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CORRECTION

In Indonesian Journal of Applied Environmental Studies Vol. 2 No. 1 April 2021 page 17, **written as** Figure 3. Species-area curve of tree species with DBH ≥ 10 cm in 100 subplots of the 100 m x 100 m plot in the forest of the midsection of BDNP core zone. **The correct one** is Figure 4. Diameter class distribution of trees with DBH ≥ 10 cm in a one-hectare plot in the forest of the midsection of the BDNP core zone, Jambi.

Cover Photo : *Coelogyne pulverula* also known as *Coelogyne dayana*, a wild orchid that lives as an epiphyte in primary sub-montane tropical forests in northern Sumatra. Photo taken in the Agusan Valley, Aceh in 2003. (©Dolly Priatna)

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GUEST EDITORIAL

Understanding the relationship between environment, agriculture and health: An interdisciplinary challenge

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INTRODUCTION

In an editorial last year, Prof. Kathryn Monk explained the importance to environmental research of an interdisciplinary approach. She has asked me to share with readers some further, personal thoughts on this topic. I am an ecologist by training, but I spent much of my career managing agricultural research programmes in tropical regions. For the last ten years, I have held a position in a school of public health. This varied disciplinary experience has given me the opportunity to explore and understand interactions between environment, agriculture and human health.

It is helpful to think of environment, agriculture, and health as points in a triangle, each having specific interactions with an adjacent sector, but also being influenced by more complex, three-way interactions. For environmental scientists, the interactions with agriculture are probably the most familiar. Extensive planting of crops like rice and oil palm has dramatic effects on biological diversity, water systems and their function, and soils. The importance of healthy environments to agriculture is repeatedly demonstrated. Thirty years ago, I had the opportunity to review the Indonesian national programme on integrated pest management in rice. Use of pesticides on rice was, paradoxically, causing severe outbreaks of pests like brown planthopper. The environmental processes behind this were actually quite complex. Soon after flooding, aquatic arthropods colonizing rice paddies provided a food source for generalist predators that moved in and built levels capable of suppressing subsequent pest invasion. Pesticides killed off this general predator community, while the pests, which lay their eggs inside plants, were less affected and their populations exploded in this predator-free environment (Settle et al, 1996), Integrated Pest Management (IPM) on rice, pioneered in countries like Indonesia, was for many years a leading example of the value of integrating environmental and agricultural research.

Environmental scientists will be less familiar, perhaps, with the interactions between agriculture and health, so here is a short introduction. Agricultural systems have two impacts on health, which for historical reasons have been treated as separate disciplines in the health sector. They produce food that contributes to nutrition, which is usually, but not always, a health benefit, and they produce distinct health risks, including diseases associated with food and food production, and toxins associated with agriculture, such as the pesticide just mentioned.

AGRICULTURE AND NUTRITION

Agriculture, and the food systems that it supports, has clear benefits. Improving the production of rice and other staples in Asia, associated with the Green Revolution of the last century, has prevented famine, and helped countries provide food security to citizens. But diets are changing rapidly worldwide, particular in urban communities that now hold over a half of the human population. Here, processed food comprising flour from cereals, fats, sugar, and salt, are increasing components of diets, leading to chronic diseases such as diabetes and heart disease, and creating a global emergency for food systems and health (Webb et al, 2020). Poorer households, where food is scarce and processed foods are popular because they are cheap, are particularly affected by this growing "triple burden of malnutrition" – undernutrition combined with obesity and micronutrient deficiency. Micronutrients are poorly provided by these largely cereal-based diets, being found more in vegetables, fruits, and animal-sourced foods. Recent studies show this problem to be particularly severe in East Asian countries, including Indonesia (Mayer et al, 2019; Blankenship et al, 2020)

The agriculture and nutrition challenge today is to shift our agriculture and food systems towards more healthy diets, including more fruits and vegetables. But achieving this is challenging. Agricultural development, which may increase incomes and access to staple foods like rice, may have fewer positive effects as well. A recent study in Indonesia compared the level of micronutrient rich foods in diets of farmers practicing different kinds of agriculture. Diets of households in forested areas characterized by swidden agriculture and agroforestry included a larger number of nutritionally important food groups than households in areas dominated by timber and palm oil plantations (Ikowitz et al, 2016). Changing from swidden to plantation farming also strongly affects time allocation in households, particularly for women who have the greatest responsibility for family nutrition (Rowland et al, 2020). The benefits to diets of agricultural development are therefore controversial (Nurhasan et al, 2020).

AGRICULTURE AND INFECTIOUS DISEASE

The other relationship between agriculture and health rests with diseases and toxins associated with agriculture and food systems. I shall not say much about toxins, which can involve both agrochemicals like pesticides, and toxins produced by crops and by microbes that inhabit them. Despite the success of IPM programmes such as that on rice in Indonesia, pesticide use on food crops continues to rise. However, some of the benefits of IPM programmes in Indonesia and other countries appear to be long-lasting (van den Berg et al, 2020).

Let me focus instead on diseases and agriculture, as this brings us quickly back to the critical importance of environmental research. A recent study used clinical records of infectious diseases from across Southeast Asia to look for associations between the frequency of infectious diseases and the environments in which people were living (Shah et al, 2020). It revealed that people who live or work in agriculture are 1.7 times more likely to be infected with a pathogen than those in non-farming professions.

A particular source of disease risk from agriculture comes from animals. This is because animals that we eat, both wild and domestic, are a historical source of many of the diseases that now affect humans. An estimated 60% of pathogens that cause human diseases originate from wild or domestic animals, and 75% of emerging human pathogens are of animal origin (Jones et al, 2008). Agriculture plays a particular role in spreading these zoonotic diseases because it contributes to the degradation and exploitation of natural environments, bringing humans in contact with other species. The recent Covid-19 pandemic is just the latest in a recent series of such zoonotic disease outbreaks, which have included include avian and swine flu, Ebola virus, Nipah virus, and many others. In many cases, livestock production creates an important conduit between diseases in wildlife and humans. For instance, Nipah virus in Southeast Asia, a disease of bats, entered humans via pig production in peri-urban areas where bats roosted in trees over pig pens, and so the pigs ingested bat feces containing the virus, which was then passed on to humans (Wongnak et al, 2020).

Despite their high-profile, these pandemic diseases from wild animals in natural environments are by no means the most important infectious diseases associated with agriculture. These are a different group of well-known pathogens, largely bacterial, associated with unsafe food, such as species of *Salmonella, Staphylococcus, Campylobacter,* and others. Until recently, food-borne diseases were not seen as key health burdens in low- and middle-income countries (LMICs), but a landmark study in 2015 revealed that the global burden of food-borne diseases is comparable to that generated by malaria, HIV/AIDs or tuberculosis (Havelaar et al, 2022), and the great majority of this burden falls in LMICs, where it is rapidly increasing. While generally not risks to life, these diseases cause considerable illness and economic loss to productivity. Further, they are now associated with the transmission of resistance to antibiotics because of unregulated use of drugs to control them in the human and livestock sector (Antimicrobial Resistance Collaborators 2019). Food safety measures are particularly difficult to implement in tropical regions, with their widespread wet markets, which often create ideal conditions for these food safety problems. Further, these diseases are not just associated with animal-sourced foods, but with fruit and vegetables as well, where handling in markets may transfer bacterial from other sources.

The environmental dimensions of this interaction between agriculture and disease are often complex and fascinating. For instance, many agriculturally associated diseases are vector borne, and their insect or snail vectors depend on the water systems which we create for agriculture. In Africa, for instance, the *Anopheles* mosquito species, which are the principal vectors of malaria, are particularly associated with shallow, temporary water environments. This makes rice cultivation a major source of infection. As efforts in Africa to eliminate malaria are progressed, rice-growing areas are emerging as hot spots of infection, which may require radical changes in the way rice is grown there (Chan et al, 2022). Fortunately, in Asia, the species that transmit malaria do not breed in rice paddies, but in wooded areas. Hence this environmental different in vector biology creates a very different disease risk profile for rural populations.

A recent study in northern Borneo illustrates this complex environment-agriculture-disease relationship. Here, the majority of malarial infections are zoonotic, caused by the parasite *Plasmodium knowlesi* which infects both humans and local species of macaque (Fornace et al, 2019). This study compared data on the distribution of individuals that were seropositive for this parasite, comparing this to environmental and population parameters, measured from drone images of habitats surrounding dwellings. Environmental and agricultural variables, such as fragmentation of landcover due to plantations and farming, predicted exposure to this disease at different spatial scales. Other studies showed that forest fragmentation changed distribution and activity of macaques, a possible cause of changes in infection.

INTEGRATING ENVIRONMENT, AGRICULTURE AND HEALTH

Let me finish on how this interdisciplinary research on environment, agriculture and health may be usefully applied to solving major societal problems. It is often the case that resolving conflicts between these sectors involve trade-offs. For instance, regulating safety in animal-sourced foods may reduce risks from food-borne diseases, but it may also make these foods more expensive, reducing their availability and nutritional benefits to children, particularly in poor communities. Economic modelling is proving a useful tool to examine these conflicts and to identify the balance of trade-offs that maximizes well being, at a household or even a national level.

An important example of this is palm oil production, an agricultural activity that has had tremendous economic benefits in Asia. At the same time, as a highly saturated fat, palm oil consumption has been associated with negative effects on cardiovascular health, while large-scale oil palm production has been linked to deforestation and other environmental impacts. How do we compare these environmental, agriculture and health outcomes and develop from this the most effective national strategy for this activity? Would a national effort to reduce palm oil consumption generate health benefits, in terms of longer, disease-free lives and a healthier workforce, that outweigh possible economic dis-benefits from reduced production, affecting farmers and food chain actors? Would reduced production lead to environmental co-benefits that, together with health benefits, create a net positive, long term effect for a producing country?

A few years ago, colleagues in our research group undertook a modelling study on oil palm production, focused on Thailand (Jensen et al, 2019). This interdisciplinary team created a national level model, calculating in economic terms the costs and benefits of oil palm production in these different sectors. They then explored the impact of a possible policy to reduce palm oil consumption by taxing this product. This modelling experiment showed long-term national economic benefits from improved health, but a need to support economic losses to some growers. They measured environmental effects only in terms of greenhouse gas production, where reduction in production was of little benefit, as plantations would be replaced by field crops less effective at capturing and storing carbon. This modelling was complex, and country-specific, and therefore generated few conclusions of broad significance. But it demonstrated the opportunity provided by interdisciplinary research to contribute to solving truly complex society problems.

Over the years, in our research programme, we have found that interdisciplinary research has been very rewarding in supporting informed policy making. At the scientific level, it requires that scientists from different disciplines be open-minded, and sensitive to the different perspectives and "languages" used by other disciplines, seeking ways to involve all of these from the start of a research collaboration. Often, the structures of university departments and government research institutions makes such collaboration difficult, and younger scientists may perceive little reward to their career progression by stepping outside their specialism to work with other disciplines, however exciting and rewarding this may be. But this pattern of rigid isolation of research disciplines is changing, and it must if scientists are going to provide society with sustainable solutions to these complex problems.

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https://doi.org/10.1186/s12917-020-02502-4

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NEWS, NOTES, & EVENTS

Environmental security and resilience – Indonesia and global challenges

KATHRYN A. MONK and **DOLLY PRIATNA** (Eds.)

We are pleased to present InJAST Volume 3 Number 1 April 2022, with research papers ranging from taxonomic studies of Lepidoptera to a phytosociological study of a lowland forest and an analysis of tourism supporting conservation efforts. This volume demonstrates again just how wide-ranging environmental studies are and how much they cross disciplines and geographies. Such studies often demand innovative approaches and disruptive thinking, and, to that end, we are excited to have a Guest Editorial from Prof. Jeff Waage OBE of the London School of Hygiene and Tropical Medicine to inspire such thought. Prof. Waage started the London International Development Centre (LIDC) in 2007 as a consortium of University of London's Bloomsbury Colleges. LIDC is based on the belief that solving today's complex development challenges starts with collaboration. It draws on an extensive diverse and active community of researchers, postgraduate students, and development professionals to deliver interdisciplinary research that creates real change. They work collaboratively across the globe, including in Indonesia. In his Guest Editorial, Prof. Waage explains the challenges of investigating and managing the interactions of the environment, agriculture, and health.

Indonesia faces tremendous challenges from climate change, biodiversity loss, and wider social and economic change. These challenges need extensive interdisciplinary approaches enabling multiple perspectives from diverse stakeholders to be recognised and utilised. Collaboration between scientists, social scientists, and economists has never been so important. As Christiana Figueres, former Executive Secretary, United Nations Framework Convention on Climate Change said: "The [global] challenges we face are massive, urgent, and interconnected. We need people across all sectors to pull together and move us to a bright and strong future. There's no time to waste!". We are therefore happy to see the growing number of community-based participatory studies being submitted to InJAST and hope these will increase in future. There are exciting and vitally important issues to be tackled and supported by environmental managers, from direct conservation work to flood risk management and pollution control. Climate change drives or affects all these of course and has been, for example, one of the key drivers for Indonesia's momentous plans to move the capital from the 256,000-hectare (990-square-mile) Jakarta on the north-western side of Java Island, the most populated island in the country, to the relatively undeveloped and biodiversity-rich East Kalimantan province. Climate change and immediate economic drivers in many parts of Indonesia also contribute to the annual toxic haze, which causes air quality to reach hazardous levels and creates major health, environmental and economic problems, especially in Sumatra and Java. Indeed, as of March this year, Riau province has already declared a state of emergency ahead of this year's main fire season.

More globally, environmental security and resilience have never been so central to issues of international importance, with hugely significant international events last year and this being planned and run despite other major global challenges. The most important of these was the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow, UK, on 31 October – 13 November 2021, which resulted in the Glasgow Climate Pact. This global agreement aims to accelerate action on climate this decade, and finally completes the Paris Rulebook. A record-breaking number of delegates gathered for this critical COP, including Indonesian President Joko Widodo, who received global attention for his exciting commitments to deforestation, early coal power retirement, and the clean energy transition. Underlining the importance of all commitments made at COP26 is that COP27 will be held in Egypt in November this year to ensure all nations are integrating their national climate change actions with the Glasgow Climate Pact. Indonesia has much opportunity for leadership here. Indonesia holds the 2022 G20 Presidency and raised three priority issues at the 2022 G20 Environment Deputies Ministerial-Climate and Sustainable Working Group meeting recently, including marine management to achieve climate change mitigation targets. They highlighted the great potential of blue carbon, especially in the mangrove ecosystem, for reducing greenhouse gas emissions. It was particularly exciting to see that the interdisciplinary nature of these problems and their solutions was being recognised. Joint meetings are planned with other working groups, such as energy transition, sustainable finance, business, and youth. Evidence to inform the development of these solutions will be imperative and interdisciplinary environmental science should be at its heart.

Biodiversity is of course also on the global agenda. The first part of the 15th meeting of the Convention on

Biodiversity (CBD) COP was held online in October last year. The latest information from the Secretariat of the CBD is unfortunately and worryingly that the second part of COP15 is delayed until the third quarter of this year. The recent Geneva pre-meeting ended without resolving any of the key issues – finance, implementation, or key targets, including protecting at least 30% of land and sea by 2030 ("30-by-30"), and the rights of Indigenous Peoples and local communities.

Against this background of global and national environmental evidence needs, the aim of InJAST is to stimulate and share the work of an increasing community of environmental researchers and managers in Indonesia and elsewhere. We encourage papers associated with local, national, and international challenges. We especially recognise the growing community of postgraduates and early career researchers and will support you in developing these materials for publication. Environmental security and resilience are at the heart of what you do, and we want to make sure you are heard.

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NOTES

Natural disasters and climate change beliefs: The role of distance and prior beliefs

Public support of climate policies crucially depends on climate change beliefs. Here we analyse the effects of natural disaster experience on the belief in the existence of climate change. The primary data source is a panel survey covering 22,251 observations from 11,194 geo-located households collected in Germany between 2012 and 2015, combined with satellite imagery of a major flood event in 2013. We find that flood experience had a significant positive effect on the beliefs in the existence of climate change for those respondents living close to the flooded area. However, the effect decreases sharply with distance. We further show that this overall effect is driven by those respondents who already believed in climate change before the flood – they saw their belief confirmed by their experience. In contrast, spatial proximity to the flood had no measurable effect on skeptics. These results imply that climate skeptics may not be influenced by the experience of natural disasters at their doorsteps.

Osberghaus, D. & Fugger, C. (2022). Natural disasters and climate change beliefs: The role of distance and prior belief. *Global Environmental Change*, 74, 102515.

The global scale, distribution and growth of aviation: Implications for climate change

Prior to the COVID-19 crisis, global air transport demand was expected to triple between 2020 and 2050. The pandemic, which reduced global air travel significantly, provides an opportunity to discuss the scale, distribution and growth of aviation until 2018, also with a view to consider the climate change implications of a return to volume growth. Industry statistics, data provided by supranational organizations, and national surveys are evaluated to develop a pre pandemic understanding of air transport demand at global, regional, national and individual scales. Results suggest that the share of the world's population travelling by air in 2018 was 11%, with at most 4% taking international flights. Data also supports that a minor share of air travelers is responsible for a large share of warming: The percentile of the most frequent fliers – at most 1% of the world population - likely accounts for more than half of the total emissions from passenger air travel. Individual users of private aircraft can contribute to emissions of up to 7,500 t CO2 per year. Findings are specifically relevant with regard to the insight that a large share of global aviation emissions is not covered by policy agreements.

Gossling, S. & Humpe, A. (2020). The global scale, distribution and growth of aviation: Implications for climate change. *Global Environmental Change*, 65, 102194.

Are we underestimating microplastic abundance in the marine environment? A comparison of microplastic capture with nets of different mesh-size

Microplastic debris is ubiquitous and yet sampling, classifying and enumerating this prolific pollutant in marine waters has proven challenging. Typically, waterborne microplastic sampling is undertaken using nets with a 333 μm mesh, which cannot account for smaller debris. In this study, we provide an estimate of the extent to which microplastic concentrations are underestimated with traditional sampling. Our efforts focus on coastal waters, where microplastics are predicted to have the greatest influence on marine life, on both sides of the North Atlantic Ocean. Microplastic debris was collected via surface trawls using 100, 333 and 500 μm nets. Our findings show that sampling using nets with a 100 μm mesh resulted in the collection of 2.5-fold and 10-fold greater microplastic concentrations compared with using 333 and 500 μm meshes respectively ($P < 0.01$). Based on the relationship between microplastic concentrations identified and extrapolation of our data using a power law, we estimate that microplastic concentrations could exceed 3700 microplastics m^{-3} if a net with a 1 μm mesh size is used. We further identified that use of finer nets resulted in the collection of significantly thinner and shorter microplastic fibres ($P < 0.05$). These results elucidate that estimates of marine microplastic concentrations could currently be underestimated.

Lindeque, P.K., Cole, M., Coppock R.L. et al (2020). Are we underestimating microplastic abundance in the marine environment? A comparison of microplastic capture with nets of different mesh-size. *Environmental Pollution*, 265(A), 114721.

Current research trends on plastic pollution and ecological impacts on the soil ecosystem: A review

Plastic pollution in the environment is currently receiving worldwide attention. Improper dumping of disused or abandoned plastic wastes leads to contamination of the environment. In particular, the disposal of municipal wastewater effluent, sewage sludge landfill, and plastic mulch from agricultural activities is a serious issue and of major concern regarding soil pollution. Compared to plastic pollution in the marine and freshwater ecosystems, that in the soil ecosystem has been relatively neglected. In this study, we discussed plastic pollution in the soil environment and investigated research on the effects of plastic wastes, especially microplastics, on the soil ecosystem. We found that earthworms have been predominantly used as the test species in investigating the effects of soil plastic pollution on organisms. Therefore, further research investigating the effects of plastic on other species models (invertebrates, plants, microorganisms, and insects) are required to understand the effects of plastic pollution on the overall soil ecosystem. In addition, we suggest other perspectives for future studies on plastic pollution and soil ecotoxicity of plastics wastes, providing a direction for such research.

Chae, Y. & An, Y.J. (2018). Current research trends on plastic pollution and ecological impacts on the soil ecosystem: A review. *Environmental Pollution*, 240, 387-395.

Soil health and climate change

Soils regulate many biological and physical processes between the atmosphere and the lithosphere. Soil health is an integrative property of soil that supports agricultural sustainability. Measurement of a single property in concern with the soil health is nonetheless always being related to particular circumstances. Conserving natural resources is a major concern in sustaining soil health for feeding the increasing population. In the current scenario of globalization, climate change is discussed as a global issue. Human influences on climate change exceed the boundaries of natural variability consequently resulting in changes in atmospheric composition, urbanization land-use changes, cropping patterns, etc. Carbon regulation in soil plays a major role in climate change in the soil system. An increase in mean annual temperature accelerates the decomposition rate of organic matter that influences the water storage capacity, nutrient balance, and aggregate stability, which are important for good soil structure, soil fertility, productivity, and sustainability. As a matter of fact, soil microbes decompose organic matter, but a rise in temperature may alter the microbial population with changing temperature regimes. Hence, it is necessary to study the climatic impact of soil health to take necessary steps to overcome the negative effects. An integrated sustainable approach linked with soil health may contribute a significant resilience under adverse conditions. Increasing soil organic carbon is the best way to mitigate climate change and to ensure food security. Hence, COP 21 launched the "4 per mille Soils for Food Security and Climate" to increase global soil organic matter stocks by 0.4% per year to mitigate the global emissions of greenhouse gases by anthropogenic sources.

Venati, G., Ch., S., Reddy, K.S. et al (2020). Soil health and climate change. In (book) Prasad, M.N.V. & Pietrzykoski (Eds.). Climate Change and Soil Interactions. *Elsevier*.

Water Pollution: Effects, Prevention, and Climatic Impact

The stress on our water environment as a result of increased industrialization, which aids urbanization, is becoming very high thus reducing the availability of clean water. Polluted water is of great concern to the aquatic organism, plants, humans, and climate and indeed alters the ecosystem. The preservation of our water environment, which is embedded in sustainable development, must be well driven by all sectors. While effective wastewater treatment has the tendency of salvaging the water environment, integration of environmental policies into the actor firms core objectives coupled with continuous periodical enlightenment on the present and future consequences of environmental/water pollution will greatly assist in conserving the water environment.

Inyinbor, A.A., Adebesin, B.O., Oluyori, A.P. et al (2018). Water Pollution: Effects, Prevention, and Climatic Impact. In (book) Glavan, M (Ed). Water Challenges of an Urbanizing World. *Intech.*

A Review of the Measurement Method, Analysis and Implementation Policy of Carbon Dioxide Emission from Transportation

This paper presents a review of carbon dioxide (CO2) emissions from transportation in an attempt to establish a quick and suboptimal update of the methods used to calculate and analyse CO2 emissions from transportation. Transportation is the largest contributor to air pollution through the release of high amounts of CO2 gas into the atmosphere. The methods for calculating and analyzing the carbon footprint of transportation; which is of critical importance in the management of greenhouse gases that contribute to global warming; are still being developed. However; there are some differences in the definitions and methods used to calculate the carbon footprint of transportation in previous studies. This review focuses on the similarities of the methods used to measure CO2emissions as well as the analyses used to evaluate the emissions. This paper will also highlight the advantages and limitations of each research work. By doing this; the present study contributes to the selection of appropriate methods for calculating CO2 emissions from transportation and draws attention to environmental issues. It is hoped that the implementation of the most appropriate framework will help to reduce CO2 emissions from transportation.

Yaacob, N.F.F., Yazid, M.R.M., Maulud, K.N.A. et al (2020). A Review of the measurement method, analysis and implementation policy of carbon dioxide emission from transportation. *Sustainability*, 12(5873), 1-22.

Agricultural water pollution: key knowledge gaps and research needs

While water pollution is starting to receive the attention it deserves, the contribution of agriculture requires greater consideration as current agricultural practices have an unprecedented impact on water quality. This paper reviews knowledge in selected areas of agricultural water pollution (AWP) and identifies future research needs. These include source attribution, emerging contaminants, costs and incentives for adoption of pollution reduction measures. Future research priorities include identification and testing of locally appropriate markers; modelling the effects of contaminants on biota and pathways of microbial contaminants; harmonization of data collection and calculation of economic costs of AWP across countries and projects; and how to better share relevant knowledge to incentivize improved agricultural practices.

Evans, A.E.V., Mateo-Sagasta, J., Qadir, M. et al (2019). Agriculture water pollution: Key knowledge gaps and research needs. *Current Opinion in Environmental Sustainability*, 36, 20-27.

Using catastrophe theory to model climate change

Catastrophe theory is a branch of mathematics and dynamical systems, which explains how some singularities in systems can be used to explain catastrophes in the real-world [1]-[2]. These can be thought of, and are often depicted as, folds within planar spaces. This theory, which came to prominence in the 1970s, can be used to model natural phenomena such as disasters and, currently, is been used to model climate change and changes in the environment. This presentation explores the current literature on catastrophe theory and climate change and discuss its potential for modelling and predicting environmental issues. A number of researchers have published recently on this topic. Some examples are discussed below. Kent has examined how mathematical modelling can be used within risk assessments for global catastrophes [3]. Levi, Hypel and Howard have discussed advances in "drama theory" for coping with global climate change and environmental catastrophe [4], while Mostafa have presented a paper which demonstrates how catastrophe theory can be used for prediction of international concerns such as global warning, and the economics of this [5]. Sunstein has discussed how decision theory can be used to predict potential disasters of all kinds, including Covid 19 and climate change [6]. Finally, Vickrey and Weitzman both discuss the direct application of catastrophe theory to climate change [7]-[8]. There is, thus, much evidence that catastrophe theory has the potential to offer us a powerful modelling tool to help us better understand, analyse and predict those catastrophes which can be encapsulated under the umbrella term of climate change including, global warming, serious flooding and other increasingly "natural" environmental disasters. We discuss the potential for catastrophe theory as a useful tool for physicists who wish to better understand recent and future environmental issues.

Smith, P. & Alfano, R. (2021). Using catastrophe theory to model climate change. *IOP Institute of Physics.*

Carbon balance of tropical peat forests at different fire history and implications for carbon emissions

Accurate assessment of tropical peat forest carbon stocks and impact of fires on carbon pools is required to determine the magnitude of emissions to the atmosphere and to support emissions reduction policies. We assessed total aboveground carbon (AGC) in biomass pools including trees, shrubs, deadwood, litter and char, and peat carbon to develop empirical estimates of peat swamp forest carbon stocks in response to fire and disturbance. In contrast to the common assumption that peat fires combust all AGC, we observed that about half of undisturbed forest AGC, equivalent to about 70 Mg C ha^{-1}, remains after one or two recent fires – mainly in dead trees, woody debris and pyrogenic carbon. Both recently burnt and repeatedly burnt peat forests store similar amounts of carbon in the top 10 cm of peat when compared with undisturbed forests (70 Mg C ha^{-1}), mainly due to increased peat bulk density after fires that compensates for their lower peat C%. The proportion of fuel mass consumed in fire, or combustion factor (CF), is required to make accurate estimates of peat fire emissions for both AGC and peat carbon. This study estimated a CF for AGC (CF_{AGC}) of 0.56, comparable to the default value of the Intergovernmental Panel on Climate Change (IPCC). This study estimated a varying CF for peat (CF_{PEAT}) that ranged from 0.4 to 0.68 as depth of burn increased. This revised CF_{PEAT} is one third to one half of the IPCC default value of 1.0. The current assumption of complete combustion of peat (CF = 1.0) is widely acknowledged in the literature as oversimplification and is not supported by our field observations or data. This study provides novel empirical data to improve estimates of peat forests carbon stocks and emissions from tropical peat fires.

Krisnawati, H., Adinugroho, C., Imanuddin, R. et al (2021). Carbon balance of tropical peat forests at different fire history and implications for carbon emissions. *Science of The Total Environment*, 799, 146365.

EVENTS

UN Biodiversity Conference (CBD COP 15) (Part 2) - Kunming, China 29 Aug-9 Sep 2022 (tentative)

This Conference comprises the 15th meeting of the Conference of the Parties (COP 15) to the Convention on Biological Diversity (CBD), the tenth Meeting of the Parties to the Cartagena Protocol on Biosafety (Cartagena Protocol COP/MOP 10), and the fourth Meeting of the Parties to the Nagoya Protocol on Access and Benefit-sharing (Nagoya Protocol COP/MOP 4).

CBD COP 15 will review the achievement and delivery of the CBD's Strategic Plan for Biodiversity 2011-2020. It is also anticipated that the final decision on the post-2020 global biodiversity framework will be taken, together with decisions on related topics including capacity building and resource mobilization.

The UN Biodiversity Conference was originally scheduled to take place from 15-28 October 2020, in Kunming, China, but was postponed several times in light of the COVID-19 pandemic. On 18 August 2021, the CBD Secretariat announced that COP 15 would take place in two parts:

- the first part took place in a virtual format, from 11-15 October 2021;
- the second part of COP 15 is scheduled to be a face-to-face meeting in Kunming, China, from 25 April-8 May 2022. It is now anticipated that these dates will be adjusted to dates later in 2022.

In November 2021, due to the emergence of the Omicron variant of the COVID-19 virus and subsequent travel restrictions announced by some countries, the resumed sessions of the subsidiary bodies were postponed from January to March 2022. The 24th meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA 24) and the 3rd meeting of the Subsidiary Body on Implementation (SBI 3) of the Convention on Biological Diversity (CBD) as well as the third Meeting of the Open-ended Working Group on the Post-2020 Global Biodiversity Framework (WG2020-3) will prepare for CBD COP 15.
Further information:
https://www.cbd.int/article/new-dates-cop15-virtual-2021-facetoface-2022

UN Climate Change Conference 2022 (UNFCCC COP 27) - Sharm El-Sheikh, Egypt 8-20 November 2021

The 27th session of the Conference of the Parties (COP 27) to the UNFCCC will take place in Sharm El-Sheikh, Egypt. COP 27 was originally expected to take place from 8-20 November 2021. Due to the COVID-19 pandemic, COP 26 was rescheduled from November 2020 to November 2021. As a result, COP 27 will take place from 7-18 November 2022. We will update this page when the agenda for COP 27 is announced. To receive updates from the SDG Knowledge Hub in your inbox, subscribe to the SDG Update newsletter. To explore more climate change reporting, read the full Earth Negotiations Bulletin summary and analysis of the Glasgow Climate Change Conference COP 26 or view all UNFCCC negotiation coverage.
Further information:
https://unfccc.int/calendar/events-list

Sustainable Energy for All Forum (SEforALL Forum) – Kigali, Rwanda 6-8 May 2022

The Sustainable Energy for ALL (SEforALL) Forum was originally scheduled to take place from 6-8 May 2020, in Kigali, Rwanda. In light of the COVID-19 pandemic, it was initially postponed until February 2021. It was subsequently postponed until 2022.

Focusing on the theme, 'Building Speed, Reaching Scale, Closing the Gap,' this Forum will provide a global platform to mobilize resources, connect partners and showcase action to realize the promise of the sustainable energy revolution for everyone. The event will bring together a diverse group of energy stakeholders to take stock of progress towards implementing SDG 7 (Affordable and Clean Energy) and provide an opportunity to develop new partnerships, launch new financial instruments to close energy access gap, and connect with energy leaders from communities, cities, politics, business and finance. The event will also seek to raise ambition under the Nationally Determined Contributions (NDCs) under the Paris Agreement on climate change.
Further information: https://www.seforall.org/forum

International Conference on Sustainable Environment, Agriculture and Tourism (ICOSEAT) 2022 – Bangka Island 21 Jul 2022 - 23 Jul 2022

We are honored and delighted to invite you to participate in the International Conference on Sustainable Environment, Agriculture, and Tourism (ICOSEAT) 2022 which will be held on July 21-23, 2022 in Bangka Island, one of the wonderful places of Indonesia. The main theme of the conference is Agroindustry 4.0, Tourism and Supportive Government for Sustainable Development. We welcome articles in the field of Agroindustry and Appropriate Technology 4.0; Environmental and Mining Engineering; Sustainable Development and Tourism Management; Agriculture and Food Engineering; and Marine, Aquaculture, and Biological Science. ICOSEAT provides a forum for academics, Busines, and governments to present and discuss topics on recent development in those fields.
Further Information: icoseat.ugm.ac.id

The 8th International Conference on Science and Technology - Yogyakarta 7–8 September 2022

Held as part of the Universitas Gadjah Mada Annual Scientific Conferences (UASC 2022) series, the 8th International Conference on Science and Technology (ICST 2022) provides an ideal academic platform for researchers to present the latest research findings and describe emerging technologies and directions in engineering and the natural sciences. This year, five symposia will be held, Computer and Information Technology symposium; Electronics, Power, Communication, Control, and Instrumentation symposium; Life Sciences, Materials, and Applied Chemistry symposium; Mechanical and Industrial Engineering symposium; and Remote Sensing and Geomatics symposium. ICST 2022 is in conjunction with the 3rd Geoscience and Environmental Management symposium. The accepted and presented papers will be submitted for possible inclusion to journals/proceedings that are indexed by Scopus/CPCI/DOAJ.
Further information: https://icst.ugm.ac.id/

SEMIRATA 2022 on the 5th International Conference on Science and Technology (ICST)

FMIPA IPB in collaboration with BKS PTN Barat for Mathematics and Natural Sciences, Universiti Putra Malaysia (UPM, Malaysia), Kasetsart University (KU, Thailand), and SEAMEO BIOTROP will hold SEMIRATA 2022 on the 5th International Conference on Science and Technology (ICST) in conjunction with the 6th International Seminar on Sciences (ISS) and the 13th International Fundamental Science Conference (IFSC) on 10-11 August 2022 (online). The study raised at this event is Science for life resilience and sustainable development with several sub-topics. We invite you and your students to participate in submitting abstracts and research articles. Articles submitted will be selected and published in several journals managed by members of the West PTN BKS for Mathematics and Natural

Sciences, such as HAYATI Journal of Biosciences (Scopus, S1), Biotropia (Scopus, S1), Microbiology Indonesia (S1), Agromet (S2), Journal of Natural Resources and Environmental Management (S2), Journal of Indonesian Agricultural Sciences (S2), etc.

Further information:

https://www.biotrop.org/othernews/semirata-2022-on-the-5th-international-conference-on-science-and-technology-icst

Meet Us Online at the 4th International Electronic Conference on Environmental Research and Public Health (ECERPH 2022), 15–30 October 2022

We cordially invite you to participate in the 4th International Electronic Conference on Environmental Research and Public Health (ECERPH2022), which will be held from 15 to 30 October 2022. Prof. Dr. Jon Øyvind Odland serves as the chair of this e-conference. He is a Professor of Global Health at NTNU, Norwegian University of Science and Technology, and a specialist in GYN/OB, environmental medicine, and epidemiology. This online event will bring together researchers from all over the world with no concerns regarding travel or other related expenditures. Health effects could be very different if the world's temperature increases from 5 to 10 °C compared to an increase from 35 to 40 °C. If we look at the mortality associated with climate change, it is obvious that the burden is higher in tropical areas. However, if we add morbidity and complications for, e.g., reproductive health and pregnancy care, the situation might be very different. The spread of infectious diseases related to vector migration is also a very important topic, as is the situation of environmental exposure to contaminants and occupational health.

This conference will provide leading scientists, working in the environmental research and public health field, with an online platform to share their latest research and engage in exciting discussions.

The main topics and sessions of the conference are:

- Pregnancy, Reproductive Health, and Climate Change;
- Vector Migration from a Climate Perspective;
- COVID-19 from a Climate Perspective;
- The Forgotten Tropical Diseases from a Climate Perspective;
- Cardiovascular Diseases and Climate Change;
- Occupational Health and Temperature Change.

The conference will be completely free of charge to attend, as well as for scholars to upload and present their latest work on the conference platform. The accepted proceedings papers from the conference will most likely be published in a dedicated issue of the MDPI journal *Environmental Sciences Proceedings* (ISSN: 2673-4931). Please note that, before publication, Proceedings Series Journals will review accepted papers using the powerful text comparison tool iThenticate. This procedure aims to prevent scholarly and professional plagiarism. Articles with a high repetition rate and lack of novelty will not be published in the conference proceedings. In addition, all participants will be encouraged to submit an extended full manuscript to one dedicated Special Issue in *IJERPH* (ISSN 1660-4601) with a 15% discount on the article processing charge (APC, the original APC is CHF 2500).

Further information:

https://www.mdpi.com/journal/sustainability/announcements/3524

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A phytosociological study of a lowland forest at the Tesso Nilo National Park, Riau

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ABSTRACT

A phytosociological study of a lowland forest was carried out at the Tesso Nilo National Park (TNNP), Riau. The objective of the study was to obtain quantitative data on the floristic composition and structure of the above-mentioned lowland forest. By establishing a plot of 1.0 ha, the quadrat method was used to collect the data. We recorded a total of 1,303 individuals of trees and saplings with diameters ≥ 2 cm, comprising 304 species, 153 genera, and 62 families. Using the dominance and density of two tree species, the forest community in the plot can be designated as ***Sloetia elongata-Pimelodendron griffithianum* Association**. The species sharing the dominance were *Sloetia elongata* (Importance Value, IV = 14.43), *Pimelodendron griffithianum* (IV = 6.17), *Santiria laevigata* (IV = 5.45) and *Xylopia caudata* (IV = 5.17). Diameter records showed that 80% of trees in the plot were dominated by small individuals with diameters between 10-30 cm. Trees with diameters > 30 cm were *Dracaena* cf. *porteri* (diam. 75.6 cm), *Artocarpus elasticus* (63.3 cm), and *Ctenolophon parviflorus* (62.1 cm). Dipterocarp species was not important since they contributed only 4%, while non-dipterocarps shared 96% comprising 61 families. The highest basal area was shared by nine species, including one dipterocarp, *Shorea leprosula*. Several dipterocarp species occurring in TNNP have been listed in the IUCN Red List of Threatened Species, including *Anisoptera megistocarpa, Hopea ferruginea, Hopea pachycarpa, Shorea atrinervosa, Shorea faguetiana, Shorea lepidota* and *Vatica gamosepala*. The presence of a large number of small trees and a few large trees indicated that the forest in the plot was regenerating after heavy disturbances. Regenerating species were divided into five categories, in which 13 species were regenerating well with *Sloetia elongata* being the best regenerating species while dipterocarps were represented by *Shorea acuminata*. The occurrence of the majority of trees with a height of < 20 m further confirmed the dynamic status of the forest. The importance of primary and secondary forests in TNNP was discussed. Restoration to the original forest was recommended by planting primary forest species, including endemic, rare, and endangered tree species.

ABSTRAK

Penelitian fitososiologi di hutan pamah dilakukan di Taman Nasional Tesso Nilo (TNTN), Riau, dengan ujuan untuk memperoleh data kuantitatif tentang komposisi floristik dan struktur hutan pamah tersebut. Penelitian ini menggunakan metode kuadrat dengan membuat petak seluas 1.0 ha Studi ini mencatat 1.303 individu pohon dan anakan, yang terdiri atas 304 spesies 153 marga dan 62 suku. Dengan menggunakan kerapatan dan dominansi dua spesies, komunitas hutan dalam plot dapat dinamakan **Asociasi *Sloetia elongata-Pimelodendron griffithianum***. Spesies yang berbagi dominansi adalah *Sloetia elongata* (NP/Nilai Penting = 14.43), *Pimelodendron griffithianum griffithianum* (NP = 6.17), *Santiria laevigata* (NP = 5.45) dan *Xylopia caudata* (5.17). Spesies *Dipterocarpaceae* tidak berperan penting karena hanya menyumbang 4% dan spesies nir-*Dipterocarpaceae* 96% ,yang mencakup 61 suku. Beberapa spesies *Dipterocarpaceae* yang terdapat di TNTN terdaftar dalam *IUCN Red List of Threatened Species*, termasuk *Anisoptera megistocarpa, Hopea ferrugineA, Hopea pachycarpa. Shorea atrinervosa, Shorea faguetiana, Shorea lepidota* dan *Vatica gamosepala*. Data diameter pohon menunjukkan bahwa 80% pohon didominasi oleh individu kecil dengan diameter 10-30 cm. Pohon dengan diameter besar >30 cm adalah *Dracaena* cf. *porteri* (diameter 75,6 cm), *Artocarpus elasticus* (63,3 cm) dan *Ctenolophon parviflorus* (62,1 cm). Kehadiran sejumlah besar pohon kecil dan beberapa pohon dengan diameter besar dalam plot menunjukkan bahwa hutan dalam plot tersebut beregenerasi setelah terjadi berbagai gangguan. Kehadiran mayoritas pohon dengan ketinggian <20 m menguatkan lebih lanjut status dinamka hutan. Hutan primer dan hutan sekunder di TNTN sebagai kawasan penting untuk konservasi dibahas. Restorasi ekologi untuk pemulihan kembali ke hutan yang mirip aslinya direkomendasikan melalui penanaman spesies hutan primer, termasuk spesies endemik, langka dan terancam punah.

Keywords: *conservation, lowland forest, national park, regeneration, restoration, species diversity, structure*

INTRODUCTION

Sumatra is one of the larger islands in Indonesia and its lowland tropical forest cover constitutes an important center for plant species and the distribution for many families and genera within the Malesian archipelago (Kartawinata, 2013; Whitmore, 1986). Yet, large areas of the forests have not been investigated. The forest in Sumatra is characterized by tall canopy trees dominated by dipterocarp species. Floristically, the forest of Sumatra remains relatively unknown (Laumonier, 1990). Scattered studies on vegetation, mainly forests, have been conducted in various parts of Sumatra, mainly in the national parks and other protected areas. They have been reviewed by Anas et al (2019) and Rahmah et al (2016). The forests in Sumatra are the habitat of many species of flora, fauna, including several endangered species, such as tigers, elephants, rhinos, and orangutans.

During the last five decades the dipterocarp forests in Indonesia, including Sumatra, have experienced heavy disturbances, particularly extensive logging and conversion into oil palm plantations, mines, and industrial timber estates (Kartawinata, 2005; Kartawinata et al, 2008). At present, the remaining relatively intact, undisturbed primary forests occur on the lowland hills and montane forests of the interior of the island, with much of them are located in national parks, conservation areas, and protected forests. Degradation and loss of tropical forests have progressed rapidly. The Riau province is one of the areas on Sumatra that has seen rapid changes in land use over the last few decades. Mining, oil palm plantations, large-scale pulp and paper industry, and wood processing plants have transformed the province through the extraction of natural resources. Although beneficent for the economy, that have exerted extensive pressure on natural resource management efforts (Sargeant, 2001; Sheil et al, 2009). Conservation is thereby urgently needed. The region has the highest rank on lowland forest biodiversity and is one of the last habitats for the threatened Sumatran elephants (Gillison, 2001). Deforestation is a major cause of biological diversity loss and is of significant global concern (Wilson, 1988; Laurance, 2007) as it is estimated that more than half of the known terrestrial plant and animal species live in the forests (Millenium Ecosystem Assessment, 2005).

The Tesso Nilo National Park (TNNP), with an area of 190,000 ha, is one of the sites in Sumatra containing lowland forests (Prawiradilaga et al, 2014). With the TNNP forest exploited since 1979, immense adverse impacts have affected the national park's ecological balance and biodiversity.

The purpose of this study was to obtain quantitative data on the floristic composition and structure of a lowland forest in Riau, particularly TNNP. To date, such a study has not been conducted much in the area. The study focused on the descriptions of forests in terms of key structural parameters, species richness, relative abundance patterns, and family composition. These data are important for their many purposes, including measuring conservation suitability and priorities, for knowing the equilibrium conditions of forest communities, for explaining interactions within and between species, for predicting trends in the future composition of stands (Whittaker, 1974; Keel et al, 1993), for the provision of basic data for ecological restoration, for documenting tree flora, for analyzing species distribution patterns and for defining ecological classifications for forest mapping purposes.

METHODS

Species Composition

The TNNP is located ± 60 km from Pekanbaru, in Indragiri Hulu, Segati, Pelalawan Regency, Riau Province, with a range of altitudes from 100-200 m asl (above sea level) (Figure 1). It is situated at the coordinates of 0º 0'5.1 "- 0º 14'56" South and 101º 31'14.6 "- 101º 52'1.9" East. The topography is relatively flat. TNNP is located adjacent to Kerumutan Wildlife Park to the east, Bukit Rimbang Nature Reserve to the west, Bukit Tiga Puluh National Park to the southeast, and Kerinci Seblat National Park to the south. The forest consists of mixed dipterocarp stands, dominated by large trees of *Dipterocarpaceae, Moraceae, Annonaceae,* and *Anacardiaceae*. Gillison (2001) indicated a high plant species diversity in TNNP, whereby in plots of 1,800 m^2 he recorded 900 species, 267 genera, and 238 vascular plants. Audley-Charles (1987) and Hamilton (1979) have described the geological and vegetation histories of Sumatra. Gillison (2002) recorded that under the USDA soil classification system, the soils in TNNP were listed as Haplochemists and Paleodults, and ranged from swampy peats to dryland with elevation from 25-100 m asl, with peat of varying thickness overlaid by sands and sandy clays.

The climate of the central region of eastern Sumatra is super wet, with an annual rainfall of 2,000-3,000 mm (Gillison, 2001). Climatically TNNP belongs to the rainfall type C described by Schmidt & Ferguson (1951). The nearest rainfall station at Pekanbaru (9 m asl) showed a mean annual rainfall of 2, 870 mm (Figure 1), with two months of slightly dry period in June-July and ten-month of wet period in August-May. The mean monthly rainfall is >200 mm with highest in January

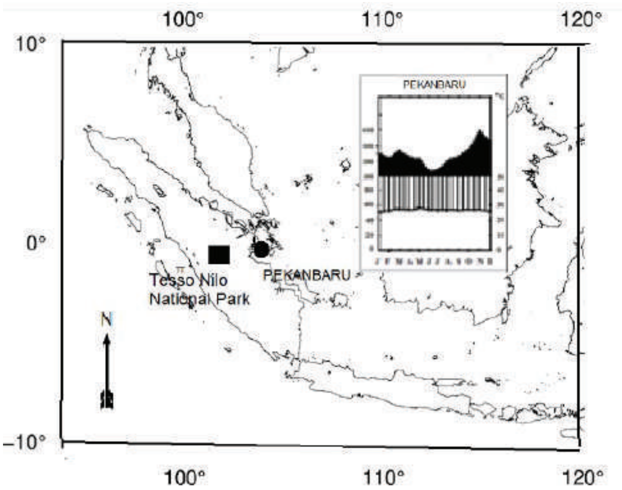

Figure 1. A map of the study site at Tesso Nilo National Park and a climate diagram for the meteorological station at Pekanbaru. The climate diagram shows the overwet climate with a slightly dry period in July (110 mm) and August (120 mm) and the ten-month wetter period in September-June with mean monthly rainfall > 1120 mm.

(400 mm). The mean temperature is between 26.2 ºC to 32.5 ºC, with only slight variation in average daily temperature.

Data Collection and Analysis

Field sampling was carried out in a lowland forest at the TNNP, using the quadrat method (Cox, 1967; Mueller-Dombois & Ellenberg, 1974, 2016). Plot size of 1 ha (100 m x 100 m) was selected to fit the topography. The plot was further divided into 100 subplots of 10 m x 10 m each. Within each subplot, trees with DBH (Diameter at Breast Height) ≥ 2 cm were counted and identified, and their positions recorded. Their diameters were measured, and their bole heights and tree heights were estimated. A forest profile diagram was constructed from a strip of 10 m x 50 m nested within the plot. Voucher specimens were collected and identified at the Herbarium Bogoriense, Center for Research in Biology, LIPI (now BRIN) Cibinong.

Definition and calculation of density, frequency, and dominance followed Cox (1967), Mueller-Dombois & Ellenberg (1974, 2016), and Rahmah et al (2016). Density is defined as the number of individuals per unit area obtained by counting individuals within subplots. The number of individuals per species is later calculated for one hectare. The Relative Density (RD) for each species is calculated using the following formula:

$$RD = \frac{\text{the number of individuals of a species}}{\text{the total number of individuals}} \text{ x } 100\%$$

Frequency is defined as the number of times a species occur in a given number of subplots within the plot and is expressed as a percentage of the total number of subplots. The Relative Frequency (RF) for each species is calculated using the following formula:

$$RF = \frac{\text{the frequency of a species}}{\text{the sum of the frequency of all species}} \text{ x } 100\%$$

Dominance for trees is defined as the stem cover, which is the same as the basal area. The basal area (BA) is obtained with the formula:

$$BA = (\tfrac{1}{2}d)^2 \text{x} \pi$$

where d stands for diameter. The Relative Dominance (RDo) is obtained with the following formula:

$$RDo = \frac{\text{the dominance of a species}}{\text{the dominance of all species}} \text{ x } 100\%$$

The sum of density, frequency, and dominance is later used to indicate the importance of a species in the plot and this can be done only if they are expressed in terms of relative values. The Importance Value will then be computed with the formula:

$$IV = RD+RF+RDo$$

RESULTS

Species composition

General observation showed that the forest at TNNP was relatively still in good condition as indicated by the occurrence of many primary forest species, including those of *Lauraceae, Dipterocarpaceae, Sapindaceae, Sapotaceae, Myristicaceae*, and *Burseraceae*. Further analysis, refers to Airy-Shaw (1975), Berg et al (2006), Keßler et al (2000), Whitmore (1986) shows that of 195 tree species recorded (Table 1) we identified 63 (32.3%) of them are secondary forest species (printed in boldface in Appendix 1). *Artocarpus heterophyllus, Pternandra galeata*, and *Scaphium macropodum* were secondary species with the highest Basal Area (Table 2), while *Artocarpus elasticus*, *Artocarpus scortechinii*, *Borassus* cf. *flabellifer,* and *Sloetia elongata* were four of the ten tree species with high Importance Value, *Sloetia elongata* having the highest (Table 3).

In the one-hectare plot, we recorded 1,303 individuals (diameter ≥2 cm) with a total basal area of 27.01 m², representing 304 tree species, 153 genera, and 62 families (Appendix 1, Table 1). They included 15 species of *Dipterocarpaceae,* but their density and frequency were low (Appendix 1): *Anisoptera megistocarpa, Hopea dryobalanoides, Hopea ferruginea, Hopea pachycarpa, Parashorea malaanonan, Shorea acuminata, Shorea atrinervosa, Shorea faguetiana, Shorea lepidota, Shorea leprosula, Shorea macroptera, Shorea parvifolia, Shorea retinodes, Vatica pauciflora,* and *Vatica ridleyana.*

Table 2 showed that big tree species with the highest mean basal area were *Dracaena* cf. *porteri* (mean BA= 0.32 m^2) and *Mangifera longipetiolata* (0.23 m^2). *Ctenolophon parvifolius* (0.20 m^2) was represented by two trees, and *Kokoona ochracea* (0.20 m^2) by one tree. *Dipterocarpaceae* was only represented by one big tree (*Shorea lepidota*) with a BA of 0.13 m^2.

Table 3 shows nine tree species with the highest IV and D in the plot. The data for IV and D are presented in Appendix 1. Based on IV the tree species could be classified into the following categories: (1) jointly dominant tree species with IV of 04.00-17.03, comprising nine species; (2) less important tree species with IV of 1.1-3.9, comprising 54 species; and (3) least important tree species with IV of ≤ 1.0. Among the jointly dominant species in category 1, *Sloetia elongata*, a secondary forest species, was the most prevalent, as indicated by IV of 17.09, while the rest of the group had low IV, ranging from 4.05 to 7.19.

Table 4 shows ten families with importance value >10, along with the number of species, density, and basal area. *Burseraceae*, *Dipterocarpaceae*, and *Moraceae* were the dominant families, and they have the highest importance value, density, and basal area. Large families containing many species were *Phyllanthaceae* (19), *Myristicaceae* (18), *Fabaceae* (17), and *Dipterocarpaceae* (16). The most common families were *Burseraceae* (15) and *Dipterocarpaceae* (45). The contribution of the *Dipterocarpaceae* species was only 4%, while the non-dipterocarp (61 families) reached 96%.

Table 1. Vegetation characteristics of the plot at the TNNP.

Status	No. of species	No. of illegally traded individuals
Not protected, no harvest quotas	68	3,884
Not protected, exceeded harvest quotas	3	4,423
Protected	13	279*
TOTAL	**84**	**8,586**

Table 2. Species with the highest mean BA in one-hectare forest plot at the TNNP.

Species	Family	Density	Mean BA
Dracaena cf. *porteri*	*Asparagaceae*	2	0.32
Ormosia sumatrana	*Fabaceae*	1	0.16
Knema conferta	*Myristicaceae*	1	0.15
Castanopsis rhamnifolia	*Fagaceae*	2	0.14
Shorea lepidota	*Dipterocarpaceae*	1	0.13
Scaphium macropodum	*Malvaceae*	1	0.13
Artocarpus heterophyllus	*Moraceae*	3	0.11
Litsea tomentosa	*Lauraceae*	1	0.11
Pternandra galeata	*Melastomataceae*	1	0.10

Table 3. Tree species with highest Importance Value (IV) and Density in one hectare forest plot at the TNNP.

Species	Family	D	IV
Sloetia elongata	*Moraceae*	30	17.03
Pimelodendron griffithianum	*Euphorbiaceae*	15	07.19
Artocarpus elasticus	*Moraceae*	10	06.19
Santiria laevigata	*Burseraceae*	7	06.13
Artocarpus scortechinii	*Moraceae*	9	06.02
Xerospermum noronhianum	*Sapindaceae*	10	00.40
Horsfieldia polyspherula	*Myristicaceae*	11	05.09
Borassus cf. flabellifer	*Arecaceae*	7	04.54
Santiria oblongifolia	*Burseraceae*	8	04.05

The tree species regeneration could be reflected in the number of saplings recorded in the plot and could be classified into five categories (Appendix 2). Group 1 (Appendix 2) consisted of 13 species with very good regeneration as indicated by sapling density of 10-28 individuals/ha. *Sloetia elongata*, a secondary forest species with 28 individuals/ha was regenerating well. The regeneration of dipterocarp species was very poor. Of the 16 species present in the plot, only *Shorea macroptera* was registered in Group 1 (Appendix 2). There was only one species (*Hopea pachycarpa*) in Group 2 (Appendix 2), 11 species (*Anisoptera megistocarpa, Hopea dryobalanoides, Hopea ferruginea, Parashorea malaanonan, Shorea atrinervosa, Shorea faguetiana, Shorea leprosula, Shorea parvifolia, Shorea retinodes, Vatica pauciflora*, and *Vatica ridleyana*) in Group 3 (Appendix 2), one species (*Shorea lepidota*) in Group 4 (Appendix 2), and none in Group 5 (Appendix 2).

Structure

The structure of a forest can be indicated by its stratification (vertical distribution), individual distribution, and abundance of each plant species (Kershaw, 1964). Figure 2 shows the vertical and lateral distribution of the trees species presented in a profile diagram that was constructed from a strip of 10 m x 50 m nested within the plot, while Figure 3 indicates the tree distribution on the ground in the plot. The vertical distribution of trees in the entire plot consisted of three (3) layers. Layer A (top layer) was 35-45 meters in height. It was composed of 48 trees, 37 species, and 24 families, which were the primary forest species,

Table 4. Ten families with Importance Value > 10, Density and Basal Area in a lowland forest at Tesso Nilo National Park.

Family	Number of species	Density (individuals/ha)	Basal Area (m^2)	Family Importance Value
Moraceae	7	88	3.58	25.38
Burseraceae	14	115	2.30	24.14
Dipterocarpaceae	16	102	2.35	22.74
Myristicaceae	18	82	1.44	17.08
Phyllanthaceae	19	83	0.97	15.63
Myrtaceae	13	57	1.36	14.25
Sapindaceae	9	70	0.87	13.02
Annonaceae	13	61	0.81	12.22
Fabaceae	17	59	0.90	11.78
Lauraceae	14	45	1.05	11.15
Euphorbiaceae	8	47	0.81	10.52

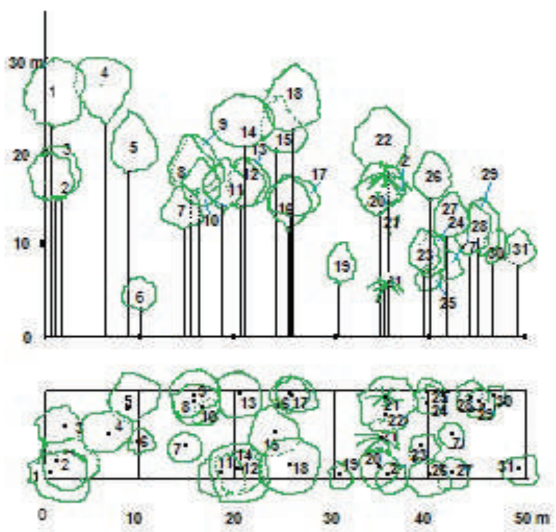

Figure 2. Profile diagram of forest in the plot. 1. *Hopea ferruginea*, 2. *Syzygium fastigiatum*, 3. *Urophyllum arboreum*, 4. *Hydnocarpus polypetalus*, 5. *Endiandra macrophylla*, 6. *Pternandra galeata*, 7. *Calophyllum macrocarpum*, 8. *Trigoniastrum hypoleucum*, 10. *Canarium littorale*, 11. *Pimelodendron griffithianum*, 12. *Canarium pilosum*, 13. *Porterandia anisophylla*, 14. *Dracaena* cf. *porteri*, 15. *Dacryodes rostrata*, 16. *Nephelium cuspidatum*, 17. *Parashorea malaanonan*, 18. *Baccaurea minor*, 19. *Mesua ferrea*, 20. *Maasia hypoleuca*, 21. *Oncosperma tigillarium*, 22. *Xylopia malayana*, 23. *Notaphoebe umbelliflora*, 24. *Triomma malaccensis*, 25. *Gymnacranthera forbessii*, 26. *Artocarpus scortechinii*, 27. *Garcinia maingayi*, 28. *Drypetes longifolia*, 29. *Dyera polypetala*, 30. *Syzygium hemsleyana*, 31. *Symplocos rubiginosa*.

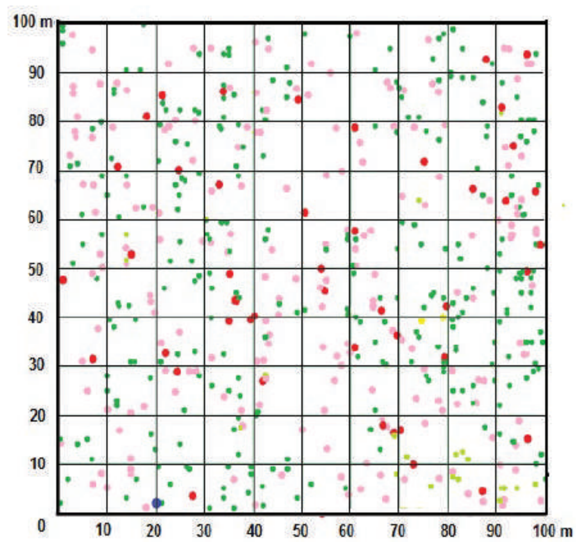

Figure 3. Map of all trees ≥ 10 cm dbh in the study plot at the Tesso Nilo National Park.

Legend:

● = 10.0-20.0 dbh ● = 30.0-40.0 ;
● = 50.0-60.0 ; ● = 70.0-80.0

including *Alseodaphne oblanceolata, Diospyros pyrrocarpa, Hopea dryobalanoides, Hopea ferruginea, Kokoona ochracea, Pouteria malaccensi, Santiria laevigata, Shorea ferruginea, Shorea lepidota,* and *Triomma malaccensis.* Layer B with the height of 20-30 m consisted of 148 species and 47 families, including 12 species of *Dipterocarpaceae* (30 trees), seven species of *Moraceae* (30 trees, of which 16 trees were *Sloetia elongata*), *Santiria spp.* (16 trees), *Xerospermum spp.* (13 trees) and *Xylopia caudata* (11 trees). Tree species in the layer with height <25 m constituted the largest share of the species in the plot. The above-mentioned canopy layers of trees reflected the structure of tropical forests and a common pattern of the dynamic process (Ogawa et al.. 1965). The largest number of individuals in the plot (80 %) was occupied by small trees (10-20 cm).

DISCUSSION

The species composition of the forest in the plot did not represent a typical undisturbed lowland forest of Sumatra. The structure, composition, and regeneration indicated that the forest had experienced various disturbances, including selective logging and harvesting by local inhabitants from the nearby villages. They frequent the forest and cut trees, which resulted in the formation of the open forest canopy. Dipterocarp species were not important as they contributed only 4% to the community, while non-dipterocarps, comprising 61 families, share 96 %. Using the dominance and density (Mueller-Dombois & Ellenberg, 1974, 2016) of the two tree species (Table 3), the forest community in the plot can be designated as ***Sloetia elongata-Pimelodendron griffithianum Association***.

Table 5 shows that the number of tree species in the present plot was comparable to those in many sites in the lowland forests of Sumatra, which were all secondary forests. It was lower than those in the Batang Gadis National Park, Ketambe, and Rimbo Panti, which were lowland primary forests. In addition to the data on regeneration in Appendix 2, our qualitative observations showed that tree regeneration took place under gaps, and the kind and density of seedlings and saplings present varied with gap size, as observed in various tropical forests elsewhere (Brokaw, 1985; Hartshorn, 1980; Poore,1968; Runkle, 1981; Whitmore, 1984). This indicated that the forest at TNNP was disturbed lowland forest, particularly a result of human activities, including commercial selective logging and tree poaching as well as harvesting by local people. Such a situation has stimulated the development of mixed forest with a high proportion of secondary forest species. The secondary forest species amounted to 63 (32.3 %), as printed in boldface and listed in Appendix 1. The most prominent species was *Sloetia elonggata* with the highest density and importance values, followed by *Artocarpus elasticus, Artocarpus scortechinii, Xerospermum noronhianum*, and *Borassus* cf *flabellifer* (Table 3). These species could grow on open sites in damaged forests as well as in small canopy gaps of primary and less disturbed forests. The occurrence of *Borassus* cf *flabellifer*, a tree palm that is typically dominant in seasonally dry forests and savannas, in the wet rain forest (Kartawinata, 2013) might be questionable, but Eagleton (2016), in his review of the genus *Borassus* and *Corypha*, stressed that *Borassus flabellifer* occurs in Sumatra naturally.

The secondary forest species occurring in the plots belonged to many families and the families that contained the highest number of secondary forest species were *Euphorbiaceae* (5), *Morceae* (6), and *Phyllanthaceae* (8). In Indonesia, they occurred in lowland to montane forests. The species of *Euphorbiaceae, Moraceae,* and *Phyllanthaceae* were dispersed by wind, birds and mammals (Berg & Corner, 2005; Berg et al, 2006; Pijl, 1982). These families can be found in the wet regions with altitudinal range of 0-1500 m asl, but they are particularly prominent in the lowland and they are very tolerant to direct solar radiation. They generally invade any open sites within and outside forests, even if mature tree individuals were present in the vicinity (Whitmore, 1984).

Because of various disturbances, the population of dipterocarp species, in general, has declined, and currently, in the plot, there were only 15 species with low density, basal area, and frequency (Appendix 1). Many species are becoming rare and threatened by extinction. Several dipterocarp species in TNNP have been listed in the IUCN Red List of Threatened Species, and they include *Anisoptera megistocarpa, Hopea ferruginea, Hopea pachycarpa. Shorea atrinervosa, Shorea faguetiana, Shorea lepidota, Vatica gamosepala.*

Most dipterocarp species were not regenerating well as shown in Appendix 2. They belonged to Group 3 (Appendix 2) and are of poorly regenerating species, and only two species, *Shorea acuminata*, and *Shorea macroptera*, occurred in Group 1 (Appendix 2) with very good regenerating species. Scarce and scattered big trees of diameters ≥ 10 cm with low regeneration and sparse structure reflected the heavily disturbed forest. Natural successions still took place but at a slow rate. Hence, the return of dipterocarp species to a population similar to that in an undisturbed forest would take a very long time. It is therefore recommended to enhance natural successions through ecological restoration by planting dipterocarp species, including the rare and threatened species, as well as non-dipterocarp species from the primary forests.

It should be noted that primary forest species of several families, including *Annonaceae, Dipterocarpaceae, Lauraceae, Myristica*, and *Sapindaceae* could reach large diameters. *Dracaena* cf. *porteri* could reach diameters of 70-80 cm, Ctenolophon parvifolius up to 60-70 cm, while *Hopea spp., Mangifera longifolia, Shorea spp.*, and *Santiria laevigata* could reach 50-60 cm. Dipterocarp species with small diameters present in the high number indicated that they were the remnants of trees left after forest cutting and they have not been able to regenerate well.

The high number of primary forest species with small diameters was related to the presence of gaps. Dominant species in primary forest that could grow in gaps of various sizes included *Canarium pilosum, Cinnamomum javanicum, Dacryodes rostrata, Horsfieldia polyspherula, Magnolia liliifera, Santiria griffithii, Santiria oblongifolia, Shorea acuminata, Shorea macroptera, Xylopia caudata* and *Syzygium fastigiatum*. The overall regeneration in all subplots was indicated by the presence of a relatively large number of individuals with diameters of ≤ 20 cm. The number of individuals in the diameter classes of 5-10 cm and 10-20 cm may be used to indicate the regeneration status of a forest stand (Mueller-Dombois & Ellenberg, 1974; Richards, 1996). The presence of a large majority of trees with height of < 20 m (85 %) further confirmed the forest's dynamic status. There were only few trees with heights > 20 m (Figure 2). The percentage of trees with heights of 20-30 m was 11 % and those with heights > 30 m were 4 %. The tree species with the highest basal areas were *Dracaena* cf *porteri* (0.32 m^2). The presence of large numbers of small trees and a small number of trees with large diameters in a forest stand showed that the forest was regenerating after disturbances.

Figure 2 shows the profile diagram of the forest in a strip of 10 m x 50 m nested within the plot at TNNP. It shows the vertical and lateral distribution of the tree species. Figure 3 indicates the tree distribution that were ≥ 10 cm dbh in the plot. It was noted that in the TNNP forest gaps were present. High number of primary species intermediates between sapling and emergent sizes suggested that opening of canopy took place and formed small natural gaps. In the field, it was difficult to separate these forest gaps since they were seldom distinguishable (Richards, 1964; Wyatt-Smith, 1963) and the change from one unit to another was gradual.

Table 5. Comparison of the number of tree species in selected plots in several sites in Sumatra

Site	Plot size (Ha)	Number of tree species	Source
Tesso Nilo National Park, Jambi	1.0	195	**Present study**
Bukit Duabelas National Park 1, Jambi	1.0	113	Rahmah et al, 2016
Bukit Duabelas National Park 2, Jambi	1.0	89	Anas et al, 2021
Harapan Rainforest, Jambi	1.0	96	Mansur et al, 2010
Sei Lepan, Leuseur National Park, Aceh	1.0	110	Ismayadi & Heriyanto, 2010
Ketambe 1 Leuseur National Park, Aceh	1.6	116	Abdulhadi et al, 1989
Sekundur, Leuser National Park, North Sumatra	2.0	133	Priatna et al, 2004
Batang Gadis National Park, North Sumatra	1.0	184	Kartawinata et al, 2004
Rimbo Panti (diam. >5cm), West Sumatra	1.0	199	Yusuf et al, 2005

CONCLUSION

The number of species in a one-hectare plot at TNNP, comprising 1,303 individuals of trees and saplings, represented by 304 species, 153 genera, and 62 families, should not be representative of the species composition of forests in the area. The plot did not even represent a minimal area, but it sufficiently illustrated the species richness of the forest locally. Floristically the forest was a poor community with low species richness and dipterocarp species were not dominant. Structurally the forest in the plot was regenerating and developing after being heavily disturbed. It was heterogeneous, in which the floristic composition consisted of primary and secondary forest species. The heterogeneity was reflected also by the very low frequency and density of the species. The forest has experienced changes in tree species dominance from dipterocarps to non-dipterocarps due to various human activities. One of many ways to manage and improve the park is to allow the disturbed forest of TNNP to develop naturally following the processes of natural successions. This will lead to the formation of a forest similar to its original state. The rate of natural succession is very slow, but it could be accelerated and assisted by applying ecological restoration through planting tree species characteristics of the original undisturbed primary forests. In particular, rare and endemic species with multipurpose uses for the sustainable living of the indigenous communities and species with high conservation values, including species listed in the IUCN Red List, can be planted. Persistent species that would regenerate and can maintain themselves in the future were represented in almost all diameter classes in the forest, although with low density. Conservation and management of TNNP applying scientific principles should be supported by further research. Future research could cover basic aspects such as the structure and composition of forests over a wider area in the park to gain data and information on various biological and ecological characteristics, including species distribution and variation in composition related to habitat factors.

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Appendix 1. Total Basal Area (BA in m^2), Total Density (D in trees/ha), Frequency (F in %), and Importance Value (IV in %) of trees and saplings recorded in the plot in the Tessonilo National Park, Riau. The secondary forest species are printed in boldface.

Species	Family	Tree				Sapling			
		D	F	BA	IV	D	F	BA	IV
Hydnocarpus kunstleri	Achariaceae	1	1	0.04	0.53	-	-	-	-
Hydnocarpus polypetalus	Achariaceae	3	3	0.31	2.31	-	-	-	-
Bouea oppositifolia	Anacardiaceae	3	3	0.21	1.93	2	2	0.00	0.62
Buchanania arborescens	Anacardiaceae	1	1	0.01	0.42	2	2	0.00	0.73
Gluta wallichii	Anacardiaceae	-	-	-	-	1	1	0.00	0.42
Mangifera longipetiolata	Anacardiaceae	2	2	0.45	2.51	7	7	0.01	2.72
Melanochyla caesia	Anacardiaceae	-	-	-	-	2	2	0.00	0.60
Melanochyla ferruginea	Anacardiaceae	-	-	-	-	1	1	0.00	0.35
Melanochyla fulvinervia	Anacardiaceae	3	3	0.18	1.82	1	1	0.00	0.37
Parishia insignis	Anacardiaceae	2	2	0.11	1.19	1	1	0.00	0.30
Semecarpus glauca	Anacardiaceae	-	-	-	-	2	2	0.00	0.64
***Swintonia* sp.**	Anacardiaceae	1	1	0.07	0.65	-	-	-	-
Anisophyllea disticha	Anisophylleaceae	-	-	-	-	2	2	0.00	0.67
Cyathocalyx sp.	Annonaceae	1	1	0.02	0.46	-	-	-	-
Goniothalamus macrophyllus	Annonaceae	-	-	-	-	8	8	0.00	2.39
Goniothalamus tapis	Annonaceae	-	-	-	-	7	7	0.01	2.58
Maasia hypoleuca	Annonaceae	3	3	0.08	1.46	1	1	0.00	0.31
Mezzettia parviflora	Annonaceae	-	-	-	-	2	2	0.00	0.64
Phaeanthus sumatrana	Annonaceae	-	-	-	-	1	1	0.00	0.31
Polyalthia lateriflora	Annonaceae	-	-	-	-	2	2	0.00	0.71
Polyalthia rumphii	Annonaceae	-	-	-	-	2	2	0.00	0.62
Polyalthia subcordata	Annonaceae	-	-	-	-	1	1	0.00	0.41
Xylopia caudata	Annonaceae	17	15	0.44	7.76	7	7	0.01	2.71
Xylopia fusca	Annonaceae	1	1	0.02	0.44	2	2	0.00	0.62
Xylopia malayana	Annonaceae	5	5	0.22	2.73	1	1	0.00	0.39
Dyera polyphylla	Apocynaceae	3	3	0.32	2.36	3	2	0.01	1.27
Ilex cymosa	Aquifoliaceae	-	-	-	-	5	5	0.00	1.7
Ilex macrophylla	Aquifoliaceae	-	-	-	-	1	1	0.00	0.3
Borassus* cf. *flabellifer	Arecaceae	7	7	0.49	4.54	-	-	-	-
Oncosperma tigillarium	Arecaceae	4	4	0.08	1.8	1	1	0.00	0.62
Dracaena cf. *porteri*	Asparagaceae	2	2	0.65	3.25	-	-	-	-
Dracaena elliptica	Asparagaceae	1	1	0.15	0.94	1	1	0.00	0.31
Deplanchea bancana	Bignoniaceae	1	1	0.05	0.58	-	-	-	-
Deplanchea glabra	Bignoniaceae	2	2	0.32	1.99	3	3	0.00	0.96
Canarium denticulatum	Burseraceae	3	3	0.04	1.27	6	5	0.01	2.53
Canarium littorale	Burseraceae	2	2	0.03	0.87	4	4	0.00	1.28
Canarium patentinervium	Burseraceae	-	-	-	-	3	3	0.00	1.2
Canarium pilosum	Burseraceae	5	5	0.07	2.16	9	9	0.01	3.28
Canarium pseudodecumanum	Burseraceae	-	-	-	-	3	3	0.00	0.93
Dacryodes incurvata	Burseraceae	7	7	0.27	3.68	3	3	0.01	1.4
Dacryodes rostrata	Burseraceae	-	-	-	-	9	9	0.01	2.98

Dacryodes rugosa	Burseraceae	4	4	0.11	1.93	3	3	0.00	0.92
Santiria apiculata	Burseraceae	4	4	0.09	1.87	4	4	0.00	1.38
Santiria griffithii	Burseraceae	3	3	0.06	1.38	6	5	0.01	1.99
Santiria laevigata	Burseraceae	7	7	0.90	6.13	7	6	0.01	2.53
Santiria oblongifolia	Burseraceae	8	8	0.26	4.05	5	5	0.01	1.84
Santiria rubiginosa	Burseraceae	2	2	0.11	1.19	2	2	0.01	1.89
Triomma malaccensis	Burseraceae	5	5	0.27	2.92	1	1	0.00	0.3
Gironniera hirta	Cannabaceae	-	-	-	-	2	2	0.01	1.39
Gironniera nervosa	Cannabaceae	3	3	0.08	1.46	2	2	0.01	1.02
Gironniera subaequalis	Cannabaceae	7	6	0.15	3.05	3	3	0.00	1.02
Gonocaryum gracile	Cardiopteridaceae	1	1	0.01	0.42	7	7	0.01	2.51
Euonymus indicus	Celastraceae	-	-	-	-	3	3	0.00	1.12
Lophopetalum javanum	Celastraceae	1	1	0.09	0.71	1	1	0.00	0.3
Calophyllum macrocarpum	Clusiaceae	5	5	0.15	2.45	4	4	0.00	1.23
Calophyllum pulcherrimum	Clusiaceae	2	2	0.08	1.07	-	-	-	-
Calophyllum rigidum	Clusiaceae	3	3	0.21	1.94	-	-	-	-
Garcinia bancana	Clusiaceae	-	-	-	-	2	2	0.00	0.97
Garcinia brevirostris	Clusiaceae	2	2	0.14	1.28	-	-	-	-
Garcinia celebica	Clusiaceae	2	2	0.08	1.06	1	1	0.00	0.47
Garcinia havilandii	Clusiaceae	2	2	0.05	0.95	-	-	-	-
Garcinia maingayi	Clusiaceae	2	2	0.03	0.88	1	1	0.00	0.31
Garcinia parvifolia	Clusiaceae	1	1	0.05	0.55	2	2	0.00	0.7
Mesua ferrea	Clusiaceae	1	1	0.03	0.5	2	2	0.00	1.02
Mesua lepidota	Clusiaceae	2	2	0.06	0.97	3	3	0.00	1.05
Ellipanthus tomentosus	Connaraceae	-	-	-	-	1	1	0.00	0.31
Mastixia pentandra	Cornaceae	1	1	0.04	0.54	8	8	0.03	5.01
Ctenolophon parvifolius	Ctenolophonaceae	2	2	0.40	2.3	14	11	0.02	5.52
Dillenia ovata	Dilleniaceae	5	4	0.42	3.32	-	-	-	-
Anisoptera megistocarpa	Dipterocarpaceae	2	2	0.05	0.95	1	1	0.00	0.3
Hopea dryobalanoides	Dipterocarpaceae	5	5	0.43	3.53	2	2	0.01	1.18
Hopea ferruginea	Dipterocarpaceae	8	6	0.57	4.84	2	2	0.01	1.66
Hopea pachycarpa	Dipterocarpaceae	4	4	0.05	1.72	7	6	0.01	2.86
Parashorea malaanonan	Dipterocarpaceae	1	1	0.02	0.44	2	2	0.00	0.75
Shorea acuminata	Dipterocarpaceae	3	3	0.07	1.41	18	17	0.02	6.24
Shorea atrinervosa	Dipterocarpaceae	1	1	0.02	0.45	2	2	0.00	0.88
Shorea faguetiana	Dipterocarpaceae	1	1	0.12	0.86	1	1	0.00	0.34
Shorea lepidota	Dipterocarpaceae	1	1	0.13	0.9	-	-	-	-
Shorea leprosula	Dipterocarpaceae	1	1	0.03	0.5	2	2	0.00	0.83
Shorea macroptera	Dipterocarpaceae	8	7	0.25	3.8	10	10	0.01	3.61
Shorea parvifolia	Dipterocarpaceae	3	3	0.06	1.35	2	2	0.00	0.68
Shorea retinodes	Dipterocarpaceae	2	2	0.06	0.98	3	3	0.00	1.07
Vatica pauciflora	Dipterocarpaceae	5	4	0.39	3.21	2	2	0.00	0.78
Vatica ridleyana	Dipterocarpaceae	2	2	0.03	0.86	1	1	0.00	0.31
Diospyros barteri	Ebenaceae	-	-	-	-	1	1	0.00	0.3
Diospyros buxifolia	Ebenaceae	-	-	-	-	2	2	0.00	0.61
Diospyros cf.*nutans*	Ebenaceae	-	-	-	-	1	1	0.00	0.35

Diospyros confertiflora	Ebenaceae	-	-	-	-	2	2	0.00	0.62
Diospyros oblonga	Ebenaceae	-	-	-	-	1	1	0.00	0.37
Diospyros oblongifolia	Ebenaceae	-	-	-	-	2	2	0.01	1.41
Diospyros pendula	Ebenaceae	1	1	0.02	0.46	1	1	0.00	0.36
Diospyros pyrrhocarpa	Ebenaceae	3	3	0.22	1.97	1	1	0.01	0.99
Diospyros rigida	Ebenaceae	-	-	-	-	2	2	0.00	0.66
Diospyros rostrata	Ebenaceae	-	-	-	-	1	1	0.00	0.54
Diospyros siamang	Ebenaceae	-	-	-	-	1	1	0.00	0.47
Diospyros sumatrana	Ebenaceae	3	3	0.07	1.42	3	3	0.00	0.96
Diospyros venosa	Ebenaceae	1	1	0.03	1.97	1	1	0.00	0.33
Diospyros virginiana	Ebenaceae	-	-	-	-	1	1	0.00	0.54
Elaeocarpus glaber	Elaeocarpaceae	-	-	-	-	2	2	0.00	0.65
Elaeocarpus palembanicus	Elaeocarpaceae	-	-	-	-	1	1	0.00	0.58
Elaeocarpus petiolatus	Elaeocarpaceae	-	-	-	-	1	1	0.00	0.49
Blumeodendron tokbrai	Euphorbiaceae	2	1	0.04	0.73	-	-	-	-
Macaranga caladiifolia	Euphorbiaceae	2	2	0.03	0.86	-	-	-	-
Macaranga denticulata	Euphorbiaceae	1	1	0.05	0.56	-	-	-	-
Macaranga tanarius	Euphorbiaceae	1	1	0.04	0.52	1	1	0.00	0.31
Macaranga triloba	Euphorbiaceae	-	-	-	-	1	1	0.00	0.33
Neoscortechinia kingii	Euphorbiaceae	2	2	0.21	1.57	2	2	0.01	1.31
Pimelodendron griffithianum	Euphorbiaceae	15	15	0.39	7.19	16	14	0.03	6.67
Ptychopyxis costata	Euphorbiaceae	1	1	0.01	0.41	3	3	0.01	1.46
Adenanthera pavonina	Fabaceae	1	1	0.03	0.51	1	1	0.00	0.5
Afzelia rhomboidea	Fabaceae	1	1	0.02	0.44	-	-	-	-
Albizia splendens	Fabaceae	1	1	0.03	0.49	-	-	-	-
Archidendron bubalinum	Fabaceae	1	1	0.03	0.48	2	2	0.00	0.6
Archidendron clypearia	Fabaceae	2	1	0.04	0.73	-	-	-	-
Archidendron microcarpum	Fabaceae	-	-	-	-	2	2	0.00	0.72
Callerya atropurpurea	Fabaceae	1	1	0.18	1.09	12	12	0.01	3.87
Dialium patens	Fabaceae	-	-	-	-	2	2	0.00	0.63
Dialium platysepalum	Fabaceae	1	1	0.03	0.5	-	-	-	-
Koompassia malaccensis	Fabaceae	1	1	0.11	0.82	3	3	0.01	2.08
Ormosia sumatrana	Fabaceae	1	1	0.16	0.98	-	-	-	-
Parkia speciosa	Fabaceae	1	1	0.06	0.61	1	1	0.00	0.3
Saraca declinata	Fabaceae	-	-	-	-	17	14	0.03	6.54
Sindora bruggemanii	Fabaceae	1	1	0.15	0.94	4	3	0.00	1.13
Sindora coriacea	Fabaceae	-	-	-	-	1	1	0.00	0.3
Sindora leiocarpa	Fabaceae	-	-	-	-	1	1	0.00	0.34
Sindora sumatrana	Fabaceae	-	-	-	-	1	1	0.00	0.67
Castanopsis costata	Fagaceae	-	-	-	-	1	1	0.00	0.54
Castanopsis megacarpa	Fagaceae	-	-	-	-	1	1	0.00	0.36
Castanopsis rhamnifolia	Fagaceae	2	2	0.28	1.83	-	-	-	-
Lithocarpus conocarpus	Fagaceae	-	-	-	-	1	1	0.00	0.59
Lithocarpus lucidus	Fagaceae	1	1	0.03	0.5	1	1	0.00	0.36
Lithocarpus wallichianus	Fagaceae	1	1	0.04	0.54	-	-	-	-
Ryparosa caesia	Flacourtiaceae	1	1	0.03	0.49	4	4	0.01	1.57

Ryparosa kunstleri	Flacourtiaceae	1	1	0.03	0.49	-	-	-	-
Fagraea racemosa	Gentianaceae	1	1	0.01	0.41	2	2	0.00	0.64
Ixonanthes icosandra	Ixonanthaceae	1	1	0.05	0.55	2	2	0.00	0.63
Teijsmanniodendron coriaceum	Lamiaceae	-	-	-	-	1	1	0.00	0.33
Vitex gamosepala	Lamiaceae	-	-	-	-	4	4	0.00	1.44
Actinodaphne gullavara	Lauraceae	-	-	-	-	1	1	0.00	0.31
Actinodaphne macrophylla	Lauraceae	-	-	-	-	1	1	0.00	0.3
Alseodaphne oblanceolata	Lauraceae	5	5	0.46	3.66	4	3	0.01	1.6
Beilschmiedia sp.	Lauraceae	1	1	0.01	0.42	2	2	0.00	0.66
Cinnamomum javanicum	Lauraceae	1	1	0.02	0.44	3	3	0.00	1.04
Cinnamomum porrectum	Lauraceae	1	1	0.07	0.63	-	-	-	-
Cryptocarya scortechinii	Lauraceae	1	1	0.01	0.41	2	2	0.00	0.85
Dehaasia caesia	Lauraceae	1	1	0.05	0.57	3	3	0.00	1.16
Dehaasia palembanica	Lauraceae	-	-	-	-	1	1	0.00	0.3
Endiandra macrophylla	Lauraceae	3	3	0.15	1.7	2	2	0.01	1.29
Litsea costalis var. *nidularis*	Lauraceae	1	1	0.02	0.44	3	3	0.01	1.28
Litsea noronhae	Lauraceae	-	-	-	-	2	2	0.00	0.65
Litsea resinosa	Lauraceae	3	3	0.10	1.52	-	-	-	-
Litsea tomentosa	Lauraceae	1	1	0.11	0.79	-	-	-	-
Notaphoebe umbelliflora	Lauraceae	3	3	0.03	1.25	-	-	-	-
Barringtonia cf *lanceolata*	Lecytidaceae	-	-	-	-	6	6	0.01	2.27
Barringtonia macrostachya	Lecytidaceae	1	1	0.01	0.41	18	17	0.03	7.29
Magnolia liliifera	Magnoliaceae	3	3	0.13	1.62	10	8	0.01	3.29
Coelostegia griffithii	Malvaceae	2	2	0.03	0.87	3	3	0.01	1.41
Durio excelsus	Malvaceae	2	2	0.05	0.93	-	-	-	-
Microcos paniculata	Malvaceae	1	1	0.03	0.49	6	6	0.00	2.04
Pentace erectinervia	Malvaceae	3	3	0.18	1.84	-	-	-	-
Scaphium macropodum	Malvaceae	1	1	0.13	0.87	-	-	-	-
Memecylon caeruleum	Melastomataceae	2	2	0.05	0.93	4	4	0.00	1.5
Memecylon edule	Melastomataceae	1	1	0.02	0.45	1	1	0.00	0.52
Memecylon excelsum	Melastomataceae	-	-	-	-	1	1	0.00	0.43
Memecylon garcinioides	Melastomataceae	-	-	-	-	1	1	0.00	0.3
Memecylon myrsinoides	Melastomataceae	3	3	0.11	1.55	3	3	0.00	1.02
Memecylon oligoneurum	Melastomataceae	-	-	-	-	1	1	0.00	0.35
Memecylon ovatum	Melastomataceae	-	-	-	-	1	1	0.00	0.37
Pternandra coerulescens	Melastomataceae	-	-	-	-	1	1	0.00	0.35
Pternandra galeata	Melastomataceae	1	1	0.10	0.78	-	-	-	-
Aglaia silvestris	Meliaceae	1	1	0.05	0.57	1	1	0.00	0.3
Aphanamixis borneensis	Meliaceae	1	1	0.07	0.66	1	1	0.00	0.3
Aphanamixis polystachya	Meliaceae	1	1	0.02	0.45	-	-	-	-
Aphanamixis sumatrana	Meliaceae	-	-	-	-	2	2	0.00	0.63
Chisocheton ceramicus	Meliaceae	-	-	-	-	2	2	0.00	0.66
Sandoricum koetjape	Meliaceae	-	-	-	-	3	2	0.01	1.46
Artocarpus elasticus	Moraceae	10	9	0.71	6.33	-	-	-	-
Artocarpus heterophyllus	Moraceae	2	2	0.34	2.08	1	1	0.00	0.39
Artocarpus kemando	Moraceae	1	1	0.03	0.51	-	-	-	-

Artocarpus nitidus	Moraceae	-	-	-	-	1	1	0.00	0.42
Artocarpus rigidus	Moraceae	-	-	-	-	1	1	0.00	0.31
Artocarpus scortechinii	Moraceae	9	9	0.68	6.02	5	4	0.01	2.3
Sloetia elongata	Moraceae	30	26	1.75	17.3	28	21	0.05	11.2
Gymnacranthera bancana	Myristicaceae	5	5	0.47	3.69	-	-	-	-
Gymnacranthera contracta	Myristicaceae	-	-	-	-	1	1	0.00	0.39
Gymnacranthera forbesii	Myristicaceae	2	1	0.14	1.12	8	8	0.02	3.97
Horsfieldia glabra	Myristicaceae	-	-	-	-	8	8	0.01	3.44
Horsfieldia grandis	Myristicaceae	1	1	0.01	0.42	-	-	-	-
Horsfieldia irya	Myristicaceae	-	-	-	-	1	1	0.00	0.3
Horsfieldia polyspherula	Myristicaceae	11	10	0.29	5.09	10	9	0.03	5.7
Horsfieldia subglobosa	Myristicaceae	2	2	0.09	1.09	1	1	0.00	0.3
Knema cinerea	Myristicaceae	-	-	-	-	1	1	0.00	0.35
Knema conferta	Myristicaceae	1	1	0.15	0.94	-	-	-	-
Knema curtisii	Myristicaceae	-	-	-	-	3	3	0.01	1.85
Knema intermedia	Myristicaceae	-	-	-	-	1	1	0.00	0.3
Knema latericia	Myristicaceae	1	1	0.01	0.42	2	2	0.00	1
Knema latifolia	Myristicaceae	4	4	0.05	1.7	3	3	0.00	1.18
Knema plumulosa	Myristicaceae	-	-	-	-	4	4	0.00	1.25
Knema pseudolaurina	Myristicaceae	-	-	-	-	1	1	0.01	0.79
Myristica iners	Myristicaceae	1	1	0.02	0.45	3	3	0.01	1.27
Myristica maxima	Myristicaceae	5	5	0.09	2.25	2	2	0.00	0.86
Rhodamnia cinerea	Myrtaceae	3	3	0.14	1.66	-	-	-	-
Syzygium cf. decipiens	Myrtaceae	1	1	0.03	0.5	-	-	-	-
Syzygium cf. grande	Myrtaceae	3	3	0.14	1.68	4	3	0.00	1.22
Syzygium fastigiatum	Myrtaceae	12	12	0.34	5.85	3	3	0.00	1.01
Syzygium hemsleyanum	Myrtaceae	4	4	0.12	1.97	-	-	-	-
Syzygium incarnatum	Myrtaceae	3	3	0.09	1.49	-	-	-	-
Syzygium lepidocarpum	Myrtaceae	1	1	0.02	0.47	2	2	0.01	1.21
Syzygium lineatum	Myrtaceae	-	-	-	-	2	2	0.00	0.61
Syzygium magnoliifolium	Myrtaceae	2	2	0.03	0.89	1	1	0.01	0.86
Syzygium palembanicum	Myrtaceae	4	4	0.28	2.61	-	-	-	-
Syzygium ridleyi	Myrtaceae	-	-	-	-	2	2	0.00	0.77
Syzygium zeylanicum	Myrtaceae	6	6	0.12	2.74	1	1	0.00	0.36
Syzygium zollingerianum	Myrtaceae	1	1	0.01	0.42	2	2	0.00	0.65
Gomphia serrata	Ochnaceae	2	2	0.04	0.91	1	1	0.00	0.31
Ochanostachys amentacea	Olacaceae	6	6	0.31	3.46	2	2	0.01	1.07
Chionanthus sp.	Oleaceae	1	1	0.01	0.43	1	1	0.00	0.3
Sarcotheca griffithii	Oxalidaceae	1	1	0.03	0.5	-	-	-	-
Galearia filiformis	Pandaceae	-	-	-	-	1	1	0.00	0.3
Galearia maingayi	Pandaceae	2	2	0.04	0.9	1	1	0.01	0.99
Adinandra sarosanthera	Pentaphylacaceae	2	2	0.09	1.1	5	5	0.00	1.62
Trigonopleura malayana	Peraceae	2	2	0.03	0.87	-	-	-	-
Antidesma cuspidatum	Phyllanthaceae	-	-	-	-	4	4	0.00	1.33
Antidesma neurocarpum	Phyllanthaceae	-	-	-	-	2	2	0.00	0.62
Aporosa frutescens	Phyllanthaceae	1	1	0.02	0.45	10	8	0.02	4.2

Aporosa grandistipula	Phyllanthaceae	-	-	-	-	1	1	0.00	0.51
Aporosa lucida	Phyllanthaceae	2	2	0.05	0.97	3	3	0.00	0.98
Aporosa nervosa	Phyllanthaceae	3	3	0.11	1.57	3	3	0.00	1
Aporosa nigricans	Phyllanthaceae	-	-	-	-	1	1	0.00	0.3
Aporosa nitida	Phyllanthaceae	1	1	0.1	0.44	14	12	0.02	5.22
Aporosa prainiana	Phyllanthaceae	-	-	-	-	5	5	0.01	2
Aporosa subcaudata	Phyllanthaceae	-	-	-	-	10	10	0.01	3.55
Baccaurea brevipes	Phyllanthaceae	-	-	-	-	1	1	0.00	0.51
Baccaurea deflexa	Phyllanthaceae	1	1	0.02	0.45	1	1	0.00	0.36
Baccaurea dulcis	Phyllanthaceae	-	-	-	-	1	1	0.00	0.4
Baccaurea macrocarpa	Phyllanthaceae	5	4	0.23	2.57	1	1	0.00	0.33
Baccaurea minor	Phyllanthaceae	3	3	0.27	2.17	1	1	0.00	0.34
Baccaurea polyneura	Phyllanthaceae	-	-	-	-	1	1	0.01	0.92
Baccaurea puberula	Phyllanthaceae	2	2	0.12	1.21	-	-	-	-
Baccaurea sumatrana	Phyllanthaceae	3	3	0.06	1.35	1	1	0.00	0.46
Glochidion rubrum	Phyllanthaceae	-	-	-	-	2	2	0.00	0.67
Austrobuxus nitidus	Picrodendraceae	3	3	0.31	2.34	5	5	0.01	1.84
Ryparosa javanica	Polygalaceae	-	-	-	-	1	1	0.00	0.33
Xanthophyllum curtisii	Polygalaceae	-	-	-	-	1	1	0.00	0.31
Xanthophyllum flavescens	Polygalaceae	1	1	0.02	0.45	6	6	0.02	3.32
Xanthophyllum rufum	Polygalaceae	6	6	0.13	2.78	4	4	0.00	1.37
Xanthophyllum scortechinii	Polygalaceae	1	1	0.07	0.64	1	1	0.00	0.3
Xanthophyllum stipitatum	Polygalaceae	1	1	0.04	0.53	0	0	0	0
Xanthophyllum vitellinum	Polygalaceae	1	1	0.03	0.51	1	1	0.00	0.31
Ardisia cf. lamponga	Primulaceae	-	-	-	-	1	1	0.00	0.3
Ardisia cf. macrocalyx	Primulaceae	-	-	-	-	2	2	0.00	0.67
Ardisia teysmanniana	Primulaceae	-	-	-	-	1	1	0.00	0.33
Kokoona ochracea	Primulaceae	1	1	0.20	1.14	1	1	0.00	0.63
Drypetes longifolia	Putranjivaceae	2	2	0.05	0.95	1	1	0.00	0.3
Carallia brachiata	Rhizoporaceae	1	1	0.03	0.48	1	1	0.00	0.31
Gynotroches axillaris	Rhizoporaceae	1	1	0.05	0.55	-	-	-	-
Parinari oblongifolia	Rosaceae	1	1	0.03	0.5	-	-	-	-
Prunus arborea	Rosaceae	3	3	0.10	1.54	1	1	0.00	0.36
Gardenia tubifera	Rubiaceae	-	-	-	-	1	1	0.00	0.35
Hypobathrum microcarpum	Rubiaceae	3	3	0.06	1.37	1	1	0.00	0.3
Ixora congesta	Rubiaceae	-	-	-	-	1	1	0.00	0.49
Lasianthus scabridus &	Rubiaceae	-	-	-	-	1	1	0.00	0.3
Lasianthus stercorarius	Rubiaceae	-	-	-	-	1	1	0.00	0.3
Porterandia anisophylla	Rubiaceae	2	2	0.05	0.94	1	1	0.01	0.9
Prismatomeris tetrandra	Rubiaceae	-	-	-	-	3	3	0.00	0.9
Psychotria viridiflora	Rubiaceae	-	-	-	-	1	1	0.00	0.37
Psydrax dicoccos	Rubiaceae	-	-	-	-	1	1	0.00	0.33
Saprosma arboreum	Rubiaceae	-	-	-	-	7	7	0.01	2.54
Timonius cf. bilitonensis	Rubiaceae	1	1	0.02	0.44	2	2	0.00	0.62
Timonius flavescens	Rubiaceae	3	3	0.06	1.36	1	1	0.00	0.4
Timonius stipulosus	Rubiaceae	1	1	0.01	0.42	3	3	0.01	1.68

Urophyllum arboreum	Rubiaceae	1	1	0.01	0.43	3	3	0.00	0.97
Urophyllum corymbosum	Rubiaceae	-	-	-	-	8	8	0.02	3.6
Urophyllum hirsutum	Rubiaceae	-	-	-	-	6	6	0.00	1.95
Evodia lunu-ankenda	Rutaceae	-	-	-	-	2	2	0.00	0.75
Tetractomia obovata	Rutaceae	1	1	0.09	0.71	-	-	-	-
Meliosma nitida	Sabiaceae	-	-	-	-	9	8	0.01	2.87
Allophylus cobbe	Sapindaceae	2	2	0.03	0.86	1	1	0.00	0.34
Mischocarpus pentapetalus	Sapindaceae	-	-	-	-	1	1	0.00	0.3
Nephelium cuspidatum	Sapindaceae	3	3	0.07	1.4	12	10	0.01	4.02
Nephelium juglandifolium	Sapindaceae	1	1	0.02	0.44	7	6	0.01	2.45
Nephelium mangayi	Sapindaceae	2	2	0.05	0.96	3	2	0.00	0.91
Nephelium ramboutan-ake	Sapindaceae	-	-	-	-	2	2	0.00	0.76
Rhysatoechia acuminata	Sapindaceae	-	-	-	-	4	4	0.01	2.07
Xerospermum laevigatum	Sapindaceae	7	7	0.24	3.58	10	8	0.01	3.55
Xerospermum noronhianum	Sapindaceae	10	10	0.40	5.33	5	5	0.01	2.32
Madhuca sericea	Sapotaceae	2	2	0.07	1.02	2	2	0.00	0.61
Palaquium calophyllum	Sapotaceae	-	-	-	-	1	1	0.00	0.58
Palaquium ridleyi	Sapotaceae	-	-	-	-	1	1	0.00	0.4
Palaquium rostratum	Sapotaceae	5	5	0.34	3.21	-	-	-	-
Payena leerii	Sapotaceae	1	1	0.02	0.45	1	1	0.00	0.3
Payena lucida	Sapotaceae	1	1	0.01	0.42	-	-	-	-
Pouteria malaccensis	Sapotaceae	3	3	0.35	2.48	3	3	0.01	1.4
Eurycoma longifolia	Simarubaceae	-	-	-	-	1	1	0.00	0.3
Symplocos lucida	Symplocaceae	1	1	0.02	0.46	1	1	0.00	0.3
Symplocos rubiginosa	Symplocaceae	1	1	0.02	0.45	4	3	0.00	1.1
Gordonia cf excelsa	Theaceae	-	-	-	-	3	2	0.01	1.92
Ternstroemia toquian	Theaceae	-	-	-	-	1	1	0.00	0.33
Tetramerista glabra	Theaceae	1	1	0.02	0.44	1	1	0.00	0.3
Aquilaria malaccensis	Thymelaceae	1	1	0.01	0.41	-	-	-	-
Gonystylus acuminatus	Thymelaceae	-	-	-	-	1	1	0.00	0.3
Gonystylus borneensis	Thymelaceae	1	1	0.03	0.5	-	-	-	-
Trigoniastrum hypoleucum	Trigoniaceae	2	2	0.13	1.27	1	1	0.00	0.3

Appendix 2. The saplings, as expressed in density (individuals/ha), indicating the regeneration in the plot of a lowland forest in TNNP are classified into five groups.

Group 1: Very good regenerating species; sapling density: 10-28 individuals/ha.

Species	Family	Density (individuals/ha)	
		Sapling	Tree
Sloetia elongata	Moraceae	28	30
Pimelodendron griffithianum	Euphorbiaceae	16	15
Shorea acuminata	Dipterocarpaceae	18	3
Barringtonia macrostachya	Lecytidaceae	18	1
Aporosa nitida	Phyllanthaceae	14	1
Ctenolophon parvifolius	Ctenolophonaceae	14	2
Nephelium cuspidatum	Sapindaceae	12	3
Callerya atropurpurea	Fabaceae	12	1
Horsfieldia polyspherula	Myristicaceae	10	11
Shorea macroptera	Dipterocarpaceae	10	8
Xerospermum laevigatum	Sapindaceae	10	7
Magnolia liliifera	Magnoliaceae	10	3
Aporosa frutescens	Phyllanthaceae	10	1

Group 2: Good regenerating species, Sapling density: 5-9/ha

Adinandra sarosanthera, Artocarpus scortechinii, Austrobuxus nitidus, Canarium denticulatum, Canarium pilosum, Gymnacranthera forbesii, Gonocaryum gracile, ***Hopea pachycarpa****, Mangifera longipetiolata, Mastixia pentandra, Microcos paniculata, Nephelium juglandifolium, Santiria griffithii, Santiria laevigata, Santiria oblongifolia, Xanthophyllum flavescens, Xerospermum noronhianum,* and *Xylopia caudata.*

Group 3. Poorly regenerating species; sapling density: 5-8/ha;

Adenanthera pavonina, Aglaia silvestris, Allophylus cobbe, Alseodaphne oblanceolata, ***Anisoptera megistocarpa,*** *Aphanamixis borneensis, Aporosa lucida, Archidendron bubalinum, Artocarpus heterophyllus, Baccaurea deflexa, Baccaurea macrocarpa, Baccaurea minor, Baccaurea sumatrana, Beilschmiedia* sp., *Bouea oppositifolia, Buchanania arborescens Canarium littorale, Calophyllum macrocarpum, Carallia brachiata, Chionanthus* sp., *Cinnamomum javanicum, Coelostegia griffithii, Cryptocarya scortechinii, Dacryodes incurvata, Dacryodes rugosa , Dehaasia caesia, Deplanchea glabra polyphylla, Diospyros pendula, Diospyros pyrrhocarpa, Diospyros sumatrana, Diospyros venosa, Dracaena elliptica, Drypetes longifolia, Dyera polyphylla, Endiandra macrophylla, Fagraea racemosa, Galearia maingayi, Garcinia celebica, Garcinia maingayi, Garcinia parvifolia, Gironniera nervosa, Gironniera subaequalis, Gomphia serrata,* ***Hopea dryobalanoides, Hopea ferruginea****, Horsfieldia subglobosa, Hypobathrum microcarpum, Ixonanthes icosandra, Knema latericia, Knema latifolia, Kokoona ochracea, Koompassia malaccensis, Lithocarpus lucidus, Litsea costalis* var. *nidularis, Maasia hypoleuca, Macaranga tanarius, Madhuca sericea, Melanochyla fulvinervia, Lophopetalum javanum, Memecylon caeruleum, Memecylon edule, Memecylon myrsinoides, Mesua ferrea, Mesua lepidota, Myristica iners, Myristica maxima, Neoscortechinia kingii, Nephelium mangayi, Ochanostachys amentacea, Oncosperma tigillarium,* ***Parashorea malaanonan,*** *Parishia insignis, Payena leerii, Porterandia anisophylla, Prunus arborea, Ptychopyxis costata, Ryparosa caesia, Santiria apiculata, Santiria rubiginosa,* ***Shorea atrinervosa, Shorea faguetiana, Shorea leprosula Shorea parvifolia, Shorea retinodes*** *Sindora bruggemanii, Symplocos lucida, Symplocos rubiginosa, Syzygium fastigiatum, Syzygium cf. grande, Syzygium lepidocarpum, Syzygium magnoliifolium, Syzygium zeylanicum, Syzygium zollingerianum, Tetramerista glabra, Timonius cf. bilitonensis, Timonius flavescen, s Timonius stipulosus, Trigoniastrum hypoleucum, Triomma malaccensi,s Urophyllum arboreum,* ***Vatica pauciflora, Vatica ridleyana,*** *Xanthophyllum rufum, Xanthophyllum scortechinii, Xanthophyllum vitellinum Xylopia malayana* and *Xylopia fusca.*

Group 4. Non-regenerating species; no saplings

Afzelia rhomboidea, Albizia splendens, Aphanamixis polystachya, Aquilaria malaccensis, Archidendron clypearia, Artocarpus elasticus, Artocarpus kemando, Baccaurea pubera, Blumeodendron tokbrai, Borassus sp. (cf *flabellifer*), *Calophyllum rigidum, Calophyllum pulcherrimum, Cinnamomum porrectum, Cyathocalyx* sp., *Deplanchea bancana, Dialium platysepalum, Dillenia ovata, Durio excelsus, Dracaena* cf. *porteri, Garcinia havilandii, Garcinia brevirostris, Gonystylus borneensis, Gymnacranthera bancana, Gynotroches axillaris, Horsfieldia grandis, Hydnocarpus kunstleri, Hydnocarpus polypetalus, Knema conferta, Lithocarpus wallichianus, Litsea resinosa, Litsea tomentosa, Macaranga caladiifolia, Macaranga denticulata, Notaphoebe umbelliflora, Ormosia sumatrana, Palaquium rostratum, Parinari oblongifolia, Payena lucida, Pentace erectinervia, Pternandra galeata, Rhodamnia cinerea, Ryparosa kunstleri, Sarcotheca griffithii, Scaphium macropodum,* ***Shorea lepidota****, Swintonia* sp., *Syzygium cf. decipiens, Syzygium incarnatum, Syzygium palembanicum, Syzygium hemsleyanum, Tetractomia obovata, Trigonopleura malayana and Xanthophyllum stipitatum.*

Group 5. Developing saplings.

Actinodaphne gullavara, Actinodaphne macrophylla, Anisophyllea disticha, Antidesma cuspidatum, Antidesma neurocarpum, Aphanamixis sumatrana, Aporosa grandistipula, Aporosa nigricans, Aporosa prainiana, Aporosa subcaudata, Archidendron microcarpum, Ardisia cf. lamponga, Ardisia cf. macrocalyx, Ardisia teysmanniana, Artocarpus nitidus, Artocarpus rigidus, Baccaurea brevipes, Baccaurea dulcis, Baccaurea polyneura, Barringtonia cf *lanceolata, Canarium patentinervium, Canarium pseudodecumanum, Castanopsis costata, Castanopsis megacarpa, Chisocheton ceramicus, Dacryodes rostrata, Dehaasia palembanica, Dialium patens, Diospyros barteri, Diospyros buxifolia, Diospyros* cf.*nutans, Diospyros confertiflora, Diospyros oblonga, Diospyros oblongifolia, Diospyros rigida, Diospyros rostrata, Diospyros siamang, Diospyros virginiana, Elaeocarpus glaber, Elaeocarpus palembanicus, Elaeocarpus petiolatus, Ellipanthus tomentosus, Euonymus indicus, Eurycoma longifolia, Evodia lunu-ankenda, Galearia filiformis, Garcinia bancana, Gardenia tubifera, Gironniera hirta, Glochidion rubrum, Gluta wallichii, Goniothalamus macrophyllus, Goniothalamus tapis, Gonystylus acuminatus, Gordonia cf excelsa, Gymnacranthera contracta, Horsfieldia glabra, Horsfieldia irya, Ilex cymosa, Ilex macrophylla, Ixora congesta, Knema cinerea, Knema curtisii, Knema intermedia, Knema plumulosa, Knema pseudolaurina, Lasianthus scabridus, Lasianthus stercorarius, Lithocarpus conocarpus, Litsea noronhae, Macaranga triloba, Melanochyla caesia, Melanochyla ferruginea, Meliosma nitida, Memecylon excelsus, Memecylon garcinioides, Memecylon oligoneurum, Memecylon ovatum, Mezzettia parviflora, Mischocarpus pentapetalus, Nephelium ramboutan-ake, Palaquium calophyllum, Palaquium ridleyi, Phaeanthus sumatrana, Polyalthia lateriflora, Polyalthia rumphii, Polyalthia subcordata, Prismatomeris tetrandra, Psychotria viridiflora, Psydrax dicoccos, Pternandra caerulescens, Rhysatoechia acuminata, Ryparosa javanica, Sandoricum koetjape, Saprosma arboreum, Saraca declinata, Semecarpus glauca, Sindora coriacea, Sindora leiocarpa, Sindora sumatrana, Syzygium lineatum, Syzygium ridleyi, Teijsmanniodendron coriaceum, Ternstroemia toquian, Urophyllum corymbosum, Urophyllum hirsutum, Vitex gamosepala* and *Xanthophyllum curtisii.*

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Range extension of the endemic Sumatran admiral *Vanessa samani* (Hagen, 1895) (Lepidoptera: Nymphalidae) in Sumatra, Indonesia

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ABSTRACT

Sumatran Admiral *Vanessa samani* (Hagen, 1895) (Lepidoptera: Nymphalidae) is a butterfly endemic to Sumatra, and can only be found in the Karo Highlands (North Sumatra) and Kerinci Mountain (southwestern Sumatra). In this paper, we report two additional records of *V. samani* from the Aceh Province in northern Sumatra, and the Jambul Highlands of South Sumatra. These records significantly extend the range of distribution of this rare Sumatran highland species. We also report three plants presumed to be the host plants of *V. samani* in Sumatra: *Boehmeria* sp., *Smilax* sp. (*Smilax leucophylla*) and *Anaphalis* sp. (*Anaphalis longifolia*).

ABSTRAK

Kupu-kupu Laksamana Sumatera *Vanessa samani* (Hagen, 1895) (Lepidoptera: Nymphalidae) merupakan kupu-kupu endemik yang hanya terdapat di Sumatera, dan hanya diketahui dari Dataran Tinggi Karo (Sumatera Utara) dan Gunung Kerinci (Sumatera bagian barat daya). Dalam paper ini, kami melaporkan dua catatan tambahan *V. samani* dari Provinsi Aceh di Sumatera bagian utara, dan dari Dataran Tinggi Jambul di Provinsi Sumatera Selatan. Catatan-catatan ini menambah kisaran distribusi spesies endemik dan langka dataran tinggi Sumatera ini. Selain itu, kami mencatat tiga tanaman yang diduga sebagai tanaman inang jenis ini, yaitu *Boehmeria* sp., *Smilax* sp. (*Smilax leucophylla*) dan *Anaphalis* sp. (*Anaphalis longifolia*).

Keywords: *brush-footed butterfly, restricted range species, Sumatra, Vanessa samani*

INTRODUCTION

The brush-footed butterflies (Lepidoptera: Nymphalidae) are the biggest group of butterflies, containing 7,000 species in about 16 subfamilies, with many of them considered as distinct families (Holloway et al, 2001). Majority of the species in this family are large, showy and often multicoloured, although two of the subfamilies feature brownish or drab-coloured butterflies (Khoon, 2010). The single characteristic that unites members of this group is the non-functional forelegs for walking in both sexes. With their forelegs reduced to brush-like stumps, this group becomes popularly known as brush-foots (Hoskins, 2015).

Vanessa is a genus under subfamily Nymphalinae (Scoble, 1992; Holloway et al, 2001), and there are currently 22 species within the genus *Vanessa* (Wahlberg & Rubinoff, 2011). Sumatran admiral *Vanessa samani* (Hagen, 1895) is the only species of genus *Vanessa* occuring in Sumatra, and this species is restricted to the highland zones of Karo and Kerinci mountains of the island (D'Abrera, 1982; Tsukada et al, 1985; Vane-Wright & Hughes, 2007).

Vanessa samani is a species restricted to the high altitudinal zones of Sumatra. It can be found in mountainous regions above 1,000 m altitude in the Karo Highlands (3° N) in the Province of North Sumatra; and has a range that extends southward to the Kerinci Mountain (0° S) in the Jambi Province of southwest Sumatra, at an altitude around 1,500 m (D'Abrera, 1982; Tsukada et al, 1985; Vane-Wright & Hughes, 2007). A male individual from North Sumatra (location details unknown) once received an offer online and sold the butterfly for as much as €40 (Theinsectcollector, 2020). *Vanessa samani*'s findings have also been reported from Aceh Province as specimen code NW80-15 taken in July 1997, but no detailed information on the location is given. (Wahlberg & Rubinoff, 2011; NSG, 2020). Another specimen with specimen ID JMOOO05 (GenBank accession number DQ028753 and DQ385863) was reported from Sumatra without further details (Otaki et al, 2006a, 2006b; Wahlberg & Rubinoff, 2011).

In this paper, we report two observations of *V. samani*. Their occurrences significantly extend the range of their distribution in Sumatra.

METHODS

Information on the first extension range of *V. samani* was from the Aceh Province, observed and shared in iNaturalist (2020) by the second author on 25 June 2016 in Kedah Village (03°58'38.84"N, 97°14'51.60"E), Gayo Highlands, Blang Jerango District, Gayo Lues District (Figure. 1). The second *V. samani* was observed and photographed on the flower of *Austroeupatorium inulifolium* on 18 August 2018 in Talang Pisang Village of Jambul Highlands (04°04'45"S, 103°20'48"E), Jarai Subdistrict, Lahat District, South Sumatra Province (Figure. 2). The Kedah Village of Gayo Highlands is approximately 1.300 m, and the Jambul Highlands is almost 1.500 m above sea level. Whitten et al (2000) defined these altitude zones (1.200 to 2.100 m) as lower montane forest of Sumatra. Unfortunately, the specimens were not collected due to a lack of preservation materials and permit restrictions during field work visitations. However, through the use of a series of photographic images, these butterflies were identified at species level based on a combination of specific morphological characteristics (Figure 3 & Figure 4). In both cases, the photographic observations were time stamped and geotagged.

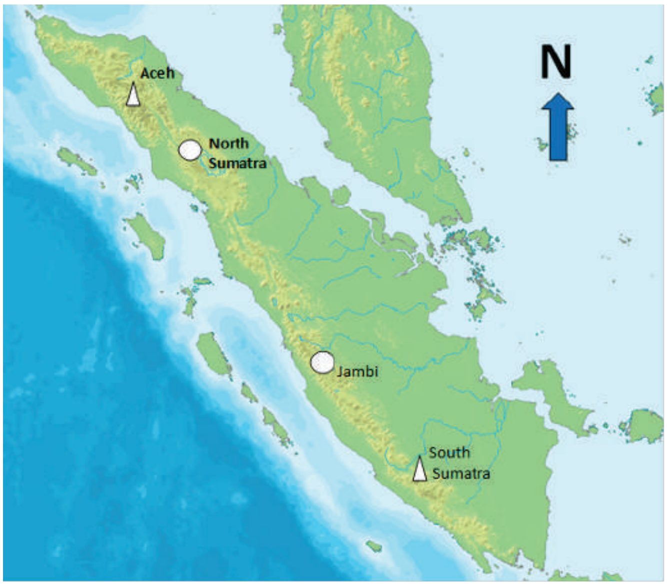

Figure 1. Recent distributions of *V. samani* in Sumatra. White triangle indicates new additional records from Gayo Highlands (Aceh Province) and Jambul Highlands (South Sumatra Province); and white circle indicates historical records before 2016.

Figure 2. Habitat of *V. samani* in Talang Pisang Village, Jambul Highlands, South Sumatra Province, Indonesia (Photo: Guntur Pragustiandi).

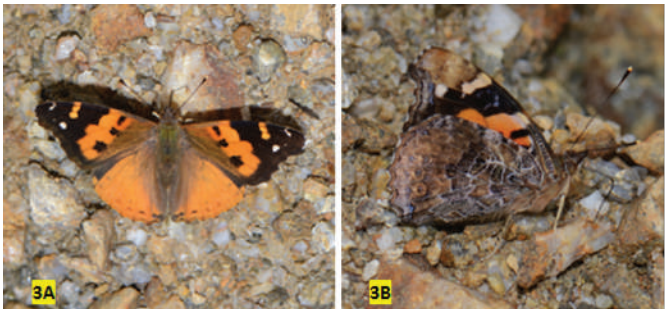

Figure 3. The male *V. samani* found on 25 June 2016 in Kedah Village, Gayo Highlands, Aceh Province, Indonesia: A. Upperside, and; B. Underside (Photo: Pavel Kirillov).

Figure 4. The male *V. samani* perched on the flower of *Austroeupatorium inulifolium* on 18 August 2018, Talang Pisang Village, Jambul Highlands, South Sumatra Province, Indonesia: A. Upperside, and; B. Underside
(Photo: Pormansyah).

RESULTS AND DISCUSSION

The two specimens found in Gayo and Jambu Highlands were identified as members of the genus *Vanessa* by its medium size and characteristic dark, reddish-orange, and white markings. The black forewing with reddish-orange patches forms a post-discal band; orange and white spots (?) were found at the apical and subapical; and the dorsal side of the hindwing is reddish-orange with a series of black submarginal spots (Figure 3 [A] & Figure 4 [A]). The colour pattern of the underside of the forewing is similar to the dorsal side but has a pale creamy-orange apex; the underside of the hindwing has a blotched appearance with many shades and patterns of light to dark brown and grey (Figure 3 [B] & Figure 4 [B]). Based on the specific features above and references made to the major guides (D'Abrera, 1982; Tsukada et al, 1985; Iqbal et al, 2021), the specimens found in the Gayo and Jambul Highlands were identified as the male of *V. samani*, an endemic Sumatran nymphalid. The sexes are similar on both sides of the wings (D'Abrera, 1985), but Tsukada et al. (1985) described the female as lacking black spots on the forewing cell.

Information on the spatial distribution of butterflies in many major islands of Indonesia (particularly Sumatra) remains relatively limited (Aprilia et al, 2020). Compared to Lepidoptera in lowland forests, the butterflies of lower mountain forests are studied less frequently. Recent surveys indicated that lower mountain forests of southern Sumatra could support a greater butterfly diversity than expected (Iqbal et al, 2020; Setiawan et al, 2020). Further field surveys are needed to document Lepidoptera diversity of lower mountain forests of Sumatra, as well as to support conservation effort to protect the forests as Lepidoptera habitats. With its distribution range restricted to the highland zones of Sumatra, combined with rare sightings in the field, we propose the global status of *V. samani* as to at least be "Vulnerable".

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Balancing infrastructure, ecosystem conservation, and community approaches on integrated development planning of Citarum Watershed

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ABSTRACT

The condition of several watersheds in Indonesia at this time has experienced a lot of decline in functions in maintaining water availability and environmental health. The number of critical watersheds in Indonesia continues to grow and is getting worse even though there have been many rehabilitation programmes for several watersheds in Indonesia, including the Citarum Watershed in West Java. Changes in the characteristics of the Citarum Watershed that can be seen include an increase in the overflow point of flood inundation, erosion of agricultural land, and sedimentation in rivers. The method used in this research is a qualitative approach through analysis based on a literature review of planning documents, regulations, books, journals, and expert judgment analysis. This study aims to assess the extent to which cross-sectoral, cross- regional and inter-disciplinary problems affect regional development and analyze problems that occur at the watershed scale. The Citarum Watershed Strategic Plan is a set of activities with steps to implement the planned strategies. The Strategic Plan reveals some activities, involvement of stakeholders, and also goals for the future which are to be achieved through the identified implementation steps. All of the activities have a main vision: "All stakeholders working together to enhance the quality of watershed carrying capacity by balancing infrastructure, ecosystem conservation, and community approaches".

ABSTRAK

Kondisi beberapa Daerah Aliran Sungai (DAS) di Indonesia saat ini banyak mengalami penurunan fungsi dalam menjaga ketersediaan air dan kesehatan lingkungan. Jumlah DAS kritis di Indonesia terus bertambah dan kondisinya semakin parah meski telah banyak dilakukan program rehabilitasi, termasuk di DAS Citarum, Jawa Barat. Perubahan karakteristik DAS Citarum yang terlihat antara lain peningkatan titik luapan genangan banjir, erosi lahan pertanian, dan sedimentasi di sungai. Metode yang digunakan dalam penelitian ini adalah pendekatan kualitatif melalui analisis berdasarkan tinjauan pustaka terhadap dokumen perencanaan, peraturan, buku, jurnal, dan analisis expert judgement. Penelitian ini bertujuan untuk mengkaji sejauh mana permasalahan lintas sektor, lintas wilayah dan antar disiplin ilmu mempengaruhi pembangunan wilayah dan menganalisis permasalahan yang terjadi pada skala DAS. Renstra DAS Citarum merupakan rangkaian kegiatan dengan langkah-langkah untuk mengimplementasikan strategi yang telah direncanakan. Rencana Strategis mengungkapkan beberapa kegiatan, keterlibatan pemangku kepentingan, dan juga tujuan ke depan yang ingin dicapai melalui langkah-langkah implementasi yang diidentifikasi. Seluruh kegiatan tersebut memiliki visi utama: “Seluruh pemangku kepentingan bekerja sama untuk meningkatkan kualitas daya dukung DAS dengan menyeimbangkan infrastruktur, konservasi ekosistem, dan pendekatan masyarakat”.

Keywords: *Citarum, development planning, integrated, watershed*

INTRODUCTION

Increasing population growth and the rate of development often impact land conversion (Soemarwoto, 1999). Area conversion results from population pressure on land, indicating that there is a role for the community, both on a specific scale and in general, that affects the sustainability of natural resources (Watson et al, 2014; Cumming, 2016). In many cases, land conversion increases the frequency and magnitude of flooding in the rainy season and water shortages in the dry season (Pambudi, 2021a, 2021b, 2021c). Water scarcity due to the destruction of watershed ecosystems has the potential to cause tensions both from an economic and social perspective due to conflicts of interest between users (Pambudi, 2019a).

The success of watershed management is always related to the conservation of water resources through increasing the flow rate and increasing the rate of rainwater infiltration, and at the same time, the conservation of water resources can also improve the quality of river water because a controlled surface water flow rate can reduce the rate of erosion (Calder, 2005; Dixon, 1992; Nakamura 2003). Thus, successful watershed management can play a significant role in managing, developing, and/or increasing the water supply needed to stabilize water- based food and energy availability (Gregersen et al, 2007).

Watershed management, which is part of regional development in Indonesia, is facing various problems such as the absence of integration among sectors, agencies, and regions (Pambudi, 2019b). The Citarum Watershed (Figure 1) is one of the supercritical watershed in Indonesia related to environmental degradation (Djuaningsih, 1993) and is the most prioritised one in the country. The river of fed irrigation scheme produces 5% of the country's rice production. Located in West Java with a length of 297 km, Citarum is the biggest and the longest river on the island of Java, Indonesia. The Citarum Watershed covers an area of 6,614 km^2 with a population of around 30 million people.

With the great potential in helping various elements of life, the Citarum river should be a magnet or attraction for all people. For this reason, the Citarum Watershed should be preserved and maintained as one of the natural resources as much as possible. With the contamination of the Citarum River, the Government as the policy holder, needs to know how much is the loss due to the contamination of the Citarum River. Such a process is complex and takes many years. The smallest damage is in the upstream of Citarum Watershed in Cisanti, followed by the industrial waste pollution in the Bandung basin, especially the Baleendah and Dayeuhkolot areas which are increasingly populated with industrial factories.

The population around the Citarum Watershed has a growth rate of up to 3% every year. Neediness in the bowl is essentially over the public normal, with 8 of 11 areas recording destitution levels of 25% or above in 2019. Situated in the Citarum Watershed are major modern places including Indonesia's fourth-biggest city and the common capital of West Java, Bandung, and satellite modern parks toward the west of Jakarta (Idris et al, 2019). The Citarum stream supplies some 80% of Jakarta's crude water and is the site of three significant dams and three huge multipurpose repositories (GoI, 2010). Potential water accessibility in Citarum Watershed comprises of 7.5 billion m^3/year or 57.9%) (currently used) and 5.5 billion m^3/year or 42.1% (future potential). The water is used as drinking water for Jakarta 6.0%, drinking water for Bandung 0.3%, businesses 2.0%, water system 86.7%, and others 5.0%. Subsequently, the Citarum River and dams along its stream have extremely high potential in terms of financial value and balancing the climate, in which they can affect community socio-cultural of the community and the environment (Fridayani, 2020).

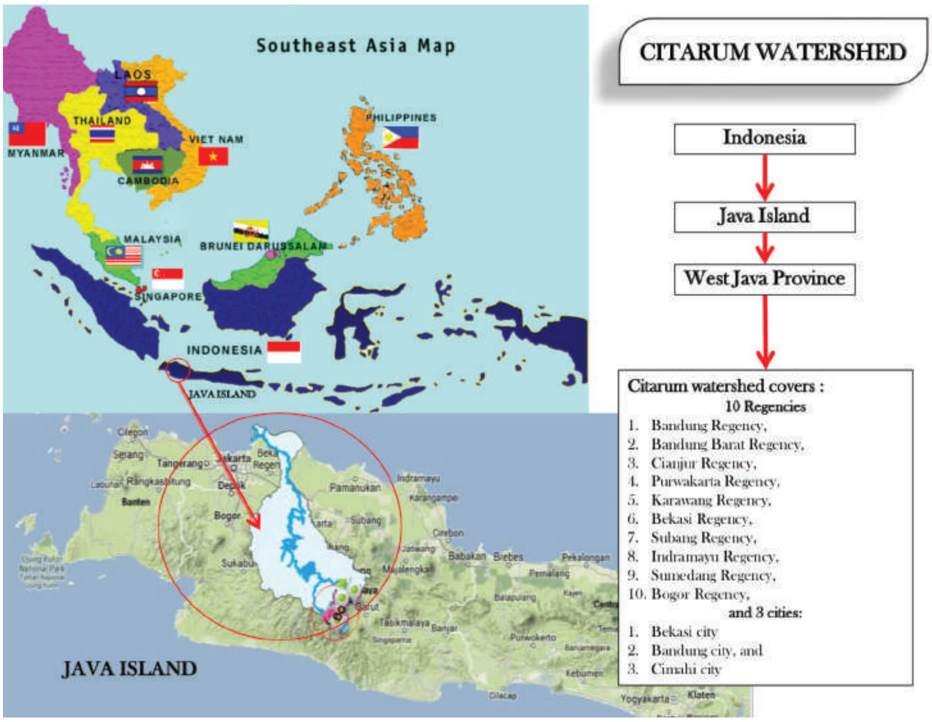


Figure 1. Map of Citarum Watershed, West Java, Indonesia.

Citarum is a watershed with heavy rainfall. Even in the driest month, there is a lot of rain. This location is classified as Af by Köppen and Geiger. The temperature here averages 23.2 °C. The rainfall here averages 2,161 mm. The temperatures are highest on average in April, at around 23.8 °C. July is the coldest month. The least amount of rainfall occurs in August, averaging 68 mm. Most of the precipitation here falls in December, averaging 293 mm (GoI, 2014).

Spontaneous land use throughout the most recent 150 years has left just little, dissipated remainders of Java's normal woodland environments and their related organic variety, particularly in the swamps. All low-lying regions continue to endure effects of human activities,

including expulsion of non-lumber backwoods items and trees for development purposes, and contamination of water and soil from homegrown, modern, and farming endeavours. Presently, there are no satisfactory or viable arrangements to manage land use and to control advancement exercises in the Citarum Watershed.

The GoI (2003) highlighted the following biodiversity assets inside the Citarum Watershed ie. 160 species of plant species, 72 species of birds (10 endemic, 2 rare), 11 species of reptiles, and at least 2 species of fishes. Among the wildlife that occurs in the forests of West Java, endangered species such as Grizzle Leaf Monkey or Javan Surili (*Presbytis comata*) as well as the endemic of Javan Gibbon (*Hylobates moloch*) are still found in Citarum Watershed. Additionally, Javan Leopard (*Panthera pardus*) is also still roaming in the area. The rare bird species of West Java are represented by Javan Tesia (*Tesia superciliaris*), Green Spectacled Pigeon (*Treron oxyurus*), and the Sunda Thrush (*Zoothera andromedae*). The Javan Hawk-eagle (*Nisaetus bartelsi*), which is endemic and one of the most endangered species, can be found in the Citarum Watershed. The Javan Scops owl (*Otus angelinae*) has also been seen on some occasions. The Citarum Watershed is also home to endemic tree species such as Rasamala (*Altingia excelsa*), Jamuju (*Dacrycarpus imbricatus*), etc., as well as the rare trees like Kiputri (*Podocarpus neriifolius*) and Kimerak (*Weinmannia blumei*), which have a high financial value as building materials.

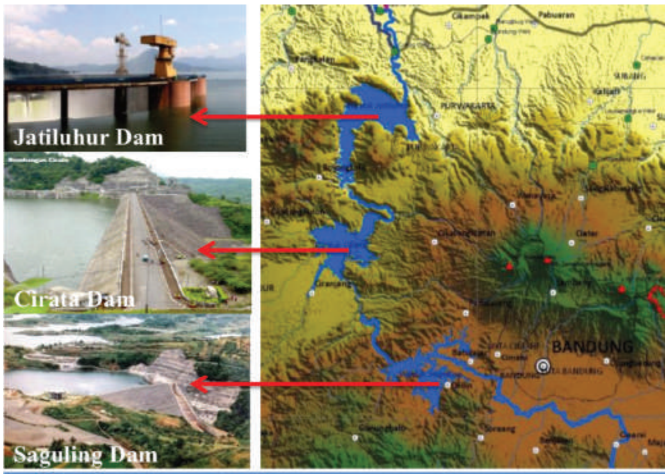
METHODS

The method used in this research is a qualitative one (Moleong, 2010), whereby analysis based on literature review of planning documents, regulations, books, journals, and expert judgment analysis with an emphasis on analysis related to the conditions of the Citarum Watershed, the root causes of the damage to the area, previous programmes/policies and the lead factors that affect the problems of the Citarum Watershed were undertaken. This study aims to assess the extent to which cross-sectoral, cross-regional and inter-disciplinary problems affect regional development and analyze problems that occur at the watershed scale. The consideration for choosing this location is due to its strategic role in national development, particularly related to food, energy and water security. The Citarum River Basin has begun to develop into a national priority because of the complexity of the problems that have a major impact on other areas outside the province of West Java.

RESULTS AND DISCUSSION

Multi-Functional Watershed

Citarum has three multipurpose-fell dams, including Saguling, Cirata, and Jatiluhur supplies (ADB, 2019). The primary dam, Saguling covers 5,340 ha of mountain regions and its principal work is to create hydroelectric power with a full limit of around 750 MW. The subsequent dam, Cirata covers 6,200 ha and has a capacity to produce hydroelectric power with a full limit of up to 1,000 MW. The third dam, Juanda previously Jatiluhur, covers 8,300 ha of area and its main function is to inundate 240 thousand hectares of rural marsh regions, in addition to providing crude water for drinking in Jakarta. The water is likewise used for hydro- electric force with full limit up to 187.5 MW. About 155 m^3/second of water from the Jatiluhur reservoir is distributed through three irrigation canals to irrigate 420,000 ha of fertile land. Three major hydropower plants used the Saguling, Cirata, and Jatiluhur reservoirs with a combined volume of 5,300 million m3 to produce electricity with an output of 1,937.5 MW (GoI, 2014)



No.	Resevoir	Volume (million m^3)	Electricity output (Mw)
1.	Saguling	900	750
2.	Cirata	1.900	1.000
3.	Jatiluhur	2.500	187,5
	Total	5.300	1.937,5

Figure 2. Three major hydropower plants used the Saguling, Cirata and Jatiluhur dams (reservoirs) with a combine volume of 5.300 million m^3 to produce electricity with an output of 1.937 Megawatt.

Around 17.6 billion m^3/year of water from the Citarum Watershed, 50% provided by surface water, was used for domestic, industrial and irrigation purposes. The rest is supplied by deep groundwater extraction. Furthermore, the Citarum Watershed provides a great potential for eco- tourism and recreation for more than 30 million people who live in the adjacent urban agglomeration of Jakarta and Bandung, due to its environmental assets like rivers, lakes, and waterfalls.

Problems of Citarum Watershed

One of the more critical problem facing the Citarum Watershed is erosion, which has affected about 31,850 ha or 4.4% of the watershed (in state forest). Due to economic pressures, people have been converting the forest since 1995 when no arable lands were left.

Uncontrolled deforestation and unsuitable land cultivation have left the land upstream exposed to severe erosion.

Average annual sedimentation into the three reservoirs is estimated at 8 million m^3/year. This has caused flooding in the rainy season and water scarcity in the dry season. Severe environmental degradation in the Citarum River, from upstream to downstream areas, has triggered floods from the Bandung regency to the Karawang Regency, through a distance of 196 km in West Java annually. Within last decade, a flood has occurred in Karawang, the downstream of Citarum Watershed (Kerstens, 2013). Flooding issues in the watershed are managed by the Citarum Flood Control Task. Remediation measures in the watershed are has been implemented such as incorporating re-greening/reforestation schemes as well as the metropolitan city seepage framework.

The upper part of the Citarum Watershed, where the Sanguling Basin is, faces heavy level of chemical and physical pollution, erosion and sedimentation. 190 tons of waste were dumped into the river from farms every day in which 8,000 cows produce 24 kg of waste each. Various activities that take place in the upper part of the Citarum Watershed will certainly affect the performance of hydroelectric power and functions of state and sustainability Saguling Reservoir.

Citarum Previous Programmes

Various programmes have been rolled out, including the "Citarum Bergetar" programme. The "Citarum Bergetar" is a response to concerns in the Citarum River. The plan was implemented to control damage and pollution, and to restore the Citarum Watershed, in hope of improving the process and quality of ecosystem-based spatial planning on the Citarum River. The "Citarum Bergetar" programme serves as a starting ground to inform researchers the extent of its success for future programmes (Andri & Aziz, 2021).

After the Citarum programme, the National Development Planning Agency (Bappenas) proposed the Citarum Integrated Water Resources Management Investment Programme (ICWRMIP) in 2008. The new programme aims to improve the quality of the Citarum River by taking a loan of 50 million US Dollars from the Asian Development Bank (ADB). With this huge amount of money, the programme should ideally be on track to achieving its planned target. However, the results of the programme have been far from promising, with residents of Majalaya, Baleendah and Dayeuhkolot still feeling the impact of the overflowing Citarum River every year.

Another programme that was rolled out in 2013 was the Citarum Bestari (Healthy, Beautiful and Sustainable) movement programme. This programme missed the expected target, which was to ensure that water in the Citarum river can be safe for consumption in 2018. But the fact is that until now the water from the river has not been suitable for direct consumption because the water quality has not met the specified quality (Pambudi, 2019b). In February 2018 the government as a policy maker issued the latest policy programme namely the "Citarum Harum" programme. "Citarum Harum" encouraged the restoration of the longest river in West Java through concepts and idea like that of the other programmes before. The only exception was that "Citarum Harum" was under direct supervision by the central government coordinated by the Ministry for Maritime Affairs. In this "Citarum Harum" programme, the handling was divided into three stages, namely upstream, middle and downstream. The implementation was carried out in an integrated manner by the central, provincial, district/city governments as well as all relevant ministries, including the Siliwangi Regional Military Command III (Kodam III) and the West Java Regional Police (Polda Jawa Barat).

The Lead Factors

The sustainability of watershed is determined not only from fulfilment status of water supply but also from the quality aspect (Pambudi et al, 2020). Flooding during the rainy season and drought during the dry season are indicators of an unhealthy watershed. It is critical to understand the conditions of the watershed, especially if erosion in the upstream areas resulted in the

reduction of carrying capacity of the water supply (Pambudi, 2021a). The Citarum River, which is located in West Java and is in the Citarum Watershed, has earned the title as one of the most polluted areas in the world. This river has three main problems. In the upstream part of the watershed, there is critical land that often provides input from soil erosion, which then flows along the stream and settles downstream. The accumulated sediment causes a potential flood disaster during the rainy season. The lead factors that influencing the degradation of the Citarum Watershed carrying capacity are:

1. *Lack of coordination and stakeholders' involvement.* The complexity of the issues that expand from its upstream to downstream areas needs to be comprehensively addressed by a variety of related institutions. Lack of community awareness about watershed ecosystem was also a problem in the Citarum Watershed.
2. *Illegal Clearing of Rainforest.* Erosion down the slope occurs when water runoff displaces surface soil during heavy rainfalls. Yet, many farmers still prefer to plant vegetables and crops annually around the slope.

3. *Industrial and Domestic Pollution.* There are 1,500 businesses in Bandung and its periphery, and they deliver 280 tons of compound waste into Citarum consistently as there is an absence of sterilization and wastewater treatment offices. This implies that pollution loads in the waterway framework will be overburdened beyond its capacity limit and its absorption rate. Water quality observed in the last part of the 1990s showed that yearly normal of Body focuses as high as 300 mg/litre.
4. *Biodiversity problems.* The upstream-downstream watershed area can only provide support as a habitat for several species of remaining flora and fauna.
5. *Increasing of Vegetable Land in Upland Area and Decreasing Rice Production.* The horticulture creation of the Upper Citarum Watershed depends as a rule on earthen porches, which are either unprotected or deficiently secured by any disintegration control measures. they are profoundly erodible and helpless against imploding during the wet season. As an effect of expanding vegetable land, a portion of the ranchers change their plants from paddies to vegetables.
6. *Solid Waste.* The yearly uncollected trash that constantly winds up gathering in the waste framework and waterways adds up to 500,000 m^3/year.
7. *Groundwater Over Extraction.* Subsidence is severe and basin-wide: From 1988 more than 3-4 meters subsidence; Severe impact on river hydraulics (and flooding); Irreversible aquifer damage starting.

Strategic Plans for Citarum Watershed Management

The Citarum Watershed Strategic Plan is a set of activities with steps to implement the planned strategies. The Strategic Plan includes activities, involvement of stakeholders, and goals for the future to be achieved through the identified implementation steps. All of the activities have a main vision: *"All stakeholders [to work] together to enhance the quality of watershed carrying capacity by balancing infrastructure, ecosystem conservation, and community approaches"*.

The main challenges of implementing the Citarum Watershed management Strategic Plans are related to sectoral coordination (inter sectors) and how to make the plan a priority on national programme supported by adequate funding (national or international). It is additionally challenging to convince local people to be involved/join actively on this plan. One of the first steps to overcoming the increasingly severe watershed damage is to form a community movement that would jointly conserve and protect the watershed ecosystem. To form a community movement, a forum is needed to accommodate aspirations and coordination in managing the watershed.

In principle, watershed institutions are formed based on the awareness and needs of the community around the watershed to carry out better watershed management. Watershed degradation is the result of problems that arise due to conflicts of interest between sectors and between local governments. The establishment of watershed institutions must be based on a shared commitment to achieve the goals of watershed

Table 1. Strategic Plans for Citarum Watershed Management.

Issues / Problems	Proposed Activities	Goal	Key Stakeholders
Lack of coordination and stakeholders' involvement	• Map out potential and constraints of Citarum Watershed. • Facilitate stakeholder participation in planning, investment, and implementation. • Prepare integrated development concept for Citarum Watershed	Institutional Coordination	National Development Planning Agency (Bappenas)
Biodiversity problems	• Biodiversity Inventory, Habitat Mapping, GIS Framework • Pilot Project for Forest Restoration/Land	Biodiversity Conservation	Ministry of Environment and Forestry

	Rehabilitation • Mainstreaming Biodiversity Conservation in the Production Landscape		
Illegal Clearing of Rainforest	• Conservation and reforestation are balanced with capacity building for farmers to adopt sustainable farming practices. • Campaign to save spring water in the watershed upstream	Conservation of Upper Watershed	Local Government, Communities, CSO, Private Sector
Community Awareness	• Activities in Pilot Demonstration Activities (PDA) is being mobilized to raise the community-driven development and community participatory, including campaign "water and environment for life" to all level communities, man or woman	Community-Driven Development and Participatory Approaches	Ministry of Social Affairs
Industrial and Domestic Pollution	• Improving sanitation and access to clean water in 15 villages along West Tarum Canal in 3 District/City.	Improvement of Water Supply and Sanitation	Ministry of Health
Increasing of vegetable land in Upland area and decreasing production of rice	• System Rice Intensification Method will be implemented in 3.000 Ha rice paddy field in Citarum Watershed (Karawang-Subang and Bandung). SRI Method using organic fertilizer and could save up to 40% water as compared to the conventional method. • Sustainable Financing for Water and Land Conservation in Upland Area through Payment for Environmental Services (PES)	Improvement of Water and Land Management	Ministry of Agriculture

Solid Waste Flooding	• Rehabilitation of Flood Control a long Citarum River (weir, siphon, etc) • Rehabilitation of West Tarum Canal /Diversion Channel	Improvement of Infrastructure	Ministry of Public Works and People Settlement

management. With such institutional membership, communication and networking among stakeholders related to watershed management will be built. Each party can obtain benefits, roles, responsibilities and build commitments to achieve common goals in improving community welfare and conserving watershed ecosystems.

CONCLUSION

The Citarum Watershed experiences many problems, both from the physical, institutional, social aspects. It is also affected by previous policy problems that have not been holistic, integrative and integrated. Physical problems that exist are generally influenced by land conversion, heavy rainfall, sedimentation and environmental problems. The lead factors that influenced the degradation of Citarum Watershed carrying capacity are: 1) Lack of coordination and stakeholders involvement; 2) Illegal Clearing of Rainforest; 3) Industrial and Domestic Pollution; 4) Biodiversity problems; 5) Increasing of Vegetable Land in Upland Area and Decreasing Rice Production; 6) Solid Waste; and 7) Groundwater Over Extraction.

Institutions in this area also face the problem of the lack of integration between existing stakeholders, be it government, private, or community in the region. Previous policies tend to solve problems partially and have not placed the social and cultural aspects of the local community as part of the development approach. This has had an impact on the ineffectiveness of the budget disbursed by the government because it does not address the real root cause of the Citarum Watershed problem at the site level.

To solve the problem related to development planning, government agencies and non- government organizations (NGOs) should join and cooperate in a series of dialogues leading to the preparation of the Citarum Watershed strategic plan to improve the management of water resources and restore the environment of the watershed. The planning of the Citarum strategic plan is based on a comprehensive assessment of the development potential and constraints of the watershed, and on multi-sector and integrated solutions for its complex challenges and problems. The National Development Planning Agency (Bappenas) is responsible for the coordination and management of the Citarum Watershed Strategic Plan. Stakeholders should be involved in all stages from planning and investment of the strategic plan to physical implementation, operation, and maintenance.

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Market surveys in Mataram, Lombok, illustrate the expanse of legal and illegal Indonesian bird trade networks

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ABSTRACT

Bird keeping is deeply rooted in Indonesian culture and markets selling large numbers of birds are found across the country. We examined bird markets in Mataram on the island of Lombok. Across five market visits, 10,326 birds of 108 species were observed, with 18 of these species being nationally protected and 10 having been assessed as globally threatened by the IUCN Red List of Threatened Species. Observed protected species, as well as non-protected species with no or exceeded harvest quotas accounted for a total of 8,586 (83.1%) illegally traded birds. In terms of trade volume, 80.8% (n=8,347) of the recorded Indonesian birds were native to Lombok, suggesting that many of the birds for sale were sourced locally. However, 63% (n=65) of the encountered Indonesian species were not native to Lombok, confirming previously described intra-national bird trade flows between the Indonesian islands. We found a strong positive relation between a species' body size and its asking price. Current legislation in Indonesia is sufficient to eradicate the open trade in illegally sourced and/or protected species. Improved enforcement of these laws, in combination with strategic demand reduction efforts, is needed to curb illegal and unsustainable bird trade in the country.

ABSTRAK

Memelihara burung telah mengakar dalam budaya masyarakat Indonesia dan pasar yang menjual burung dalam jumlah besar dapat ditemukan di seluruh negeri. Kami menelaah pasar burung di Mataram, Pulau Lombok. Dalam lima kunjungan pasar, teramati 10.326 burung dari 108 spesies, dengan 18 spesies diantaranya dilindungi secara nasional dan 10 dengan status terancam secara global berdasarkan Daftar Merah IUCN. Spesies dilindungi yang diamati, serta spesies yang tidak dilindungi yang melebihi kuota panen berjumlah 8,586 (83.1%) burung yang diperdagangkan secara ilegal. Dalam hal volume perdagangan, 80.8% (n=8,347) burung Indonesia yang tercatat adalah asli Lombok, menunjukkan bahwa banyak burung yang dijual berasal dari lokal. Namun, 63% (n=65) spesies Indonesia yang ditemukan bukan asli Lombok, mengkonfirmasikan arus perdagangan burung intra-nasional yang dijelaskan sebelumnya antara pulau-pulau di Indonesia. Kami menemukan adanya hubungan positif yang kuat antara ukuran tubuh spesies dan harga permintaan. Peraturan perundang-undangan yang berlaku di Indonesia saat ini cukup untuk memberantas perdagangan terbuka spesies yang bersumber dan/atau dilindungi secara ilegal. Peningkatan penegakan hukum ini, yang dikombinasikan dengan strategi upaya pengurangan permintaan, diperlukan untuk mengendalikan perdagangan burung ilegal dan tidak berkelanjutan di negara ini.

Keywords: *bird trade, conservation, enforcement, harvest quotas, illegal wildlife trade*

INTRODUCTION

Keeping birds as a pastime in Indonesia has deep and diverse cultural roots. An estimated 60% of all Indonesian households have chickens, ducks and/or quail in their backyards (Padmawati & Nichter, 2008), one in three households keep a cage bird, and on the island of Java alone six million households keep up to 84 million cage birds (Marshall et al, 2020). Throughout Indonesia, cultural concepts exist for the way that birds are kept that are not captured by either the 'pet' or 'livestock' concepts of the West. Birds are kept as pets, they are kept as livestock, but also as something in between whereby birds add a sense of completeness to the household (Forster, 2009). Indonesia's extensive cage bird trade is widely recognized as a leading threat to many of the country's native bird species (Collar et al, 2012; Eaton et al, 2015; Harris et al, 2017; Marshall et al, 2020). Indonesia currently has the world's highest number of threatened native birds (n=175) (IUCN Red List, 2021), with illegal and unsustainable overexploitation for the pet trade being one of the major reasons for this. Songbirds, kept for their melodious song and used in highly popular singing competitions, are traded in high volumes, pushing many of these species perilously close to extinction (Chng et al, 2015; Chng, Shepherd, & Eaton, 2018a; Chng, Krishnasamy, & Eaton, 2018b; Marshall et al, 2020; Shepherd, 2006). Bird markets can be found across Indonesia with birds frequently being shipped between the country's islands and markets (Indraswari et al, 2020).

The Act of the Republic of Indonesia (No.5) of 1990 concerning Conservation of Living Resources and their Ecosystems is Indonesia's main species conservation legislation. Protected species are listed in Regulation of the Minister of Environment and Forestry no. P.106/MENLHK/SETJEN/KUM.1/12/2018, which currently includes ~30% (n=557) of Indonesia's native bird species. The harvest of unprotected species is regulated by a quota system under the Decree of the Minister of Forestry no. 447/Kpts-II/2003. Harvest and trade quotas are set annually by the country's CITES Scientific Authority (Indonesian Institute of Sciences), and its CITES Management Authority (under the Ministry of Environment and Forestry) in collaboration with traders and various other stakeholders. It is illegal to trade in unprotected species for which no harvest quotas have been set. Illegal trade in both protected and unprotected species is frequently carried out openly in markets throughout the country (Haryoko, 2010; Iskander; 2014, Iskander & Iskander; 2015; Leupen & Shepherd, 2018; Nijman, Nekaris, & Imron, 2019), and quotas are regularly ignored (Auliya, 2010; Schoppe, 2009; Shepherd, Eaton, & Chng, 2016).

Much of the research into the Indonesian bird trade has focused on specific taxa, e.g. straw-headed bulbul (*Pycnonotus zeylanicus*) (Bergin et al, 2017), black-winged myna (*Acridotheres melanopterus*) (Nijman et al, 2018), Bali myna (*Leucopsar rothschildi*) (Jepson, 2016) and Sumatran laughingthrush (*Garrulax bicolor*) (Bušina, Pasaribu, & Kouba, 2018; Shepherd, 2007; Shepherd & Gomez, 2018). Those studies focusing on a wide range, or all, of species in trade, have often been often restricted to major cities such as Indonesia's capital, Jakarta, situated on the island of Java, or Medan, the capital of the province of North Sumatra (Bušina et al, 2018; Chng et al, 2015; Harris et al, 2015; Nash, 1992; Shepherd, 2006). Only relatively few studies have focused on bird markets on smaller islands such as Bali (Chng et al, 2018b; Widodo, 2007) or in lesser-studied areas such as West Kalimantan (Rentschlar et al, 2017) and Southern Sumatra (Mutiara, Rizal, & Royan, 2020; Setioko et al, 2019). These studies have been vital in gaining a better understanding of the scale, scope, and dynamics of the Indonesian bird trade. Here we aim to contribute to this body of information, and to the overall effort to end the illegal and unsustainable bird trade in Indonesia, by reporting on findings from market surveys in Mataram on the island of Lombok, a location for which very little published bird trade data is available.

Lombok is situated just east of Bali in the province of West Nusa Tenggara and is part of the Lesser Sundas island chain, which includes Bali to the west and islands such as Sumbawa, Komodo, Flores, Sumba, Timor and Alor to the east. Although shared endemism is high among the western members of the Lesser Sundas, single island endemics are less common here (Eaton et al, 2016; Myers & Bishop, 2005). Lombok's only endemic bird species, the Rinjani scops-owl (*Otus jolandae*), was recently described in 2013 (Sangster et al, 2013; King, Verbelen, & Trainor, 2013). Since then, the island has received more interest from ornithologists and birdwatchers, where it was previously largely neglected (Suana et al, 2016). Lombok's largest city, Mataram, is the provincial capital and has just over 400,000 inhabitants. Although there are multiple smaller bird markets across the island, Lombok's main markets, Pasar Sindu and Pasar Chakranegara, are both situated in Mataram. We surveyed these markets in order to obtain an indication of trade levels and species composition, and to assess levels of illegal trade for the benefit of future enforcement efforts.

METHODS

Data Acquisition

We conducted five market visits in Mataram, Lombok; Pasar Sindu (aka Pasar Panglima) was visited on four occasions (10 June, 6 July, 19 July 2018 and 3 June 2019) and Pasar Chakranegara on one occasion (3 June 2019). During each market visit, a full inventory of the birds on sale was made. Poultry, domesticated birds and individuals with unnatural colour morphs (such as those found in captive-bred budgerigars) were not recorded. Only birds that were on open display were counted. Price information was gathered where possible. No bargaining attempts were made and only first given prices were recorded. All recorded birds were identified to a species level and, where possible, a subspecies level. National protection status, IUCN Red List of Threatened Species (hereafter IUCN Red List) classification and natural range were recorded for each species. Species names and baseline taxonomy follow the Handbook of Birds of the World (HBW) and BirdLife International Checklist of the Birds of the World Version 4.0 (2019).

Analysis

Observations from our five market visits were pooled to obtain an abundance ranking of species. Mataram's bird markets have been surveyed in 2015 and 2016 (Asrori, 2017; Syaputra, 2016) and we intended to integrate these results in our analysis. However, during review, at least part of that data was judged to be based on erroneous identifications of species. It was therefore decided to not include these studies in this analysis.

In addition to the price data gathered during our surveys, price data was extracted from online price lists, online vlogs (whereby the vlogger visits the bird market and gets quotes for a large number of bird species), published literature (Syaputra, 2016), as well as from online price lists. For several more frequently encountered species we did not manage to obtain price data for Lombok; in these cases, we used price data from neighbouring Bali instead, which were collected during the same period as our surveys in Lombok. For species for which more than one quote was obtained, we used the mean price for analysis. All data were collected in Indonesian Rupiah; we corrected prices for inflation to November 2020 (i.e., IDR100,000 in June 2018 equals IDR102,009 in November 2020), and then converted to US Dollar (IDR100,000 = USD7.07). We calculated the monetary value of each species by multiplying the number of individuals observed by the mean price, and the overall monetary value of the trade by summation of the individual species' monetary values. For those species for which price data were obtained, we also gathered data on body size, taken from Eaton et al. (2016). To assess relationships between species abundance in the bird market, size and asking price, we log-transformed the data to approach a normal distribution more closely, and calculated Pearson's correlation coefficients. We compared body size, price, numbers, and total monetary value for protected versus non-protected species and globally threatened versus non-threatened species with unpaired t-tests. We accepted significance when $P<0.05$ in a two-tailed test.

RESULT AND DISCUSSION

Species Provenance

In total, 10,326 individual birds, belonging to 108 different species were recorded across the five market visits. Only 24 of these birds, belonging to five different species, were not native to Indonesia (Annex 1). All of these species were native to other parts of Asia (West, East and/or Southeast). Only one of the non-native species, the silver-eared mesia (*Leiothrix argentauris*), is currently listed in CITES (Appendix II). Note that Sumatran mesia (*L. laurinae*), endemic to Indonesia, is newly described and split from (*L. argentauris*) (BirdLife International, 2020). The lemon-bellied white-eye (*Zosterops chloris*) was by far the most frequently encountered species with a total of 4,217 individuals, all of which were recorded during the 2019 survey. In total, the top ten most numerous bird species (see Appendix 1) accounted for 8,499 individuals, or 82.3% of the total birds observed.

Of the encountered native species, 38 (36.9%), accounting for 8,347 (80.8%) individuals, occur on Lombok. Of the 65 native species that do not occur on Lombok, 20 are Indonesian endemics. These endemics include species restricted to the Lesser Sundas (n=5), Java (n=3), Sulawesi (n=2), Sumatra (n=2) and Bali (n=1), as well as species that occur across multiple Indonesian islands and regions (n=7) (Figure 1).

Seventeen species (15.7%), accounting for 3,546 (34.3%) individuals and all native to Indonesia, were observed in each of the surveys (see Annex 1). Two of them, black-winged myna and Javan pied starling (Gracupica jalla), are currently listed as Critically Endangered on the IUCN Red List. Commercial captive breeding occurs for both species (Eaton et al. 2015; Nijman et al. 2018). Nine individuals of Lombok's only endemic bird, the Rinjani scops-owl, were observed.

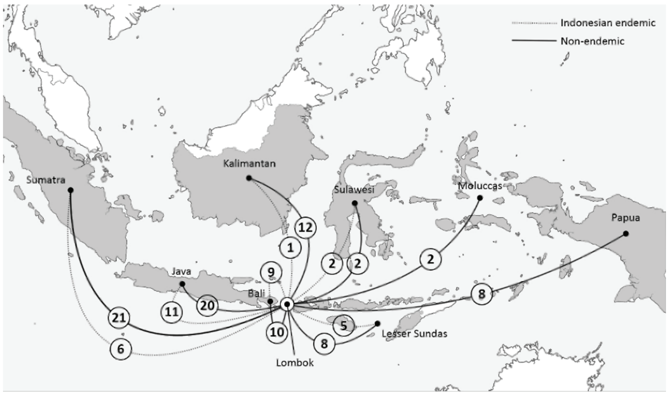

Figure 1. Provenance of Indonesian species not native to Lombok encountered in Mataram's bird markets.
Note: 28 recorded native (but not endemic) species occur across multiple Indonesian islands and regions and have therefore been included in the totals of all the locations in which the species occur. Similarly, seven of the recorded Indonesian endemic species occur across multiple Indonesian islands and regions and have therefore been included in the totals of all the locations in which the species occur.

Legality of Observed Trade

Eighteen encountered species, accounting for 378 individuals, are currently protected under Indonesian law (Appendix 1). Twelve of these species only received their protected status on 11 July 2018 when the first of that year's renewed protected species lists (the later amended Government Regulation No. 20/MENLHK/SETJEN/KUM.1/6/2018) came into effect. Of these twelve species, four had been allotted harvest and trade quotas for the months leading up to the legislative changes. Therefore, 78 of the 378 recorded individuals were lawfully traded at the time they were observed (10 June and/or 6 July 2018). Two of the four species with pre-protection harvest quotas common hill myna (*Gracula religiosa*) and fire-tufted barbet (*Psilopogon pyrolophus*) were observed in markets a few days after obtaining their protected status, albeit in low numbers (n=2 for both species). Three of the four species (common hill myna, greater green leafbird (*Chloropsis sonnerati*), and Sumatran laughingthrush) were observed in the market in 2019, a year after they had received their protected status. A small number of these individuals could be second generation captive-bred birds in which case their trade would be legal, although there was no data such as closed leg-rings or captive-breeding certificates to suggest any of them were.

Of the 108 encountered species, 33 had harvest quotas set for 2018 and/or 2019. Of the 55 non-protected native species encountered in 2018, 19 (34.5%) had allotted harvest quotas that year, as well as one non-native species (common myna (*Acridotheres tristis*)). For one of these species, the streaked weaver (*Ploceus manyar*), more individuals (n=148) were found across the three 2018 surveys than the total annual quota (n=20) allowed. In 2019, eighteen (30.5%) of the 61 observed native non-protected species had allotted harvest quotas for that year. Again, one species, the lemon-bellied white-eye, was observed in volumes (n=4,217) that largely exceeded the national annual quota set at 110. When taken together, protected species, non-protected species without harvest quotas and non-protected species with exceeded harvest quotas, accounted for 8,586 (83.1%) illegally traded birds belonging to 84 (77.8%) different species (Table 1).

Table 1. Numbers of illegally traded birds observed across the five market visits in 2018 and 2019.

Status	No. of species	No. of illegally traded individuals
Not protected, no harvest quotas	68	3,884
Not protected, exceeded harvest quotas	3	4,423
Protected	13	279*
TOTAL	**84**	**8,586**

*Note: *Excluding the 78 individuals belonging to species that are currently protected, but for which observed trade numbers were within the limits of set harvest and trade quotas before they received their protected status.*

Ten of the encountered species, accounting for 750 individuals, are currently considered threatened by the IUCN Red List (Appendix 1). Three of these species (n=116 individuals) are classified as Critically Endangered, three (n=208) as Endangered and four (n=426) as Vulnerable. Of the remaining species, 11 are currently classified as Near Threatened and 87 as Least Concern.

Price, Protection status and Conservation Status

Price data were obtained for 62 of the 108 species, including 35 of the 40 most frequently recorded birds. This accounted for 95% of the individual birds (9,802/10,326). Some of the more valuable species were present in relatively low numbers and commanded a high individual price, i.e. common hill myna (total value: IDR145,800,000 [USD10,302]). Others were present in intermediate numbers and had mid-range asking prices, i.e. Javan myna (*Acridotheres javanicus*) (total value: IDR74,370,000 [USD5,254]), while cheaper species i.e. lemon-bellied white eye (total value: IDR113,160,000 [USD9,995]) and brown honeyeater (*Lichmera indistincta*) (total value: IDR62,230,000 [USD4,397]) were present in high numbers. The overall value of the observed birds was IDR790,071,000 (USD56,038).

We found a weak negative relationship between the observed number of birds of a given species, its body size (Pearson's R=-0.298, N=64, R^2=0.089, P=0.017) and its asking price (R=-0.436, N=64, R^2=0.190, P=0.0003). Asking price was strongly and positively related to body size (R=0.712, N=64, R^2=0.507, P<0.00001) and total monetary value of a species was positively related to the bird's body size (R=0.3122, N=64, R^2=0.098, P=0.012).

Protected species had larger body sizes than unprotected species (means of 27.0 vs 19.8 cm; t=2.734, P=0.008), commanded higher prices (means of IDR853,071 vs IDR275,208 [USD60.28 vs USD19.44]: t=4.024, P=0.0002) and were observed in smaller numbers (means of 25.7 vs 217.7: t=2.379, P=0.020). The mean monetary value of protected species did not significantly differ from that of unprotected species (means of IDR18,944,714 vs IDR10,996,770 [USD1,338.60 vs USD777.03: t=0.793, P=0.431]).

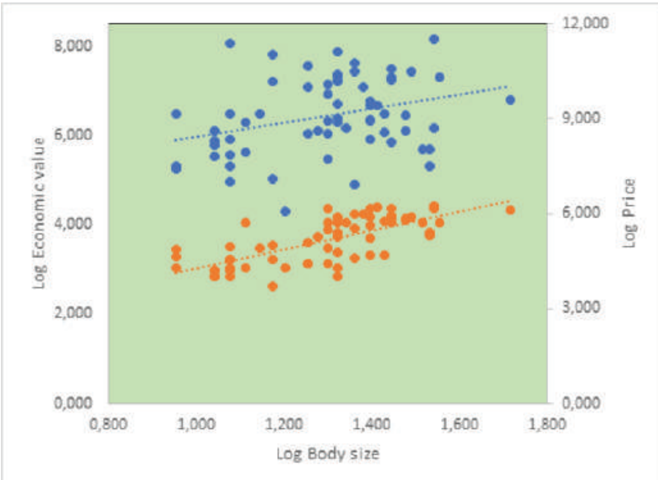

Figure 2. Relationships between body size of birds observed in the bird markets in Mataram, Lombok, Indonesia (range 9-52 cm) and price (orange: range IDR5,000-1,800,000 [USD0.35-127.19]) and economic value for each species (blue: range IDR20,000-145,800,000 [USD1.41-10,302.23]).

Globally threatened species (i.e. those listed as Critically Endangered, Endangered, Vulnerable on the IUCN Red List) did not differ in body size from non-threatened species (means of 20.9 vs 21.4 cm: t=0.098, P=0.922), nor did they differ in the numbers observed in the markets (means of 84.5 vs 188.7

individuals: t=0.035, P=0.972), their asking prices (means of IDR549,375 vs IDR384,407 [USD38.82 vs USD27.16]: t=1.265, P=0.211) or the overall monetary value (means of IDR21,106,875 vs IDR11,559,555 [USD1,491.41 vs USD816.79]: t=1.121, P=0.266).

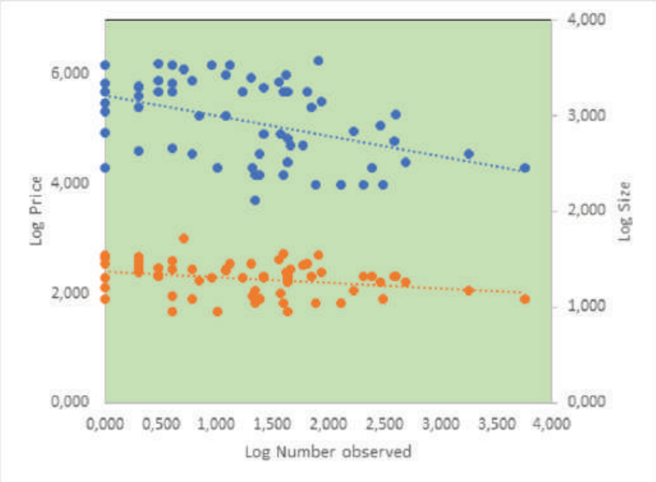

Figure 3. Relationships between the number of birds observed in the bird markets in Mataram, Lombok, Indonesia (range 1-5,658 birds / species) and price (blue: range IDR5,000-1,800,000 [USD0.35-127.19]) and size (blue: range 9-52 cm).

Local Sourcing

The observed bird volumes across this study's relatively low number of market visits indicate a large-scale songbird trade on Lombok, as seen in many other locations in Indonesia. Although the largest markets continue to be found on Java, this study reconfirms that high-volume songbird trade occurs in smaller and less populated Indonesian cities. When looking at the number of recorded individuals, Lombok native birds far outnumbered Lombok non-natives, suggesting that the majority of the individuals found in the markets were locally sourced. A good example of this is the Lemon-bellied White-eye. This Lombok native and Indonesian endemic is restricted to the Lesser Sundas, Sulawesi and parts of the Moluccas. It was by far the most frequently observed (n=4,217) white-eye – and species – of this study. The traditionally much more commonly traded Sangkar white-eye (*Zosterops melanurus*), restricted to Java and Bali, was found in much lower numbers (n=22). This is illustrative of the numerical dominance of local birds in Lombok's markets. Additionally, the much lower number of encountered Sangkar white-eyes may reflect previously identified population declines in that species as a result of trapping for trade. Chng et al (2018b) recorded a relatively high number of lemon-bellied white-eyes during recent surveys in Bali, which is outside the species' range, and suggested that the species may function as a substitute for the increasingly scarce Sangkar white-eye. Unpublished surveys on Java appear to confirm this theory, recording high volumes of lemon-bellied white-eyes in 2019 (Monitor, unpublished data), where previously such records in Javan markets were very scarce (Chng et al, 2015; Chng, Guciano, & Eaton, 2016; Chng & Eaton, 2016). The large number of lemon-bellied white-eyes found in Mataram's markets, as well as surging trade numbers in other parts of Indonesia, warrant more research into the threat trade may pose to this species.

Another bird which was found in high volumes (n=1,778) is the Brown Honeyeater. This species occurs in Australia, Papua New Guinea, Timor-Leste and Indonesia, where it is restricted to Bali, the Lesser Sundas and small parts of the Moluccas and Papua. It was previously protected under Indonesian law as part of a blanket listing of species from the Meliphagidae family. In 2018, when the country's protected species list was amended, the blanket listing was annulled, and the brown honeyeater lost its protected status. Trade records for the species outside its natural range are scarce, suggesting that the high trade numbers found during our surveys are another indication of the dominance of locally sourced birds in Lombok's markets, rather than the result of the recent legislative changes. The fact that no harvest quotas were set for the species in 2018 and 2019 and all observed trade was therefore technically illegal, further shows that demand, rather than the removal of the species' protected status, is likely to be the main explanation behind the observed high trade numbers observed during our surveys.

Other Lombok native species that were found in much higher numbers than in previous studies, and therefore indicate the predominance of locally sourced birds in Mataram's markets, are the short-tailed starling (*Aplonis minor*) (n=495) and pale-headed munia (*Lonchura pallida*) (n=150). Within Indonesia, short-tailed starlings are distributed across Java, Bali, Sulawesi and the Lesser Sundas. Nevertheless, there are no trade records for the species in Java in recent published studies (Chng & Eaton, 2016; Chng et al, 2015, 2016), nor have they been recorded in studies in Sumatra (Shepherd, 2006; Chng et al, 2018a). The only recent trade numbers for the species are from Bali (n=175) (Chng et al, 2018b) and Makassar, Sulawesi (n=42) (Shepherd & Leupen, 2021). Pale-headed munias, occurring on Sulawesi, the Lesser Sundas and Timor-Leste, have not been recorded in previously published Indonesian market surveys. The white-headed munia (*L. maja*), which occurs on Sumatra, Java and Bali and highly resembles the pale-headed munia, is much more commonly encountered in bird markets outside of Lombok. Pale-headed munias have been observed in trade in Europe, where recorded individuals are most likely derived from both captive and wild sources (S. Bruslund, in litt., December 2020). For both the brown honeyeater and the pale-headed munia, national trade is not indicated on the IUCN Red List

(BirdLife International, 2016; BirdLife International, 2018).

Observations of Lombok's only described endemic bird, the Rinjani scops-owl, have also been largely absent from the published literature, with Syaputra (2016) and Asrori (2017) being exceptions (Shepherd et al, 2020). Previously considered conspecific with the Moluccan scops-owl (*Otus magicus*), the species was described in 2013 (Sangster et al, 2013). It is restricted to the Mount Rinjani area in northern Lombok and is considered Near Threatened on the IUCN Red List, with habitat loss being indicated as the main threat to its conservation status (BirdLife, 2017). Our records show that trade may pose an additional threat to the species, as recently highlighted in Shepherd et al (2020).

The fact that several of the most numerous species in this study are native to Lombok and have not been recorded in large numbers outside their natural ranges illustrates the predominance of, and demand for, local birds in Lombok's markets. However, it must be noted that all but one of the observed Lombok natives also occur in other parts of Indonesia, making it possible that at least some of them were shipped in from other islands. Indonesia has an elaborate intra-national trade network, with birds being shipped between the different islands (Indraswari et al, 2020), as illustrated by the fact that the majority (63%) of the recorded native Indonesian species were not native to Lombok. Some of the most heavily traded species, such as sooty-headed bulbul (*Pycnonotus goiavier*) and Java sparrow (*Lonchura oryzivora*), do not naturally occur on Lombok. Non-native species can pose a threat to local biodiversity when escaped birds prey on – or compete with – local (avi-)fauna. Such risks are especially high on small islands such as Lombok. Regional supply appears to be significant in Lombok, with several of the encountered species originating from the Lesser Sundas, including cream-browed white-eye (*Heleia superciliaris*), crested white-eye (*H. dohertyi*), thick-billed white-eye (*H. crassirostris*) and yellow-spectacled white-eye (*H. wallacei*), the first two of which were found in relatively high numbers (n=21 and n=13 respectively) compared to published studies in locations outside the Lesser Sundas, from which they are mostly absent. Thick-billed white-eyes have previously been recorded in relatively large numbers in Java and Bali (Chng & Eaton, 2016; Chng et al, 2018b). Further examples of encountered Lesser Sunda endemics which have rarely been recorded in published studies outside the region are Timor leaf-warbler (*Phylloscopus presbytes*), black-fronted flowerpecker (*Dicaeum igniferum*), Timor oriole (*Oriolus melanotis*) (n=1), Timor sparrow (*Lonchura fuscata*) and tricoloured parrotfinch (*Erythrura tricolor*) (n=1). These records suggest that there are unique trade flows within the Lesser Sunda region.

Captive Breeding vs. Wild Sourcing

Of the ten recorded threatened species, nine are Indonesian endemics, with greater green leafbird being the only non-endemic. Scarlet-breasted lorikeet (*Trichoglossus forsteni*) was the only encountered threatened species native to Lombok. For some of these threatened species commercial captive breeding occurs, including Bali myna, Javan pied starling and Java sparrow, although this has not led to significant recuperation of wild populations. Other endangered species such as the Sumatran laughingthrush, Sangkar White-eye, ruby-throated bulbul (*Rubigula dispar*), greater green leafbird and Javan myna, are all assumed to be caught from the wild, with no confirmed significant commercial captive breeding taking place. The vast majority of the recorded species not assessed as threatened are also likely to have been taken from the wild, which may negatively impact their wild populations as well.

Enforcement Efforts

Open illegal trade has been recorded in all recently published surveys of Indonesian bird markets, as well as in older studies. While legislation is in place, it is often not effectively enforced, and traders do not appear to fear punitive action from enforcing bodies. This is illustrated by our observation of protected species in the markets, as well as non-protected species for which no harvest and trade quotas had been set. Only three of the non-protected species for which quotas had been set were found to have been traded in numbers that exceeded these quotas. One of these species was the zebra dove (*Geopelia striata*), which is often commercially bred, suggesting that its trade may not have been in violation of harvest quotas. However, set quotas concern the total number of birds allowed for harvest and trade per year across all of Indonesia (with harvest quotas specifying allowed offtake numbers per region). Due to the very nature of one-off surveys or spot checks on markets, the trade volumes observed during our surveys only represent a small fraction of actual annual trade numbers in Lombok's markets, let alone across the country. Total annual trade volumes across Indonesian markets are likely to far exceed set quotas for most of the observed species. Trappers and traders in Indonesia may not respect these quotas, as shown by the above-mentioned case of the Lemon-bellied White-eye for which observed numbers represented 38 times the annually set harvest quota. It must also be noted that all set quotas were for regions outside of Lombok. Technically, this means that none of the observed species may be trapped in Lombok. As mentioned above, it is nevertheless likely that a large proportion of the 8,347 observed Lombok native birds had been caught locally.

The recorded transgression of Indonesia's wildlife laws must be seen within the country's wider cultural framework. Birds are such an integral part of Indonesian society that in some respects they are more important than legislation or regulation. Thus, despite many of the rarest bird species receiving protection on paper, in practise, protected species are commonly kept and traded (Eaton et al, 2015; Jepson, 2016). Recognition of these cultural contingencies is of high importance if future conservation efforts are to be successful.

CONCLUSION

An increasingly long list of bird species in Indonesia are being pushed towards extinction. The demand for cage birds in the country is a major driver behind these declines and therefore strategies to reduce the demand for unsustainably sourced birds should be developed and implemented. Along with improved enforcement of the existing laws, reducing such demand will be key to significantly decreasing illegal trade, and ultimately to preventing further loss of bird species in Indonesia. Continued surveys of Indonesia's physical and online bird markets will be essential to determine trade trends and flag species of concern. Local researchers should continue to carry out these surveys, with technical support where needed from other local or international experts, especially with regards to current taxonomy and species identification. The same support should be made available to law enforcement officers working to effectively regulate the trade in birds and to eliminate the illegal trade from these markets.

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Appendix 1. Bird species observed across five market visits in Mataram, Lombok in 2018 and 2019 (non-native species in bold).

No.	Species	Total no. of indiv.	IUCN Red List status	Protected
1	lemon-bellied white-eye (*Zosterops chloris*) [1]	4,217	LC	no
2	brown honeyeater (*Lichmera indistincta*) [3]	1,778	LC	no
3	short-tailed starling (*Aplonis minor*)	495	LC	no
4	Javan myna (*Acridotheres javanicus*) [1,3]	402	VU	no
5	zebra dove (*Geopelia striata*)	388	LC	no
6	scaly-breasted munia (*Lonchura punctulata*)	309	LC	no
7	chestnut-capped thrush (*Geokichla interpres*) [3]	294	NT	no
8	sooty-headed bulbul (*Pycnonotus aurigaster*) [3]	244	LC	no
9	yellow-vented bulbul (*Pycnonotus goiavier*) [3]	203	LC	no
10	Java sparrow (*Lonchura oryzivora*) [1]	169	EN	yes
11	streaked weaver (*Ploceus manyar*)	155	LC	no
12	pale-headed munia (*Lonchura pallida*)	130	LC	no
13	barred buttonquail (*Turnix suscitator*)	100	LC	no
14	orange-headed thrush (*Geokichla citrina*) [3]	85	LC	no
15	common hill myna (*Gracula religiosa*) [3]	81	LC	yes
16	white-headed munia (*Lonchura maja*)	76	LC	no
17	chestnut-backed scimitar-babbler (*Pomatorhinus montanus montanus*) [3]	71	LC	no
18	Javan pied starling (*Gracupica jalla*) [1,3]	69	CR	no
19	black-naped oriole (*Oriolus chinensis*)	64	LC	no
20	barred dove (*Geopelia maugeus*)	60	LC	no
21	chestnut-backed thrush (*Geokichla dohertyi*)	60	NT	no
22	long-tailed shrike (*Lanius schach*) [3]	45	LC	no
23	orange-spotted bulbul (*Pycnonotus bimaculatus*) [1]	43	NT	no
24a	oriental magpie-robin (*Copsychus saularis amoenus/pluto*) [3]	31	LC	no
24b	oriental magpie-robin (*Copsychus saularis musicus*) (spp)[3]	12	LC	no
25	red-chested flowerpecker (*Dicaeum maugei*)	43	LC	no
26	black-winged myna (*Acridotheres melanopterus*) [1,3]	42	CR	yes
27	helmeted friarbird (*Philemon buceroides*) [3]	40	LC	no
28	olive-backed sunbird (*Cynniris jugularis*)	40	LC	no
29	thick-billed white-eye (*Heleia crassirostris*) [1]	37	LC	no
30	black drongo (*Dicrurus macrocercus vieillot*)	36	LC	no
31	bar-winged prinia (*Prinia familiaris*) [1]	33	NT	no
32	Asian glossy starling (*Aplonis panayensis*)	26	LC	no
33	greater green leafbird (*Chloropsis sonnerati*)	26	EN	yes
34	olive-backed tailorbird (*Orthotomus sepium*) [1]	24	LC	no
35	white-rumped munia (*Lonchura striata*)	24	LC	no
36	hooded butcherbird (*Cracticus cassicus*)	23	LC	no
37	Eurasian tree sparrow (*Passer montanus*)	22	LC	no
38	Sangkar white-eye (*Zosterops melanurus melanurus*) [1]	22	VU	no
39	cream-browed white-eye (*Heleia superciliaris*) [1]	21	LC	no
40	white-rumped shama (*Kittacincla malabarica*) [3]	20	LC	no

41	Timor leaf-warbler (*Phylloscopus presbytes*)	18	LC	no
42	grey-capped emerald dove (*Chalcophaps indica*)	14	LC	no
43	crested white-eye (*Heleia dohertyi*) [1]	13	LC	no
44	Sumatran laughingthrush (*Garrulax bicolor*) [1]	13	EN	yes
45	chestnut-capped laughingthrush (*Garrulax mitratus*)	12	NT	no
46	**common myna (*Acridotheres tristis*)**	12	LC	no
47	white-breasted waterhen (*Amaurornis phoenicurus*)	12	LC	no
48	mountain warbler (*Phylloscopus trivirgatus trivirgatus*)	10	LC	no
49	scarlet-headed flowerpecker (*Dicaeum trochileum*) [1]	10	LC	no
50	Rinjani scops-owl (*Otus jolandae*) [2]	9	NT	yes
51	elegant pitta (*Pitta elegans*)	7	LC	yes
52	spotted kestrel (*Falco moluccensis*)	7	LC	yes
53	coconut lorikeet (*Trichoglossus haematodus*)	6	LC	no
54	dark-necked tailorbird (*Orthotomus atrogularis*)	6	LC	no
55	Sunda laughingthrush (*Garrulax palliatus*)	6	NT	no
56	Bali myna (*Leucopsar rothschildi*) [1]	5	CR	yes
57	Brahminy kite (*Haliastur indus*) [3]	5	LC	yes
58	brown quail (*Synoicus ypsilophorus*)	5	LC	no
59	black-fronted flowerpecker (*Dicaeum igniferum*) [1]	4	LC	no
60	black-naped monarch (*Hypothymis azurea*)	4	LC	no
61	**black-throated laughingthrush (*Garrulax chinensis*)**	4	LC	no
62	copper-throated sunbird (*Leptocoma calcostetha*)	4	LC	no
63	purple-backed starling (*Agropsar sturninus*)	4	LC	no
64	Sulawesi myna (*Basilornis celebensis*) [1]	4	LC	no
65	**black-collared starling (*Gracupica nigricollis*)**	3	LC	no
66	fire-tufted barbet (*Psilopogon pyrolophus*)	3	LC	yes
67	grey-cheeked bulbul (*Alophoixus tephrogenys*)	3	LC	no
68	iris lorikeet (*Psitteuteles iris*)	3	NT	no
69	northern variable pitohui (*Pitohui kirhocephalus*)	3	LC	no
70	orange-banded thrush (*Geokichla peronii*)	3	NT	no
71	scarlet minivet (*Pericrocotus flammeus*)	3	LC	no
72	**silver-eared mesia (*Leiothrix argentauris*)**	3	LC	no
73	yellow-spectacled white-eye (*Heleia wallacei*) [1]	3	LC	yes
74	black laughingthrush (*Garrulax lugubris*)	2	LC	no
75	black-naped fruit-dove (*Ptilinopus melanospilu*)	2	LC	no
76	black-winged kite (*Elanus caeruleus*)	2	LC	no
77	eyebrowed thrush (*Turdus obscurus*)	2	LC	no
78	island thrush (*Turdus poliocepahlus whiteheadi*) [1]	2	LC	no
79	lineated barbet (*Psilopogon lineatus*)	2	LC	yes
80	pheasant coucal (*Centropus phasianinus*)	2	LC	no
81	southern variable pitohui (*Pitohui uropygialis*)	2	LC	no
82	**white-crested laughingthrush (*Garrulax leucolophus*)**	2	LC	no
83	white-shouldered triller (*Lalage sueurii*)	2	LC	no
84	Australasian reed-warbler (*Acrocephalus australis*)	1	LC	no

85	blue nuthatch (*Sitta azurea*)	1	LC	no
86	blue-and-white flycatcher (*Cyanoptila cyanomelana*)	1	LC	no
87	blue-crowned hanging Parrot (*Loriculus galgulus*)	1	LC	yes
88	blue-masked leafbird (*Chloropsis venusta*) [1]	1	NT	no
89	brown prinia (*Prinia polychroa polychroa*)	1	LC	no
90	brush cuckoo (*Cacomantis variolosus sepulcralis*)	1	LC	no
91	chestnut-cheeked starling (*Agropsar philippensis*)	1	LC	no
92	common barn-owl (*Tyto alba*)	1	LC	no
93	common moorhen (*Gallinula chloropus orientalis*)	1	LC	no
94	grosbeak starling (*Scissirostrum dubium*) [1]	1	LC	no
95	indigo flycatcher (*Eumyias indigo*) [1]	1	LC	no
96	little pied flycatcher (*Ficedula westermanni*)	1	LC	no
97	little spiderhunter (*Arachnothera longirostra*)	1	LC	no
98	long-tailed sibia (*Heterophasia picaoides*)	1	LC	no
99	pied imperial pigeon (*Ducula bicolor*)	1	LC	no
100	racquet-tailed treepie (*Crypsirina temia*)	1	LC	yes
101	red-winged parrot (*Aprosmictus erythropterus*)	1	LC	yes
102	ruby-throated bulbul (*Pycnonotus dispar*) [1]	1	VU	no
103	scarlet-breasted lorikeet (*Trichoglossus forsteni*) [1]	1	VU	yes
104	Timor oriole (*Oriolus melanotis*)	1	LC	no
105	Timor sparrow (*Lonchura fuscata*)	1	NT	no
106	tricoloured parrotfinch (*Erythrura tricolor*)	1	LC	no
107	Wallacean drongo (*Dicrurus densus*)	1	LC	no
108	western koel (*Eudynamus scolopaceus*)	1	LC	no
	TOTAL	**10,326**		

Note: [1]Indonesian endemic, [2]Lombok endemic, [3]encountered in all five surveys

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Ecological carrying capacity of Cidahu Nature Tourism Object, Gunung Halimun Salak National Park

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ABSTRACT

The nature tourism sector plays an important role in national economic growth. Cidahu Nature Tourism Object, Gunung Halimun Salak National Park (GHSNP) is one of the natural attractions that has provided many benefits for the government, especially in supporting local community's economy. Natural tourism activities in Cidahu, which have been tended for mass tourism, can both benefit the economy and have a negative impact on conservation areas. The purpose of this study was to determine the tourism carrying capacity in Cidahu Nature Tourism Object by examining the maximum number of tourists that can be accommodated so that the physical, environmental and management aspects are not damaged ecologically and tourism actors may still receive satisfaction from the activities. Through a descriptive research method, data processing techniques using the Cifuentes method was used to calculate the physical carrying capacity (PCC), real carrying capacity (RCC) and effective carrying capacity (ECC). Based on the results of the study, the physical carrying capacity value was 10,593, the real carrying capacity was 148 and the effective carrying capacity was 133. With the PCC value > RCC > ECC, the tourism carrying capacity in Cidahu Natural Tourism Object is still in good condition.

ABSTRAK

Sektor pariwisata alam memegang peranan penting dalam pertumbuhan ekonomi nasional. Obyek Wisata Alam Cidahu, Taman Nasional Gunung Halimun Salak (TNGHS) merupakan salah satu obyek wisata alam yang telah memberikan banyak manfaat bagi pemerintah khususnya dalam menunjang perekonomian masyarakat setempat. Kegiatan wisata alam di Cidahu yang selama ini cenderung bersifat mass tourism dapat memberikan manfaat ekonomi dan juga berdampak negatif bagi kawasan konservasi. Tujuan dari penelitian ini adalah untuk mengetahui daya dukung pariwisata di Obyek Wisata Alam Cidahu dengan mengkaji jumlah maksimal wisatawan yang dapat ditampung sehingga aspek fisik, lingkungan dan pengelolaan tidak rusak secara ekologis dan pelaku pariwisata tetap dapat memperoleh kepuasan dari kegiatan. Melalui metode penelitian deskriptif, teknik pengolahan data menggunakan metode Cifuentes, digunakan untuk menghitung daya dukung fisik (PCC), daya dukung nyata (RCC) dan daya dukung efektif (ECC). Berdasarkan hasil kajian nilai daya dukung fisik sebesar 10.593, daya dukung riil sebesar 148 dan daya dukung efektif sebesar 133. Dengan nilai PCC > RCC > ECC maka daya dukung wisata di Obyek Wisata Alam Cidahu masih dalam kondisi baik.

Keywords: *carrying capacity, Cidahu, ecological, national park, nature tourism, Sukabumi*

INTRODUCTION

Nature tourism is a type of tourism activity that utilizes the potential of natural resources and environmental management (Suwantoro, 2004). Nowadays, tourism activities in conservation areas tend to increase alongside an increasing awareness about nature conservation (Pickering & Hill, 2007). Conservation areas are expected to contribute to economic development and reduce poverty. As an attraction for tourists and managers, conservation area-based tourism activities can both be a challenge and a significant opportunity. A lack of proper planning and management will contribute to significant negative impacts on the ecosystem environment in the area and its surroundings, and also on the lives of its people (Sheppard, 2006).

In general, there are two types of nature tourism activities in conservation areas: (1) a small scale or special interest (ecotourism) activity that may only have a small impact on the ecosystem, and (2) a large scale/mass tourism activity that involves many components and will have a large impact on the ecosystem (McCool & Moisey, 2008). The trend of ecotourism internationally is indeed increasing, but economically, mass tourism with a large and continuous number of tourists is seen as more profitable than ecotourism with a small and uncertain number of tourists (Fandeli & Nurdin, 2005).

Gunung Halimun Salak National Park (GHSNP) has been used for nature tourism activities. The GHSNP area is located within three local government administrative areas, namely Sukabumi Regency, Bogor Regency and Lebak Regency. In the Sukabumi Regency, GHSNP has been in great demand as a natural tourist destination by domestic and foreign tourists. GHSNP is a tourist hotspot due to its beautiful natural scenery, cool air, and relatively short distance from the Greater Area of Jakarta (TNGHS, 2018).

Cidahu Nature Tourism Object, located at geographical coordinates of 106°43'8.9"E – 6°45'5.50"S, is one of the natural attractions in the GHSNP. Administratively, Cidahu Nature Tourism Object is in Cidahu Village, Cidahu District, Sukabumi Regency, West Java Province. Cidahu Nature Tourism Object is located at an altitude of 953 meters above sea level at the foot of Mount Salak. This location offers the scenaries of the beauty of natural mountain with a lot of camping grounds by the stream and waterfalls.

Its hilly topography is dominated by damar (*Agathis dammara*) trees, some of which are more than 40 years old. There are 4 (four) blocks of camping grounds, namely Block-1, Block-2, Block-3, and Block Cek Dam camping grounds. In addition to the *Agathis dammara* forest, another interesting tourist attraction is a waterfall (or its locally called *curug*) with five waterfalls, namely Curug-2 Undak, Curug-4, Curug Taraje, Curug Buleud and Curug Sawer. In terms of tourism infrastructure, there is a gate, ticket post, management office, visitor center, prayer room, toilet, shelter, wooden dack, tourist track and bridge. Apart from its tourism potential, the area is also rich in wildlife biodiversity, such as primates and birds. Primates coocurs in this area includes Javan gibbon (*Hylobates moloch*) and surili (*Presbytis comata*). Other interesting bird species to observe include the Javan eagle (*Nisaetus bartelsi*), snake eagle (*Spilornis cheela*), and black eagle (*Ictinaetus malayensis*) (TNGHS, 2018).

Cidahu Nature Tourism Object has a very high level of tourist arrivals as compared to other tourist locations within GHSNP such as the natural attractions of Curug Nangka and Sukamantri. The following graph shows the number of visitors to natural tourism objects in GHSNP (Figure 1).

As a main natural tourism attraction, Cidahu must maintain natural environment preservation. To make sure tourism activities and existing conservation activities can run well, it is necessary to know how many tourists the Cidahu Nature Tourism Object can accommodate. As mentioned by Sayan & Atik (2011) the Cifuentes method can be used to calculate the Physical Carrying Capacity (total area), Real Carrying Capacity (ecology) and Effective Carrying Capacity (managerial) to determine the carrying capacity of tourism. Determination of carrying capacity or the ability of the area to accommodate a number of tourists at a given time is important in nature tourism activities, because it involves environmental and regional sustainability. Based on this background, we wish to carry out an in-depth analysis on the carrying capacity of tourism in Cidahu Nature Tourism Object.

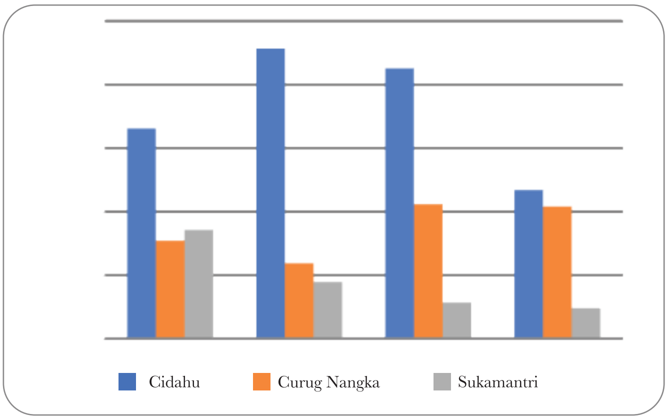

Figure 1. Number of tourists at some natural tourism objects within GHSNP between 2017 to 2020.

The research objectives for analysing tourism carrying capacity of Cidahu Nature Tourism Object as natural tourist attractions are 1) Analyzing the Physical Carrying Capacity of the Cidahu Nature Tourism Object, 2) Analyzing the Real Carrying Capacity of the Cidahu Nature Tourism Object, and 3) Analyzing the Effective Carrying Capacity of the Cidahu Nature Tourism Object.

As a main natural tourism attraction, Cidahu must maintain natural environment preservation. To make sure tourism activities and existing conservation activities can run well, it is necessary to know how many tourists the Cidahu Nature Tourism Object can accommodate. As mentioned by Sayan & Atik (2011) the Cifuentes method can be used to calculate the Physical Carrying Capacity (total area), Real Carrying Capacity (ecology) and Effective Carrying Capacity (managerial) to determine the carrying capacity of tourism. Determination of carrying capacity or the ability of the area to accommodate a number of tourists at a given time is important in nature tourism activities, because it involves environmental and regional sustainability. Based on this background, we wish to carry out an in-depth analysis on the carrying capacity of tourism in Cidahu Nature Tourism Object.

The research objectives for analysing tourism carrying capacity of Cidahu Nature Tourism Object as natural tourist attractions are 1) Analyzing the Physical Carrying Capacity of the Cidahu Nature Tourism Object, 2) Analyzing the Real Carrying Capacityof the Cidahu Nature Tourism Object, and 3) Analyzing the Effective Carrying Capacity of the Cidahu Nature TourismObject.

The environmental carrying capacity of natural tourism objects explores their ability to accommodate a number of tourists in a certain area and time unit (Soemarwoto, 2004). Further Soemarwoto (2004) argues that geobiophysical factors in natural tourism locations affect the strength or vulnerability of an ecosystem's carrying capacity. Tourism carrying capacity simlarly looks into the biogeophysical, socio-economic and socio-cultural carrying capacity of a tourist location supporting tourism activities without reducing environmental quality and tourist satisfaction. In general, there are two aspects of carrying capacity in tourism, namely protecting resources and quality of travel experience (Sayan & Atik, 2011). Carrying capacity, in a general sense, relates to the amount and type of use that can be accepted by protected areas and related areas without causing negative impacts on the area and the quality of tourism (Manning, 2001). Cifuentes (1992) has developed an equation to calculate carrying capacity of a conservation area. The equation can be applied to determine the number of tourists that can be received optimally/effectively without causing damage to the conservation area. Carrying capacity of tourism can be determined through 3 factors, namely Physical Carrying Capacity (PCC), Real Carrying Capacity (RCC) and Effective Carrying Capacity (ECC). They can be examined using the method developed by Cifuentes, which has been recommended by the International Union for Conservation of Nature (IUCN) (Sayan & Atik, 2011).

METHODS

This research used a descriptive research method. Data collection techniques were conducted through observation, questionnaires, and documentation. To determine carrying capacity, we included (1) tourists who have visited Cidahu Nature Tourism Object, (2) biotic variables (tree vegetation and birds) and abiotic variables such as landscape potential, slopes, soil erosion sensitivity, dry month to wet month ratio, (3) key informants of the Cidahu Nature Tourism Object such as the Chairman of the Cooperative Wana Lestari, Head of village owned enterprise (BUMDES-*Badan Usaha Milik Desa*) Bangkit Sejahtera Cidahu Village and Section Head of GHSNP Sukabumi.

We used Garmin Global Positioning System (GPS) with GPSmap type 60CSx as a tool to measure the area of Cidahu's natural attractions and the Samsung Galaxy J 7 Core for taking pictures/photos. The clinometer was also used to measure the land slopes.

Research data obtained was processed and organized to ensure readability and interpretability (Azwar, 2012). The carrying capacity method proposed by Cifuentes in Sayan & Atik (2011) was used to analyze the processed data. The details of the analysis carried out are as follows.

Physical Carrying Capacity (PCC), which is the maximum number of tourists that can physically fulfill the space provided at a certain time (Sayan & Atik, 2011), is calculated using the following formula:

$$PCC = A \ x \ \frac{V}{a} \ x \ Rf$$

Notes:
A = Total area for tourism
V = Total area of visitors per m^2
a = The area required by a tourist to get satisfaction (0.009 Ha based on Douglas, 1975 cited in Fandeli & Nurdin (2009).
Rf = Rotation factors (open period/average of time spent in each visit)

Real Carrying Capacity (RCC), which is the number of visitors allowed to visit a tourist area, with a correction factor (Correction Factor /CF) based on the characteristics of the area that has been applied to the PCC (Sayan & Atik, 2011), is measured using the formula:

RCC = PCC - Cf1 - Cf2 - Cf3 – Cf4

Notes:
RCC = Real Carrying Capacity,
PCC = Physical Carrying Capacity,
Cf = Correction factors (The calculation of the correction factor for the diversity of flora and fauna in the Cidahu Nature Tourism Object uses the Simpson's equation: I-DS = 1 – ג)

Real Carrying Capacity shows the number of tourists that can be accommodated by a tourist area with various tourism activities without damaging the environment or ecosystem. The correction factors used in this study are:

a. Tree-level vegetation diversity
b. Diversity of bird species
c. Landscape potential index
d. Slope index
e. Soil sensitivity index to erosion
f. Precipitation index

Since the value of correction factor was in percentage, the calculation of RCC in percentage was done using this equation: RCC = PCC x (100-Cf1)/100 x (100 – Cf2)/100 x (100 – Cf3)/100 x (100 – Cf4)/100.

According to Sayan and Atik (2011), Effective Carrying Capacity (ECC) is the maximum number of visits where the area remains sustainable, with consideration to its Management Capacity (MC). The ECC shows the number of tourists that can be served optimally by the managements and tourism activities without damaging or with minimized damage to the ecosystem in the tourist area. ECC is calculated using the formula:

ECC = RCC x MC

Notes:
ECC: Effective Carrying Capacity
MC: Management Capacity
RCC: Real Carrying Capacity

In this research, MC is calculated using following equation:

MC = Total number of staff/Total number of staff needed x 100%

The tourism carrying capacity was determined by comparing data generated from the analysis of PCC, RCC and ECC. The provisions are PCC > RCC and RCC > ECC. The results of this analysis will be used as a standard in determining the carrying capacity of tourism in Cidahu Nature Tourism. If PCC > RCC > ECC, then the tourism carrying capacity in an area, in this case the Cidahu Nature Tourism, is good. This means that managers can still make efforts to increase the number of tourists to the limit of the calculated value from the equation above. However, if ECC is greater than RCC and RCC is greater than PCC, then the area has exceeded its maximum carrying capacity.

RESULTS AND DISCUSSION

Physical Carrying Capacity (PCC)

Physical Carrying Capacity in this study is the maximum number of tourists that can be accommodated in the area of Cidahu Nature Tourism Object. It takes into consideration the needs of tourists for an area to travel comfortably and the rotation factor. To calculate the PCC, the data obtained are the area (24.33 ha), the opening hours (operational hours; 07:30-16:00, that is 8.5 hours per day), and the length of tourist visits to the Cidahu Nature Tourism Object. Based on the results of a questionnaire with 46 tourists visiting Cidahu's natural attractions, the average length of tourist visits is 3 hours. The rotation factor for the Cidahu Nature Tourism Object is 2.83, while the PCC value is 10,593. This means that the Cidahu Nature Tourism area can physically accommodate up to 10,593 tourists/day.

Real Carrying Capacity (RCC)

Real Carrying Capacity (RCC) is the number of tourist visits that can be accommodated by an area with consideration to the correction factor according to the characteristics of the area. Tree-level vegetation diversity is one of the correction factors. Based on the results of the tree-level vegetation inventory, 13 types of vegetation were obtained with a total of 188 individual trees. A table of values/indices for the diversity of flora of Cidahu Nature Tourism, according to the Simpson equation, is shown Table 1.

According to Table 1, the Simpson diversity index for tree-level vegetation (SDI) is 0.44. From the results of the Simpson's diversity index for tree-level vegetation of 0.44, then from this value approach the Simpson index ranges from 0 to 1, The closer the SDI value to 0, the greater the habitat diversity. As such, the flora diversity in Cidahu Nature Tourism Object is in the high category.

Another correction factor is the diversity of bird species. Based on the results of bird species inventory

Table 1. Results of tree-level vegetation inventory.

No	Tree Species	ni	ni (ni-1)
1	Damar (*Agathis dammara*)	140	19.460
2	Manii (*Maesopsis eminii*)	4	12
3	Puspa (*Schima walilcii*)	12	132
4	Mara (*Macaranga tanarius*)	6	30
5	Salam (*Eugenia poliantha*)	1	-
6	Saninten (*Castanopsis argentea*)	6	30
7	Rasamala (*Altingia excelsa*)	5	20
8	Pinus (*Pinus merkusii*)	2	2
9	Pasang (*Quercus* sp.)	5	20
10	Sempur (*Dillenia indica*)	2	2
11	Nangka (*Artocarpus heterophyllus*)	2	2
12	Lame (*Alstonia scholaris*)	2	2
13	Sungkai (*Peronema canescens*)	1	-
	Total	**188**	**19.712**

along the tourist area, we obtained 6 species of birds with a total of 15 individuals. The results of bird species inventory and the calculation of SDI value is shown in Table 2.

According to Table 2, the Simpson diversity index (SDI) for bird species is 0.684. Based, on the Simpson's index range, the closer the SDI value to 1, the lower the bird diversity. Thus, a SDI of 0.648 shows that the level of diversity of bird species in Cidahu Nature Tourism Object is within medium category.

Table 2. Results of bird species inventory.

No	Birds Species	ni	ni (ni-1)
1	Kutilang (*Pycnonotus aurigaster*)	9	72
2	Sri Gunting (*Dicrurus macrocercus*)	1	-
3	Elang Jawa (*Nisaetus bartelsi*)	2	2
4	Sepah Gunung (*Pericrocotus miniatus*)	1	0
5	Bubut Besar (*Centropus sinensis*)	1	-
6	Kedasi Hitam (Surniculus lugubris)	1	-
	Total	**15**	**74**

The tourist area of Cidahu Nature Tourism has landscape potentials that include canyon/steep slope at the waterfall. Landscape colors were also included to look into the differences in the green color of the vegetation, the brown and gray on the ground, and the white from the waterfall foam. No extreme colors, such as red or orange that may enrich the landscape, were found. A comprehensive assessment of the index of the landscape potential of tourism areas can be seen in Table 3.

Table 3. Assessment of the tourism area landscape potential index.

No	Criteria	Score	Value
1	Low and choppy hills; hills at the foot of the mountain or the bottom of the valley are not interesting landscaping features.	1	
	Steep canyons/ slopes, volcanic cones or nteresting erosion patterns or variations in the size and shape of the land or the dominant detailed features.	3	1
	High vertical relief aimed at the presence of striking peaks; peaks like towers; giant rock outcrops or amazing surface variations; easily eroded formations or very striking dominant features.	5	
2	Little or no difference in vegetation.	1	
	Some types of vegetation but only 1-2 species are dominant.	3	3
	A variation of vegetation type is indicated by interesting patterns, textures, and shapes.	5	
3	Subtle and contrasting color are generally dull.	1	
	There are different types of colors, there is opposition from soil, rocks, and vegetation but not the dominant scenery.	3	3
	A combination of colors of various types or beautiful opposition and colors of soil, rocks, aquatic vegetation and others.	5	
4	The nearby scenery has little or no effect on the quality of the scenery.	0	
	The scenery nearby is quite influential on the quality of the scenery.	3	5
	The scenery nearby greatly affects the quality of the scenery.	5	

5	It has an interesting background but is almost the same as the general situation in an area.	1	
	Typical though almost the same as a certain area.	3	3
	An area that is distinctive / different from other objects so as to make an impression.	5	
6	Modifications add variety but are very much at odds with nature and give rise to disharmony.	-4	
	Modifications add little or no diversity to the landscape.	0	0
	The construction of facilities such as installations / electricity, waterways, houses provide modifications that can add visual diversity; there is no modification.	2	
	Total	27	15
	Indeks Potensi Lansekap		**0.55**

Based on Table 3, the correction value of the landscape potential of Cidahu Nature Tourism Object is 0.55 or 55%.

According to field observations, the topography of tourist areas visited greatly by tourists can be grouped into seven trail segments. The seven segments are tourist trails and main tourist areas. The tourist trails from the Cidahu gate to the Check Dam campground and Curug 2 are relatively steep. As a result, on their way home, some tourists complained about the steepness of the climb. The opposite was experienced by tourists who entered from the steep trail of Cidahu gate to Pos Kancil as well as the path to Curug Sawer, as the trails allowed for 2-wheeled and 4-wheeled vehicles to pass, thus reducing the burden to tourists. The seven trail segments were thus assessed based on the general level of slope steepness. The assessment was carried out using a scoring system on the slope class criteria as shown in Table 4. The estimated slope index value was 0.46, or 46%.

With reference to the secondary data collated by Pirngadie (2012) the type of soil in the Cidahu Nature Tourism Object is andosol type. This soil type is highly sensitive to erosion, as it has a sensitivity index of 0.60, or 60%.

Based on data on rainfall and rainy days from 2016 - 2020, the number of dry months (months with rainfall <60 mm) is 12 and the number of wet months (months with rainfall >100 mm) is 44. The index value, Q, which compares of the number of dry months and wet months for the last five years, is 0.272.

By calculating the six correction factors, namely tree diversity (Cf1), bird species diversity (Cf2), landscape potential (Cf3), slope steepness (Cf4), soil erosion

Table 4. Slope index assessment of tourist areas.

No	Location	Estimation	Value	Notes
1	The trail from the gate to the camping ground block 1	A bit steep	60	Assessment criteria: Flat = 20 Ramps = 40 A bit steep = 60 Steep = 80 Very steep = 100
2	The trail from the *camping ground* blok 1 to *camping ground* blok 3	Ramps	40	
3	The trail from *camping ground* blok 3 to Pos Kancil	Flat	20	
4	Trail from *wooden deck* to *camping ground* cek dam	Steep	80	
5	Trail from *camping ground* cek dam to amber forest	A bit steep	60	
6	Trail from amber forest to Curug 2 Undak	Ramps	40	
7	Trail to Curug Sawer	Flat	20	
	Average	**46**		**(ramps and a bit steep)**
	Slope Value Index (x100%)	**0.46**		

sensitivity (Cf5), and rainfall (Cf6), the Real Carrying Capacity value (RCC) can be determined. Summary of data regarding the value of the correction factor can be seen in Table 5.

Based on Table 5, the value of the Real Carrying Capacity with the correction factors in Cidahu Nature Tourism Object is 148 tourists per day.

Table 5. Value of correcting factors in determining the value of carrying capacity of nature tourism.

Parameters	Index Value	Index Value (%)
Tree-level vegetation diversity (Simpson Diversity Index);	0.440	44
Bird diversity (bird density, Simpson Diversity Index);	0.648	64.8
Landscape potential index (Indeks *Bureau Of Land Management);*	0.55	55
Slope index;	0.46	46
Soil sensitivity index to erosion;	0.60	60
Precipitation index (Q value index [dry month/wet month])	0.272	27.2

Effective Carrying Capacity (ECC)

Effective Carrying Capacity (ECC) in Cidahu Nature Tourism is the maximum number of tourists that can be accommodated at the Cidahu natural attractions at a certain time by considering the correction factors and the Management Capacity (MC), such as the availability of employees.

Cidahu Nature Tourism has a total of 45 workers or officers consisting of BTNGHS, Wana Lestari Cooperative and BUMDES Bangkit Sejahtera. According to Anonymous in Sayan & Atik (2011), for an area to be managed properly, the area must have a minimum of 26 employees including managers, administration, security, drivers. As such, it appears that the quantitative needs for employees or management officers at Cidahu Nature Tourism Object have been met. However, due to the large area (24.33 Ha), the manager of the Cidahu Nature Tourism felt that he still needs an additional 5 people to 50 people, assuming that an area of 1 ha would be managed/supervised by 2 management officers. Based on this understanding, the value for Management Capacity (MC) would be 0.9259, and the Effective Carrying Capacity value in Cidahu Nature Tourism would be 133 people. Thus, the number of tourists who are expected to travel in Cidahu natural attractions without causing disturbance to the conservation area ecosystem would be a maximum of 133 people/day. The number of tourist visits to Cidahu's natural attractions in 2012-2020 was 273,577 tourists or an average of 84 tourists per day. From this figure, the area can still accommodate 49 more tourists a day.

Tourism Carrying Capacity

By calculating the Physical Carrying Capacity (PCC), Real Carrying Capacity (RCC) and Effective Carrying Capacity (ECC), we conclude that PCC > RCC > ECC (i.e., 10,593 > 148 > 133). Based on this result, the maximum number of tourists that can be accommodated physically or in the area in the Cidahu Nature Tourism Object is 10,593 tourists per day. With the correction factors that took into account the physical landscape and tourist activities, the maximum number of tourists that can be accommodated is 148 people per day. The maximum number of accommodated tourists with the correction factors and with consideration the Cidahu Nature Tourism's Management Capacity is 133 tourists per day. It can thus be concluded that the carrying capacity of tourism in Cidahu's natural attractions as of now can still accommodate tourists, with all tourism activities carried out properly and fully functioning.

The study carried out on the Cibodas Botanical Gardens by Sasmita (2014) also revealed that the maximum number of accommodated tourists is 593 people per day while the maximum number of accommodated tourists with consideration to the correction factors and Management Capacity is 549 tourists per day. Based on our research and the work done by Sasmita (2014), it can be concluded that the natural tourism objects have a greater carrying capacity for natural tourism if they are supported by biotic and abiotic factors in the area properly maintained and with adequate management.

CONCLUSION

Based on PCC value, the maximum number of visitors that can be carried within the total area of tourism area in Cidahu is 10,591 visitors per day. Based on the RCC value, taking into account the six correction factors used for this study, the maximum number of tourists who can be allowed to visit Cidahu Natural Tourism Object is 148 tourists per day. Under the ECC value, the maximum number of tourists visiting Cidahu's natural attractions, by considering the physical, ecological, and management aspects, is 133 tourists per day. The results of the calculation of the carrying capacity of Cidahu Nature Tourism Object show PCC > RCC > ECC. This means that it can accommodate tourists with all their activities properly when the actual number of tourists does not exceed the maximum limit of the ECC value.

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Development of community empowerment based on zonation in the Gunung Halimun Salak National Park, Indonesia

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ABSTRACT

Local communities surrounding Gunung Halimun Salak National Park are highly dependent on the national park area. Economic development is crucial to improve the livelihood of the local communities around the park area. Additionally, to ensure that the preservation of the national park will be supported by the surrounding communities, activities within the local communities can also align with the management of the national park. In Indonesia, national parks are managed through a zonation system, in which potential areas that satisfy the biophysical conditions will be considered for development activities that support the local communities. We analyze the biophysical condition of the area, zonation of area, and socio-economic conditions of communities to identify the types of potential community development activities. We conducted a survey of biophysical conditions, as well as interviews and focus group discussions with relevant stakeholders. The results of the study reveal five types of community development activities with the most potential, namely 1) development of tourism; 2) conservation partnership schemes; 3) cooperation on ecosystem restoration; 4) development of forest plant cultivation to provide seeds for economic benefits; 5) utilization of ecosystem services, such as water and hydroelectric power plants.

ABSTRAK

Masyarakat sekitar Taman Nasional Gunung Halimun Salak sangat bergantung pada kawasan taman nasional. Pembangunan ekonomi sangat penting untuk meningkatkan mata pencaharian masyarakat lokal di sekitar kawasan taman. Selain itu, untuk memastikan pelestarian taman nasional didukung oleh masyarakat sekitar, kegiatan masyarakat lokal juga dapat diselaraskan dengan pengelolaan taman nasional. Di Indonesia, taman nasional dikelola melalui sistem zonasi, di mana kawasan potensial yang memenuhi kondisi biofisik akan dipertimbangkan untuk kegiatan pembangunan yang mendukung masyarakat setempat. Kami menganalisis kondisi biofisik kawasan, zonasi kawasan, dan kondisi sosial ekonomi masyarakat untuk mengidentifikasi jenis kegiatan pengembangan masyarakat yang potensial. Kami melakukan survei kondisi biofisik, serta wawancara dan diskusi kelompok terfokus dengan pemangku kepentingan terkait. Hasil penelitian mengungkapkan lima jenis kegiatan pengembangan masyarakat yang paling potensial, yaitu 1) pengembangan pariwisata; 2) skema kemitraan konservasi; 3) kerjasama restorasi ekosistem; 4) pengembangan budidaya tanaman hutan untuk penyediaan benih yang bermanfaat secara ekonomi; 5) pemanfaatan jasa ekosistem, seperti pembangkit listrik tenaga air dan air.

Keywords: *buffer zone, conservation area, conservation partnership scheme, national park management, zonation*

INTRODUCTION

Gunung Halimun Salak National Park (GHSNP), which has a very high biodiversity and is a life support system for the surrounding communities, is a conservation area on the island of Java, Indonesia, (BTNGHS, 2007; JICA, 2007). Survey conducted by BTNGHS (2007) showed that there were 348 villages located in and around the GHSNP area with a population of around 99,000 people. Most of the communities around GHSNP used forest resources, such as firewood, animal feed, water, medicinal plants, bamboo, agricultural land, etc., to meet their daily needs (Widada & Darusman, 2004; Harada, 2005; Wardah, 2009). With an average income of around IDR 1,155,000/month (Adalina et al, 2015), the economic condition of surrounding communities was relatively low-income.

Sahab, Darusman, & Muladno (2015) suggest that threats faced by the GHSNP area, such as encroachment, illegal logging, illegal mining, poaching, etc., result in forest degradation and deforestation. Therefore, local community involvement (i.e., that prioritizes the welfare of the people living in and around forest areas) needs to be carried out in order to achieve sustainable forest management (Sahab, Darusman, & Muladno, 2015; Rochaedi, Priatna, & Rahayu, 2021). Economic development of local communities around this park area is crucial to ensure improvement on their livelihood. Additionally, activities that align with the management of national park can encourage surrounding communities to support the preservation of the national park. Adiprasetyo et al (2009) stated that the socio-economic situation and condition of the surrounding community is an important aspect to be considered in the management of the national park.

Understanding the socio-economic problems of the surrounding community is one of the necessary management considerations for a national park (Kadir et al, 2012). According to Junaedi & Maryani (2013), there is a close relationship between the existence of the forest and the socio-economic conditions of the community around the forest and the biophysical (environmental) conditions.

Community empowerment in GHSNP has been developed since 2006 using the Conservation Village Model (CVM) concept, or "Model Kampung Konservasi" in Bahasa. At the site level, community empowerment schemes are carried out in three villages directly adjacent to the GHSNP forest area, namely Cikiray, Mekarnangka, and Gunung Malang. In addition, various other community development programmes have been implemented to improve the standard of living of communities around the GHSNP area (Pratidina & Purnamasari, 2012; Keliwar, 2013; Sahab, Darusman, & Muladno, 2015). However, it seems that only a few programmes have succeeded in realizing development sustainable society, which is to improve the community's economy in the long term.

The purpose of this study is to analyze biophysical conditions (environment) based on area zonation as well as to assess the socio-economic conditions of the surrounding communities, to identify potential community empowerment programmes that can be developed in the GHSNP.

METHODS

Location

The research was conducted between March and May 2021, in Cikiray and Mekarnangka villages, Cikidang Subdistrict, Sukabumi District. The villages are included in the management area of the Cimantaja Resort, GHSNP (Figure 1). Both villages have forest areas that were part of the GHSNP previously managed by Perhutani (a government-owned forestry company) as production areas. The Conservation Village Model ("Model Kampung Konservasi"), a community empowerment scheme implemented by the management of GHSNP in those two villages, focuses on non-land-based cultivation activities. However, the community empowerment programme since 2006 does not seem to show optimal results and has not made a significant contribution to the sustainability of the GHSNP area and the improvement of the welfare of the surrounding community.

Research Methodology and Source of Data

Research was conducted qualitatively and supported by quantitative approach (Arikunto, 2006; Sugiyono, 2009; Silalahi, 2012). Data was collected through surveys and interviews using questionnaires, deep interview with selected respondents (such as the head of GHSNP Agency, head of villages, and community leaders), as well as a focus group discussion with community members. The data consist of primary data and secondary data taken from the Agency of GHSNP, local government of Sukabumi District, as well as from the other neighboring villages.

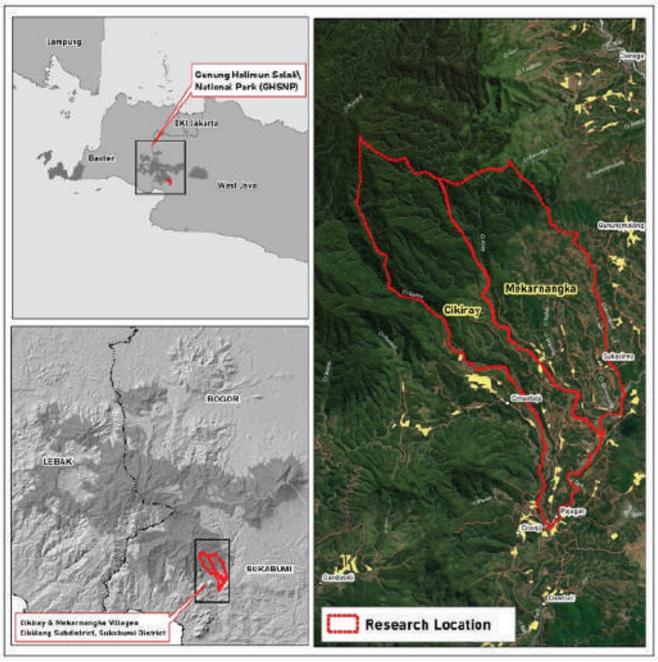

Figure 1. Study area in Cikiray and Mekarnangka villages within the GHSNP, West Java.

Data Collection

All available information and studies on biophysical data of the area available were collected through secondary data obtained from the GHSNP Agency and other related parties such as the government offices of Sukabumi District, village offices in both research locations, and the offices of neighboring villages. Other relevant scientific studies were also documented. According to Arikunto (2006), documentation is an activity to find and collect data sourced from notes, transcripts, books, newspapers, magazines, minutes of meeting, reports, agendas, etc. Secondary data collected for the purposes of this study were monographs or village profiles, as well as reports or documents containing the biophysical conditions of the GHSNP area.

Primary data were collected through field observations in the management area of the Cimantaja Resort, GHSNP (Figure 1). The results of field observations were recorded in tables and analyzed descriptively. This field observation data is needed to complete and verify the information collected from the secondary data.

Collection of community socio-economic data was carried out by interview method using a questionnaire survey, as well as in-depth interviews with selected respondents or key informants. An interview is a meeting of two people to exchange information and ideas through question and answer so that meaning in a study topic can be constructed. Through interviews, researchers will find out various things in greater depth about situations and phenomena that occur, which are impossible to find through observation. Key informants are stakeholders or parties who are able to represent the community and have the potential to provide information about the object of the study. Respondents were determined by purposive sampling.

According to Sugiyono (2009), purposive sampling is a sampling method using certain considerations, for example, respondents are considered to have knowledge and information about what researchers need, or respondents have structural positions that make it easier for researchers to explore an object. The socio-economic aspects of the respondents studied included age, education, income, area of cultivation land, type of land cultivation, length of time the land was cultivated, the financial value of the cultivation, and their social status. Furthermore, the data were analyzed descriptively and presented in the form of tables and graphs. To describe the individual characteristics of society, it is done by using the equation between values (Supranto, 2000), with the number of classes categorized into three classes, namely low, medium, and high.

Data Analysis

All the data gathered were analyzed using methods following Sugiyono (2015), which processed and described data tabularly, and then presented them in the form of tables and graphs. From the analyzed results, a synthesis was made to identify potential programmes that could be developed for community empowerment in Cikiray and Mekarnangka villages.

RESULTS AND DISCUSSION

Existing Programme of Community Empowerment

One of the locations for community empowerment activities in GHSNP is at the management area of the Cimantaja Resort, which includes Cikiray and Mekarnangka villages, Cikidang Subdistrict, Sukabumi District, West Java. Community empowerment activities commonly used by the management of GHSNP are based on the scheme of the Conservation Village Community Model (or Model kampung Konservasi) (Pratidina & Purnamasari, 2012).

The community empowerment programme in the management area of the Cimantaja Resort of GHSNP was implemented under the "Conservation Village Model" scheme, through a land rehabilitation programme in Gunung Malang Village in 2006 and in Mekarnangka Village in 2009. Meanwhile, the silkworm cultivation programme was implemented in Cikiray Village in 2017, while the broiler cultivation programme was implemented in Mekarnangka Village in 2019 (Table 1).

Table 1. Community empowerment programme in the management area of the Cimantaja Resort of GHSNP, West Java.

Village	Programme	Year
Gunung Malang	Land rehabilitation	2006
Mekarnangka	Land rehabilitation	2009
Cikiray	Silkworm cultivation	2017
Mekarnangka	Broiler cultivation	2019

Currently, the land rehabilitation programme in the villages of Gunung Malang and Mekarnangka has been terminated. Meanwhile, the silkworm cultivation programme in Cikiray Village which was carried out in 2017 was part of the work programme of the GHSNP Agency for the period of 2015-2019. The monitoring results showed that the silkworm cultivation programme in Cikiray Village (located in Sampalan Hamlet) was not successful. Mekarnangka Village later started on a new programme - the broiler cultivation in 2019. The broiler cultivation programme is a non-land-based community empowerment programme, the implementation of which is carried out with 35 members by the Gandasoli Forest Farmers Group (or KTH-*Kelompok Tani Hutan*) in Gandasoli Village, Mekarnangka Village. The idea for this boiler cultivation programme emerged from and was the desire of community groups, who previously deliberated on the type of development of their business. Broiler cultivation begins with the purchase of livestock breeds (Day Old Chicken), which are reared and raised until they are ready to be sold to the market. The net financial profit generated from this broiler cultivation is around IDR 5 million per year. This broiler cultivation programme has entered its second year, but still has not shown significant results in improving the economic level of rural communities, especially group members.

Biophysical Condition

The biophysical conditions in the management area of Cimantaja Resort (2,976.87 Ha) are represented by six national park's zoning, namely the core zone (1,568.20 Ha), forest zone (331.12 Ha), rehabilitation zone (812.22 Ha), utilization zone (247.11 Ha), traditional zone (16.27 Ha), and special zone (1.94 Ha). Zones that can be used for community involvement, in accordance with current policies and regulations, are rehabilitation zone, utilization zone, traditional zone, and special zone. According to Gunawan et al (2007), to reduce pressure from community activities whose livelihoods are highly dependent on conservation areas, these community activities need to be accommodated in possible zones based on environmental physical conditions and existing policies and regulations. These activities, apart from being able to improve the community's economy, can also stimulate the community to voluntarily be aware of the preservation of the national park area.

The total area of Cikiray and Mekarnangka Villages is 1,721.98 Ha, of which the entire area of the two villages is included in the management area of the Cimantaja Resort, GHSNP. The core zone is 1,027.22 ha, the forest zone is 110.57 ha, the rehabilitation zone is 373.26 ha, and the utilization zone is 210.93 ha (Figure 2). Small rivers are quite abundant and flow down to the Citarik River which then goes to the Cimandiri water catchment area. In the flow of rivers, there are small waterfalls, namely Curug Cimantaja in Cikiray Village, as well as Curug Cipeuteuy and Curug Cikiray Leutik in Mekarnangka Village.

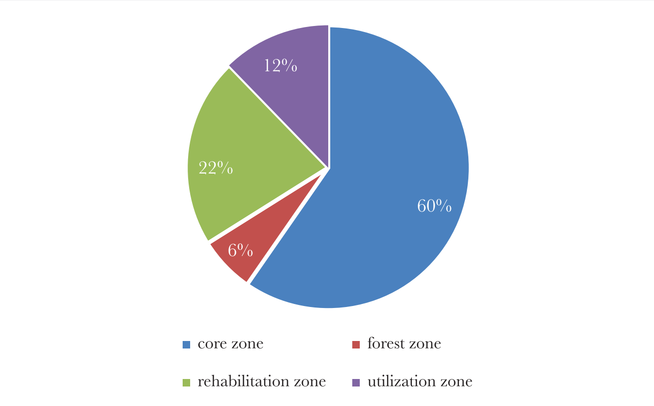

Table 2. Zonation of study site in Cikiray and Mekarnangka villages.

The areas of Cikiray and Mekarnangka villages are at an altitude of 650-1,200 m asl, with a predominance of gentle and steep slopes (20-35%). In general, the topography of the area is a hilly area with an average rainfall of 200 mm/year, and an air temperature of 20-31 ^{o}C. The place with the highest elevation in this area is the peak of Mount Malang (897 m asl) and the peak of Mount Andam (1,069 m asl), both of which are included in the administrative area of Mekarnangka Village. Soil types in both villages include brown latosol, brown andosol association, brown regosol, red yellow podzolic. The rock types are volcanic rock such as breccias, basalite and andesite.

The physical condition of the environment, such as the presence of water resources in the management area of Cimantaja Resort of GHSNP, particularly in Cikiray and Mekarnangka villages, is one of the important factors affecting people's lives in the two villages. Napitupulu (2013) argues that the physical condition of the environment in sustainable development can describe the carrying capacity of an area in supporting human life. Thus, the existence of physical aspects of the environment such as water resources, soil types, and topographical conditions in Cikiray and Mekarnangka villages can also describe the carrying capacity that meet the needs of the community living in those villages.

The forest area in Cikiray and Cimantaja villages is classified as lowland tropical rain forest (500-1,000 m asl) and sub-montane forest (1,000-1,400 m asl). The lowland forest vegetation is dominated by various types of trees, such as rasamala (*Altingia excelsa*), puspa (*Schima wallichii*), saninten (*Castanopsis javanica*), kiriung anak (*Eurya accuminatisima*), and pasang (*Quercus sundaica*). Within sub-montane forest vegetation, tree species that can be found include huru bodas (*Acer laurinum*), ganitri (*Elaaeocarpus ganitrus*), kiriung anak (*Eurya accuminatisima*), kiara (*Ficus* sp.), kayu putih (*Cinnamomum* sp.), kileho (*Saurauia pendula*), and kimerak (*Weinmania blumei*) (Table 2). The diversity of wildlife found in the two villages is also relatively high, among which there are charismatic animals such as the Javan eagle (*Nisaetus bartelsi*), Javan gibbon (*Hylobates moloch*), and Javan leopard (*Panthera pardus melas*) (Table 3).

The biological diversity in the forest area within the Cikiray Village area is generally similar to that in the entire management area of Cimantaja Resort, GHSNP. The findings during observations in the forest area in Cikiray Village can be seen in Table 4.

The name of the area block is based on the presence of the Curug Cimantaja waterfall in this area. The height of this waterfall reaches 35 meters, with a pool of water about 700 m^2 below. This waterfall has the potential to be developed into a natural tourism attraction. The existing biological diversity, which is supported by other aspects, is a natural resource that can be developed in Cikiray Village. Alikodra (2012) argues that natural resources are one of the natural capitals that can be used to fulfill human needs.

Similar with the Cikiray Village, the biological diversity in the forest area within the Mekarnangka Village area resembles that in the entire management area of Cimantaja Resort, GHSNP. However, apart from the similarity in Mekarnangka, several types of plants that can be developed into non-timber forest products, such as aren (*Arenga pinnata*), bambu (*Bambusa* sp.), rotan (*Calamus* sp.), karet (*Hevea brasiliensis*), and cultivated plants like durian (*Durio zibethinus*) and pala (*Myristica* sp.) can also be found.

Field observations in Mekarnangka Village were carried out in three different observation blocks, namely Kiara Gendol, Hulu Sungai Cigandasoli, and Pasir Ampin. The area of Kiara Gendol is a hilly ridge that extends from southeast to northwest, with a rather steep to steep slopes (15-40%) at an elevation of 650-700 m asl. This area is a transition (ecoton) between primary forest and secondary forest, and is included in the utilization zone, rehabilitation zone, forest zone, and the core zone of GHSNP. Vegetation that grows in primary forest areas of Kiara Gendol, such as puspa (*Schima wallichii*), rasamala (*Altingia excelsa*), leungsar (*Pometia pinnata*), kiara (*Ficus* spp.), saninten (*Castanopsis javanica*), kileho (*Saurauia pendula*), kimerak (*Weinmannia blumei*), etc., are typical of lowland tropical rain forests. Meanwhile, the secondary forest vegetation is dominated by puspa (*Schima wallichii*), rasamala (*Altingia excelsa*), mahoni (*Sweitenia mahagoni*), karet (*Hevea brasiliensis*), and kayu afrika (*Maesopsis eminii*), which were planted during rehabilitation land activities carried out by the previous manager (Perhutani) when this area was still a production forest.

Table 2. Species of flora found in forest areas within Cikiray and Mekarnagka villages, in the area management of Cimantaja Resort, GHSNP.

No	Local Name	Scientific Name	Remarks
1	Kayu afrika	*Maesopsi eminii*	Not protected
2	Anggrek besi	*Dendrobium filopuphanen*	Not protected
3	Anggrek tanah	*Spathoglottis plicata*	Not protected
4	Angrit	*Adina polycephala*	Not protected
5	Bambu tali	*Gigantochloa apus*	Not protected
6	Bingbin	*Pinanga coronate*	Not protected
7	Calik angin	*Molatus paniculatus*	Not protected
8	Canar	*Smilax macrocarpa*	Not protected
9	Cente/Canaan	*Lantana camara*	Not protected
10	Ceuri	*Garcinia diodica*	Not protected
11	Harendong bulu	*Clidemia hirta*	Not protected
12	Huru	*Actinodaphne glomerata*	Not protected
13	Huru bodas	*Acer laurinum*	Not protected
14	Huru madang	*Beilschmiedia madang*	Not protected
15	Huru payung	*Litsea accedentoides*	Not protected
16	Ilat	*Ficus callosa*	Not protected
17	Ipis kulit	*Decapermum paniculatum*	Not protected
18	Jamuju	*Dacrycarpus imbricatus*	Not protected
19	Jangkurang	*Trevesia sundaica*	Not protected
20	Jengkol	*Archidendron pauciflorum*	Not protected
21	Jirak	*Symplocos fasciculata*	Not protected
22	Kaliandra	*Calliandra calothyrsus*	Not protected
23	Kenung	*Helicia robusta*	Not protected
24	Kibeusi	*Dodonaea viscosa*	Not protected
25	Kibulu	*Ficus annulata*	Not protected
26	Kijambe	*Memecylon excelsum*	Not protected
27	Kipiit	*Picrasma javanica*	Not protected
28	Kisireum	*Syzygium lineatum*	Not protected
29	Kitapen	*Macaranga rhizinoides*	Not protected
30	Kitarasi	*Viburnum coreaceum*	Not protected
31	Kirinyuh	*Eupatorium pallescens*	Not protected
32	Leungsar	*Pometia pinnata*	Not protected
33	Mangong	*Macaranga rhizinoides*	Not protected
34	Pakis haji	*Cycas rumphii*	Not protected
35	Parengpeng	*Cliptocarea densiflora*	Not protected
36	Pasang	*Quercus sundaica*	Not protected
37	Pasang batarua	*Quercus gemelliflora*	Not protected
38	Pasang parengpeng	*Cliptocarea densiflora*	Not protected
39	Peuris	*Aporosa aurita*	Not protected
40	Pinding	*Diospyros siamang*	Not protected

41	Pohpohan gunung	*Pilea melastomoides*	Not protected
42	Puspa	*Schima wallichii*	Not protected
43	Rane	*Sellaginella* sp.	Not protected
44	Rasamala	*Altingia axelsa*	Not protected
45	Riung anak	*Castanopsis acuminatissima*	Not protected
46	Rotan bungbuai	*Plectocomia elongata*	Not protected
47	Salam gunung	*Syzygium polyanthum*	Not protected
48	Sungkai	*Peronema cenescen*	Not protected

Table 3. Species of wildlife found in forest areas within Cikiray and Mekarnagka villages, in the area management of Cimantaja Resort, GHSNP.

No	Species		Remarks
	Local Name	**Scientific Name**	
1	Elang jawa	*Nisaetus bartelsi*	Protected
2	Elang hitam	*Ictinaetus malayensis*	Protected
3	Elang ular	*Spilornis cheela*	Protected
4	Elang brontok	*Spizaetus cirrhatus*	Protected
5	Macan tutul jawa	*Panthera pardus melas*	Protected
6	Kucing hutan	*Prionailurus bengalensis*	Protected
7	Owa jawa	*Hylobates moloch*	Protected
8	Surili	*Presbytis comata*	Protected
9	Lutung	*Trachypitecus auratus*	Protected
10	Kijang	*Muntiacus muntjak*	Protected
11	Kukang jawa	*Nycticebus javanica*	Protected
12	Julang emas	*Rhyticeros undulatus*	Protected
13	Landak	*Hystix javanica*	Protected

Wildlife in the Kiara Gendol forest area include the Javan leopard, binturong/bear cat, Javan gibbon, grizzled leaf monkey or surili, Javan langur or lutung, long tailed macaque, Javan eagle, crested serpent eagle, black eagle, changeable hawk-eagle, black-winged kite, wreathed hornbill, rhinoceros hornbill, Javan slow loris, and Javan porcupine (Table 3).

The name of Hulu Sungai Cigandasoli was given by the community based on the existence of a spring whose water flows in the Cigandasoli River, part of the Citarik watershed. This area is hilly with steep slopes (25-40%) at elevation of 650-800 meters asl. This area is a primary forest included in the core zone of the national park, with plants including puspa (*Schima wallichii*), rasamala (*Altingia excelsa*), leungsar (*Pometia pinnata*), kiara (*Ficus* spp.), saninten (*Castanopsis javanica*), kileho (*Saurauia pendula*), kimerak (*Weinmannia blumei*), etc.

Pasir Ampin Block is included in the core zone and rehabilitation zone of GHSNP. The name "Pasir Ampin" was also given by the community because the area is a plain on a ridge. The slope of the area varied from rather steep to steep (15-40%), with elevation of 600-800 m asl. The forest area in Pasir Ampin is primary forest and lowland tropical secondary forest, with various types of plants forming the same vegetation as in the forest area in the Kiara Gendol and Hulu Sungai, Cigandasoli blocks. Like the forest condition in Kiara Gendol, there are also several species of trees in Pasir Ampin planted during rehabilitation land activities, carried out by the previous manager (Perhutani) when the area was still a production forest.

Socio-economic Conditions of the Community

Administratively, both Cikiray Village and Mekarnangka Village each consist of several hamlets (Table 5). Just like the other people living in neighboring villages around GHSNP, the communities of Cikiray and Mekarnangka Villages have a strong dependence and attachment to the GHSNP area, especially those are living in the hamlets of Sampalan and Balandongan (in Cikiray Village), as well as the community living in the hamlets of Bongbang, Cibitung, Tapos, Nyalindung, Pasirnangka, Sukasirna and Gandasoli (in Mekarnangka Village).

The results of the Focus Group Discussion (FGD) conducted in Cikiray Village, which involved the

Table 4. Fauna and flora found in forest areas within Cikiray Village.

No	Location / Site	Species	
		Local Name	Scientific Name
1	Curug Cimantaja Block:		
	Fauna / Mammals	Owa jawa	*Hylobates moloch*
		Monyet ekor panjang	*Macaca fascilcularis*
		Macan tutul jawa	*Panthera pardus melas*
		Surili	*Presbytis comata*
		Lutung	*Trachypitecus auratus*
	Fauna / Birds	Luntur gunung	*Apalharpactes reinwardtii*
		Luntur macan	*Harpactes sp.*
		Elang jawa	*Nisaetus bartelsi*
		Elang ular	*Spilornis cheela*
		Elang hitam	*Ictinaetus malayensis*
		Srigunting	*Dicrurus* sp.
		Meninting	*Enicurus* sp.
	Flora	Pasang	*Quercus sundaicus*
		Puspa	*Schima wallichii*
		Rasamala	*Altingia excelsa*
		Leungsar/Leungsir	*Pometia pinnata*
		Kiriung anak	*Castanopsis acuminatissima*
		Benying air	*Ficus* sp.
		Kiputri	*Podocarpus neriifolius*
		Huru	*Actinodaphne glomerata*

Table 5. Hamlets are located within the administrative area of Cikiray and Mekarnangka Villages, Cikidang Subdistrict, Sukabumi District, West Java, which are directly adjacent to the GHSNP Area.

No	Village / Hamlets	Total population (N of family) in 2020
	Cikiray :	**4,649 (804)**
1	Balandongan	
2	Sampalan	
	Mekarnangka :	**3,526 (1,129)**
1	Bongbang	
2	Cibitung	
3	Tapos	
4	Nyalindung	
5	Pasir Nangka	
6	Sukasirna	
7	Gandasoli	

community from Sampalan Hamlet, showed that the community knew that the forest area in their village is currently a conservation area previously managed as a production forest by Perhutani. This understanding is evident by the absence of legal land ownership certificate documents. For the community to support cultivation activities, such as for the fulfillment of livestock feed and firewood, about 0.5-1.5 Ha/family of forest land would be needed. It means that with a total of 804 families, the community in Cikiray Village would need around 402-1,206 Ha of land. Seeing that the Cikiray Village is currently included in the GHSNP area, the community is worried that their access to natural resources in the national park will be forbidden. This would make it increasingly difficult for the community to find necessities to support their way of living. The community hopes that the GHSNP Agency can provide them access to participating in managing the area so that they can develop existing potentials for nature tourism or fruit crop cultivation to aid in the community's economic growth. At the FGD in Cikiray Village, the community also conveyed that village development programmes and arrangements for management access to the area were still in the socialization and identification stage, and was being carried out by the GHSNP Agency in the form of access to a conservation partnership scheme.

Two FGDs in Mekarnangka Village were held. The results of the first FGD involving the Gandasoli hamlet community showed that the community knew that the forest area in their village is currently a conservation area of HGSNP. The community in Gandasoli Hamlet has even been involved in conducting forest security or patrols with GHSNP Agency officers for area conservation and animal monitoring. For cultivation activities, the people in this village also need an area of 0.5-1 ha per family. This means that the 1,129 families in Mekarnangka Village would need about 565-1,129 hectares of arable land for their economic fulfilment. The community is also worried that their access to natural resources in the national park will be prohibited. Some community members have already left their cultivated land, which they have been working on since this area was managed as a production forest. As a result, the community may have found it harder to find necessities to support their way of living. The community hopes that the GHSNP Agency can provide them access to participating in managing the area so that they can develop existing potentials for nature tourism or fruit crop cultivation to aid in the community's economic growth.

The same issues were raised by the community in the second FGD in Mekarnagka Village which involved the communities of Pasir Nangka, Cibitung, and Bongbang Hamlets. In general, the community already understood that the forest area in their village is currently a GHSNP conservation area, but they do not really understand the function of the existing zones in the GHSNP management spatial planning.

The results of the interview survey with 25 heads of families living in the villages of Cikiray and Mekarnangka illustrated that majority of residents only have elementary school education. Previous study by Adalina et al (2015) showed that majority (87%) of community living around GHSNP have low level of formal education. To support their families, each family head would cultivate rice in paddy fields, farm on land (cassava and vegetables), farm fruits (bananas, durians, coconuts, nutmeg, cloves, dog fruit/jengkol, and stink bean/petai), and plant sap-producing trees (rubber). From the survey results, majority of people in both Cikiray and Mekarnangka villages used their arable land to grow fruit-producing plants (44%) (Figure 3). All of these community agricultural activities were carried out within the GHSNP area.

People cultivating land in Cikiray and Mekarnangka Villages generated the highest income, between IDR 8-12 million/year (40%). Others only earned IDR 4-8 million/year (32%), with some only able to generate a maximum amount of IDR 4 million/year (28%) (Figure 4). This finding is almost similar with Adalina et al (2015), which stated that the average income of community living around GHSNP is only IDR 13.8 million/year, and it is below the minimum regional wage of West Java and Banten Provinces.

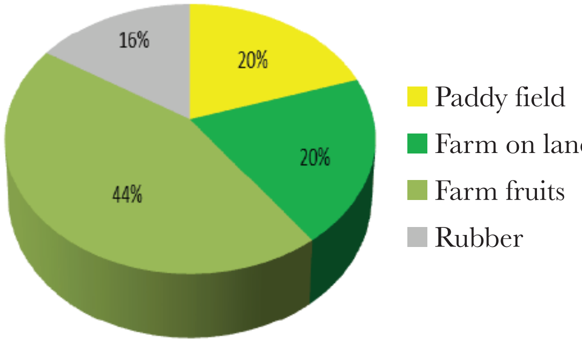

Figure 3. Classification of cultivation activities conducted the community of Cikiray and Mekarnangka Villages in the GHSNP area.

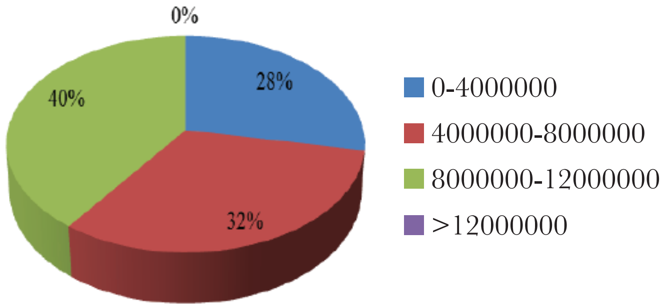

Figure 4. The average annual income (IDR) of the community living in Cikiray and Mekarnangka villages from cultivation activities on their arable lands in the GHSNP area.

Potential Development of Community Empowerment Programmes

Based on the results of the questionnaire survey, in-depth interviews, and FGDs in the villages of Cikiray and Mekarnangka, several options can be made for the development of community empowerment programmes in both villages. These programmes include: (a) nature tourism, (b) special interest tourism, (c) culture-based tourism (local wisdom), (d) traditional use, (e) ecosystem restoration cooperation, (f) forest plant cultivation as a source of seeds for economic development, and (g) utilization of environmental services (water and hydropower plant). A summary of the results of the study on the development of community empowerment programmes in the Cikiray and Mekarnangka villages is presented in Table 6.

Table 6. Opsi-opsi programme pemberdayaan masyarakat yang dapat dikembangkan di desa Cikiray dan Mekarnangka, di dalam Kawasan GHSNP.

No	Village	Hamlet	Options for development of community empowerment programmes*
1	Cikiray	Balandongan	d,e,f,g
2		Sampalan	a,c,d,e,f,g
3	Mekarnangka	Bongbang	a,d,e,f,g
4		Cibitung	d,e,f,g
5		Tapos	a,d,e,f,g
6		Nyalindung	d,e,f,g
7		Pasirnangka	d,e,f,g
8		Sukasirna	d,e,f,g
9		Gandasoli	a,b,d,e,f,g

Note: a) nature tourism, b) special interest tourism, c) culture-based tourism (local wisdom), d) traditional use, e) ecosystem restoration cooperation, f) forest plant cultivation as a source of seeds for economic development, and g) utilization of environmental services (water and hydropower plant).

Nature tourism development

Natural tourism at the waterfalls of Curug Cimantaja, Curug Cikiray, Curug Cipeuteuy, and Curug Cimantaja can be developed by encouraging the community of Sampalan and Balandongan hamlets in Cikiray Village to manage these natural tourism objects through a cooperation scheme with the GHSNP Agency. With the same scheme, Curug Cipeuteuy and Curug Cikiray Leutik can also be developed as natural tourism objects for the people of Mekarnangka Village. If nature tourism is implemented, national park managers must ensure that tourism activities are low impact and extremely well managed (Drumm et al, 2005).

Special interest tourism development

The high potential for biodiversity in the Kiara Gendol Block can be developed into a research location that involves the community (especially the Gandasoli Hamlet community) as interpreters or guides for researchers. The success of nature tourism depends in large part on the abilities of naturalist guides to interpret the environment in ways that inspire and educate visitors (Drumm, 2005). The Kiara Gendol Block can be designated as a research station whereby researchers can observe the rich biodiversity of the area. This activity can generate financial benefits for the community, and can stimulate the community to care more about the existence of protected wildlife.

Culture-based tourism (local wisdom) development

The people of Sampalan Hamlet in Cikiray village still carry out various activities that make use of their local wisdom in their daily lives. For instance, the people in this hamlet continues to perform the "Seren Taun" ceremony, an annual traditional ritual executed to express the village's gratitude to God for the gift of an abundant harvest. The village community also maintains the skills for constructing their unique residential buildings, and the tradition of storing rice in "Leuit", a type of vernacular rice barn used to store rice after harvest for future daily use. All of these can be packaged into a culture-based tourism, which may have an impact on improving the community's economy.

Traditional use development

There are various species of forest plants surrounding the villages of Cikiray and Mekarnangka. However, there are also many plant species due to community cultivation on land within the GHSNP Area. Agricultural cultivation activities (rubber, durian, cloves, dog fruit/jengkol, sugar palm and nutmeg) have been carried out by the community for a long time, long before their village area became part of the GHSNP area. Through existing regulations, collaboration and community empowerment, a traditional utilization-based conservation partnership scheme can be implemented.

Development of ecosystem restoration cooperation

The lands in the villages of Cikiray and Mekarnangka included in the management area of Cimantaja Resort, GHSNP, are not entirely covered by forest vegetation, as there are agricultural lands belonging to the people from both villages. Therefore, to restore the land functions in compliance with the GHSNP zonation, a community-based ecosystem restoration cooperation scheme can be executed (Rochaedi, Priatna, & Rahayu, 2021). The community can work on area restoration activities by planting native species such as rasamala (*Altingia excelsa*), puspa (*Schima wallichii*), huru (*Actinodaphne glomerata*), saninten (*Castanopsis javanica*), aren (*Arenga pinnata*), etc., or by planting other species associated with native species, so as to produce an economic source for the community.

Forest plant cultivation as a source of seeds for economic development

Many species of forest plants in Cikiray and Mekarnangka villages have the potential to improve the community's economy. However, the most prominent species being cultivated in the community currently is the aren or sugar palm (*Arenga pinnata*) plant. In addition to its high abundance, aren trees are also easy to cultivate inside and outside the forest area. Aren trees can produce sap (or locally called "air nira") that can be processed into brown sugar, a commodity that has a very wide market. In one year, one aren tree can generate an average economic value of IDR 2.8 million (Aulin, 2019).

Development of utilization of environmental services (water and hydropower plant)

Another potential that exists in the forest area in the villages of Cikiray and Mekarnangka is the abundance of rivers and tributaries that goes into the Citarik sub-watershed. Through a community-based scheme, the rivers and their tributaries can be developed to fulfill the community's need for clean water. This programme will be able to minimize the community's expenses in obtaining clean water for their daily needs. Additionally, cultivation of various species of native fish can also be done in the rivers to improve the community's economy. Hydropower plants can also be developed in several locations on a microhydro scale to meet the electricity needs of the community.

CONCLUSION

Considering the biophysical conditions of the area of Cikiray and Mekarnangka villages, the community empowerment programmes that can be developed in both villages include nature tourism, through the development of the potential of the waterfalls of Cimantaja, Cikiray Leutik, and Cipeuteuy. Special interest tourism can also be developed, namely research nature tourism in the Kiara Gendol Block. The development of cultural-based nature tourism (local wisdom) can also be implemented in Sampalan Hamlet, Cikiray Village. Interested community members can be trained and prepared to become interpreters or guides. The development of traditional uses can be carried out through a conservation partnership scheme, to develop agricultural and plantation commodities (e.g., rubber, durian, cloves, dog fruit/jengkol and nutmeg) that have the potential to increase the economic level of the community.

The collaboration between the community and the GHSNP Agency to restore forest ecosystems can be carried out by involving the community in the rehabilitation of the area through the cultivation of tolerant intercrops planted as forest restoration trees. Sugar palm or aren (*Arenga pinnata*) is a forest plant that currently has the potential to be cultivated in the villages of Cikiray and Mekarnangka, both inside and outside the forest area.

The rivers and their tributaries in the Cikiray and Mekarnagka villages can be utilized to fulfill the need for clean water, managed as part of the community-based scheme. Apart from that, the cultivation of various species of native fish can also be developed to improve the community's economy. Hydropower plants can be developed in some locations with a microhydro scale, which can be used to meet the electricity needs of the community.

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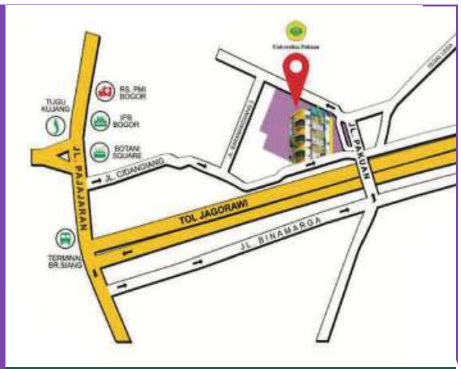

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