provides basic information about the medicinal flora and conservation status of the Pilavakkal dam Foothills of Western Ghats. It would also be helpful for the identification of flora and to derive conservation policies and make sustainable use of plant resources.

Keywords: Western Ghats, Fabaceae, Malvaceae, IUCN, Vulnerable, *Psydrax dicoccos*

KERAGAMAN DAN STATUS KONSERVASI TUMBUHAN OBAT DI KAKI BUKIT BENDUNGAN PILAVAKKAL, GHATS BAGIAN BARAT, TAMIL NADU, INDIA. Studi floristik diperlukan untuk memahami keanekaragaman dan konservasi keanekaragaman hayati hutan. Telah disadari bahwa studi tentang flora lokal atau regional jauh lebih penting daripada studi di wilayah yang luas karena eksplorasi dapat dilakukan secara intensif di wilayah kecil. Memahami keanekaragaman spesies dan pola distribusi penting untuk mengevaluasi kompleksitas dan sumber daya hutan ini. Dalam penelitian ini, keanekaragaman tumbuhan obat pada kaki bukit bendungan Pilavakkal Ghats Barat terdiri dari 127 spesies yang termasuk dalam 42 famili dan 100 marga. Fabaceae, Malvaceae dan Lamiaceae merupakan famili yang dominan dengan 23 jenis, 11 jenis dan 10 jenis. Jumlah spesies meliputi 55 herba, 23 semak, 37 pohon dan 12 pemanjat. Sebanyak 127 spesies tanaman obat penting dicatat di Bendungan Pilavakkal, Lereng Kaki Ghats Barat. Dalam daftar ini Psydrax dicoccos statusnva rentan, 27 spesies statusnya kurangmendapatperhatian dan Mangifera indica statusnya Data Deficient dan 98 spesies tumbuhanlainnya belum dievaluasi oleh IUCN. Studi ini memberikan informasi mendasar tentang flora obat dan status konservasinya di Kaki Lereng Bendungan Pilavakkal Ghats Barat. Data ini akan membantu identifikasi flora dan menjadipertimbangan kebijakan konservasi dan pemanfaatan yang berkelanjutan.

Kata kunci: *Ghats Barat, Fabaceae, Malvaceae, IUCN, Rentan,* Psydrax dicoccos

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I. INTRODUCTION

The forests of the Western Ghats of India are best representatives of non-equatorial tropical evergreen forests of the world (Pascal, 1988; Pascal, 1991). The Western Ghats cover only 5% of the country's total land area but contain more than 5,000 or 27% of the country's total plant species. The Western Ghats is one of the richest centers of endemism in India and nearly 63% of India's arborescent evergreen taxa are endemic to this region (Ramesh & Pascal, 1991). The number of endemic plant species in the Western Ghats is estimated to be about 1,500 (MacKinnon and MacKinnon, 1986). The higher levels of biodiversity and endemism have earned the area to be recognized as one among the biodiversity hotspots of the world (Myers, 1988). The floristic diversity of the Western Ghats is very significant as this hill range accommodates different vegetation types such as wet evergreen forests, moist and dry deciduous forests, montane forests, sholas, scrubs and savannas.

India is endowed with rich and diverse forest resources (Nayar & Sastry, 1987) of the more than 250,000 higher plant species on earth, more than 80,000 are medicinal. India is one of the world 12 biodiversity centres with the presence of over 45,000 different plant species. India's diversity is unmatched due to 16 different agro-climatic zones, 10 vegetation zones, 25 biotic provinces and 426 biomes. About 15,000-20,000 plants have good medicinal value (Joy, Thomas, Mathew & Skaria, 2001). Biodiversity includes diversity within species and between species, and ecosystems (Chaudhary, 1998). It is not evenly distributed everywhere, rather it varies greatly across the globe as well as within different geographical regions. The Convention of Biological Diversity defines documentation of biodiversity as one of the most prioritized tasks by the world. Biodiversity documentation is possible through extensive botanical exploration and floristic studies (Chalise et al., 2018). The floristic study refers to documentation of all plants species in a given geographical region (Simpson, 2006). Such studies help in botanical enumeration, update nomenclature changes, add herbarium specimens in the existing herbaria and compare close or distantly related plants (Chalise et al., 2018). The results of such floristic studies mostly come in the form of floras (Palmer, Wade & Neal, 1995) which may be local, regional, country-wise and so on, or they may be in the form of checklists (Chalise et al., 2018). Floristic wealth is an indispensable part of the natural balance that interprets the effects of the total environment (Billings, 1952). Floristic composition fluctuates from one season to another season in recurring conduct over the years in a succession way. The decline of plant species changes the pattern of the species distribution in the community (Watt, 1964; Heady, 1958).

Medicinal plants which form the backbone of traditional medicine have in the last few decades been the subject of very intense pharmacological studies. This has been brought about by the acknowledgement of the value of medicinal plant as potential source of new compounds of therapeutic value and as source of new compounds in drug development. In many parts of the world medicinal plants are used for antibacterial, antifungal and antiviral activities. A plant derived drugs serve as a prototype to develop more effective and less toxic medicinal products (Manikandan et al., 2019;). Plants have been an important source of medicine for thousands of years. Use of plants for the treatment of many diseases dated back to prehistory and people of all continents have this old tradition (Manikandan et al., 2020). The traditional methods, especially the usage of medicinal plants, still play a vital role to cover the basic health needs in the developing countries and moreover, the use of herbal remedies has risen in the developed countries in the last decade. Plants have provided a source of inspiration of novel drug compounds, as plant derived medicines have made large contributions to human health and well-being. Their role is twofold namely; they provide key chemical structure for the development of new antimicrobial drugs and also as a phytomedicine

to be used for the treatment of diseases (Manikandan & Ramasubbu, 2020). Plants used for the traditional medicine contains a wide range of substance used to treat chronic as well as infectious diseases. A vast knowledge of the plants used against different illnesses may expected to have accumulated in areas where the use of plants is still of great importance (Manikandan et al., 2017). The present study was carried out to survey and document the Assessment of Medicinal Floristic Diversity and conservation status of Pilavakkal dam Foothills of Western Ghats, Tamil Nadu, India.

II. STUDY AREA AND METHOD

The present study was conducted in Srivilliputhur Pilavakkal Dam Foothills of Western Ghats, Virudhunagar District, Tamil Nadu, India. The study area of Pilavakkal Dam lies between 9°64'03"N latitude and 77°52'52"E longitude, it is situated at around 90 km from Madurai and 45 km from Virudunagar. The dam comprises 2 divisions namely the Kovilar and Periyar Dam. The limit of the Periyar dam is 192 million cubic feet (mcft) and the Kovilar Dam is 133 mcft. From October to December, the dam will be loaded with water. The study area of Pilavakkal Dam foothills of Western Ghats is covered by scrub and dry deciduous forest and it has rich and different kinds of medicinal plant diversity (Figure 1 & 2).

Field trips were conducted frequently during summer, winter and in rainy seasons of 2019-2020. All the plant species were collected in the months of the flowering season. Field data were noted in the field diary. Collected plants were identified by referring to Flora of Presidency of Madras (Gamble, 1935; Gamble & Fischer, 1937) Flora of Tamil Nadu Carnatic (Matthew, 1981; Matthew, 1982) and matching with authentic specimens. We collected information about the uses of medicinal plants through the literature and local people. Photographs were taken and herbaria were prepared, which later were deposited at the Department of Botany, Sri Kaliswari College (Autonomous), Sivakasi.

Figure 1. Map of the Study area (Pilavakkal Dam)

Figure 2. View of Pilavakkal Dam

III. RESULT AND DISCUSSION

In the present study, the medicinal floristic diversity of Pilavakkal dam Foothills of the Western Ghats comprised of 127 species belonging to 42 families and 100 genera (Table 1; Figure 4). The total number of species includes 55 herbs, 23 shrubs, 37 trees and 12 climbers. Fabaceae, Malvaceae and Lamiaceae were dominant families with 23, 11 and 10 species, respectively (Figure 3). In this list *Psydrax dicoccos* is Vulnerable and this species is rare in this study area, 27 plants species are Least Concern, *Mangifera indica* is categorized as Data Deficient, and 98 plant species are not evaluated by the International Union for Conservation of Nature (IUCN). There is no effort of the local people to conserve the medicinal plants and there is no local wisdom regarding the sustainable use of these valuable resources.

Plant resources are presented with materials for survival, which has economic, medicinal, or forage values (Morgan, 1981). Many medicinal and economic important tree species are considered as Rare Endangered Threatened (RET) species owing to rapid agricultural and urban development, deforestation and indiscriminate collection (Manikandan et al., 2017). As a plant species is lost from a region, the information enclosed in it will also be slowly distorted and finally become lost forever. The documentation of indigenous knowledge and conservation of a plant species, both are basic burning issues (Cunningham, 1996). The floristic study is necessary to understand the present diversity status and conservation of forest biodiversity. It has been realized that the study of local or regional flora is of much more significance than those covering big areas because explorations can be carried out intensively in small areas with damaging effect. Understanding species diversity and distribution patterns are important to evaluate the complexity and resources of these forests. Floristic studies include species lists, life form spectra, geographical distribution, and identification of threatened species that are useful for evaluating ecological issues such as biodiversity, growth capacity, conservation and regulation (Ali et al., 2018). Documenting the distribution of biodiversity is the first and most fundamental step for effective conservation and sustainable utilisation of natural resources for the future (Gaston, 2000).

Plants have been an important source of medicine for thousands of years

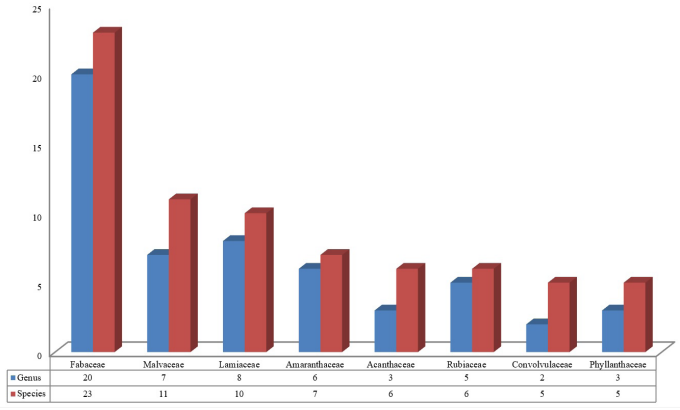

Figure 3. Dominant families with numbers of genus and species recorded in the study area

(Packiyalakshmi et al., 2017; Manikandan et al., 2020). India is a veritable emporium of medicinal and aromatic plants. It has been estimated that out of 15,000 higher plants occurring in India, 9,000 are commonly useful, of which 7,500 are medicinal, 3,900 are edible, 700 are culturally important, 525 are used for fibre, 400 are fodder, 300 for pesticide and insecticide, 300 for gum, resin and dye and 100 for incense and perfume (Anonymous, 1994). In the present study 127 medicinally important plant species were distributed in the Pilavakkal Dam Foothills of the Western Ghats and their uses are described in Table 1. These are taken internally, or applied externally in infusion, decoction, paste or powder. Most of the plants used in medicine are either mixed with other ingredients or used singly.

One hundred twenty-seven plant species were found in the area with medicinal properties. These are depleting rapidly because of unsustainable harvesting, lack of awareness, and unrestricted grazing by domestic animals from nearby villages. Nonetheless, many people from far and wide come to this area to collect medicinal plants and share their knowledge on the medicinal uses of these plants. So, proper conservation and establishment plans are needed to conserve the medicinal plant resources of this area. It would be helpful for the identification of flora and to derive conservation policies and make sustainable use of plant resources.

IV. CONCLUSION

This study provides basic information about the medicinal flora of the Pilavakkal Dam Foothills of Western Ghats, which comprised of 127 species with medicinal properties, belonging to 42 families and 100 genera. *Psydrax dicoccos* is Vulnerable in this list, 27 plants species are under the Least Concern and *Mangifera indica* comes under the Data Deficient, and 98 plants species are Not Evaluated by IUCN. . These medicinal plants are depleting rapidly because of unsustainable harvesting, lack of awareness, and unrestricted grazing by domestic animals from nearby villages. So, proper conservation and establishment plans are needed to protect the medicinal plant resources of this area. .

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Appendix 1. List of Medicinal Floristic Diversity of Pilavakkal Dam Foothills of Western Ghats

No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
Acanthaceae				
1.	*Dicliptera paniculata* (Forssk.) I.Darbysh.	Herb	NE	An essential oil is obtained from the plant showed tuberculostatic activity (Raj Singh et al., 2020)
2.	*Justicia procumbens* Blume.	Shrub	NE	To treat leprosy, ulcers, headaches, gonorrhoea, and bladder infection (Chinnaperumal et al., 2012)
3.	*Justicia Prostrata*(Roxb. ex C. B. Cl.) Gamble	Herb	NE	A decoction of the root is used to treat aches and pains and sore eyes (Sanmugapriya et al., 2015)
4.	*Justicia tranquebariensis*L.f.	Herb	NE	In Comoros a leaf decoction is used as a massage cream to treat the pain of the joints. (Saritha & Brindha, 2013)
5.	*Ruellia patula* Jacq.	Herb	NE	The macerated root is used to relieve the pain of scorpion stings (Ramadevi et al., 2016)
6.	*Ruellia tuberosa* L.	Herb	NE	The people of Biharuse use the plant as a treatment of diarrhoea, cholera and dysentery. (Moronkola, et al., 2015)
Aizoaceae				
7.	*Trianthema portulacastrum* L.	Herb	NE	The bark is febrifuge and can be used as a treatment against Asthma, bronchitis. (Jason Yamaki et al., 2016)
Amaranthaceae				
8.	*Achyranthes aspera* L.	Herb	NE	Treatment of malaria and coughs (MirutseGiday & Gobena Amen, 2003)
9.	*Aerva javanica* (Burm.f.) Juss. ex Schult	Herb	NE	The leaves and seeds are used in the treatment of eye problems such as ophthalmia (Qureshi & Bhatti, 2008)
10.	*Alternanthera sessilis* (L.) R.Br. ex DC.	Herb	LC	The plant is said to be abortifacient, cholagogue, febrifuge and galactagogue (Sanoussi et al., 2015)
11.	*Amaranthus spinosus* L.	Herb	NE	The plant is used as anti-inflammatory and stomach ache (Anisuzzaman et al., 2007)
12.	*Amaranthus viridis* L.	Herb	NE	It is used in the treatment of internal bleeding, diarrhoea. (Ignacimuthu et al., 2008)
13.	*Gomphrena celosioides*Mart.	Herb	NE	A decoction of the entire plant is used to stop dysentery and inflammations (Ayyanar et al., 2010)
14.	*Ouret lanata* (L.) Kuntze	Herb	NE	The whole plant, but especially the leaves and the roots, is a powerful astringent (Upadhyay et al., 2008)
Anacardiaceae				
15.	*Mangifera indica* L.	Tree	DD	It destroys a wide range of parasitic organisms and is spermicidal (Rasingam, 2012)

No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
Annonaceae				
16.	*Monoon longifolium* (Sonn.) B.Xue&R.M.K.Saunders	Tree	NE	It is used to treat liver disorder such as hepatitis and jaundice. (Dattatray et al., 2021)
Apocynaceae				
17.	*Cascabela thevetia* (L.) Lippold	Tree	LC	The root is used as a diuretic to treat jaundice, enlarged spleen, gonorrhoea (Dhivya & Kalaichelvi, 2016)
18.	*Dregea volubilis* (L. f.) Benth. ex Hook. f.	Climber	NE	The ash of the flower is taken to relieve heartburn and enlarged spleen and liver (Kakrani & Saluja, 2002)
19.	*Hemidesmus indicus* (L.) R. Br.	Climber	NE	The wood ashes are used to treat general body pains (Nandy et al., 2020)
20.	*Pergularia daemia*(Forsk.) Chiov.	Climber	NE	The leaf juice has been used as a treatment for earache (Xavier et al., 2014)
21.	*Wrightia tinctoria* (Roxb.) R. Br.	Tree	LC	A bark or leaf decoction is taken to loosen the bowels, as an emetic, and is said to be an effective cure for intermittent fevers (Reddy et al., 2006)
Arecaceae				
22.	*Borassus flabellifer* L.	Tree	NE	A decoction of the twigs is used for treating swelling (Ganesh et al., 2016)
Asteraceae				
23.	*Parthenium integrifolium* L.	Herb	NE	It is used for obesity and diabetes (Shaheen et al., 2014)
24.	*Tridax procumbens* L.	Herb	NE	An infusion of the roots is used as a medicine for chest pain, the leaves to treat diarrhoea (Chiranjibi et al., 2008)
Bignoniaceae				
25.	*Millingtonia hortensis* L.f.	Tree	NE	A decoction of the seeds is used to treat rheumatism, gonorrhoea, diarrhoea and dysentery, and as a wash to treat piles (Kavitha & Mary Kensa, 2016)
Cactaceae				
26.	*Opuntia dillenii* (Ker Gawl.) Haw.	Shrub	NE	The powdered, ripe seeds are aperient and purgative (Ayyanar & Ignacimuthu, 2011)
Capparaceae				
27.	*Cadaba fruticosa* (L.) Druce	Shrub	NE	The juice of the roots and leaves is considered to be a useful treatment for diabetes (Arulappan et al., 2015)
28.	*Crateva religiosa* G.Forst.	Tree	LC	The leaves are pounded and soaked in warm water and then the solution is drunk to treat diarrhoea (Kannan et al., 2015)
29.	*Maerua apetala* (Roth) M. Jacobs	Tree	NE	The leaves have been used to increase appetite, as an aid to digestion. (Johnson Gritto et al., 2015)

No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
Casuarinaceae				
30.	*Casuarina equisetifolia* L.	Tree	LC	The leaves are used as plaster to reduce swelling. (Harsha et al., 2003)
Cleomaceae				
31.	*Cleome gynandra* L.	Herb	NE	The bark is a laxative and also stimulates the appetite (Bedi, 1978)
32.	*Cleome viscosa* L.	Herb	NE	A decoction made of the roots is used in local medicine against fever (Ravindra, 2009)
Combretaceae				
33.	*Terminalia arjuna* (Roxb. ex DC) Wight &Arn.	Tree	NE	Poultices of the leaves are used to treat minor cuts and bruises (Elavarasi & Saravanan, 2012)
34.	*Terminalia catappa* L.	Tree	LC	A decoction of the whole plant is used as a treatment for conditions such as anasarca, anuria (Bhargava, 1983)
Commelinaceae				
35.	*Commelina benghalensis* L.	Herb	LC	The plant is used in piles, dysentery and eye diseases (Ayyanar & Ignacimuthu, 2009)
Convolvulaceae				
36.	*Evolvulus alsinoides* (L.) L.	Herb	NE	It serves as an antidote to snake poison (Singh, 2008)
37.	*Ipomoea aquatica* Forssk.	Herb	LC	The leaf paste is used to treat rheumatic pain, cough, fever and severe cold (Kumar, 2013)
38.	*Ipomoea carnea* Jacq.	Shrub	NE	In folks medicine, to increase fertility in women, fresh leaves are ground with *Oryza sativa* and the extract is drunk after menses (Singh et al., 2020)
39.	*Ipomoea pes-tigridis* L.	Climber	NE	The roots and leaves are often employed to alleviate fever (Shanmugam, 2012)
40.	*Ipomoea sagittifolia* Burm.f	Climber	NE	The stem, taken internally, is famed as a treatment for asthma, bronchitis and various other lung complaints (Chakraborty, 2020)
Cucurbitaceae				
41.	*Coccinia grandis* L. Voigt	Climber	NE	It is used extensively as a febrifuge and tonic. (Rasingam, 2012)
Euphorbiaceae				
42.	*Acalypha indica* L.	Herb	NE	It is serving as anthelmintic, anti-inflammation, anti-bacterial, anti-cancer, anti-diabetes, anti-hyperlipidemic, anti-obesity, anti-venom, hepatoprotective, hypoxia, and wound healing medicine (Zahidin et al., 2017)
43.	*Euphorbia hirta* L.	Herb	NE	The juice of the root is used in the treatment of fevers (Ayyanar & Ignacimuthu, 2009)

No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
44.	*Jatropha glandulifera* (Roxb.)	Shrub	NE	Treatment for Anorexia, Dyspepsia, Cough and Spleen (Basha et al., 2020)
45.	*Ricinus communis* L.	Shrub	NE	The leaf sap is used as a demulcent to treat gonorrhoea and cough, and is also applied to wounds and ulcers (Roy & Janbandhu, 2020)
Fabaceae				
46.	*Abrus precatorius* L.	Climber	NE	It is used to cure respiratory problems and skin infections (Garaniya & Bapodra 2014)
47.	*Acacia auriculiformis* A. Cunn. ex Benth.	Tree	LC	The gum is used externally to cure gonorrhoea (Bhasha & Reddy, 2017)
48.	*Albizia amara* (Roxb.) Boivin	Tree	LC	The root of the plants is used to the treatment of demulcent, astringent, diuretic (Ganesh et al., 2016)
49.	*Albizia lebbeck* (L.) Benth.	Tree	NE	The leaves are used for the treatment of Jaundice, inflammation and diabetes (Kichu et al., 2015)
50.	*Alysicarpus monilifer* (L.) DC.	Herb	NE	The seed and a paste of the stem bark is used in treating ringworm (Karthikeyan et al., 2014)
51.	*Clitoria ternatea* L.	Climber	NE	Applied externally, the leaves are made into an ointment for treating skin diseases, wounds, sores, ulcers and haemorrhoids (Pulok et al., 2008)
52.	*Dichrostachys cinerea* (L.) Wight &Arn.	Tree	LC	A tincture of the seed is used in India to kill lice (Shubashini & Uma 2010)
53.	*Erythrina variegata* Linn.	Tree	LC	It is used as carminative, lessens inflammation and fever (Bhandary et al., 1995)
54.	*Hardwickia binata* Roxb.	Tree	LC	An infusion is used as a remedy for dysentery and as a blood purifier (bitter tonic) to reduce blood-sugar levels (Basha et al., 2011)
55.	*Indigofera linifolia* (L. f.) Retz.	Shrub	LC	The mashed leave are applied as a poultice on sores, boils and pimples (Savithramma et al., 2007)
56.	*Indigofera tinctoria* L.	Shrub	NE	It is used for curing sterility in women (Johnsy Mary et al., 2020)
57.	*Mimosa pudica* L.	Herb	LC	The seed oil is sometimes used as a cathartic, although it may cause strong irritation and even poisoning (Singh & Singh, 2009)
58.	*Peltophorum pterocarpum* (DC.) Backer ex K. Heyne.	Tree	NE	The juice of the leaves is used in ophthalmia (Jeeva & Femila, 2012)
59.	*Pongamia pinnata* (L.)	Tree	LC	It gives antiulcerogenic effects (Ayyanar & Ignacimuthu, 2009)
60.	*Prosopis juliflora* (Sw.) DC.	Tree	NE	It has been used for poisonous bites (Qasim et al., 2014)
61	*Samanea saman* (Jacq.) Merr.	Tree	LC	The root is sweet and bitter-tasting, refrigerant, antifebrile (Vaidyanathan et al., 2013)

No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
62.	*Senegalia catechu* (L. f.) P.J.H.Hurter&Mabb	Tree	NE	The leaf sap is used to treat sores of the eyes and nose (Dinesh & Aruna, 2010)
63.	*Senna auriculata* (L.) Roxb.	Shrub	NE	They are used in the treatment of coughs, colds and bronchitis (Ignacimuthu et al., 2008)
64.	*Senna occidentals* (L.) Link	Shrub	NE	A paste of the root is applied for leucoderma (Singh & Singh, 2009)
65.	*Tamarindus indica* L.	Tree	LC	The bark is astringent, homeostatic and antirheumatic (Rasingam, 2012)
66.	*Tephrosia purpurea* L.	Herb	NE	It is used for edema, cough and aphrodisiac (Perumal Samy et al., 2008)
67.	*Vachellia leucophloea* (Roxb.) Maslin, Seigler&Ebinger	Tree	LC	The leaves are used to treat colds, rheumatism, eczema (Koche et al., 2008)
68.	*Vachellia nilotica* (L.) P.J.H.Hurter&Mabb	Tree	LC	Leaves and roots of cork tree used as antiasthmatic and antimicrobial activity. (Raj Kumar Verma, 2014)
Lamiaceae				
69.	*Anisomeles malabarica* (L.) R. Br	Herb	NE	The leaves are bitter, mildly sudorific, tonic (Shanmugam et al., 2020)
70.	*Endostemon viscosus* (Roth) M. R. Ashby	Shrub	NE	It helps to the management of toothaches, amenorrhoea, dyspepsia and sore throat (Kottaimuthu, 2008)
71.	*Leucas aspera* (Willd.) Link	Herb	NE	The flowers have been used to treat leprosy and blood diseases (Ayyanar et al., 2011)
72.	*Mesosphaerum suaveolens* (L.) Kuntze.	Herb	NE	It reduces the Hypertension (Kommidi et al., 2020)
73.	*Ocimum basilicum* L.	Herb	NE	The roots, leaves and fruits may have anthelmintic and anti-oxidant properties (Ayyanar & Ignacimuthu, 2009; Manikandan & David noel, 2019)
74.	*Ocimum filamentosum* Forssk.	Herb	NE	It is used to treat headache, cough, diarrhoea and warts. (Qwarse et al., 2018)
75.	*Ocimum tenuiflorum* L.	Herb	NE	The leaves used to treatment of bronchitis, malaria, diarrhoea, skin disease (Ayyanar & Ignacimuthu, 2011)
76.	*Orthosiphon aristatus* (Blume) Miq.	Herb	NE	The essential oils from the leaf have shown antibacterial and antifungal activity (Mina & Mina, 2017)
77.	*Tectona grandis* L.f.	Tree	NE	A decoction of the leaves is used as a wash for poisonous bites (Bhandary et al., 1995)
78.	*Vitex negundo* L.	Shrub	LC	The fruit is said to have a value in the treatment of diabetes (Morvin Yabesh et al., 2014)

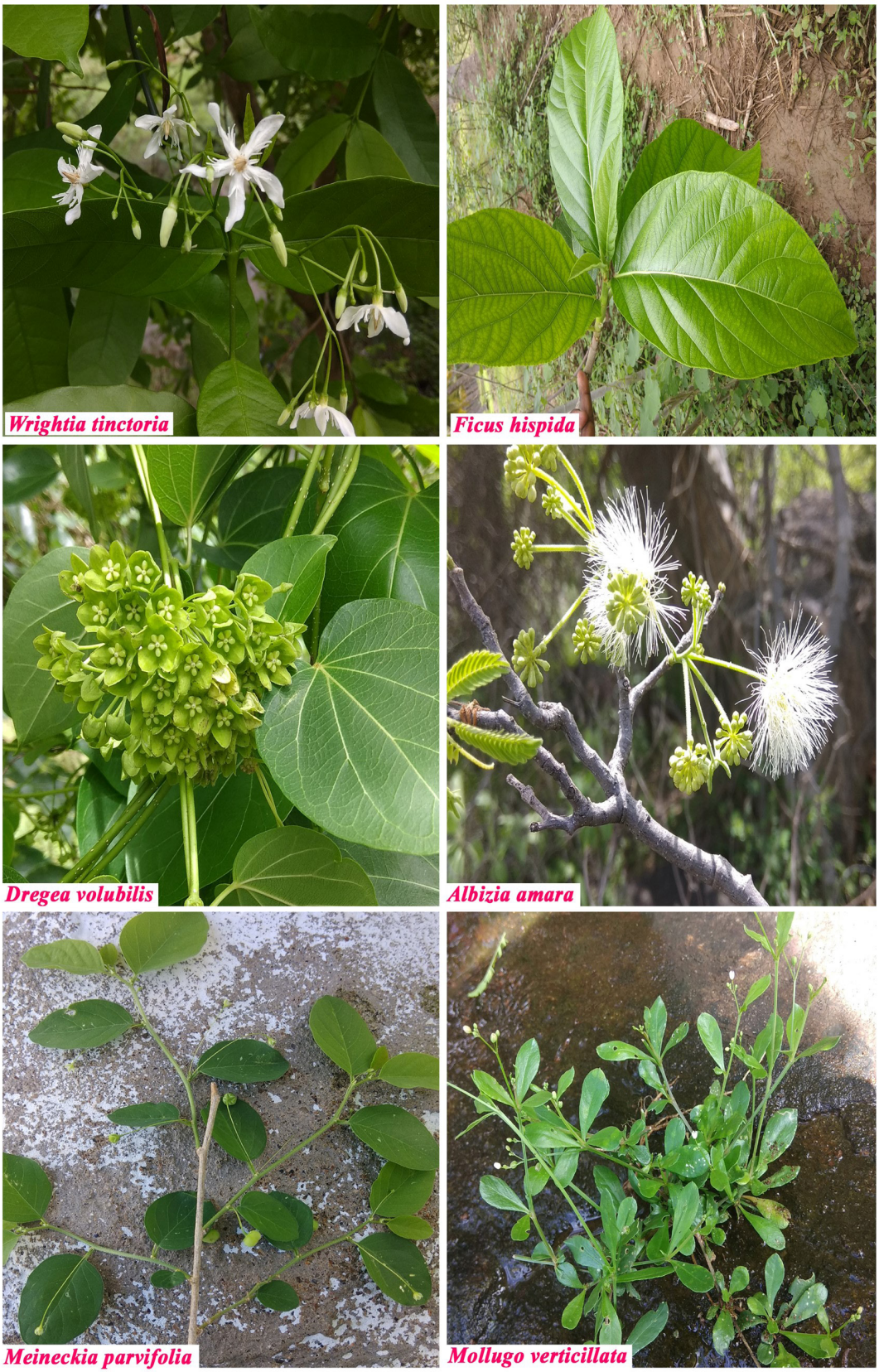
No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
Malvaceae				
79.	*Abutilon indicum* (L.) Sweet	Shrub	NE	They were widely used in traditional medicine to prevent diseases such as diabetes, kidney stone, edema, rheumatism, hepatitis, hypertensive and jaundice. (Shubashini & Uma, 2010)
80	*Corchorus capsularis* L.	Herb	NE	The roots are used to treat headache, as a demulcent, to cure coughs and as a vermifuge (Dutta et al., 2016)
81.	*Corchorus tridens* L.	Herb	NE	It is indicated for general bacteria, bronchitis, colitis, cold, cough, fatigue, immune depression, and non-specific infections (Choudhary et al., 2016)
82.	*Hibiscus vitifolius* L.	Shrub	NE	The leaf contains substances that have possible antimicrobial activity (Basha et al., 2011)
83.	*Pavonia procumbens* (Wright &Arn.) Walp.	Shrub	NE	The leaf extracts having high antioxidant potential (Ignacimuthu et al., 2008)
84.	*Pavoniazeylanica* (L.) Cav.	Shrub	NE	It is used to treat viral warts and chronic disease of the nervous system (Ignacimuthu et al., 2008)
85.	*Sida acuta* Burm.f.	Herb	NE	The plant is taken as an emmenagogue and oxytocic and the root is considered antibilious (Datta et al., 2014)
86.	*Sida cordata* (Burm.f.) Borss. Waalk.	Herb	NE	It is used for gargles and tooth powders (Ignacimuthu et al., 2008)
87.	*Sida cordifolia* L.	Herb	NE	The whole plant is used as an anthelmintic, antiseptic, antivenin. (Savithramma et al., 2007)
88.	*Sida rhombifolia* L.	Herb	NE	It is also used by mothers after childbirth to bring relief to painful wombs and to treat colic (Bhandary et al., 1995)
89.	*Sterculia foetida* L.	Tree	NE	The fruits have diuretic, laxative and purgative activities and also show molluscicidal and antimicrobial properties. (*Putri & Bashri, 2019)*
Meliaceae				
90.	*Azadirachta indica* A. Juss	Tree	LC	It is used for antiseptic, head ache, earache and ophthalmia (Ayyanar & Ignacimuthu, 2011)
Menispermaceae				
91.	*Cyclea peltata* (Lam.) Hook. f. &Thoms.	Climber	NE	The seed oil is given as a stomachic and cholagogue (medicinal agent which promotes the discharge of bile from the system, purging it downward) in the treatment of dyspepsia and cases of sluggish liver (Begum & Nath, 2000)

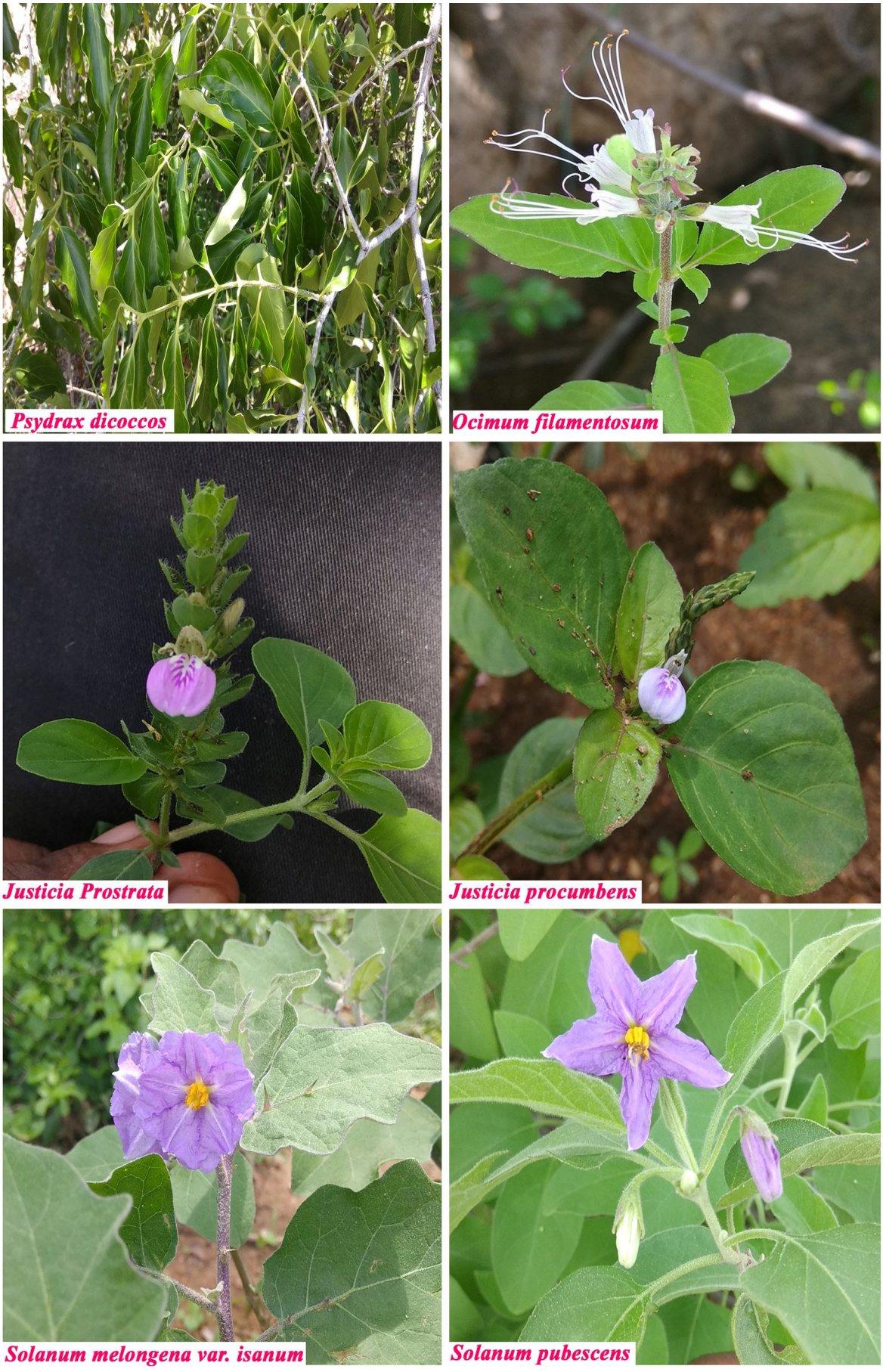
No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
Molluginaceae				
92.	*Mollugo verticillata* L.	Herb	NE	It is used to treat diarrhoea and cure ulcer (Core, 1967)
93.	*Trigastrotheca pentaphylla* (L.) Thulin	Herb	NE	The leaves have been shown to have antibacterial, antibiotic, antispasmodic and astringent (Balkrishna et al., 2018)
Moraceae				
94.	*Ficus benghalensis* L.	Tree	NE	The bark extracts applied on fracture and used in fever (Ayyanar & Ignacimuthu, 2011)
95.	*Ficus hispida* L. f.	Tree	LC	It is so effective that it is regularly used to clear the digestive tract in cases of poisoning (Bhargava, 1983)
Myrtaceae				
96.	*Syzygium cumini* (L.) Skeels	Tree	LC	It is used to cure eye sore, renal infection, cough (Dahare & Aruna et al., 2010)
Nyctaginaceae				
97.	*Boerhavia diffusa* L.	Herb	NE	It has been used as a diuretic, anti-diabetic (Aeri et al., 2014)
98.	*Boerhavia erecta* L.	Herb	NE	The plant decoction is used for treatment of skin problems such as dermatitis, eczema and pruritus (Rao et al., 2006)
Passifloraceae				
99.	*Passiflora foetida* L.	Climber	NE	The plant is strongly astringent, encouraging clotting of the blood (Ajesh et al., 2012)
Pedaliaceae				
100.	*Pedalium murex* L.	Herb	NE	The seeds are used to cure eye diseases, gonorrhoea and gout (Balakrishnan et al., 2009)
Phyllanthaceae				
101	*Flueggea leucopyrus* Willd.	Shrub	NE	All plant parts are said to have tonic, diuretic, stomachic and febrifuge properties (Jagtap et al., 2009)
102.	*Meineckia parvifolia* (Wight) G. L. Webster	Shrub	NE	A decoction of the whole plant is used as a treatment for fevers (Sreeja et al., 2016)
103.	*Phyllanthus amarus* Schumach. &Thonn.	Herb	NE	The juice of the leaves is used to treat cuts and wounds (Ignacimuthu et al., 2008)
104.	*Phyllanthus emblica* L.	Tree	NE	The plant is antipruritic, aphrodisiac, astringent, diuretic, emollient, febrifuge and tonic (Savithramma et al., 2007)
105.	*Phyllanthus maderaspatensis* L.	Herb	NE	The juice of the leaves is mixed with vinegar to make an anti-inflammatory and digestive remedy (Meyanungsang et al., 2015)

No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
Poaceae				
106.	*Cymbopogon citratus* (DC.) Stapf	Herb	NE	Various parts are used in decoction, cholera, bronchitis, dysuria. Essential oil used for anti-microbial activity (Machraoui et al., 2018; Manikandan et al., 2021)
107.	*Cynodon dactylon* (L.) Pers.	Herb	NE	It is used to treatment of headache, menstrual pain and ulcer (Ignacimuthu et al., 2008)
Rubiaceae				
108.	*Mitracarpus hirtus* (L.) DC.	Herb	NE	A tincture of the leaves is said to alleviate neuralgic pains (*Rizki et al., 2019)*
109.	*Morinda tinctoria* (Roxb.)	Shrub	NE	It is used to heal stomach ailments and also used as a tonic and anti-dandruff (Ayyanar & Ignacimuthu, 2009)
110.	*Oldenlandia umbellata* L.	Herb	NE	The sap is used to treat eczema, worms and ringworm (Savithramma et al., 2007)
111.	*Psydrax dicoccos* Gaertn.	Tree	VU	It is used in the treatment of gonorrhoea (Ranjithkumar et al., 2014)
112.	*Spermacoce hispida* L.	Herb	NE	Leaves and bark extracts are used for controlling blood pressure (Shubashini & Uma, 2010)
113.	*Spermacoce ocymoides*Burm.f.	Herb	NE	A decoction of the flower buds is used as a remedy for children's bedwetting and urinary complaints (Ayyanar & Ignacimuthu, 2009)
Rutaceae				
114.	*Toddalia asiatica* (L.) Lam.	Shrub	NE	The bark has been used as an astringent and in the treatment of bronchitis (Ayyanar & Ignacimuthu, 2009)
Sapindaceae				
115.	*Cardiospermum halicacabum* L.	Climber	LC	A fruit extract is used to relieve bodily pains and inflammatory problems (Shubashini & Uma, 2010)
Sapotaceae				
116.	*Madhuca longifolia* (J. Koenig. ex L.) J.F.Macbr	Tree	NE	The juice from the leaves is used traditionally to treat earache (Ayyanar & Ignacimuthu, 2009)
Simaroubaceae				
117.	*Ailanthus excels* Roxb.	Tree	NE	Various parts of the tree, such as the leaves and fruit, contain tannins and are astringent (Savithramma et al., 2007)
Solanaceae				
118.	*Solanum melongena* var. *isanum* (L.)	Herb	NE	It is used to boost digestive function and to treat fevers (Ignacimuthu et al., 2008)

No.	Name of the Species	Habit	IUCN Status 2021-1	Medicinal uses
119.	*Solanum pubescens* Willd.	Shrub	NE	The leaves are diuretic and are applied in the treatment of oedema, jaundice, painful discharge of urine and dropsy (Sasi & Rajendran, 2012)
120.	*Solanum virginianum* L.	Shrub	NE	The stems are used in the treatment of scabious skin diseases and psoriasis (Sadaf et al., 2014)
Typhaceae				
121.	*Typha angustifolia* L.	Herb	NE	They are used as a treatment against bronchial catarrh, dysentery, and diarrhoea (Punnam Chander et al., 2015)
Ulmaceae				
122.	*Holoptelea integrifolia* (Roxb.) Planch.	Tree	NE	The whole plant is used as a mild laxative medicine and also as stomachic, antiseptic and emmenagogue. (Raj Kumar Verma, 2014)
Verbenaceae				
123.	*Gmelina arborea* (Roxb.) ex Sm.	Tree	LC	The leaves have been mixed with oil and used as a poultice on sores (Murtem and Pradeep, 2016)
124.	*Lantana camara* L.	Shrub	NE	The pods and foliage are a protein-rich fodder source. (Ignacimuthu et al., 2008)
125.	*Priva cordifolia* (L. f.) Druce	Herb	NE	The root has been used to treat tuberculosis and is also said to cure impotence (Ignacimuthu et al., 2008)
Vitaceae				
126.	*Cissus quadrangularis* L.	Climber	NE	The aromatic leaves are astringent, febrifuge, sedative, tonic and vermifuge (Reddy et al., 2016)
Zygophyllaceae				
127.	*Tribulus terrestris* L.	Herb	LC	The seeds are anthelmintic, aphrodisiac, astringent and febrifuge (Ayyanar & Ignacimuthu, 2011)

Appendix 2. Medicinal Floristic Diversity of Pilavakkal Dam Foothills of Western Ghats




Psydrax dicoccos
Ocimum filamentosum
Justicia Prostrata
Justicia procumbens
Solanum melongena var. isanum
Solanum pubescens


Ipomoea sagittifolia


Mimosa pudica


Spermacoce ocymoides


Endostemon viscosus


Cascabela thevetia


Ipomoea pes-tigridis

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ECONOMIC VALUE OF WILDLIFE SANCTUARY: A CASE STUDY FROM THE WESTERN GHATS IN KARNATAKA, INDIA

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ECONOMIC VALUE OF WILDLIFE SANCTUARY: A CASE STUDY FROM THE WESTERN GHATS IN KARNATAKA, INDIA. Goods and services of the ecosystem provided by the natural environment have not been considered in terms of their economic value. There are a number of studies that have estimated the economic value of forest ecosystem services in India, but very few studies have estimated these economic values of other important ecosystem services. Biligiri Rangaswamy Temple Wildlife Sanctuary (BRTWLS) is a unique place as a bridge between the Western Ghats and the Eastern Ghats in Karnataka, India. There are 12,500 *Soligas* (tribal community) living in this area. Non-timber forest products constitute more than 60% of the *Soliga* household income. A number of studies have been conducted in the BRTWLS. However, there is a lack of studies on the economic value. The primary objective of this study is to estimate the value of ecosystem services provided by BRTWLS. This study has used the market price methods for estimating the value of provisioning services and individual travel cost method for estimating the value of recreation services, while the value of carbon sequestration and soil erosion prevention has been estimated based on secondary data. This study has estimated the total annual value of provisioning, regulating and cultural services of BRTWLS at Rs 23.9 million y-1. The findings of the study will be helpful to the local policy makers to increase the entry fee at the BRTWLS, as it provides valuable ecosystem services and reinvests the same in natural capital to achieve environmental sustainability at the local level.

Keywords: Ecosystem services, economic value, brt wildlife sanctuary, travel cost method

NILAI EKONOMI SUAKA MARGASATWA: STUDI KASUS DARI GHATS BARAT DI KARNATAKA, INDIA. Barang dan jasa ekosistem yang disediakan oleh lingkungan alam belum dipertimbangkan dari segi nilai ekonominya. Ada sejumlah penelitian yang memperkirakan nilai ekonomi jasa ekosistem hutan di India, tetapi sangat sedikit penelitian yang memperkirakan nilai ekonomi jasa ekosistem penting lainnya. Suaka Margasatwa Kuil Biligiri Rangaswamy (BRTWLS) merupakan area unik sebagai jembatan antara Ghats Barat dan Ghats Timur di Karnataka, India. Ada 12.500 Soliga (komunitas suku) yang tinggal di daerah ini. Hasil hutan bukan kayu menyumbang lebih dari 60% pendapatan rumah tangga Soliga. Sejumlah penelitian telah dilakukan di BRTWLS. Namun, studi tentang nilai ekonomi masih kurang. Tujuan utama dari studi ini adalah untuk memperkirakan nilai jasa ekosistem yang disediakan oleh BRTWLS. Penelitian ini menggunakan metode harga pasar untuk memperkirakan nilai jasa penyediaan dan metode biaya perjalanan individu untuk memperkirakan nilai jasa rekreasi, sedangkan nilai penyerapan karbon dan pencegahan erosi tanah telah diperkirakan berdasarkan data sekunder. Studi ini memperkirakan total nilai tahunan dari jasa penyediaan, pengaturan dan budaya BRTWLS sebesar Rs 23,9 juta y-1. Temuan studi ini akan membantu pembuat kebijakan lokal untuk meningkatkan biaya masuk di BRTWLS, karena memberikan jasa ekosistem yang berharga dan menginvestasikan kembali modal alam yang sama untuk mencapai kelestarian lingkungan di tingkat lokal.

Kata kunci: Jasa ekosistem, nilai ekonomi, suaka margasatwa, suaka margasatwa kuil biligiri rangaswamy, metode biaya perjalanan

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I. INTRODUCTION

Biligiri Rangaswamy Temple Wildlife Sanctuary (BRTWLS) is a unique place as a bridge between the Western Ghats and the Eastern Ghats in Karnataka, India. BRT wildlife sanctuary has spread over 574.8 km^2 with a very rich biodiversity. According to 2011 Census, there are 12,500 *Soligas* (the tribal community) living in the BRT wildlife sanctuary. Non-timber forest products constitute more than 60% of the *Soliga* tribal household income. Already, a number of studies have been conducted in the BRTWLS, for example, human dependence and ecological impacts, biodiversity conservation and livelihoods (Bawa, Rai and Sodhi, 2011) and extraction of non-timber forest products, assessing biodiversity status, use of traditional knowledge for forest management, ecological sustainability of non-timber forest products, human - wildlife conflict (Karanth et al., 2013), and invasive species (Sundaram et al., 2012). However, there is a lack of studies on the economic value of the BRTWLS. Therefore, this study estimates the economic value of provisioning, carbon sequestration, soil erosion prevention and recreational services of the BRTWLS in Karnataka, India. In addition, better conservation of natural resources can help to achieve Sustainable Development Goals at the local level. (Wood et al., 2017; Veidemane et al., 2019; Yin et al., 2021; Palacios et al., 2021).

There are a number of studies that have dealt with the economics of ecosystem services in India. For example, Verma et al., (2017) estimated the economic value of six tiger reserves at US $ 128 million to US$ 271 million and US $ 344 million to US$ 10.08 billion respectively. Badola et al., (2010) estimated the recreational value of the Corbett Tiger Reserve at US$ 167,619 and the value of carbon sequestration at US$ 63.6 million. Ninan and Kontoleon, (2016) estimated the economic value of 10 ecosystem services and 2 disservices (wildlife damage and forest fire) of the NagarholeNational Park in Karnatakaat between US$13 -148 million.

Manoharan (1996) estimated the value of ecotourism in Periyar Tiger Reserve in Kerala using the contingent valuation and travel cost methods, at Rs 676 per ha. The economic value of recreational services of sacred lake in Sikkim (Khecheopalri Lake) has been estimated at US $ 0.88. million. Many works have been conducted in respect of the Yamuna river Basin. Balasubramanian (2017) estimated the economic value of recreation services at Rs 4.4 million provided by Lalbagh botanical garden based on the travel cost method, while, the value of forest was estimated to Rs 0.93 million for Karnataka (Balasubramanian, 2013).

In the Indian context there are a number of studies that have estimated the economic value of forest ecosystem services (see table 1), but, very few studies have estimated these economic values of other important ecosystem services, for examples Ninan and Kontoleon (2016); Verma et al (2017; Chopra and Kadekodi (1997). Moreover, considering that India accounts for a major global biological diversity, ecosystems like forests, wetlands etc., provide more benefits to human beings. But, the existing economic growth models being followed the world over has increasingly led to the degradation of the ecosystems and their valuable services. Therefore, there is a need for quantification of the economic valuation studies for a better understanding of the importance of the ecosystem services as well as sustainable use of the ecological resources. Moreover, most of the studies focus mainly on the tangible benefits of a very few ecosystem services. But intangible benefits are more important to human well-being (MEA, 2005). Hence, the present study focuses on both the tangible and intangible benefits of the ecosystem services provided by the BRT protected area.

II. MATERIAL AND METHODS

A. Study Area

The BRTWLS is located in the Western Ghats of Karnataka. The altitude of BRT wildlife sanctuary ranges from 600m to 1,800m and the total average annual rainfall is 1,500mm. The present study focuses on the value of

Table 1. Economics of Ecosystem services studies in India

No.	Author	Area	Types of ESS	Methods	Value
1.	Badola& Hussain 2005	Bhitarkanika Mangrove Ecosystem	Provisioning services	Damaged cost avoided approach	$153.74 (per household)
2.	Anneboina& Kavi Kumar 2016	India	Coastal protection, carbon sequestration	Direct market valuation approach	US $ 5.9 billion
3.	Murali, Redpath & Mishra, 2017	Spiti Valley, Indian Trans-Himalaya	Provisioning, regulating and cultural services	Market price method, replacement cost method	US$2,667 per household
4.	Joshi & Negi, 2011	Western Himalaya	Provisioning and regulating services	Market price method, replacement cost method	US$ 74.05US$
5.	Verma, 2007	Uttarakhand	Provisioning services, regulating services	Market price method, replacement cost method	US$$ 0.86 million
6.	Ramachandra, 2016	Karnataka	Provisioning services, regulating services	Market price method, replacement cost method	US$ 1,100.16
7.	Bulov and Lundgren, 2007	Kerala	Recreational services	Travel cost method	$15 billion
8.	Chaudhury, 2006	Chandigarh	Recreational services	Travel cost method and Contingent valuation method	$0.3 million
9.	Chaudhury and Tewari 2010	Chandigarh	Recreational services	Zonal Travel cost method	$1.2 million
10.	De and Devi, 2011	Meghalaya	Recreational services	Travel cost and Contingent valuation	$ 4.8 million
11.	Gera et al 2008	Uttarakhand	Recreational services	Zonal Travel cost method	US $4019
12.	Ninan and Kontoleon, 2016	Karnataka	Provisioning, regulating and cultural services	Market price method, replacement cost method	$ 13.07 million to 147.11 million
13.	Manoharan	Kerala, Karnataka	Recreational services	Contingent valuation method	$ 22.8 million
14.	Nadkarni et al 1994	Karnataka	Provisioning services,	Net Present Value	$0.07 million
15.	Bisht N S (2017)	Mizoram	Provisioning, regulating and cultural services	Market price method, replacement cost method	$ 72 million
16.	Bahuguna and Bisht (2013)	India	Regulating services, value of		US$ 0.9 million
17.	Badola et al (2010)	Uttarakhand	Provisioning, regulating and cultural services	Travel cost, replacement cost	$ 105.2 million
18.	Pandit et al (2015)	Assam	Provisioning and cultural services	Travel cost	US$ 6.2 million
19.	Sinha and Mishra (2015)	Uttarakhand	Provisioning, regulating and cultural services	Market price method, contingent valuation method	Indirect services per hectare US $ 14.4 and direct services US$ 14.11

Sources: Various publications

minor forest products which are produced by the locals such as coffee, fruits and silver wood as provisioning services and carbon sequestration and soil prevention as regulating services while recreation as cultural services. BRTWLS is home to a number of species such as hanuman langur and giant flying squirrel, leopard sandcats in the moist deciduous and evergreen forests, Asian palm civet, sambar deer, chital and wild pig. Tigers and sloth bears are also found in the wildlife sanctuary. BRTWLS has a number of Asian elephants, the density of which has been estimated at 1.7/ km^2. Moreover, BRTWLS has a large density of herbivore species per km2 such as chital (13.96), gaur (5.08), muntjac (3.70), wild pig (5.33), bonnet macaque (6.56),the Hanuman langur (6.34) and the total biomass density is 4,127.82 kg/km^{-2} (Kumara and Rathnakumar, 2010).

B. Provisioning Services

Soliga is one of the predominant tribes in the Western Ghats of Karnataka. *Soligas* are dependent on the forest for their basic requirements such as food, fodder, fiber, fuelwood and other raw materials. After being declared as a wildlife sanctuary, agriculture is the main occupation (coffee, pepper, other cash, and non-cash crops and collection of non-timber forest products being the other vital sources of income for the *soliga* tribe. Fuelwood is an important source of livelihood for *soliga* tribe in BRT hills. For example, as estimated by Shankar et al.,(1998) fuel wood consumption per day is 7,522 kg in the core area (within the legal boundaries) and in the fringe area (corridor); it is 37,043 kg per day. The present study has collected information, based on the interview method, from 148 households spread across four podus (villages). This survey collected both quantitative and qualitative data for the study. Most households are still using fuelwood as a major source of cooking in the study area.

This study used the direct market price method for estimating the value of provisioning services used earlier by some studies, for example, (Ninan and Kontoleon, 2016; Kibria et al., 2017; Costanza et al., 2011). It therefore used the actual price of non-timber forest products, which is fixed by Large Scale Adivasi-Multi Purpose Co-operative societies (LAMP).

C. Carbon Sequestration

The present study has also estimated the value of carbon sequestration in respect of BRTWLS, using the following method (Kibria et al, 2017; Ninan and Kontoleon, 2016; Ninan and Inoue 2013; Xi 2009; IPCC 2000):

$$V_c = Q.P.S. \quad \text{.....(1)}$$

where V_c denotes the service value of carbon sequestration (US$), Q represents net carbon sequestration rate (tC $ha^{-1}yr^{-1}$) and P denotes the international carbon price (India) (US$/tC) and S stands for area of forest in hectare. The social cost of carbon is US$ 86 per tC (Ricke et al., 2018) has been used in this study. Social Cost of Carbon is defined as "the social cost of carbon (SCC) represents the economic cost associated with climate change (or benefit) that results from the emission of an additional tonne of carbon dioxide (tCO_2) (Ricke et al., 2018:895). The present study has estimated the value of carbon sequestration based on Kibria et al., (2017) methods. Particularly, previous Indian studies have used these methods for estimating the value of carbon sequestration, using the social cost of carbon followed by Nordhus (2011) for India at a low discount rate US$ 37.17 (Verma et al., 2017); World Bank (2014) social cost of carbon US$54/tC in (Ninanand Kontoleon, 2016). The present study has used the new value of the social cost of carbon for India US$ 86 per t/C (Ricke et al., 2018). This study has estimated the economic value of carbon sequestration in vegetation (above ground level biomass) and soil organic carbon from BRT wild life sanctuary in Karnataka.

D. Soil erosion

A number of studies have explained the value of soil erosion prevention (Kibria et al., 2017; Ninan and Kontoleon, 2016; Ninan and

Inoue, 2013; Xi 2009). This study has used the following methods of estimating the value of soil erosion prevention by forests:.

$$Vsc = Csr.G \sum Si.D \text{ [here, } D=(di - do)] \quad .....(2)$$

where Vsc denotes the economic value of soil conservation (US$); Csr denotes the cost of sediment deletion per ton (US$); Si stands for area of the respective type of forest in hectare; D is erosion reduction in forest land (t ha-1); G denotes the ratio of amount of sediments present in rivers or reservoirs to the total soil lost; di designates the rate of erosion of broad leaved forest (t ha-1). The present study has used Ninan and Inoue, 2013; Ninan and Kontoleon, 2016 and Kibria et al., 2017) for estimating the value of soil erosion prevention. The economic value of soil erosion prevention includes sediment removal cost and the rate of erosion of broad leaved forest and the rate of erosion of non-forest land (Xi, 2009).

E. Recreational Value

The present study has used the travel cost method for estimating the value of recreational services in the BRT wildlife sanctuary. Travel cost method (TCM) basically refers to an adding of conventional household production function models that the households make the most of utility based on many uses and production decisions. The individual travel cost method implies the assessment of a person engaging of his or her expenditure for non-market goods. Khan (2004) observed that the TCM applied the cost of spending to a non-priced interesting location in order to assume the recreational benefits provided by the site. Therefore, the present study surveyed 125 visitors who were visiting the Biligiri Rangasamy Temple Wildlife Sanctuary. However, a standard econometric model applied to the study observes the number of visitors to the recreational site as functional factors, for example socio economic characteristics such as age, family size, marital status, educational status, household income, travel cost, time spent in the travel to the recreational site and quality of the park. The econometric model is as follows:

$$r_i = \beta_0 + \beta_1 travel\ cost + \beta_2 age + \beta_3 marital\ status + \beta_4 household\ size + \beta_5 educational\ level + \beta_6 D_1 residential\ location + \beta_7 household\ income + \beta_8 D_2 quality\ of\ the\ park + e_i \quad .....(3)$$

The study has used the dependent variable r_i denotes the number of visits by the ***I***th person, his or her, to the recreational site per period of time; *travel cost* implies the total round trip cost from a person residence to and from of the tourism site and includes the opportunity cost of travel time and stay at the park. D_1 denotes 1, if urban dweller, and 0 otherwise, D_2 denotes 1 if the visitor's perception about the site's recreational facilities is good and 0, if bad.

III. RESULT AND DISCUSSION

3.1. Provisioning Services

Local people collect a wide range of non-timber forest products from the BRT wildlife sanctuary. Table 2 and 3 shows the economic value of provisioning services at the household level. The collection of non-timber forest products per season has been estimated at US$ 9,4721 from the sanctuary. Non-timber forest products are available only season-wise, for example, honey is available during the months from March to July. Honey is one of the major non-timber forest products and a major contributor to the household income in the BRT wildlife sanctuary. Honey is available only inside the forest with the frequency of collection being 3 times per season in the study area. More than 50 kg honey is extracted from the forest and they traverse more than 25 km from their home for this purpose. Every non-timber forest product has its own time period to be ready for harvesting, for instance, Shikakai (*Acacia concinna*) is one of the important livelihood sources of the households. The maximum Shikakai harvest takes place in the months of January and February, involving about 10 working days with 50 kg per season

1 This study has estimated per season the economic value of non-timber forest product collection at US $ 9,472 multiplied by three (season= US$ 28,416) per year value of NTFPs of the entire respondent

collected from the forest. Gooseberry is one of the important sources of income for the sample households and is harvested from March to April, involving about 10 working days on the average spent for the collection of each non-timber forest product, working 8 to 10 hours per day. All the non-timber forest products are sold through the LAMP located in the wildlife sanctuary, for example, honey at Rs 170 ($2.46) per kg. This study has found that per hectare value of non-timber forest products is US$ 6.2 from the sanctuary.

The study has estimated that the average annual income from non-timber forest products is between Rs 10,000 and 12,000 (US$ 144 and 173) for the sample households in the BRT wildlife sanctuary. Fuelwood is the main sources of cooking in the sample households. This study has found that 3,715 kg has been collected per annum from the wildlife sanctuary. More than 60% of the household income is received from these agricultural products. Further, only 40% of the households have 2 acres of land and more than 50% of the households do not possess any land for cultivation of agricrops. One of the respondents observed during the household survey that, the total income from non-timber forest products had been reduced as compared to the two previous decades due to weather changes and a number of restrictions enforced by the forest officials in the wildlife sanctuary. The study has also found that a few minor

Table 2. Economic value of provisioning services provided by BRT wildlife sanctuary

Services	Quantity (kg)	US$
Honey	3,583	5,145.75
Pacchi	1,593	34,72.17
Magaleberu	580	147.29
Shikakai (*Acacia concinna*)	1,125	112.97
Paduvanache	220	41.89
Aroleoil	260	35.13
Gooseberry	3,865	412.01
Amla	1,110	60
Fuel wood	3,715	0
Total		9,427.21

Source: Author's calculation

Table 3 Income from silver wood, fruits and coffee in the BRT

Production	Quantity	Amount (RS)
Silverwood	2,810	992,000
Coffee	10,660	1319,750
Pepper	1,611	4,58950
Goava	1,870	11,185
Chakkotta	940	10,150
Lemon	3,005	15,500
Jackfruit	4,450	131,900
Ginger	20	13,500
Banana	800	600
Total		2,953,535

Source: Author's calculation

forest products have been considered in the market through the LAMPS. These services are creating employment opportunities in farming, fisheries, timber harvesting and extraction of building materials (Kettunen, M. and ten Brink, P. eds., 2013). Provisioning services are contributing more than 14.5% of the total income of the households, marginalised households highly benefiting from the forest in Bhitarkanika conservation area, east coast of India (Hussain and Badola, 2010).

3.2. Regulating Services

3.2.1. Carbon sequestration

Carbon sequestration is another important ecosystem service provided by BRTWLS wildlife sanctuary. Moreover, this study is used secondary data for estimating the value of carbon sequestration in the BRT wildlife sanctuary. The secondary data is available only on physical quantity of forest area in hectare for the wildlife sanctuary and we calculated the value of carbon sequestration through the (IPCC, 2000) on net carbon sequestration in logged evergreen forest and semi-evergreen forest (2.65tC ha^{-1} yr^{-1}). The present study has found that the forest in BRT wildlife sanctuary sequesters carbon worth US$ 0.2 million (Table 5).

3.2. Recreation

The value of recreation services has been estimated based on the travel cost method. The present study interviewed 125 tourist visitors to the BRT wildlife sanctuary. The average number of recreational trips (2) and the amounts spent on ecotourism yearly average Rs 1,700 ($24.55). Visitors come from a maximum distance of 1,200 km and a minimum of 20 km to the wildlife sanctuary from their home. Most of the visitors spend a minimum of only 2 hours in the wildlife sanctuary. The total value of recreational services provided by the BRT wildlife sanctuary has been estimated at US$ 0.054 million. This study has also estimated the consumer surplus of visitors. The per capita consumer surplus amounts to Rs 38.24 (US$ 0.05) per visit. Previous studies have used travel cost method for estimating the value of ecotourism in this region, for example, Ninan and Kontoleon (2016) estimated the value of recreational services provided by Nagarhole national park at US$ 0.41 million. Another study Verma et al. (2017) estimated the value of recreational services across various protected areas at US$ 13.8 million.

3.4. Discussion

There are a number of studies that have documented the economic value of ecosystem services across protected areas of India. Already we have discussed in the first chapter services along with the value of many of national parks and wildlife sanctuaries. The present study has found the value of ecosystem services at Rs 23.9 million (US$0.64million), including provisioning services, carbon sequestration, soil erosion prevention and recreational services provided by BRT wildlife sanctuary (see table 5 and figure 1). The previous section has mentioned there is a lack of economic valuation of ecosystem services studies in the region. For example, Ramachandra (2016) estimated the value of provisioning services at Rs 15,171 crore (US $ 1.8 billion) per year provided by Uttara Kannada forest in Karnataka. Carbon sequestration is one of the vital ecosystem services provided by BRT wildlife sanctuary. The value of carbon sequestration has been estimated at Rs 14.4 million (US$0.2 million) from the sanctuary. There is no previous estimation recorded of carbon sequestration in the protected area. For instance, Ninan and Kontoleon, (2016) examined the value of carbon sequestration at US$0.38 million in respect of the Nagarhole national park of the Western Ghats in Karnataka which is located next to BRT wildlife Sanctuary. In addition, Verma et al (2017) estimated the economic value of carbon sequestration in Periyar tiger reserve at US$2.8 million. BRT Soil erosion prevention is another service provided by BRT wildlife sanctuary in the Western Ghats of Karnataka. The present study has estimated

the value of soil erosion prevention at Rs 2.1 million (US$0.03 million). The soil erosion prevention service is very vital for minimizing the sedimentation of rivers (Kibria et al., 2017). Previous studies have estimated the economic value of soil erosion prevention at US$ 0.07 million in respect of Nagarhole national park (Ninan and Kontoleon, (2016). The economic value of sedimentation regulation has been estimated at US$0.2 million in the Periyar Tiger Reserve in the Western Ghats of Kerala (Verma et al., 2017). The present study has estimated the value of soil erosion prevention at US$0.03 million. The earlier studies in India, for example Verma et al. (2017) examined the value of soil erosion prevention across various tiger reserves at US$ 17.9 million. In addition, Ninan and Kontoleon (2016) estimated the economic value of soil erosion prevention at US$ 0.38 million in respect of Nagarhole national park in the Western Ghats of Karnataka. Protected areas play a vital role in generating more income from ecotourism in India. The present study has estimated the value of recreational services provided by BRT wildlife sanctuary, using the travel cost method, at Rs 3.8 million (US$0.03 million). In Karnataka, there are 30 protected areas (National Park, Wildlife Sanctuary etc). BRT wildlife sanctuary is one of the famous spiritual and tourism places in Karnataka. This is the first economic estimation of the recreation services from the wildlife sanctuary. Table 4 shows the regression results of recreational value of BRT wildlife sanctuary. Household size shows a positive and significant relation in respective of those visiting the protected area. In addition, residential location and household income show a negative and significant relation

Table 4. Regression results

Variables	Coefficients (t-statistics)
Intercept	1.444 (2.757)
Travel Cost	-0.013 (-0.115)
Age	-0.115 (-1.148)
Marital Status	0.080 (0.803)
Household size	0.228 (1.936)**
Educational status	-0.082 (-0.864)
Residential location	-0.178 (-1.714)**
Household Income	-0.184 (-1.714)**
Quality of the park	-0.072 (-0.795)
R^2	0.70
F-Statistics	1.097

Remarks: ** 5% level of significance

Table 5. Ecosystem services and their value provided by BRT wildlife sanctuary

Ecosystem services	Total value in Rs (US $)
Provisioning services (Non-timber forest products and production of silver wood, fruits and coffee)	Rs 3.6 million (US$0.05 million)
Recreational services	Rs 3.8 million (US$0.054 million)
Carbon sequestration	Rs 14.4 million (US$0.2 million)
Soil erosion	Rs 2.1 million (US$0.03 million)
Total	Rs 23.9 million (US$0.634 million)

Source: Author's calculations

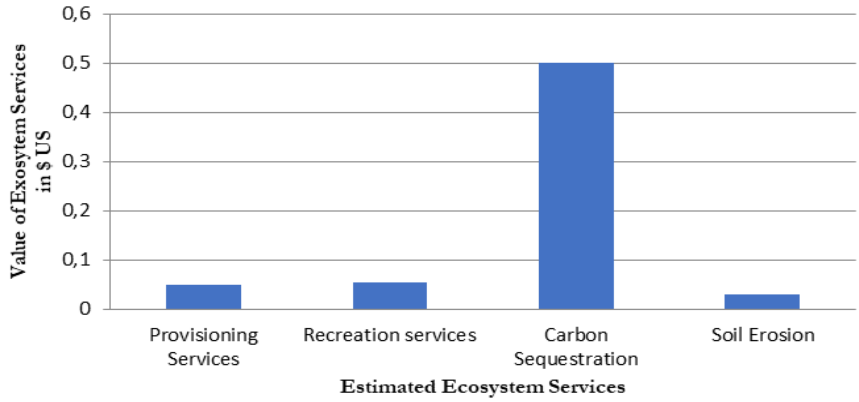

Figure 1. The composition of the values of ecosystem services

to the visit of this area. Table 4 clearly shows that travel cost has a negative association between the number of visits and the location of the wildlife sanctuary. There are a number of studies that have estimated the economic value of ecotourism in respect of other protected areas, for instance, Ninan and Kontoleon, (2016) estimated the value of ecotourism at US$ 0.41 million for Nagarhole national park and Balasubramanian (2017) estimated at US$ 0.2 million provided by lalbagh botanical garden in Bangalore. The economic value of recreational services provided by Dachigam national park in Jammu and Kashmir has been estimated at US$ 3,930,395, using the individual travel cost method (Bhatt and Bhat, 2019). Previous studies have used travel cost method for estimating the value of ecotourism in this region, for example, Ninan and Kontoleon (2016) estimated the value of recreational services provided by Nagarhole national park at US$ 0.41 million. Another study Verma et al (2017) estimated the value of recreational services across various protected areas at US$ 13.8 million.

IV. CONCLUSION

Biligiri Rangasamy Temple Wildlife Sanctuary (BRTWLS) provides a number of eco-benefits to the people. The value of a few ecosystem services is worth about Rs 23.9 million (US$0.634 million)$yr^{-1}$. The value of carbon sequestration is the highest as compared to other ecosystem services in the study area. The present study has only estimated the economic value of four ecosystem services i.e. provisioning, carbon sequestration, soil erosion prevention and recreational services provided by BRT wildlife sanctuary. The study has also found that the Non-Timber Forest Products (NTFPs) has been the vital role to their household consumption and income of the local tribal community. In addition, the protected area is also contributed as a major carbon sequestration by various forest types inside the sanctuary. The result of the study could also help in achieving Sustainable Development Goals (SDGs) at the local level. There are a number of ecosystem services still to be estimated in economic value terms. Moreover, assessing the economic value of ecosystem services would help design entry fee for the wildlife sanctuary as well as create awareness regarding the economics of ecosystem services provided by the protected areas. In addition, investment in natural capital is particularly vital in the protected areas for achieving sustainable development goals at the local level. Further, the allocation of the budget at the state level (TEEB, 2010b) as well as the value of protected areas contributes to national income accounts. This study has a number of limitations, for instance, there are a number of ecosystem services identified in the wildlife sanctuary but due to lack of data, only four ecosystem services have been estimated in terms of their economic value.

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THE IMPACTS OF INVESTMENT IN THE FORESTRY SECTOR ON THE INDONESIAN ECONOMY

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THE IMPACTS OF INVESTMENT IN THE FORESTRY SECTOR ON THE INDONESIAN ECONOMY. Indonesia has abundant forest resources, reaching 120 million hectares of forest area. However, the forestry sector's contribution to the national economy continues to decline. The low performance of the forestry sector cannot be separated from the limited availability of round-wood materials for its processing industries and insufficient development of the multi-businesses activities among the forestry companies. Therefore, increasing the forestry sector's productivity is necessary through raising investment. This study investigates the impacts of investment in the forestry sector on Indonesian economic performance, including output, income, employment, and import, using the Input-Output (I-O) Model. The results show that investment in the forestry sector will increase output, income, and labour in the forestry sector and its related sectors. However, with the increase in its output, the demand for inputs, including round-wood materials, will also increase, encouraging a rise in imports. Thus, an increase in investment in the forestry sector needs to be balanced with the availability of roundwood materials and other associated inputs in Indonesia. For the follow-up research, it is important to separate the investment into upstream and downstream activities along the forestry value chain and include a regional aspect in the analysis.

Keywords: Backward and forward linkages, input-output, multiplier

DAMPAK INVESTASI DI SEKTOR KEHUTANAN TERHADAP KINERJA PEREKONOMIAN INDONESIA. Indonesia merupakan negara yang kaya akan sumberdaya hutan dimana luas areal kawasan hutan mencapai 120 juta hektar. Namun demikian kontribusi sektor kehutanan terhadap perekonomian nasional terus menurun. Kinerja sektor kehutanan tidak lepas dari semakin terbatasnya ketersediaan bahan baku kayu bulat dan masih belum berkembangnya kegiatan multiusaha oleh perusahaan-perusahaan yang bergerak di sektor kehutanan. Oleh karena itu, perlu dilakukan peningkatan produktivitas di sektor kehutanan melalui peningkatan investasi. Penelitian ini bertujuan untuk menganalisis dampak investasi di sektor kehutanan terhadap kinerja perekonomian Indonesia yang meliputi kinerja output, pendapatan, tenaga kerja, dan impor dengan menggunakan Model Input-Output (I-O). Hasil analisis menunjukkan bahwa investasi di sektor kehutanan akan meningkatkan output, pendapatan, dan tenaga kerja di sektor kehutanan dan sektor-sektor perekonomian lainnya. Namun seiring dengan peningkatan output, permintaan input termasuk kayu bulat juga meningkat sehingga mendorong peningkatan impor sektor kehutanan itu sendiri dan sektor-sektor lainnya. Dengan demikian, peningkatan investasi di sektor kehutanan perlu diimbangi dengan ketersediaan material kayu bulat dan input terkait lainnya di dalam negeri. Untuk penelitian selanjutnya, penting untuk memisahkan investasi ke dalam kegiatan hulu dan hilir di sepanjang rantai nilai sektor kehutanan dan memasukkan aspek regional dalam model.

Kata kunci: Keterkaitan ke belakang dan ke depan, input-output, multiplier

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I. INTRODUCTION

Globally Indonesia is endowed with diverse tropical forests, covering 120 million hectares (KLHK, 2019) or 64.1% of its total land area (Asosiasi Pengusaha Hutan Indonesia, 2019). Forests provide wood, non-timber goods, biodiversity conservation, and environmental services, including protection of water systems, ecotourism, and carbon sequestration and storage (Dayneko et al., 2021; Nur et al., 2018; Rossita et al., 2021; v. P. Hmyria et al., 2019). The tremendous economic potential of forest resources can be used as capital in developing the forestry sector (Nurfatriani et al., 2015; Sheriffdeen et al., 2020). However, the performance of the forestry sector in the economy tends to decline (Asosiasi Pengusaha Hutan Indonesia, 2019; Mäkelä, 2017; Zendrato et al., 2020). The contribution of the forestry sector to Indonesia's GDP was 0.83% in 2010. However, it has consistently decreased until 2020 to 0.54% of Indonesia's total GDP (BPS, 2021).

A decrease in forest resources caused a decline in the performance of the forestry sector (Darusman & Nurrochmat, 2001; Yovi & Nurrochmat, 2018). The rapid population growth, the use of timber and non-timber forest products, and illegal logging lead to increasing deforestation (Ahmad et al., 2016; Defries et al., 2010; Djaenudin et al., 2016; Nurrochmat et al., 2017). Deforestation causes increasingly limited timber production from natural forests (Asosiasi Pengusaha Hutan Indonesia, 2019). To combat this, the government encourages timber production with sustainable forest management and social forestry programs, one of which is the development of Community Plantation Forests (Hutan Tanaman Rakyat-HTR). HTR is an option to revitalize the forestry industry to increase the availability of round-wood materials for the forestry industry (Alviya et al., 2020). However, the Social Forestry Program and HTR development performances are still relatively slow (Wiyono et al., 2018; Wulandari et al., 2017).

The increasingly limited timber materials led to a decline in Indonesia's processed wood production (M. Nur et al., 2018; Marbun, 2017). The shortage of timber materials forced the forestry sector to import more materials to support the production process. Based on the 2016 Indonesian Input-Output Table, the most significant imports of raw materials were in the paper and pulp industries, about 22.78% and 11.72%, respectively of the total inputs were used in the sector (BPS, 2021).

The decline in productivity and performance of the forestry sector needs to be improved through investment (Masru'ah & Soejoto, 2013). The presence of investment can have implications for increasing the production and productivity of forestry-related sectors (Arshaf et al., 2020). However, investment in the forestry sector is still relatively low; investment in the forestry sector in 2016 was only 1.10% of Indonesia's total investment and consistently decreased until 2020 to only 0.21%. (BKPM, 2021).

The value of the investment in the forestry sector, which has consistently decreased from year to year, impacts the decline in the forestry sector's contribution to the Indonesian economy (Nurrochmat et al., 2017). Also, the productivity of the forestry sector depends on the availability of raw materials. The availability of raw materials can certainly be increased through increased investment. However, an increase in investment, if not balanced with an increase in the availability of raw materials in the country, will increase imports of raw materials.

Previous literature has examined the relationship between investment and economic growth in developing countries using the partial model, particularly the econometrics model (Felix N, 2021). Banday et al. (2021) studied BRICS countries from 1990 to 2018 using an autoregressive distributed lag model. The results reveal that Foreign Direct Investment (FDI) positively impacts long-term economic growth in BRICS countries. Kobilov & Kurbonov

(2020) applied a vector error-correction model (VECM) to the quarterly data of FDI and GDP from 2010 to2019 in Uzbekistan and found that investment has a significant impact on growth in the country.

Similarly, Sohail and Mirza (2020) investigated the impact of FDI on economic growth in Pakistan by using the data from 1996 to 2015. The results confirmed the significant relationship between FDI and Gross Domestic Product in Pakistan by applying a correlation matrix and regression analysis. Felix (2021) utilized Ordinary Least Square by using the data of FDI, Real Gross Domestic Product (RGDP), and Exchange Rate (EXR) over the period 1989-2019 in examining the impact of FDI on economic growth in Nigeria and concluded that FDI has a positive and significant influence on economic growth in the country. The government needs to stabilize the exchange rate to attract more investors to Nigeria. By employing a stochastic frontier model on the data from 45 countries, Wijeweera et al. (2010) found similar results related to the positive and significant impact of FDI and economic growth. Important to note from the study that the positive relationship between the two variables only occurred when the investment was accompanied by high-skill labor.

The econometrics model is clearly shown as a partial analysis focusing on the causal relationship between investment, economic growth, and GDP. Only a few studies examined the impact of economic performance investment using the I-O model, one type of computable general equilibrium model. Using the I-O model, the impact of investment in a particular sector on economic growth, labour absorption, household income, and the trade balance (import or export performance) can be calculated. Anas et al. (2015) investigated the impact of a transportation project on the regional economic growth in West Java Province, Indonesia. They found increasing RGDP of the province when investment in the transportation sector was increased. Using a similar model, Vukić et al. (2021) found that investment in the transportation sector increased economic growth in Croatia. Kim et al. (2019) reported that increasing public investment in the service sector in Turkey created more jobs and promoted gender-inclusive growth. In Indonesia, the I-O model has been widely used in various studies (e.g., Junari et al., 2020; Widyawati, 2017; Yunitasari & Priyono, 2021; Zendrato et al., 2020). In general, the research examines the relations between various economic sectors and the extent to which the economic sectors promote economic growth, income distribution, and job creation.

Most previous studies focus on the entire investment in the country and pay less attention to the impact of investment in particular sectors, including the forestry sector. Additionally, the previous literature using the I-O model has not captured the impact of investment on imports. This research contributes to the literature by examining the impacts of investment in the forestry sector on economic growth, labour absorption, household income, and import.

This research aims to investigate the impact of investment in the forestry sector on the performance of the Indonesian economy, including output, income, employment, and import. The forestry sector covered in this study includes the upstream and downstream forestry activities, including the timber sub-sector, other forest products sub-sector, sawn and processed wood sub-sector, plywood, and similar sub-sectors, wooden building materials sub-sector, other wood goods, cork, bamboo, and rattan, the pulp sub-sector, and the paper sub-sector. These sectors are listed in the latest Indonesian I-O Table published by the Indonesian Central Statistics Agency (BPS).

II. MATERIALS AND METHOD

A. Study Site

The scope of this research is at the national level (Indonesia) using secondary data from the Indonesian Input-Output (I-O) Table for the classification of 185 sectors published by the

Indonesian Central Statistics Agency (BPS) in 2021. In addition to I-O Table, the data in this study were obtained from various sources and agencies such as BPS, KLHK, and APHI.

B. Methods

The I-O model was conducted to measure the impact of investment in the forestry sector on the performance of output, income, employment, and imports in Indonesia. The I-O table is a statistical description made in a matrix containing information about transactions of goods and services and the interrelations among economic activities (sectors) in a region at a given period (Sahara, 2017). In the case of the I-O table it consists of an "n x n" matrix which is described in Table 1.

Based on Table 1, the equations in Table (I-O), when viewed in rows, can be written in the form of algebraic equations as follows:

$$\begin{array}{ccccccccccc} x_{11} & + & x_{12} & + & \dots & + & x_{n1} & + & F_1 & = & X_1 \\ x_{12} & + & x_{22} & + & \dots & + & x_{n2} & + & F_2 & = & X_2 \\ \vdots & & \vdots & & \vdots & & \vdots & & \vdots & & \vdots \\ x_{1n} & + & x_{2n} & + & \dots & + & x_{nn} & + & F_n & = & X_n \end{array} \quad \dots(1)$$

In general, the above equation can be reformulated into the following:

$$\sum_{j=1}^{n} x_{ij} + F_i = X_i; \text{for n} = 1,2,3, \text{and so forth}$$

Where x_{ij} is the value of outputs of the sector used as input by sector j, F_i is the final demand for sector i, and X_i is the number of outputs of sector i. the technical coefficient matrix (technological coefficient) can be expressed in the mathematical form as stated in equation 2:

$$a_{ij} = \frac{x_{ij}}{x_j} \quad \dots(2)$$

If equation (2) is substituted into equation (1), the following equation will be obtained:

Table 1. Input-Output Table Framework

Economic Activities		Products (Industries) 1	2	…	n	Total Intermediate Demands	Final Demands: Household consumption, Government expenditure, Investment, Export	Total Final Demand	Total Output
Product (Industries)	1	x_{11}	x_{12}	…	x_{1n}		F_1		X_1
	2	x_{21}	x_{22}	…	x_{2n}		F_2		X_2
	⋮	Quadrant I			⋮		Quadrant II		
	n	x_{n1}	x_{n2}	…	x_{nn}		F_n		X_n
Taxes – Subsidies		Taxes – Subsidies on Products					–		
Import for Intermediate input		Intermediate Consumption for Imported Products							
Primary Input (Added Value)		V_1	V_2	…	V_n				
		Quadrant III							
Total Input		X_1	X_2	…	X_n				
Number of Employment		E_1	E_2	…	E_n				

Source: BPS 2021 (modified)

$$\begin{array}{ccccccccccccc} a_{11}X_1 & + & a_{12}X_2 & + & \dots & + & a_{1n}X_n & + & F_1 & = & X_1 \\ a_{21}X_1 & + & a_{22}X_2 & + & \dots & + & a_{2n}X_n & + & F_2 & = & X_2 \\ \vdots & & \vdots & & \vdots & & \vdots & & \vdots & & \vdots \\ a_{n1}X_1 & + & a_{n2}X_2 & + & \dots & + & a_{nn}x_n & + & F_n & = & X_n \end{array} \quad \dots(3)$$

If equation (3) is written in the matrix equation:

$$\begin{vmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{vmatrix} \begin{vmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{vmatrix} + \begin{vmatrix} F_1 \\ F_2 \\ \vdots \\ F_n \end{vmatrix} = \begin{vmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{vmatrix} \quad \dots(4)$$

$$A \qquad X + F = X$$

If equation (4) is written in the form of a mathematical equation, the following equation will be obtained :

$$AX + F = X \text{ or } (I-A)X = F \text{ or } X = (I-A)^{-1} F \quad (5)$$

Where:

I = matrix identity
F = final demand
X = total output
(I-A) = Leontief Matrix
$(I-A)^{-1}$ = Leontief's inverse matrix

The simulation used in the I-O model was increasing investment in the forestry sector by IDR 3.28 trillion or USD234.3 million (USD1=IDR14,000). This investment amount was obtained from the KLHK budget allocation for the sustainable forest management program in the 2021 work plan, which was allocated for the forestry sector from upstream to downstream sectors. Details of investment allocation in the forestry sector are presented in Table 2.

C. Sector Aggregation

Product coverage in the forestry sector includes wood and other forest products (natural honey, natural sap, lacquer, resin, natural cork,

Table 2. Budget allocation for the KLHK sustainable forest management program in 2021

No.	Program/Activities	Budget (IDR Billion)
1.	Improved Production Forest Management Planning	109.8
2.	Production Forest Business Improvement	24.8
3.	Improvement of Orderly Administration of Forest Products and forest fees	12.1
4.	Enhancing Environmental Services Business for Production Forests and Non-Timber Forest Products (NTFPs)	14.8
5.	Forestry Industry Business Improvement	26.2
6.	Forest Rehabilitation and Reclamation, Land Rehabilitation, and Soil and Water Conservation	1 599.2
7.	Protection Forest Management Unit	37.3
8.	Watershed Management	23.1
9.	Forest Plant Seed Development	164.6
10.	Patterning and Nature Conservation Information	79.1
11.	Conservation Area Management	368.3
12.	Species Conservation and Genetics	238.5
13.	Utilization of Protected Area Environmental Services	87.4
14.	Establishment and Administration of Forest Areas	130.3
15.	Forest Resource Inventory and Monitoring	11.9
16.	Forest Area Planning	8.9
17.	Extension Improvement	8.5
18.	Granting Access to Manage Forest Areas	50.4
19.	Capacity Building for Social Forestry Groups and Environmental Partnerships	221.3
20.	Forest Prevention and Protection	70.9
	Total	3,288.2

Source: KLHK 2021

or wild plants that can be consumed as food and used for webbing and natural dyes). These products include upstream activities in the forestry value chain. The downstream activities at the forestry value chain include services and processing activities of forestry sectors. In many cases, the forestry sector's contribution is only calculated based on wood products and other forest products (upstream activities). As such, to find out the actual contribution of the forestry sector to the Indonesian economy, the expansion of the scope of the forestry sector is needed to include timber, non-timber forest products, timber-based processing industries, and forestry services. This process is similar to the Forestry Satelite Account (FSA), which is a framework for analyzing policies related to forestry and measuring the contribution of forestry to the economy. Therefore, the forestry activities in the I-O table used in the study are classified into one sector, including upstream and downstream activities along the forestry sector value chain. The study team aggregated 185 sectors of the I-O table produced by BPS into 18 sectors, and the forestry sector is coded as sector 18 (Table 3).

D. Impact Analysis

After the 18 aggregation sectors were obtained, the study team measured the impact of investments in the forestry sector by utilizing these formulas (Firmansyah, 2006):

a. Impact on output

$$\Delta X = (I-A)^{-1} \Delta Y \quad \text{.....(6)}$$

b. Impact on household income

$$\Delta H^* = h_i(I-A)^{-1} \Delta Y \quad \text{.....(7)}$$

c. Impact on labour absorption

$$\Delta E^* = e_i(I-A)^{-1} \Delta Y \quad \text{.....(8)}$$

d. Impact on import

$$\Delta M^* = m_i(I-A)^{-1} \Delta Y \quad \text{.....(9)}$$

e. Income coefficient

$$h_i = \frac{h_j}{X_j} \quad \text{.....(10)}$$

f. Labour coefficient

$$e_i = \frac{E_j}{X_j} \quad \text{.....(11)}$$

g. Import coefficient

$$m_i = \frac{m_j}{X_j} \quad \text{.....(12)}$$

Table 3. Sector aggregation

Codes of Sectors	Sectors
1.	Agriculture and Fisheries
2.	Mining and Quarrying
3.	Processing Industries
4.	Provision of electricity and gas
5.	Water supply, waste management, Waste, and Recycling
6.	Construction
7.	Wholesale and Retail Trade, Car and Motorcycle Repair
8.	Transportation and Warehousing
9.	Provision of Accommodation and Food and Drink
10.	Information and Communication
11.	Financial Services and Insurance
12.	Real Estate
13.	Company Services
14.	Government Administration, Défense and Mandatory Social Security
15.	Education Services
16.	Health Services and Social Activities
17.	Other Services
18.	Forestry Sector

Where:

ΔX = impact on output
ΔH^* = impact on household income
ΔE^* = impacts on labour absorption
ΔM^* = impacts on import
ΔY = changes in final demand in the form of investment in the forestry sector
$(I-A)^{-1}$ = Leontief's inverse matrix
h_i = income coefficient
e_i = labour coefficient
m_i = import coefficient
h_j = wage/salary of sector j
E_j = number of labour of sector j
m_j = the value of import of sector j

III. RESULT AND DISCUSSION

A. Results

1) Forward and Backward Linkages

Table 4 presents backward and forward linkages of the 18 sectors focused in the study. The Leontief inverse matrix shows the values of backward and forward linkages. The backward linkage shows the relationships of the forestry sector to its upstream sectors. The forward linkage refers to the relationships of the forestry sector to its downstream sectors. The value of the forward linkage is 1.3481

Table 4. Forward and Backward Linkage of the 18 Sectors

Codes of Sectors	Sectors	Forward Linkage		Backward Linkage	
		Value	Ranking	Value	Ranking
1.	Agriculture and fisheries	1.8097	5	1.3133	18
2.	Mining and quarrying	1.9532	3	1.4527	13
3.	Manufacturing industry	3.8969	1	1.7528	5
4.	Provision of electricity and gas	1.4062	9	1.9263	1
5.	Water supply, waste, and Recycling	1.0530	16	1.4103	15
6.	Construction	1.3363	11	1.8206	2
7.	Wholesale and retail trade, car and motorcycle repair	2.0335	2	1.4220	14
8.	Transportation and warehousing	1.8286	4	1.7566	4
9.	Provision of accommodation, food, and drink	1.2348	13	1.7838	3
10.	Information and communication	1.6963	7	1.5520	11
11.	Financial services and insurance	1.6768	8	1.3792	16
12.	Real estate	1.2806	12	1.3531	17
13.	Company services	1.7643	6	1.5785	10
14.	Government administration, defense, and mandatory social security	1.1131	15	1.6970	7
15.	Education services	1.0503	17	1.4812	12
16.	Health services and social activities	1.0327	18	1.7079	6
17.	Other services	1.1131	14	1.6269	9
18.	Forestry	1.3841	10	1.6494	8

shows that an increase in final demand in the forestry sector by IDR. 1 million will stimulate the development of its downstream industry by IDR. 1.3481 million. The value of the backward linkage shows that an increase in final demand in the forestry sector by IDR. 1 million will attract the development of its upstream industry by about IDR. 1.6494 million. The values of the forestry sector's forward and backward linkages are more than one (1) and are included in the top 10 among other economic sectors showing the important roles of the forestry sector in the Indonesian economy.

2) Impact on Output

Table 5 shows that the impact of investment in the forestry sector will increase the output in all sectors by about IDR 5.4 trillion. The forestry sector received the most significant effect, with an increase of IDR 3.9 trillion or 73.14% of total output. The rise in output is because the investment will contribute to the capital accumulation in the forestry sector, and thus increasing productivity (Satibi, 2020). Increasing productivity will thereby boost production in the sector. The importance of investment in production enhancement is also appointed in the Solow growth model, emphasizing investment's vital role in the physical capital accumulation process. According to this model, an increase in investment promotes capital stock and thus increases output (Mankiw, 2006).

The manufacturing industry follows, with an increase in output of IDR411 billion or 7.61%. An economic stimulus in the form of investment in the forestry sector directly or indirectly impacts other sectors. The forestry sector is one of the upstream sectors of the manufacturing industry; therefore, an increase in production due to the specific injection (in this

Table 5. Impacts of investment in the forestry sector on the performance of output, income, labour absorption, and import in Indonesia

Codes of Sectors	Output (IDR Million)		Income (IDR Million)		Labour (Person)		Imports (IDR Million)	
	Values	Percentage	Values	Percentage	Values	Percentage	Values	Percentage
1	67,447	1.25	22,006	1.91	1,339	3.78	1,821	0.47
2	85,290	1.58	14,191	1.23	107	0.30	3,506	0.90
3	411,461	7.61	56,526	4.90	787	2.22	51,641	13.26
4	56,358	1.04	4,271	0.37	37	0.11	2,005	0.51
5	2,966	0.05	334	0.03	13	0.04	139	0.04
6	41,123	0.76	7,721	0.67	113	0.32	3,834	0.98
7	300,966	5.56	93,038	8.07	2,690	7.60	8,929	2.29
8	192,058	3.55	28,186	2.44	643	1.82	15,795	4.05
9	15,753	0.29	3,518	0.31	109	0.31	510	0.13
10	63,521	1.17	11,398	0.99	59	0.17	2,018	0.52
11	95,763	1.77	32,117	2.79	233	0.66	1,882	0.48
12	20,285	0.37	1,365	0.12	9	0.03	290	0.07
13	74,656	1.38	20,760	1.80	171	0.48	4,044	1.04
14	9,747	0.18	3,701	0.32	64	0.18	254	0.07
15	4,186	0.08	2,058	0.18	41	0.12	132	0.03
16	3,574	0.07	966	0.08	22	0.06	223	0.06
17	8,043	0.15	3,082	0.27	101	0.28	203	0.05
18	3,956,901	73.14	847,793	73.53	28,864	81.53	292,348	75.04
Total	5,410,097	100.00	1,153,032	100.00	35,401	100.00	389,574	100.00

case, the investment) will enhance production in the manufacturing industry through their linkages in the input markets. In other words, as production in the forestry sector increase, the availability of raw materials needed by the manufacturing industry in input markets will increase. The third sector experiencing the most significant increase in output is the wholesale/ retail trade, car, and motorcycle repair, with IDR301 billion or 5.56%.

3) Impact on Household Income

Investment in the forestry sector will provide an additional income in all sectors of IDR 1.1 trillion (Table 5). The forestry sector received the most significant impact amounting to IDR 847 billion or 73.53% of the total income increase. As outlined previously, the forestry sector experienced the highest additional output when investment in the sector was boosted. The forestry sector needs extra inputs to produce additional output, including labour. In the economic context, the household provides labour, meaning that an increase in labour absorption offers other income for the family (Safina & Rahayu, 2011).

4) The wholesale/retail trade, car, and motorcycle repair sector receive the second-largest impact of household income with an additional household income of about Rp 93 billion or 8.07%. The manufacturing industry also experienced extra household income of approximately IDR 57 billion or 4.90%. The increase in revenue in these two sectors shows that the two sectors have strong relationships with the forestry sector.

5) Impact on Labour

Table 5 shows that the impact of investment in the forestry sector will provide additional employment for 35,401 people in all sectors of the economy. The forestry sector receives the most considerable other effects on employment, amounting to 28,864 people or 81.53% of the total increase in the workforce as a result of the investment. The additional workforce is due to new investments that allow the creation of new jobs (Mankiw, 2006).

The wholesale/retail trade, car, and motorcycle repair sector receive the second-largest impact, experiencing an additional labour force of 2,690 people or 7.60%. The agriculture and fisheries sector obtains the third most significant impact, with an additional workforce of 1,339 people or 3.78%. The forestry sector has strong forward and backward linkages to these two sectors. Therefore, increasing investment in the forestry sector will increase production capacity, providing new jobs in the forestry sector and other sectors having strong linkages with the forestry sector.

Impact on Import

Investments in the forestry sector will provide additional output to other economic sectors (Table 5). An increase in output in the forestry sector will consequently increase the need for raw materials in the production process leading to an increase in the value of imports. The additional investment in the forestry sector will increase total imports by about IDR 389 billion. The forestry sector receives the most significant impact amounting to IDR 292 billion or 75.04% of the total increase in imports.

Mankiw (2006) stated that an increase in imports would impact a decline in a country's economic level. The increase in imports also occurs in other sectors having strong linkages with the forestry sector. The manufacturing industry receives the second-largest impact, increasing about IDR 51 billion or 13.26% of imports. The wholesale/retail trade, car, and motorcycle repair sector experience the third most significant impact, with an additional import of about IDR 8.9 billion or 2.29%. The results show that investment in the forestry sector needs to be carried out carefully because acquisition enhances its demand for intermediate and primary inputs. If the domestic market fails to increase the demand for the production factors, imports for such inputs, particularly intermediary inputs, will increase.

B. Discussion

Investment in the forestry sector will increase production in the forestry sector. It means that timber availability is crucial in supporting the increase in production. It is important to note that timber production for holders of Business Permits for Utilization of Natural Forest Timber Products (IUPHHK-HA) tends to decline. Timber production in 1992 IUPHHK-HA reached 26.05 million m3, but in 2018, the production only reached 7 million m3 (Kementrian Lingkungan Hidup dan Kehutanan, 2019). With the decreasing availability of timber, increased productivity due to increased investment will encourage import in the forestry sector, as stated in Table 5.

The presence of plantation forests also supports the production of timber. However, compared to several other countries globally, the addition of plantation forests in Indonesia is still low. Based on Table 6, the growth of plantation forests in Indonesia durng 15 years was only 1.72 million hectares or 0.11 million hectares annually. This condition is far below that of China, whose plantation forests increased by 1.64 million hectares yearly or increased by 24.59 million hectares in 15 years (FAO, 2016).

This issue became a dilemma because, in 1986, the government imposed a ban on the export of logs to encourage the development of domestic forestry, which stimulated the growth of the forest industry at that time (Asosiasi Pengusaha Hutan Indonesia, 2019). Theoretically, with the log ban export policy, the availability of round-wood materials in the country became abundant, but this did not pull through in practice. The inefficiency in the production and supply of timber from natural forests combined with the low number of additions or realization of plantation forests have provided challenges for the forestry industry to obtain timber, resulting in many wood processing companies closing their businesses. To deal with the challenges, some companies have imported timber from other countries (APHI, 2019).

According to Hersaputri & Santoso (2017), excessive extraction of natural resources requires a relatively long recovery time. An increase in static land can lead to a decline in production (Putra & Nasir, 2015). If this condition persists, the forestry sector will face some challenges in obtaining timber supplies. The existence of land conversion and forest fires causes forests to be increasingly degraded. Therefore, investment in the forestry sector aiming at increasing productivity, if not balanced with the availability of timber, will increase imports in the forestry sector.

The Government of Indonesia (GoI) is continually pushing forest productivity to boost the production of logs through intensive silviculture or SILIN. The GoI also provides wider business opportunities in forest production through a multi-business policy. This policy is an incentive for businesses to optimize their

Table 6. The development of plantation forests in various countries

Countries	Plantation Forest Area (million hectares)				Increase in the area (million hectares)	
	2000	2005	2010	2015	2000-2015	Average/Year
China	54.39	67.22	73.07	78.98	24.59	1.64
United States Of America	22.56	24.43	25.56	26.36	3.80	0.25
Russia	15.36	16.96	19.61	19.84	4.48	0.30
Canada	9.35	11.71	13.98	15.78	6.44	0.43
Indonesia	3.22	4.66	4.80	4.95	1.72	0.11

Source: FAO (2016)

forest resources. Apart from wood, companies can also invest in other forest products, such as non-timber and environmental services, increasing the forestry sector's contribution to the Indonesian economy.

IV. CONCLUSION AND IMPLICATION

The forestry sector has an essential role in the economic development in Indonesia, as shown by its forward and backward linkages that is higher than one (1). Investment in the forestry sector positively impacts output, income, and employment, both in the forestry sector itself and in other economic sectors in Indonesia. Thus, efforts to encourage investment in the forestry sector must continue to be pursued.

There is an important note from this study that investment in the forestry sector will inevitably encourage imports. The increase in imports is feared to harm Indonesia's trade balance. Therefore, efforts to increase investment in the forestry sector need to be focused not only on the downstream forestry sector but also on the upstream forestry sector as a provider of raw materials for the forestry industry. Moreover, investment in forest utilization needs to be expanded to timber production and non timber forest products and environmental services. Potentially, it will increase the role of the forest industry sector in the Indonesian economy.

The availability of domestic raw materials, especially wood, is essential to reduce the import of raw materials. Reducing imports will support the trade balance of Indonesia. The multi-business activities (wood, non-timber products, and environmental services) are also important to be promoted among forestry companies to optimize the utilization of their forest resources and to secure their inputs.

For the follow-up research, it is important to separate the investment into the upstream and downstream activities to capture which activities along the forestry value chain need to be prioritized by the GoI. Including regional aspects (provincial level) in the analysis can also be considered to determine in which province the increasing investment should be conducted..

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SOIL EROSION OVER DIFFERENT SLOPES UNDER PINE STANDS

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SOIL EROSION OVER DIFFERENT SLOPES UNDER PINE STANDS. Forests have an important role in controlling soil erosion. Pine stands are considered effective in controlling erosion due to high interception and thick litter. This study compares the level of erosion on land with a slope > 40% to land with a slope <40%, as one of the references used in reviewing standards for determining the slope of a protected forest area. The study was conducted from November 2016 to February 2017, under *Pinus merkusii* stand in the Education Forest of Hasanuddin University in Maros Regency. Erosion was measured in a land of 22 m x 4 m having long slopes > 40% and < 40% with 3 replicates. Surface runoff was measured during rain and suspension levels was determined based on a dry oven heated at 105°C. Actual erosion (gr) is calculated by multiplying total runoff volume (m^3/plot) by suspension level (gr/m^3). The results show the average erosion on the slopes >40% was 54.94 g/plot or 0.006 tons/ha while on the slopes <40% was 36.74 g/plot or 0.004 tons/ha. The average difference of the two test results, with a 95% confidence interval, shows differences in the erosion average on the slopes> 40% and <40%. However, when there is an increase in the percentage of canopy cover the erosion becomes smaller even on the slopes > 40%. This research can be used as a reference for considering the increase in the upper limit of the slope of the protected forest area, and the need for further evaluation on the existing upper limit value.

Keywords: Erosion, rainintensity, slope, pine stands, closure

EROSI TANAH PADA BERBAGI LERENG DI BAWAH TEGAKAN PINUS. Hutan memiliki peran penting dalam mengendalikan erosi tanah. Tegakan pinus dianggap efektif mengendalikan erosi karena intersepsinya yang tinggi serta serasah yang tebal. Penelitian ini bertujuan untuk membandingkan tingkat erosi antara kemiringan lereng >40% dengan lereng <40%, sebagai rujukan dalam tinjauan ulang standar penetapan Kawasan hutan lindung berdasarkan kelerengan >40%. Penelitian dilakukan mulai bulan Nopember 2016 sampai Februari 2017 di bawah tegakan Pinus merkusii Hutan Pendidikan Universitas Hasanuddin di Kabupaten Maros. Pengukuran erosi dilakukan dalam plot lahan berukuran 22 m x 4 m pada lereng >40% dan <40% masing-masing 3 ulangan. Pengukuran limpasan permukaan dilakukan setiap kejadian hujan, sebanyak 39 kali hujan. Kadar suspense diperoleh dengan cara mengeringkan air limpasan dalam oven suhu 105°C. Erosi aktual (gr) dihitung dengan mengalikan total volume limpasan (m^3/plot) dengan kadar suspensi (gr/m^3). Hasil penelitian menunjukkan rata-rata erosi pada lereng >40% 54,94 g/plot atau 0,006 ton/ha dan 36,74 g/plot atau 0,004 ton/ha pada lereng <40%. Hasil uji beda 2 rata-rata dengan selang kepercayaan 95%, menunjukkan perbedaan rata-rata erosi pada lereng >40% dan <40%. Namun ketika terjadi peningkatan persentase penutupan tajuk, erosi menjadi lebih kecil meskipun pada lereng 40%. Penelitian ini merekomendasikan peningkatan batas atas kemiringan kawasan hutan lindung dan perlunya peninjauan kembali atas nilai batas atas yang berlaku saat ini.

Kata kunci: Erosi, intensitas hujan, lereng, tegakan pinus, penutupan

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I. INTRODUCTION

Indonesia is included in the three countries after Brazil and the Democratic Republic of Congo with a high level of primary forest destruction (Weisse & Goldman, 2020). This damage reduces the ability of forests to carry out their ecological functions. The interaction of the forest with its environment begins to be disturbed so that floods, erosion, landslides are inevitable. Forest stands have an important role in controlling erosion (Razafindrabe, He, Inoue, Ezaki, & Shaw, 2010). The dense canopy can reduce the kinetic energy of rain falling to the ground. Forest cover can affect infiltration (Gupita & Murti, 2017), and increase soil resistance to raindrop damage. Dense vegetation can control the rate of erosion even on slopes and high rainfall. Erosion gets smaller with increasing vegetation density (Jianbo L et al., 2018)

Maintaining and or rebuilding forests, especially on lands with high slope, are the answer to controlling the rate of erosion, where erosion causes a decrease in land quality. In this regard, various efforts have been carried out to rebuild forests, including through planting programs known as reforestation, planting a million trees, Reforestation Week and the National Movement for Forest and Land Rehabilitation. Specifically in South Sulawesi, a large-scale reforestation program, in the context of overcoming critical lands in forest areas, has been promoted since the early 70s. The most widely used species is *Pinus merkusii*.

The reality on the ground shows that the rate of increase in critical land is faster than the success rate of forest rebuilding, due to the high level of land demand for various purposes. Fulfilment of land requirements is intended to make forest areas the main target, including protected forest areas. In many cases, the fulfilment of these no longer needs to consider the carrying capacity of the forest land, whether that is done legally or illegally.

According to the Law No. 41 of 1999 concerning Forestry article 6 (2), the government determines forests based on the main functions of conservation, protection, and production. While Article 19 paragraph (1) of the Law states that the government determines changes to the designation and function of forest areas based on integrated research results.

Zulkarnain and Widayati (2013) stated that the determination of forest areas with slope, soil type and rainfall criteria could not be used as a basis for criteria in determining protected forest areas. The main criteria that can be used in determining forest areas is calculating the community of trees as forest formers. The community factor of the trees is not sufficient to be used as a reference for establishing protected areas, it still needs to consider the slope aspect. Therefore, the slope standard from 40% needs to be reviewed. Facts on the ground show many parts of the forest with a slope above 40% are also exploited and converted. This invites a fundamental question of whether this 40% number will remain a basic reference to develop all parts of the forest area with the main function as protected forest areas or should it be realistic to say that the figure limit should be reviewed to determine further the boundary that is more likely to be applied in the field.

Answering this question requires data and information support, in this case, data that can prove the difference in the level of erosion on slopes above 40% with those below 40%. Data and information are influenced not only by slope inclination, but also by the closure. Therefore further information is needed about the significance of the difference in the level of erosion in the two slope categories with vegetation cover type.

One species of forest cover that should be considered for this purpose is *Pinus merkusii*. Based on consideration since the early 70s, this species has been widely used for reforestation planting. Based on existing records, this species has been used as a reforestation trees since the Dutch colonial administration era, especially in Java. This species has the potential to control erosion and landslides because it has a high interception (Rosmaeni et al., 2019), deep roots,

high evapotranspiration, binding the soil, and the trees are not too heavy or light (Lan H et al., 2020).

Research of Topic et al. (2008) found that the soil loss in the black pine (*Pinus nigra* Arn.) stand with a thick layer of natural litter and grass with a slope of 32° (62.49%) was 0.0116 ton/ha. In the black pine stand with complete canopy and no grass, the soil loss is 0.0204 ton/ha. In the stand of Pinus aleppo (*Pinus halepensis* Mill.) with complete cover at a slope of 20° (36.4%), the soil loss was 0.044 ton/ha.

This paper studies the role of pine plantations to reduce erosion rates. Specific research is needed to compare erosion rates on land with slope classes > 40% and on the slope classes <40%. It is considerable that land, which according to applicable regulations, should be managed as a protected area.

II. MATERIAL AND METHOD

A. Location and Materials

This research was carried out for four months from November 2016 to February 2017. The research was conducted under a stand of pine (*Pinus merkusii*) forests located in the Educational Forest of Hasanuddin University, Maros Regency, South Sulawesi Province. The study site is located at an altitude of 300-800 m above sea level. The average annual rainfall based on records from 2007 to 2016 was 2,863.2 mm.

The pine forest has been planted since 1970 as a result of reforestation covering an area of 291.13 ha. This stand is generally found in the northern part that spreads on lands with topographic conditions that vary from bumpy to steep.

Stand density on slope plots >40% and <40% were the same, i.e. 11 trees per 400m^2, consisting of four classes, namely trees, poles, saplings and seedlings. On slope plots >40% there are 11 trees, 2 poles, 2 saplings, and 3 seedlings. There are 11 pine trees and 2 other species. The average pine diameter is 49.36 cm. While on the slope plot <40% there are 11 trees, 7 poles, 7 saplings, 7 seedlings. There are 9 pine trees and 2 other species. The average pine diameter is 51.72 cm.

Tools and materials used in the field are observatory-type rainfall gauges, haga meters, roll meters, compasses, GPS, machetes, crowbars, hoes, rubber gutters for erosion test plots. Tools to collect runoff water from plastic buckets with capacities of 25 and 40 liters, bamboo for clamping rubber gutters, paralon pipes to drain runoff water into buckets, measuring cups, 600 ml plastic bottles, plastic caps for reservoirs, sample rings to take soil samples for analysis of organic matter, permeability and physical properties of the soil. Other tools are stationary, camera, stopwatch, label paper, and tally sheet. In this study, erosion plots using rubber gutters are cheaper and easier to install than using zinc and wooden boards. Some laboratory equipments used for sediments analysis included small funnels, measuring cups, filter paper for sediment solutions, digital scales, ovens, petri dishes, desiccators, and glitches.

B. Methods

The erosion plot is placed under the pine stand. Each plot contained several pine trees, between 1 to 6 trees per plot. Apart from pine trees, both in and around the plot, there are also other species found in the plots, such as *Cinnamomum* Sp., *Sapindaceae* and *Alstonia scholaris* (total 1 to 2 trees). The trees around the plot partially cover the canopy of erosion plot. Stand density around the plot is 11 trees per 400 m^2 consisting of seedlings, saplings, poles and trees.

This research was conducted through direct measurements, including observations of rainfall per rainfall event, rain duration, rainfall intensity, the volume of surface runoff and dissolved suspensions, slope rates, undergrowth, litter thickness, canopy cover per plot, and soil physical properties. Rain intensity is classified into 4, e.i. light (1-5mm/hour), moderate (5-10mm/hour), heavy (10-20mm/hour) and very heavy (> 20mm/hour) (Meteorology and

Table 1.Persentage of canopy closure, number of trees and thickness of litter

Slope Class	Plot	Slopes (%)	Canopy Closure (%)	Number of Trees	Thickness of Litter (cm)
> 40%	1	58	68.66	5	3
	2	61	55.68	4	1.6
	3	72	71.2	5	3.3
< 40%	1	25	92.61	5	0.8
	2	27	71.02	4	2
	3	29	46.02	4	1.9

Geophysics Agency, 2017).

Table 1 shows percentage of canopy closure, number of trees and thickness of litter in the observation plots.

Rainfall data were obtained from rainfall measurement placed in an open space around the observation plot. Observations were made for each rain event with a total of 39 rain events. The test plots were placed on a slope of > 40% and <40% with a length of 22 m and a width of 4 m . This plot size was used to adapt to the slope length of the landscape and this has been applied as an international standard of the USLE (Universal Soil Loss Evaluation) plots to predict erosion and considered as the best measure for field research of erosion. The same plot length was also used by a study conducted by (Paimin, 2003). Plots are installed on slopes between 15-30% for slope classes <40%, slopes between 45-75% for slope classes> 40%. Each slope class was replicated 3 three times.

The plot is made of tarpaulin from rubber. The height of the tarpaulin side above the ground is 20 cm. On the outer side of the erosion plot, a small ditch is made as a barrier, so that runoff that occurs outside the plot does not flow into the erosion test plot. Each plot is described starting from the percentage of pine canopy cover, to litter thickness and slope level. Pine stand density consists of 3 categories: rare (10% -40%), moderate (41% -70%) and dense (> 70%) (Badan Standarisasi Nasional, 2010). While the slopes are also divided into four categories: hilly sloping (15-30%), rather steep (30-45%), steep (45-65%) and very steep (> 65%).

Runoff and sediment content reservoirs use three buckets with a capacity of 50 litres. The magnitude of the actual erosion that occurs every time a rain event is known through sediment analysis. The method of taking samples is by stirring runoff water accommodated in a bucket until the sediment is evenly mixed. Then the sample is put into a 600 ml plastic bottle. The erosion plot can be seen in Figure 1.

C. Analysis

Primary data in the form of sediment concentration 20 ml is taken from each sample and then filtered using filter paper until the water runs out. Then it is dried at 105°C until the weight of dry soil is obtained. The dried samples were then weighed.

The formulas used to calculate sediment concentrations are: .....(1)

$$C = \frac{(b-a)}{v}$$

where:

C = Sediment concentration (g/m^3)

b = Weight of filter paper containing erosion (g)

v = Volume of erosion sample (m^3)

The amount of actual erosion can be calculated by multiplying the total runoff volume (m^3) by the level of suspension (g/m3),

Actual Erosion (g)= Total runoff volume (m^3) x Sediment concentration (g/m^3) .....(2)

which can be written as follows:

Linear regression analysis was performed to determine the relationship between the factors that influence erosion. Diversity

analysis (ANOVA) was conducted to determine which variables were different by comparing the average value of erosion based on the Independent Samples T-Test.

III. RESULT AND DISCUSSION

A. Result

Results of erosion regression analysis with independent variables (rainfall intensity, closure and slope) are shown in Table 2.

As shown in Table 2, the regression analysis results show that rainfall intensity, closure, and slope together have a significant statiststical relationship to erosion, that is shown by the value of significance level below 0,05 (Sig 0.000b).

Furthermore, in Table 3 it can be shown the relationship of each independent variable with erosion.

As shown in Table 3, the regression analysis results show that rainfall intensity and closure have a significant relationship with erosion. While other variables, namely the contribution of the slope to the effect of intensity (Z. Intensity) and the contribution of the slope

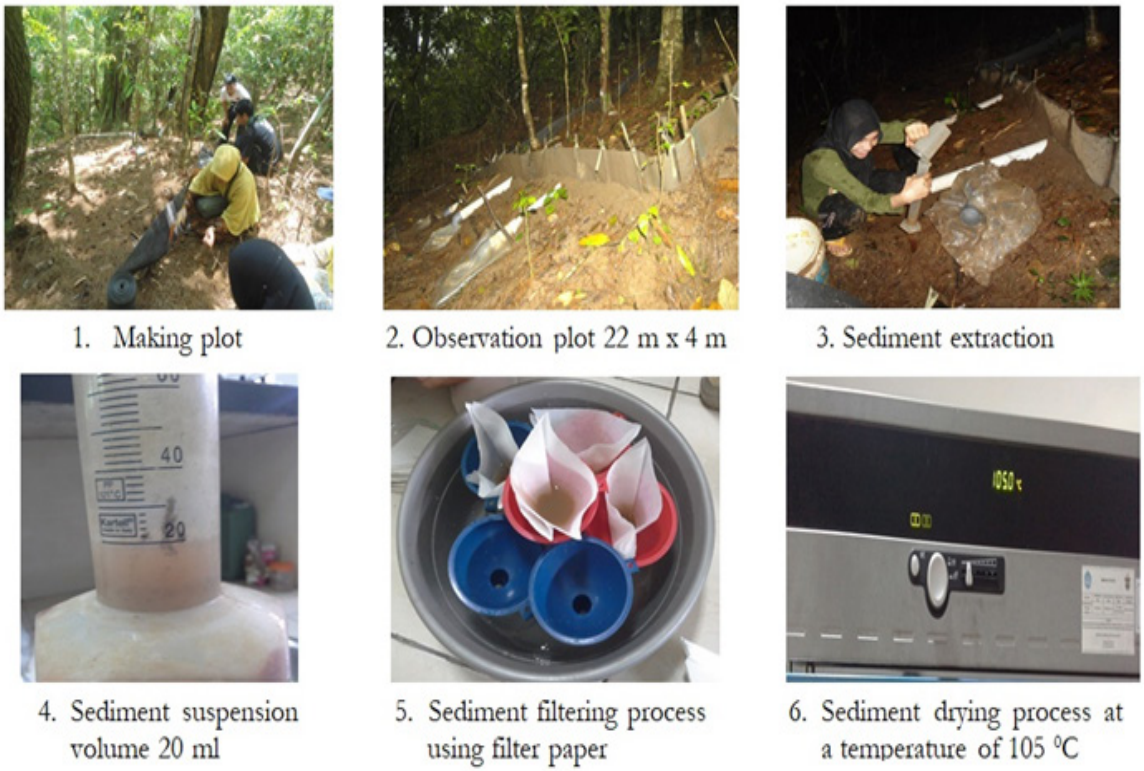

Figure 1 Erosion plot

Table 2. Regression analysis of the relationship between erosion and intensity, closure and slope

ANOVA[a*]					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	144335.62	4	36083.91	9.808	0.000[b]
Residual	842540.29	229	3679.22		
Total	986875.91	233			

Remarks: a*. Dependent Variable: erosion

b. Predictors: (Constant), closure, intensity

Table 3. Regression analysis of the relationship between erosion and rainfall intensity, closure, Z. intensity, Z. closure on slopes below 40% and above 40%

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	49.42	21.60		2.287	0.023
	Rainfall intensity	17.53	7.29	0.208	2.405	0.017
	Closure	-25.22	6.87	-0.224	-3.672	0.000
	Z.Intensity	10.87	10.31	0.202	1.054	0.293
	Z.Closure	-3.03	11.79	-0.047	-0.257	0.797

Note: a. Dependent Variable: erosion

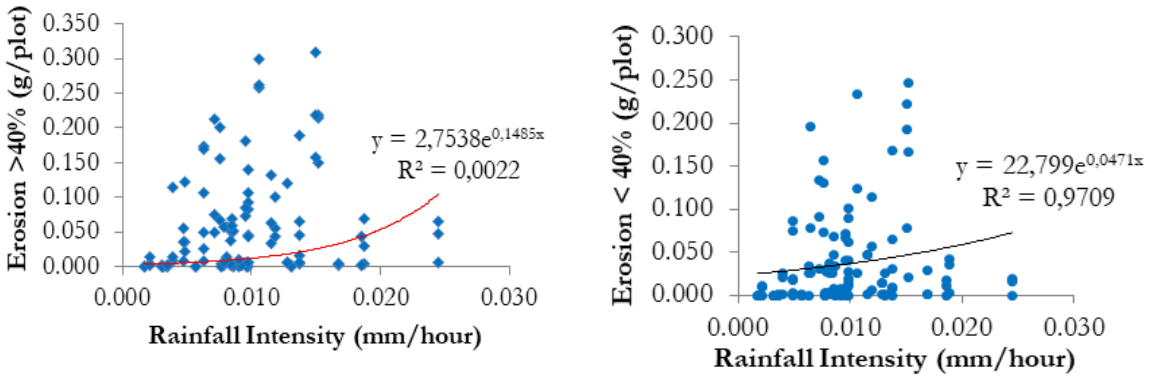

Figure 2 Graphic relationship between rainfall intensity and erosion on slopes> 40% and <40%

to the effect of closure (Z. Closure), do not have a significant relationship with erosion. The effect of rainfall intensity is positive 17.53. This means that each increase in one unit of intensity will increase surface erosion by 17.53 g/plot, assuming other variables are of a fixed value. The closure coefficient value of the negative variable is 25.22, meaning that each increase of one unit of closure will reduce the surface erosion by 25.22 g/plot, assuming the other variables are of a fixed value.

Based on the regression test, closure is significantly associated with erosion at slopes below 40% and above 40%. The independent variable Z.intensity is not evident on slopes above 40%, meaning that the slope does not contribute to the effect of intensity on erosion. Therefore it can be explained that the effect of intensity and slope on erosion can be eliminated by the presence of dense closure both on slopes below 40% and above 40% (E1-Hassanin et al., 1993) ; (Ispriyanto et al., 2001).

The relationship of rainfall intensity with erosion on slopes> 40% and <40% can be seen in Figure 2.

Figure 2 shows that rainfall intensity is positively correlated with erosion. The higher the intensity of rainfall, the greater the rate of soil loss. On slopes <40% the influence of rainfall intensity is greater, namely 97.59%. This shows that high rainfall intensity can cause high erosion even on low slopes (Cao et al., 2015)

Further tests of the relationship of intensity to erosion on slopes below 40% and above 40% can be seen in Figure 3.

Figure 3 shows that the average value of

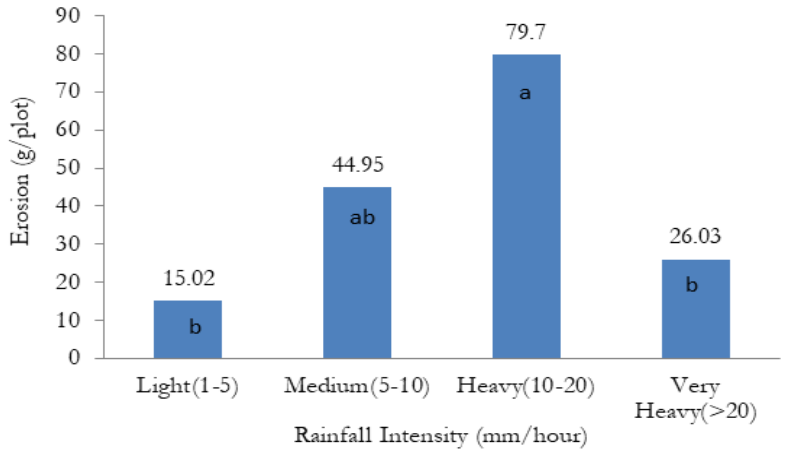

Figure 3. Graph of the Duncan test resultsin the relationship of rainfall intensity with erosion on slopes> 40% and <40%

Table 4. Duncan test results of closure relationship to erosion on slopes on slopes> 40% and <40%

% canopy closure	Erosion > 40%		% canopy closure	erosion < 40%		
	1	2		1	2	3
68.66%	33.46^{c}		92.61%	9.79^{d}		
71.20%	49.92^{bc}		71.02%		40.21^{c}	
55.68%		81.44^{a}	46.02 %			60.22^{b}

erosion at the intensity of heavy rainfall is 79.7 g/plot not significantly different from the moderate intensity of 44.95 g/plot, both are significantly different from the intensity of very heavy and light rain, respectively - each resulted in erosion of 26.03 g/plot and 15.02 g/plot. The erosion on very heavy rainfall intensity was lowerthan that on medium and heavy because the rain was short, 21 minutes and 24 minutes. The average erosion that occurred in all plots was smaller even though the intensity of the rain was very heavy at 24.5 mm/hour.

The relationship between cover and erosion on slopes below 40% and above 40% can be seen in Table 4.

Table 4 shows that on slopes> 40%, 55.68% closure results in erosion of 81.44 g/plot, significantly higher than 68.66% and 71.20% closure, with erosion rates of 33.46 g/plot respectively and 49.92 g/plot. While the three are significantly different on the slopes <40%,46.02% closure is significantly higher than 71.02% closureand significantly different at 92.61% closure. It produces erosion of 60.22 g/plot, 40.21 g/plot and 9.79 g/plot respectively. The higher the closure, the smaller the erosion will occur. Erosion will decrease with increasing plant cover (Luo et al., 2020).

Measurements were carried out for 4 months, starting at the beginning of the rainy season until the peak of the rain until the end of the rainy season, starting from November 2016 to February 2017, results shows that average soil erosion is 54.84 gr/plot or equal to 0.006 ton/ha.

The relationship between the slope and the amount of erosion can be seen in Figure 4.

Figure 4 shows that erosion at a slope of 61% and 27%, the resulting erosion is significantly different at a slope of 72%, 58%, 29%, 27% and 25%. There is no significant difference between erosion generated at a slope of 25%,

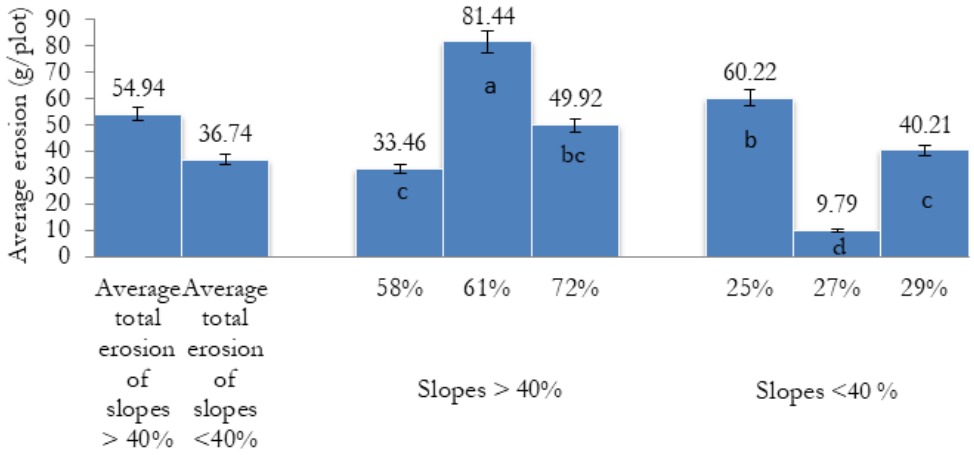

Figure 4. Graph of average erosion and Duncan test on slopes >40% and <40%

72% and 58%. Likewise at the slope of 29% the erosion produced was not significantly different from the slope of 58%.

To find out whether the level of erosion that occurs on slopes> 40 and <40% is different or not, a 2-difference test is used (Independent Samples T). Figure 4 shows the total average value of slope erosion> 40% and <40% of 54.09 g/plot and 36.74 g/plot. The average two different test results (Independent Samples T) the calculated T value = 2.500 is greater than T table that is 1.969 at a significant test level of 0.025 (2-tailed test), then H0 is rejected. At the 95% confidence interval, there was a difference in the average erosion on the slopes of >40% and <40%.

B. Discussion

1. Relationship between rainfall intensity and erosion

Some factors that influence the rate of erosion are rainfall pattern, slope, soil type, topography, crop system and management practices (USLE, 2012). Rain intensity has a significant effect on the test level of 5%. The effect is positive, i.e. the higher the rainfall intensity, the higher the erosion (see figure 1). This is in line with the opinion of (Cao et al., 2015) that rainfall intensity positively influences erosion. It's just that the relationship between rainfall intensity and erosion is not strong due to the influence of the dominant pine canopy.

Dense canopy closure will eliminate the effect of rainfall intensity on erosion (E1-Hassanin et al.,1993); (Ispriyanto et al., 2001). Pine headers can reduce the raindrops so that the kinetic energy of the rainwater will be reduced before it reaches the ground surface. When it reaches the ground, it is also blocked by a thick layer of pine litter. When the rain water has reached thesoil's surface, the ability to destroy soil particles is getting smaller and even lost. Layered canopy and thicker litter can protect against the effects of rainfall against erosion (Valeria A et al., 2018).

2. Relationship of slopes to erosion

The slope affects the rate of erosion through the amount of runoff (Nanko, 2006). The steepness of slope affects the magnitude flow coefficient, sediment carrying capacity and displacement of soil particles by rainwater. The steeper the slope greater the rate and amount of runoff, greater the sediment flow (Aburto F et al., 2021).Slopes are linearly related to erosion (Zhang et al., 2018). Slope has a positive correlation with erosion. In contrast to this study, the slope does not significantly contribute to the effect of intensity and cover on erosion. Plot 1 on slopes> 40%, slope of 58% produces erosion of 33.46 g/plot or equivalent to 0.004 tons/ha. This is smaller

than in a four-slope plot <40% slope 25% with an average erosion value of 60.22 g/plot 0.007 tons/ha. This happened because of the influence of dominant vegetation.

The thickness of litter in the pine can inhibit sediment of movement so that it affects the amount of loss of soil particles (Li Xiang et al., 2014). The thickness of pine litter in this study was between 1.6 and 2.6 cm. Pine litter is very instrumental in controlling the rate or speed of runoff water. Pine litter is like a filter that will inhibit sediment transport by runoff water. The flowing water will form a zig-zag, each time it passes through the composition or pile of litter in the form of twigs, leaves that are piled thick, the speed will decrease. Before runoff water reaches the foot of the slope, the concentration of sediment will be smaller. High biomass can provide a protective effect from soil erosion (Valeria A et al., 2018). Slopes do not affect the amount of erosion if the closure is tight or more dominant. Therefore forest stands are very important in controlling erosion (Wang S et al., 2020).

3. Effect of pine closure on erosion

There is a significant effect of closure on erosion. There is a significant influence on the test level of 5%, with a negative regression coefficient indicating that closure can reduce erosion. If the percentage of closure is high it will, produce small erosion even on high slopes. This is evidenced at the slope of 58%, significantly different compared to the slope of 25%. Conversely, if the percentage cover is small, it will produce large erosion even on low slopes. This can be proven at a slope of 25% not significantly different from 72%. Likewise, the slope of 29% is not significantly different from 58% and 72%. Therefore the higher the percentage of pine canopy cover, the smaller the erosion so that it can be explained that erosion is significantly correlated with closure(Suryatmojo et al., 2014); (E1-Hassanin et al., 1993).

A thick pine canopy captures more precipitation and breaks it into smaller particles or particles. Rainwater with a very small particle size, when it falls on the surface of the ground, its kinetic energy becomes weak. Conversely on large rainwater grains have considerable kinetic energy and can destroy soil particles. Every time there is a decrease in forest vegetation cover will have an impact on vulnerability to erosion. Therefore canopy or canopy cover becomes an ecological factor that plays an important role in determining soil erosion (Li Xiang et al., 2014). The existence of forest vegetation as a protector(Cerdà & Doerr, 2008)greatly influences the hydrological cycle (Suryatmojo et al., 2014).

Erosion on a slope of 58% is smaller than a 25% slope due to the multistrata canopy so that the cover becomes denser and thicker. The top canopy layer, *Pinus merkusii*, has a cover percentage of 53.41%.The second is *Alstonia scholaris*, and the third is *Cinnamomum* sp. Sapindaceae's, have total cover percentage was 15.25%. Multilayers vegetation cover can suppress the influence of slope. A dense and thick canopy layer can break down precipitation particles into smaller ones so that they evaporate more easily. This study perception of pines 42.92% of total rainfall 904.50 mm (Rosmaeni et al., 2019). High interception will decrease the amount of rainfall and weaken kinetic energy on the ground surface, so the ability of rainfall particles to destroy is very low and even lost.

Similarly with the researchresults by Suryatmojo et al.(2014) that suspended sediment in primary natural forests is smaller at 0.15 tons/ha/year compared to a plantation of 10 years old 3.6 tons/ha/year. Although this figure is slightly larger thanthe figure found in research under the stands of *Pinus merkusii*, both show that good forest vegetation can control erosion even with high slopes (Li Xiang et al., 2014).Ispriyanto et al. (2001) suggested that length and slope factors are not always positively correlated with surface runoff while vegetation cover is dominant. Thus it can be concluded that the vegetation cover factor greatly affectsthe erosionrate (El Kateb H et

al., 2013).

Vegetation type and level of cover are the most important indicator influencing differences in soil loss (Jianbo L et al., 2018). Empty land without forest cover will lose soil along with the slope and length of the slope. If the lenght slope increases from 5 to 20 m , soil loss per unit of rainfall increases 2-fold, and sediment concentration increase 5-fold (E1-Hassanin et al., 1993). What we found at a slope of 25% with a canopy cover of 32.95%/ plot resulted in an erosion of 60.22 g/plot or equivalent to 0.007 tons/ha, higher than 27% slope only resulted in an erosion of 9.79 g/ plot is equivalent to 0.001 tons/ha with a pine canopy cover of 77.27%. Therefore, if the canopy closure is more than 70%, erosion will be close to zero.

A high percentage of canopy cover at a slope of 27% contributes very significantly to slopes below 40%, causing a difference in the average value of erosion with slopes above 40%. This can be shown in the average two difference test (Independent Samples T-Test) with a 95% confidence interval stated that there is a difference in the average erosion on slopes> 40% with slopes <40%.

Dense and layered vegetation reduces the kinetic energy and speed of rainwater before it reaches the ground surface. Large raindrops are broken up into small particles by the upper layer's canopy, then fall on the second layer until the rain particles get smaller. Before, the surface layer of the soil is still held back by the litter layer. Pine in the shape of needles can break rainwater particles into particles so small that rainwater no longer can sprinkle soil. Its ability to break rainfall particles into granules is very small, causing the rain water to evaporate back into the atmosphere before falling on the surface of the land.

Comparing with the study results of Topic et. al., (2008) found the amount of soil loss in black pine stands *(Pinus nigra* Arn.) With a layer of natural humus and thick grass, slope 320 (62.49%) of 0.0116 tons/ha. Dark black pine with complete canopy, no grass, soil loss 0.02 tons/ha. Then in pine aleppo stands (*Pinus halepensis* Mill.) Preserved complete crown cover at a slope of 200 (36.4%), soil loss of 0.044 tons/ha, whereas in pine aleppo stands with 200 (36.4%) soil loss the land is 19.93 t/ ha. The result is that soil loss due to erosion in burnt areas with a 20° (36.4%) slope is 463 times higher than under the canopy of pine aleppo preserved at a slope of 26°. In general, it can be said that pine stands are effective in controlling erosion.

IV. CONCLUSION

Erosion rates on slopes of >40% and <40% are significantly affected by rainfall intensity and closure. Erosions on the slope class of >40% and < 40% area significantly related to the intensity of rain and cover, where the larger slope class has smaller erosion due to closure effect.

The results of this study will have implications for a review of the determination of protected forest areas with a slope of 40%. This number limit is not an absolute number. The results show that erosion occured less even on slopes >40%, due to the effect of vegetation cover. Based on these results, the delimitation of protected forest on slopes starting at 40% can be reviewed, considering many forest lands with a slope of 40% have been encroached and converted into other uses. Regarding the slope percentage, further research is needed on various species of forest vegetation.

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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.

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