Jurnal Ilmu Kehutanan

https://jurnal.ugm.ac.id/v3/jik/
ISSN: 2477-3751 (online); 0126-4451 (print)

Carrying Capacity Based on Ecosystem Services for Biodiversity Conservation in the Petungkriyono Essential Ecosystem Area Candidate

(Daya Dukung dan Daya Tampung Lingkungan Hidup Berbasis Jasa Lingkungan dalam Mendukung Konservasi Biodiversitas di Calon KEE Petungkriyono)

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RESEARCH ARTICLE

DOI: 10.22146/jik.v17i1.5762

MANUSCRIPT:
Submitted : 30 September 2022
Revised : 20 March 2023
Accepted : 28 March 2023

KEYWORD
KEE, Petungkriyono,
Carrying Capacity, Conservation,
Biodiversity

ABSTRACT

The Petungkriyono protected and production forests qualified for the Essential Ecosystem Area (EEA). Perhutani manages the area, covering approximately ±7,683.33 ha, with 80% being secondary natural forests and the habitat for endangered flora and fauna. This research aimed to analyze the suitability of Petungkriyono EEA for biodiversity preservation, protection, sustainable use, and ecosystem restoration using carrying capacity based on ecosystem services (CCES). This research used a participatory approach and expert opinion with a weighting sum on land cover and landscape variables. The results showed that approximately 74.12% of the Petungkriyono AAE candidate had high and very high CCES classes and were suitable for biodiversity and area protection priorities. Meanwhile, 14.35% was in a low class and suitable for ecosystem restoration and sustainable use priorities.

KATA KUNCI
KEE, Petungkriyono, DDDTLH, Konservasi, Biodiversitas.

INTISARI

Kawasan Hutan Petungkriyono merupakan hutan lindung dan hutan produksi yang saat ini dikelola oleh Perhutani dan menjadi kandidat Kawasan Ekosistem Esensial (KEE). Total luas kawasan ±7.683,33 Ha dan sekitar 80% merupakan hutan alam sekunder dan menjadi habitat flora fauna terancam punah. Penelitian ini menggunakan Daya Dukung dan Daya Tampung Lingkungan Hidup (DDDTLH) berbasis jasa lingkungan dan bertujuan untuk mengetahui wilayah di KEE Petungkriyono yang diprioritaskan untuk kegiatan pengawetan keanekaragaman hayati, perlindungan wilayah, pemanfaatan berkelanjutan, dan pemulihan ekosistem. Penelitian ini menggunakan pendekatan partisipatif and pendapat para ahli dengan perhitungan penjumlahan berbobot pada variabel tutupan lahan dan bentang alam. Hasil analisis menunjukkan bahwa 74,12% dari total wilayah Kawasan Hutan Petungkriyono memiliki klasifikasi DDDTLH tinggi dan sangat tinggi yang dapat diprioritaskan untuk kegiatan pengawetan keanekaragaman hayati dan perlindungan wilayah calon KEE Petungkriyono. Sementara itu, sekitar 14,35% dari total wilayah kawasan termasuk dalam klasifikasi DDDTLH rendah yang dapat diprioritaskan untuk pemulihan ekosistem dan pemanfaatan berkelanjutan.

Introduction

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) reported that approximately 25% of global plant and animal species are at risk of extinction (Diaz et al. 2019). Indonesia experiences a high ecosystem deterioration and species extinction. Approximately 80% of endangered species in the country are outside the conservation areas (Geldmann et al. 2013). As a response, conservation area management seeks new ways to engage policy instruments and consider regions and natural resources outside the conservation areas (Sahide 2020). The Ministry of Environment and Forestry established sustainable biodiversity management policy strategies in areas with high conservation values outside the conservation areas through the Essential Ecosystem Area (EEA) designation stipulated by Government Regulation No. 28/2011.

Central Java Province has initiated efforts to support the preservation of flora, fauna, and ecosystems in its region through the designation of EEA both within and outside of forest areas, following Law No. 23/2014, concerning provincial authority in the sub-affairs of conservation of biological natural resources and ecosystems. Perum Perhutani, a state-owned forest company, currently manages Petungkriyono forest areas, with its protected and production forests. A protected area intended to prevent extinction and preserve ecosystem function (Allan et al. 2017). By Law No 41/1999, a production forest is a region primarily producing forestry products. The Petungkriyono forest area was approximately 7,683.3 ha, covering areas in Petungkriyono, Doro, and Talun districts. Its management falls under the East Pekalongan Forest Management Unit (FMU), Perum Perhutani Regional Division of Central Java.

In 2019, the Central Java Natural Resources Conservation Agency (BKSDA) reported that the Petungkriyono forests had high biodiversity. The Central Java BKSDA Report (2019) reported that Petungkriyono forests meet the essential ecosystem criteria with high priority based on the uniqueness/representativeness and essential function of the terrestrial ecosystem, accessibility, threats, biodiversity, and socio-economic conditions, stipulated in the ecosystem identification and inventory guidelines for terrestrial ecosystems outside conservation areas (2012). For this reason, the Central Java government designated the Petungkriyono forests as the EEA candidate.

Petungkriyono forests hosted several protected fauna species, such as leopard *(Panthera pardus)*, binturong (*Arctictis binturong*), Javan hawk-eagle (*Nisaetus bartelsi*), black eagle (*Ictinaetus malayensis*), surili (*Presbytis comata*), helmeted hornbill *(Aceros undulates/Rhyticeros undulatus*), and Javan gibbon (*Hylobates moloch*), as well as flora species, such as Pelahlar tree *(Dipterocarpus littoralis)*, pitcher plant *(Nephentes)*, and orchid *(Orchidaceae)*. The Javan gibbon (*Hylobates moloch*) is a critically endangered primate species (IUCN, 2009) and has become one of the endemic and the key species in Petungkriyono forests (Nijman and Van Balen 1998) in Setiawan et al. (2012). This species is protected by the Minister of Environment and Forestry Regulation Number P.106/Menlhk/Setjen/Kum.1/12/2018 concerning protected plant and animal species. The Central Java BKSDA has also been monitoring the Javan gibbon from 2015-2019 based on decree No. 180/IV-KKH/2015 concerning the priorities of twenty-five endangered species.

Based on the guidelines for identifying and inventorying terrestrial ecosystems, the assessment for EEA candidates must consider the ecosystem services and natural resource values for the environment and living organisms. Therefore, the

management plan for Petungkriyono forests should consider the carrying capacity based on ecosystem services (CCES), although an EEA requires no CCES. The CCES information could facilitate the evaluation and determination of the EEA candidates based on the actual condition in the field. Understanding the CCES in Petungkriyono forests could estimate the ecosystem services values related to biodiversity in the area.

Law No. 32/2009 on Environmental Protection and Management defined *environmental carrying capacity* as the ability of the environment to support the survival of humans and other living organisms and their balance. The environmental support capacity is the ability of the environment to absorb substances, energy, and other components. Law No. 5/1990 on Conservation of Natural Resources and Ecosystems, Law No. 41/1999 on Forestry, Law No. 4/2009 on Minerals and Coal, Law No. 41/2009 on the Protection of Sustainable Agricultural Land, Law No. 1/2014 on Coastal and Small Island Management, Law No. 3/2014 on the Industry, Law No. 10/2009 on Tourism, Law No. 39/2014 on Plantations, and Law No. 39/2014 on Plantations Mandated the Use of Carrying Capacity and Environmental Support Capacity Data. Law No.32/2009 on Environmental Protection and Management also mandated that the formulation of the Environmental Protection and Management Plan must be based on the carrying capacity and consider ecosystem services.

Ecosystem services are natural ecological functions that can benefit humans and enrich biodiversity (Harris 2022). The Millennium Ecosystem Assessment 2005 (MEA 2005) grouped the ecosystem services into provisioning, regulating, cultural, and supporting services, and identified 20 sub-services within these four groups. They were food provision, clean water provision, fiber provision, fuel provision, genetic resources, climate regulation, water regulation and flood control, natural disaster prevention and protection, water purification, waste processing and decomposition, air quality maintenance, natural pollination regulation, pest and disease control, habitat and living space, recreation and ecotourism, aesthetics, soil formation and fertility maintenance, nutrient cycling, primary production, and biodiversity.

This research aimed to determine the areas in the Petungkriyono EEA suitable for biodiversity conservation, area protection, sustainable utilization, and ecosystem restoration priorities. This research focuses on four biodiversity-related ecosystem services, namely Genetic Resource Provider, Climate Regulator, Primary Production Support, and Biodiversity Support. The results could contribute to identifying the spatial distribution of areas in the Petungkriyono EEA that must be protected, preserved, and developed concerning their biodiversity condition.

Methods

Data Collection

This research used primary and secondary data (Table 1). The primary data were obtained from the ground truthing and FGDs, while secondary data were collected online and from relevant agencies. Ground check activities validated the land cover data with actual field conditions on June 7th -10th, 2021. Several misinterpretations of the Google Earth data occurred, such as rubber plantations distorted as pine forests. The FGD resulted in scores and weights of land cover and landscape for each ecosystem service. This research used the Topographic Map 2006 from the Geospatial Information Agency to extract the administrative map. The distribution of Javan Gibbon from the Central Java Provincial Natural Resources Conservation Agency indicated the location of Javan Gibbon's existing habitat in the Petungkriyono EEA

Table 1. Research data

No	Data	Source
1.	Land cover map scale 1:50,000	Google Earth data, April 2021
2.	Land cover map scale 1:50,000	SRTM image, February 2015
3.	Javan gibbon distribution data	Natural Resources Conservation Agency (BKSDA), Ministry of Environment and Forestry (KLHK), 2021
4.	Topographical map of Indonesia at 1:25,000 scale	Geospatial Information Agency, 2006
5.	Visited Location coordinates	GPS Garmin GPSmap 64s

candidate to prevent disturbances and intervention from human activities.

Data Analysis

The CCES determination used land cover and landscape proxies from the Center for Ecological Region Development Control of Java, Ministry of Environment and Forestry (P3EJawa, KLHK). The P3EJawa (KLHK) also interpreted and delineated Google Earth and SRTM data to create the land cover and landscape maps at 1:50,000 scale. The relationship assessment between proxies and types of ecosystem services used Participatory Approaches and Expert Opinion method in Focus Group Discussion (FGD). The FGD was conducted on July 7th, 2021, and involved seven scientific experts from Gadjah Mada University (UGM) in forestry, regional development, and geography. The FGD discussed the land cover and landscape definition and their relationship with the ecosystem services in the Petungkriyono EEA candidate to determine the score and weight for each ecosystem service. The experts suggested four types of ecosystem services related to biodiversity conservation efforts for this research, including Genetic Resource Provider, Climate Regulation, Primary Production Support, and Biodiversity Support.

The ecosystem service provided by natural resources differed in each land cover and landscape. For example, land cover dynamics had a more significant influence on the provision of genetic resources than the landscape. For this reason, the land cover obtained more weight than the landscape. In contrast, the landscape had a more significant influence on the cultural ecosystem services, such as the aesthetic functions of nature. Therefore, the landscape obtained more weight than the land cover. The discussion resulted in an agreement between P3EJawa (KLHK) and the experts on the weight of land cover and landscape for each ecosystem service (Table 2).

Subsequently, the expert assessed the score of land covers (Table 3) and landscape (Table 4) for each ecosystem service in the Petungkriyono EEA candidate. The scores presented in Table 3 and Table 4 were the median values. The land cover with forest stands scored the highest for genetic resource provider, climate regulator, and biodiversity support ecosystem services. In contrast, village settlements and rice fields scored the lowest for the respective ecosystem services.

The calculation of the performance of four ecosystem services used the scores and weights resulting from the FGD using the following formula (Directorate General of Natural Resources and Ecosystem Conservation, Ministry of Environment

Table 2. The weight of land cover and landscape for each ecosystem service

Ecosystem Services	Code	Land Cover Weight	Landscape Weight
Provider of genetic resources	JEP5	0.7	0.3
Climate regulator	JER1	0.6	0.4
Primary production support	JED3	0.7	0.3
Biodiversity support	JED4	0.7	0.3

Table 3. The score of land cover for each ecosystem service

No.	Land Cover	JEP5	JER1	JED3	JED4
1.	Village settlements (associated with home garden vegetation)	2	2.5	2.5	3
2.	Community forest	4.5	4	4	3
3.	High-density primary upland forest	5	5	5	5
4.	Low-density secondary upland forest	4	5	5	5
5.	High-density secondary upland forest	4.5	5	5	5
6.	Dense pine forest	4.5	5	4.5	4
7.	Other plantation (industrial) forests	3	4	4	4
8.	Mixed agriculture	3.5	4	4	4
9.	Dryland agriculture with seasonal crops	3	3	3.5	3
10.	Dryland agriculture with horticultural crops	3	3	3	3
11.	Dense rubber plantation	3	4	4	3.5
12.	Tea plantation	3.5	4	4	3
13.	Paddy fields with continuous rice production	3	2	3	2
14.	Paddy fields with crop rotation/fallows	3	2.5	3	3
15.	Bush	3	2	3	3
16.	Shrubs	3	2.5	3	3
17.	River	5	4	2.5	4.5

Table 4. The score of landscape for each ecosystem service

No.	Landscape	JEP5	JER1	JED3	JED4
1.	Caldera	3.5	4	2.5	2
2.	Anticlinal hills of the Kuningan-Kendal with limestone clay materials	3.5	5	4.5	4.5
3.	Anticlinal foothills of Kuningan-Kendal with The slopes of the hills are structural folds (anticlines) of the Kuningan-Kendal with limestone clay materials	3.5	4	4	3.5
4.	Inter-volcano valleys with pyroclastic material	4	4	4	3
5.	Lava field mountains	3	4	4	3.5

and Forestry, 2018). The visualization of results used maps for each ecosystem service, and a map for the synthesis. The synthesis analysis used the overlays of four ecosystem services performances to produce the area of the CCES classes for biodiversity conservation. The Directorate General of Natural Resources and Ecosystem Conservation, Ministry of Environment and Forestry (2018) classified the performance of ecosystem services as Very High (4.21 – 5.00), High (3.41 – 4.20), Moderate (2.61 – 3.40), Low (1.81 – 2.60), and Very Low (1.00 – 1.81).

Current Environmental Service Performance = f {Landscapes, Land Cover}

$$= (w_{ba} \times s_{ba}) + (w_{pl} \times s_{pl})$$

Remarks: w_{ba} = landscape weight; s_{ba} = landscape score; w_{pl} = land cover weight; s_{pl} = land cover score.

Result and Discussion

The Central Java BKSDA reported that the Petungkriyono EEA candidate had high biodiversity, including 112 flora species in various strata, seedlings, saplings, poles, and trees. The Petungkriyono forests served as habitats for various wildlife, such as the Javan eagle *(Nisaetus bartelsi)*, Javan langur *(Trachypithecus auratus)*, *rekrekan (Presbytis fredericae),* leopard *(Panthera pardus)*, and the critically important endemic species, Javan gibbon (*Hylobates moloch*). The wildlife monitoring in 2019 found 26 individuals from nine groups, including five groups from indirect encounters (acoustic). The Petungkriyono management should use conservation principles and CCES to preserve, maintain, and utilize this high-potential biodiversity to sustain the biodiversity and its ecosystems. The CCES in this research referred to the ability of an area to create a conducive ecosystem as a habitat for various flora and fauna and to support

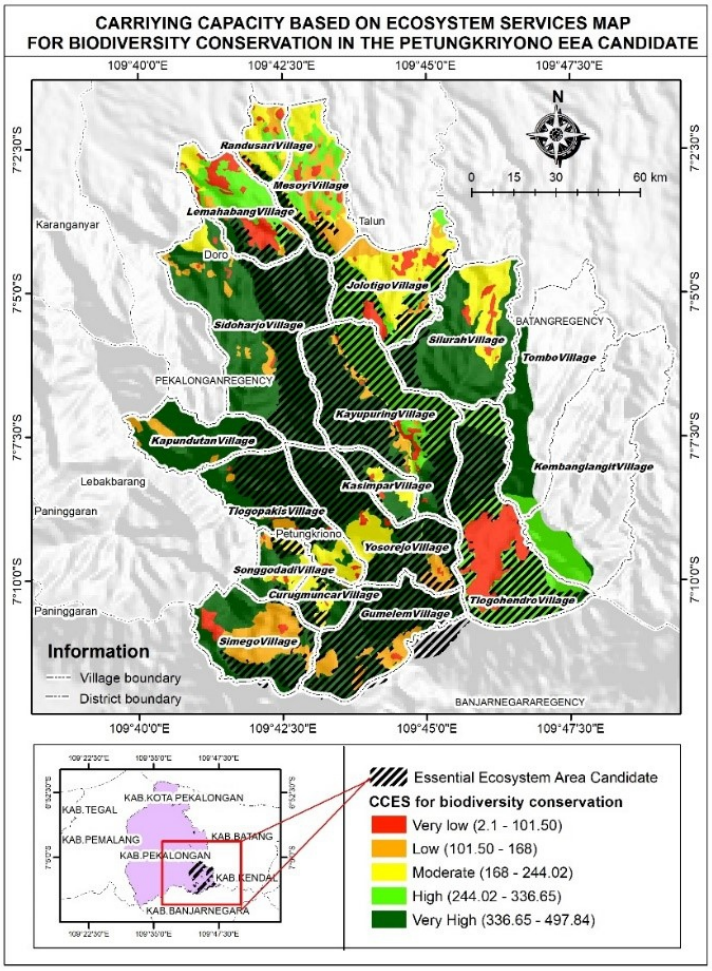

Figure 1. CCES classes map for biodiversity conservation in the Petungkriyono EEA candidate

biodiversity conservation efforts. A higher CCES indicated a higher area's ability to support biodiversity conservation efforts and vice versa.

The higher CCES class of genetic resources provider, the area had more available genetic resources. The higher CCES class of biodiversity support, the area had more diverse species and could create the breeding habitats for various flora and fauna. With the higher CCES class of climate regulator, the area had better microclimate conditions (temperature, humidity, and precipitation) to create suitable habitats for various flora and fauna. In this research, the CCES of primary production referred to oxygen production. Forest ecosystems produce oxygen and reduce the level of carbon dioxide in the atmosphere through photosynthesis. Oxygen becomes the primary input for living organisms to carry out activities and enable the growth of habitats. The amount of oxygen production depends on the presence of vegetation and forests. With the higher CCES class of primary production, the area had a higher oxygen production to support suitable habitats for various species. The CCES classification resulted in very high (±51.57%), high (±22.55%), moderate (±11.53%), low (±8.01%), and very low (±6,33%) classes (Figure 1). The CCES classification indicated that more than 50% of the Petungkriyono EEA candidate could provide ecosystem services related to biodiversity conservation for living organisms and their habitats.

The overlay of the CCES and distribution data of Javan Gibbons indicated that their habitats were within the very high CCES class areas, such as in Kayupuring, Tlogopakis, and Jolotigo Villages. However, the Javan Gibbon's habitat in Jolotigo Village was adjacent to

rubber and tea plantations with moderate and low CCES classes, which could risk the Javan Gibbon habitat due to human interventions, such as encroachment of plantation expansions. These human interventions could lead to a decrease in ecosystem services for biodiversity conservation. Therefore, this area could become the Javan Gibbons protection and preservation focus. Government Regulation No. 7/1999 on the Conservation of Plant and Animal Species defined *conservation* as an effort to prevent the extinction of plant and animal biodiversity, including their ecosystems, both inside and outside the habitats. Biodiversity preservation included efforts in the designation and classification of protected and unprotected species, the management of flora and fauna and their habitats, and the nurturing and breeding of these species. The Petungkriyono EEA candidate should collaborate with local stakeholders or communities who interact directly with the area.

The area with very high and high CCES classes, such as high-density secondary forests and pine forest covers, could create suitable habitats for various flora and fauna and be suitable for areas protection activities to maintain and enhance their high biodiversity potential. Around 74.12% of the Petungkriyono EEA candidate area required area protection efforts because they had high biodiversity potential (Figure 2). The Government Regulation Number 45 of 2004 concerning forest protection suggested that area protection could include preventing and limiting damage to forests and forestry

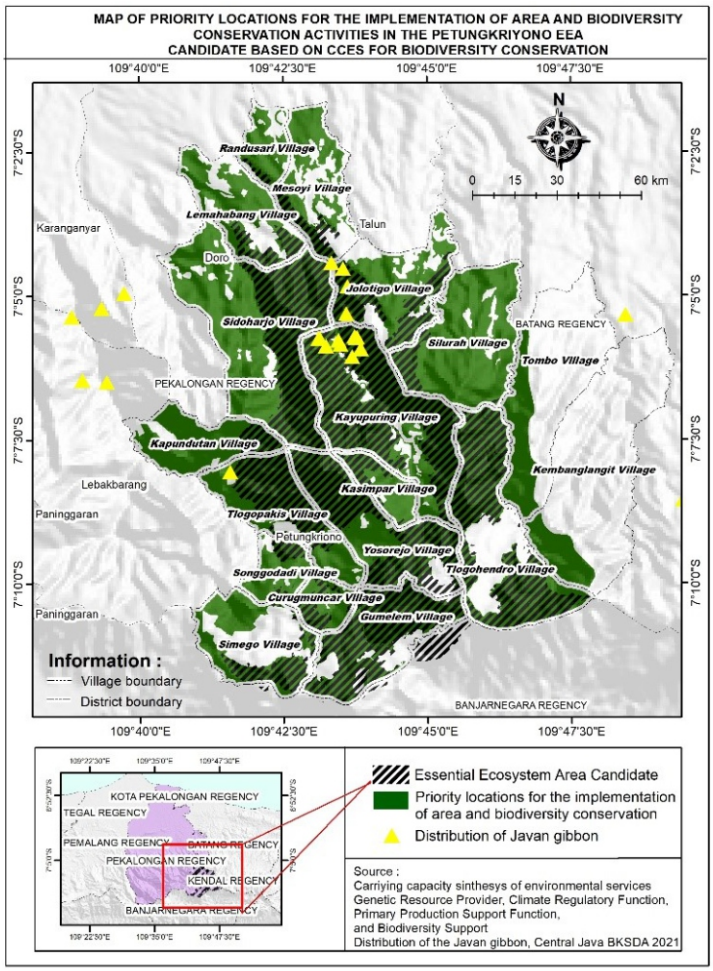

Figure 2. Map of priority locations for the implementation of area and biodiversity conservation activities in the Petungkriyono EEA candidate based on CCES for biodiversity conservation

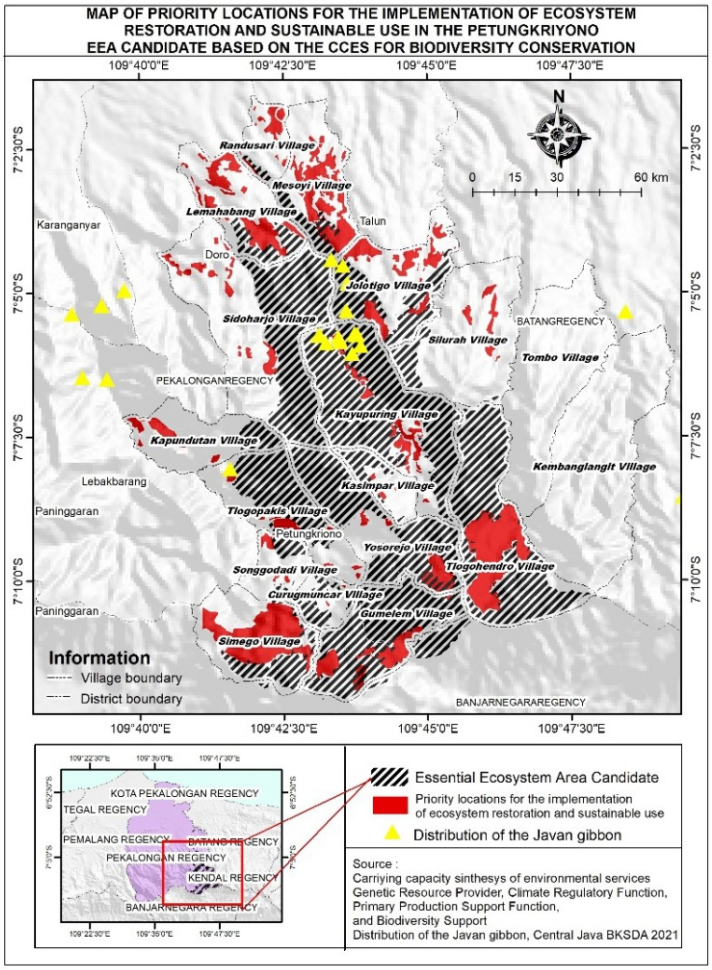

Figure 3. Map of priority locations for the implementation of ecosystem restoration and sustainable use in the Petungkriyono EEA candidate based on the CCES for biodiversity conservation

products caused by human activities, natural events, pests, and diseases, and maintaining and safeguarding the rights of the state, society, and individuals to forests, forest areas, forest products, investments, and instruments related to forest management.

The priority locations for implementing area and biodiversity conservation activities indicated that the Javan Gibbon habitats were in the priority areas based on the CCES for biodiversity conservation (Figure 2). The Petungkriyono EEA candidate management and the community could use this information to plan activities around these locations, such as preventing wildlife and natural resources exploitation and selecting areas for ecotourism activities.

The areas with low and very low CCES classes covered around 14.35% of the Petungkriyono EEA candidate and were suitable for ecosystem restoration and sustainable utilization activities (Figure 3). The dominant land covers were rice fields interspersed with other crops, paddy fields with continuous rice production, rubber plantations, and dryland agriculture with horticultural crops. These areas had a low capacity to create suitable habitats for flora and fauna and required activities to improve their CCES classes, including land and forest rehabilitation and enrichment planting using native species in the forest areas. The sustainable utilization activities in these areas include practicing natural crop cultivation, maintaining the genetic diversity in agricultural systems, producing good quality agricultural products, preserving soil fertility, avoiding pollution

from agricultural practices, and implementing agroforestry systems.

Conclusion

The information on CCES for biodiversity conservation could indicate the size and distribution of priority areas suitable for area conservation, biodiversity preservation, ecosystem restoration, and sustainable utilization activities in the Petungkriyono EEA candidate. This information could guide the authorities, communities, and other stakeholders in managing the Petungkriyono EEA candidate. Around 74.12% of the area had very high and high CCES classes for biodiversity conservation, suitable for area conservation and biodiversity preservation activities priorities. The area conservation activities could include dissemination of Petungkriyono EEA candidate boundaries, law enforcement to support the management objectives of the Petungkriyono EEA candidate, development of silviculture techniques, agricultural patterns, and tourism landscape based on CCES to control environmental disturbances, and involvement of local government and local communities (LMDH) through collaborative management with Perhutani in managing the Petungkriyono EEA candidate area. The biodiversity preservation activities could include area classification (protected and unprotected), management of flora and fauna and their habitats, and nurturing and breeding programs. Around 14.35% of the area had low and very low CCES classes for biodiversity conservation, suitable for ecosystem restoration and sustainable utilization activities priorities. The ecosystem restoration activities could include land and forest rehabilitation and enrichment planting with native species within the forest areas to improve the natural habitats of flora and fauna. The sustainable utilization activities in these areas include practicing natural crop cultivation, maintaining the genetic diversity in agricultural systems, producing good quality agricultural products, preserving soil fertility, avoiding pollution from agricultural practices, and implementing agroforestry systems.

Acknowledgment

The authors thank the Head of the Java Eco-Region Development Control Center, Ministry of Environment and Forestry, for supporting this research and providing opportunities to contribute to knowledge development. The authors are also grateful to colleagues from the Inventory Division of Environmental Carrying Capacity and Natural Resources of Java Eco-Region Development Control Center in 2021 for their cooperation and contribution to the successful completion of this research.

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SK Balai KSDA Jawa Tengah 180/IV-KKH/2015 tentang penetapan dua puluh lima satwa terancam punah prioritas