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Vulnerability of multi-designated landscape and its connectivity toward conservation: a case study in Kampar Kerumutan, Riau, Indonesia

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Abstract*. Indonesia is declared by the United Nations as a country that meets its conservation targets. However, Indonesia has not maximized the potential conservation of its territory, and the ecosystem is still threatened by anthropogenic activity, particularly due to small and large-scale cultivation. In addition, the Government of Indonesia (GoI) built taskforces at the national level to avoid greenhouse gas emissions through FOLU Net Sink 2030, which could tackle climate and biodiversity crises. Therefore, identifying other effective area-based conservation measures (OECMs) and creating a sustainable management framework by elaborating on the carbon pool and its dynamics across the Indonesian landscape is crucial for meeting the targets of the global conservation agenda. Kampar Kerumutan Landscape (KKL) is one of the critical landscapes in Indonesia with high potential conservation for biodiversity and high intervention from various concessions. Our results showed that most KKLs were potential restoration areas. Industrial forest plantations (IFP) pose the highest threat to conservation. To connect the potentially highly conserved areas within KKL for species mobility, restoration projects (particularly in the IFP, Protected Areas, and Non-managed areas) should be conducted to achieve human and natural balance in the KKL.*

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INTRODUCTION

The Convention of Biodiversity (CBD), which was enacted in December 1993, is the first global agreement aimed at the conservation and sustainable use of biological biodiversity (Chandra and Idrisova 2011). The CBD's overarching goal is to reduce the rate of biodiversity loss and safeguard the contributions of nature to people (Díaz et al. 2020). The CBD, with strategic plans and targets, becomes a binding instrument that requires countries to implement it in the form of the National Biodiversity Strategic Action Plan (NBSAP) and mainstream it into relevant sectors. Countries must also report the progress and achievements of the Convention's targets (Chandra and Idrisova 2011). One of the most important frameworks for halting biodiversity loss is 20 'Aichi Targets' (CBD Strategic implementation for 2010–2020). Although all parties have already adopted the Aichi target in the national plan, none of the Aichi targets have been fully met (Xu et al. 2021). In January 2020, the CBD secretariat released a zero-draft of new targets in the Post-2020 Global

Biodiversity Framework. In March 2020, Indonesia and 167 other countries were prepared to update a new document of strategic action on conservation planning (NBSAPs).

Two of the world's biodiversity hotspot regions with a high concentration of endemic species seriously endangered by habitat loss have been found in the Indonesian archipelago (Rintelen et al. 2017). The ecosystem is threatened by deforestation and forest degradation by many drivers, which increases the probability of species extinction (Hughes 2017). Numerous studies have reported that road development (Laurance et al. 2009), agricultural expansion (de Almeida et al. 2020), wildfires (Goldammer and Seibert 1990), and illegal logging and encroachment (Wendland et al. 2015) contribute to deforestation in Indonesia. On the other hand, one of the proposed targets in the post-2020 Global Biodiversity Framework (GBF) draft states that the government must make safeguards in the protection of 30% (30 by 30) of land and sea areas in an effort to reduce threats to biodiversity, even though Indonesia is not one of the countries that support this; not part of the High Ambition Coalition (HAC) for people and nature (Plumptre et al. 2021), when this target is agreed upon it must be a consideration for the state.

Indonesia has not yet maximized the potential conservation of its territory. The CBD has defined other effective conservation measure areas (OECMs) as areas that have critical functions for biodiversity outside of recognized protected areas (WCPA 2019). The latest report submitted to the CBD committee is that only around 15.53% of the total land and sea area is managed to improve conservation, including 733 Protected Areas, 12.2% terrestrial, 3.1% marine, and no OECMs, which is considered low because currently there are 272 (74%) areas with important biodiversity that have no coverage of protected areas and OECM (UNDP 2021). In addition, to avoid climate crisis effects at the national level, The Government of Indonesia (GoI) has built a commitment to achieve net zero emissions by 2060, particularly in forest and other land use sectors (FOLU) (MoEF 2022), which is related to the carbon dynamics within the landscape and the prevention of loss through conservation efforts and protection of biodiversity inside and outside protected areas. Therefore, identifying OECMs and creating a sustainable management framework by elaborating on the carbon pool and its dynamics across the Indonesian landscape is crucial for meeting the targets of the global conservation agenda.

One of them is located in the Kampar-Kerumutan Landscape (KKL), Riau, where 30% of its area is covered by peatland forest (Sari et al. 2021). This landscape is also home to 34 globally threatened species of plants and animals, nine plant species, ten amphibians and reptiles, and 16 mammal species, including the Sumatran tigers (RER 2020). However, in the last few years, KKL has been degraded by drainage, forest conversion to agriculture, and forest fires (Riggs et al. 2021). Several conservation NGOs (non-governmental organizations) have been working on this landscape to identify potential conservation priorities, but during that period, the landscape was mostly under various industrial concession authorities, so the exploitation of natural resources within the landscape intensively occurred (Forest Peoples Program 2011). Many industrial companies have installed drains and degraded wetlands for acacia and oil palm plantations within the KKL, which could harm biodiversity and the surrounding environment (Sari et al. 2021). Moreover, sectoral approaches to landscape management are no longer adequate to meet global challenges such as food security, biodiversity conservation, and poverty reduction (Scherr et al. 2013). Integrated landscape management can serve as a basis for balancing competing demands and integrating regulations for land use within a landscape (Reed et al. 2017). Nevertheless, characterizing landscape approaches through spatially explicit information (e.g., potential areas, vulnerability, and connectivity) should be performed a priori to gain a better understanding of landscape management.

OECMs play an important role in the Post-2020 Global Biodiversity Framework as the ‘main course’ of the next conservation agenda (Keeley et al. 2021). The potential conservation value of OECMs in Indonesia, particularly in the Kampar Kerumutan Landscape, Riau, should be revealed using the recently available information. In this study, we examined where the conservation of a multi designated landscape could be mapped to support biodiversity. This study also assessed the conservation vulnerability of biodiversity by assessing the opportunities and threats to the landscape. Furthermore, we explored habitat connectivity for one of the charismatic species in the Sumatran landscape, as habitat connectivity is essential for the future global conservation agenda (Dinerstein et al. 2020).

METHODS

Study Area

This study was conducted in the Kampar Kerumutan Landscape (KKL), Riau Province, Indonesia, with a total area of approximately 2,068,800 ha. KKL is one of the most significant landscapes on Sumatra Island, surrounded by designated anthropogenic pressures, mainly cultivation activities that might harm the biodiversity within the landscape. More than 50% of the landscape was designated as an industrial concession (e.g., an industrial forest plantation, logging concession, and oil palm plantation). Hence, only 7% of the area was occupied by the protected area (Figure 1).

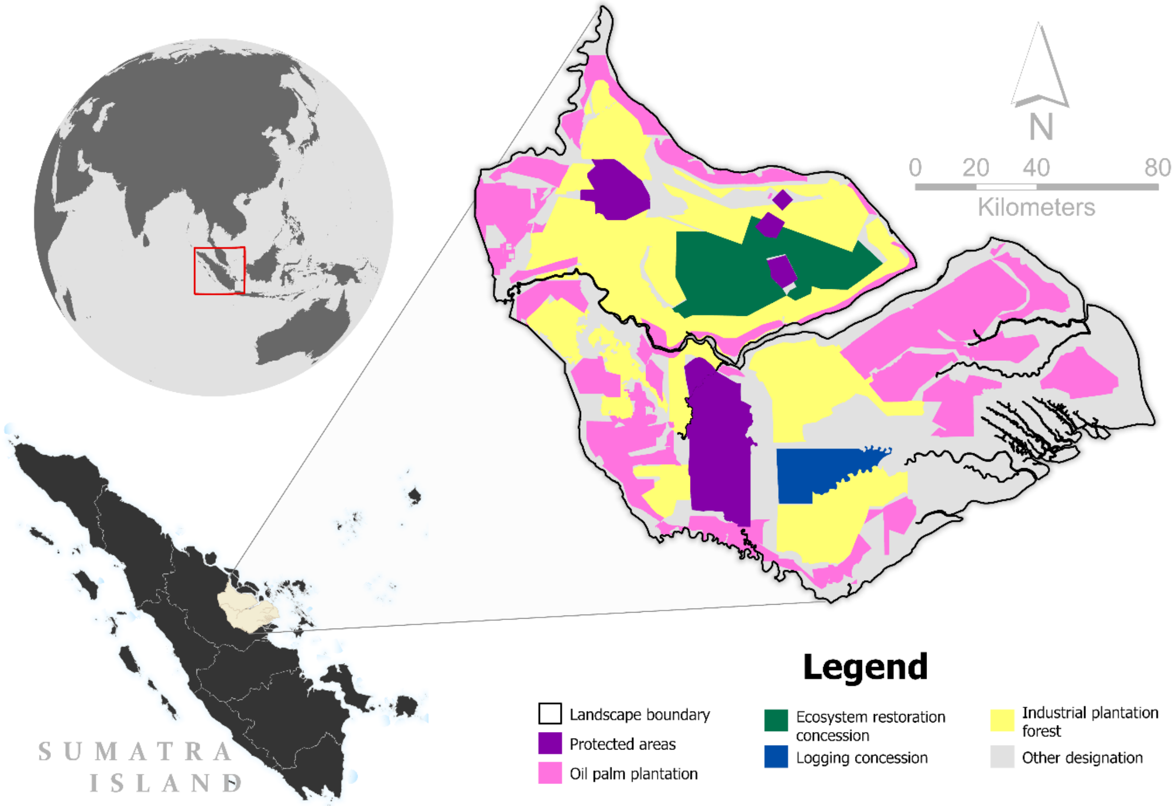

Figure 1 Map of the study area (Kampar-Kerumutan landscape and its designations)

Potential Conservation Areas Identification

We used total carbon stock spatial data to capture the opportunity for conservation within the landscape. This study used aboveground and belowground biomass carbon density datasets from Spawn et al.(2020). To capture carbon from the peatland, we used soil organic carbon data from SoilGrids version 2.0 (Poggio et al. 2021). We then accumulated the aboveground biomass, belowground biomass, and soil organic carbon to assess the potential conservation areas with high carbon stocks. We resampled the dataset to 300 m using bilinear interpolation in ArcGIS Desktop 10.5. In addition, we extracted statistical descriptions of carbon stocks (i.e., average, standard deviation, maximum, and minimum) for each designation (i.e., protected areas, logging concessions, ecosystem restoration, industrial forest plantations, oil palm plantations, and non-managed areas).

Potential Threats Identification

To assess the current anthropogenic pressure within the landscape, we used tree cover loss data version 1.9, retrieved from The Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland over the 2001–2021 period, following recent available temporal data (Hansen et al. 2013) to capture all forest dynamics within the landscape. We then performed zonal statistics (i.e., sum) for each designated area to assess the total deforestation within a multi-designated landscape in the 2001–2021 period. In addition, we calculated historical deforestation based on time-series data to capture tree cover loss dynamics within a multi-designated landscape. This study also quantified the rate of deforestation using the compound Interest Law (Saranya et al. 2022). We also used forest-extent data to capture potential areas. We generated forest cover data by creating binary classes of tree cover data from The Global Land Analysis and Discovery (GLAD) laboratory at the University of Maryland over the 2001–2021 period. An 80% threshold (Gasparini et al. 2019) was used to represent tropical humid forests within the study area. All geoprocessing analyses were conducted using the ArcGIS Desktop 10.5.

Landscape Vulnerability in the Context of Conservation

In this study, we elaborated on the total carbon stocks with net carbon fluxes to determine the conservation vulnerability of the landscape. We classified the carbon stocks and net carbon flux into three classes to represent ordinal potential carbon pools and carbon dynamics due to anthropogenic activities, respectively, using a bivariate plot following the vulnerability assessment of Watson et al. (2013). Areas with high potential carbon stocks and low exposure to net carbon flux were classified as potential conservation areas. In contrast, areas with low potential carbon stocks and high exposure to carbon emissions were classified as highly vulnerable to conservation.

Habitat Connectivity for Critical Species

In addition to assessing the conservation value based on carbon entities, we also measured the critical aspect of forest connectivity for biodiversity conservation. We highlight Sumatran tigers (*Panthera tigris sondaica*) as an umbrella species for landscape conservation in KKL. In this study, wildlife corridor identification was conducted to represent the habitat connectivity of Sumatran tigers. Most studies have used circuit-based approaches to predict wildlife corridors (Dickson et al. 2019; Hodgson et al. 2016; Saura and Rubio 2010). This study performed least-cost corridor and path analysis using the SDMToolbox plugin (Vandergast et al. 2011) in ArcGIS Desktop to identify Sumatran tiger connectivity based on potential conservation patches within the study areas. We also used the inversion of habitat suitability for the Sumatran Tigers, retrieved from Rahman et al. (2022), as the friction layer for corridor analysis. This friction layer reflects landscape permeability, cost of energy, movement difficulties, and mortality risk associated with species dispersal (Scriven et al. 2015).

RESULTS

Potential High Carbon Stocks

Combining living biomass and soil organic carbon, the results found that the average carbon stock in KKL was 859.90 ± 400.46 MgC per ha with a total carbon stock of 1,778.97 (950.50–2,607.44) TgC. The highest carbon stock average was located in protected areas (PA) with 1,218.33 ± 311.23 MgC per ha. Extrapolated to the total PA area of 669,968 ha, the amount of carbon stock in KKL's protected areas was 816.24 (1,024.76–607.73) TgC. For Ecosystem Restoration Areas (ERA), the average carbon stock was 1,157.55 ± 279.16 MgC per ha. Extrapolated to the total ERA area of 130,259 ha, the amount of carbon stock in Kampar Kerumutan's ERA was 150.78 (114.42–187.15) TgC. For Logging Concession (LC), the average carbon stock was 989.57 ± 305.31 MgC per ha. Extrapolated to the total LC area of 44,493 ha, the amount of carbon stock in Kampar

Kerumutan's LC was 44.03 (30.45–57.61) TgC. For Industrial Forest Plantation (IFP), the average carbon stock was 916.15 ± 370.51 MgC per ha. Extrapolated to the total IFP area of 490,931 ha, the amount of carbon stock in Kampar Kerumutan's IFP was 449.76 (267.87–631.66) MgC. For non-managed areas (NA), the average carbon stock was 800.43 ± 390.47 MgC per ha. Extrapolated to the total NA area of 701,402 ha, the amount of carbon stock in Kampar Kerumutan's NA was 561.42 (287.55–835.30) MgC. The lowest carbon stock average was in oil palm concession (OP) with 693.22 ± 385.88 TgC. Extrapolated to the total OP of 592,881 ha, the amount of carbon stock in Kampar Kerumutan's OP was 816.24 (607.73–1024.76) MgC (Figure 2).

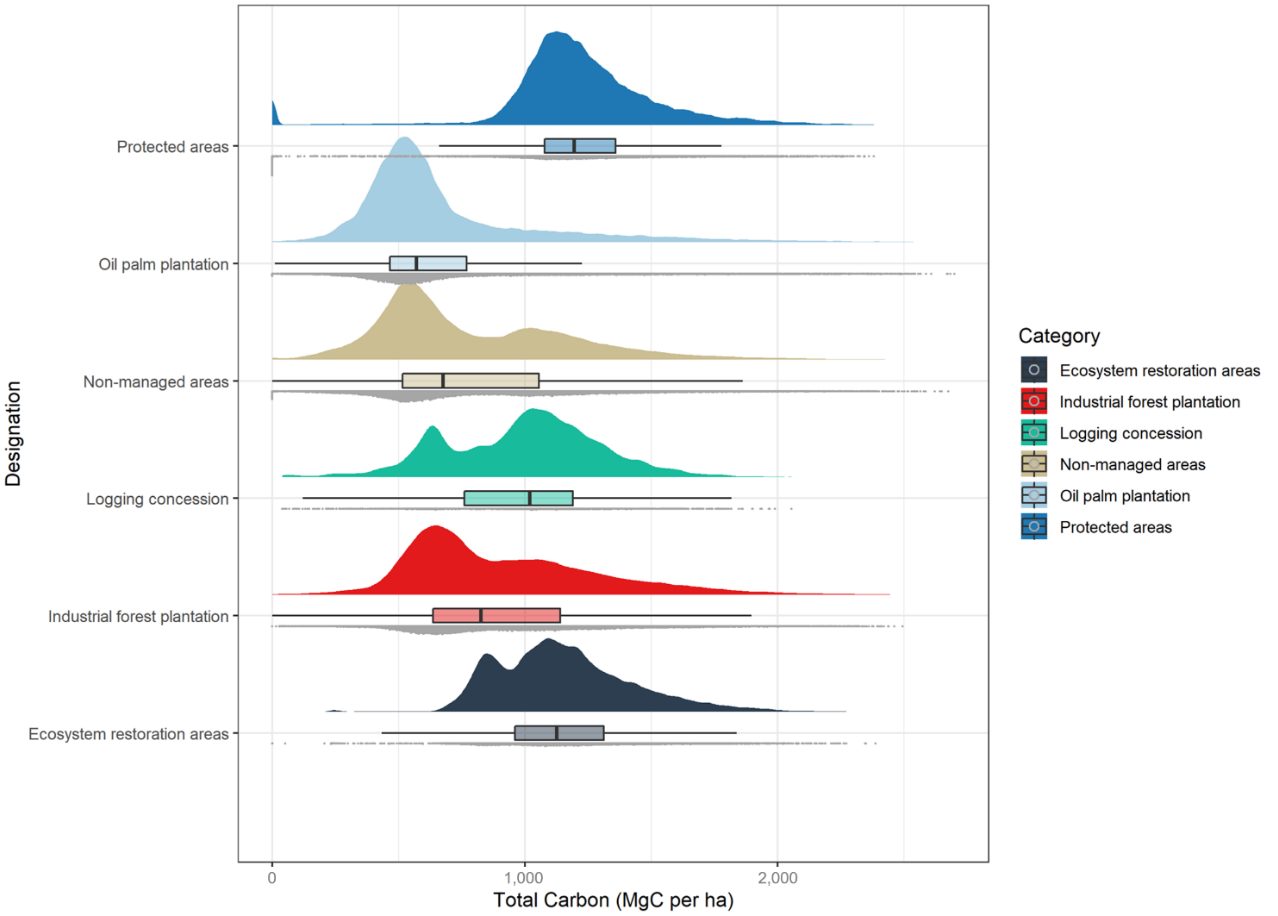

Figure 2 Total carbon density within the multi-designated Kampar Kerumutan Landscape

Historical Deforestation

From a general landscape perspective, this study found that overall deforestation in the Kampar Kerumutan landscape from 2001–2021 was accumulated to 908,593 ha, with a linear rate of 45,430 ha per year or 44% based on the Compound Interest Law (CIL) (Figure 3). The highest deforestation was located in IFP areas with a total area of 403,368 ha (Linear Rate: 20,168 ha per year, CIL: 82%), following OP with a total area of 275,172 ha (Linear rate: 13,759 ha per year, CIL: 46%), NA with total area of 701,402 ha (Linear rate: 11,285.46 ha per year, CIL: 32%), LC with a total area of 21,573 ha (Linear rate: 1,079 ha per year, CIL: 48%), PA with a total area of 3,204 ha (Linear rate: 160 ha per year, CIL: 0%) and ERA with a total area of 965 ha (Linear rate: 48 ha per year, CIL: 1%).

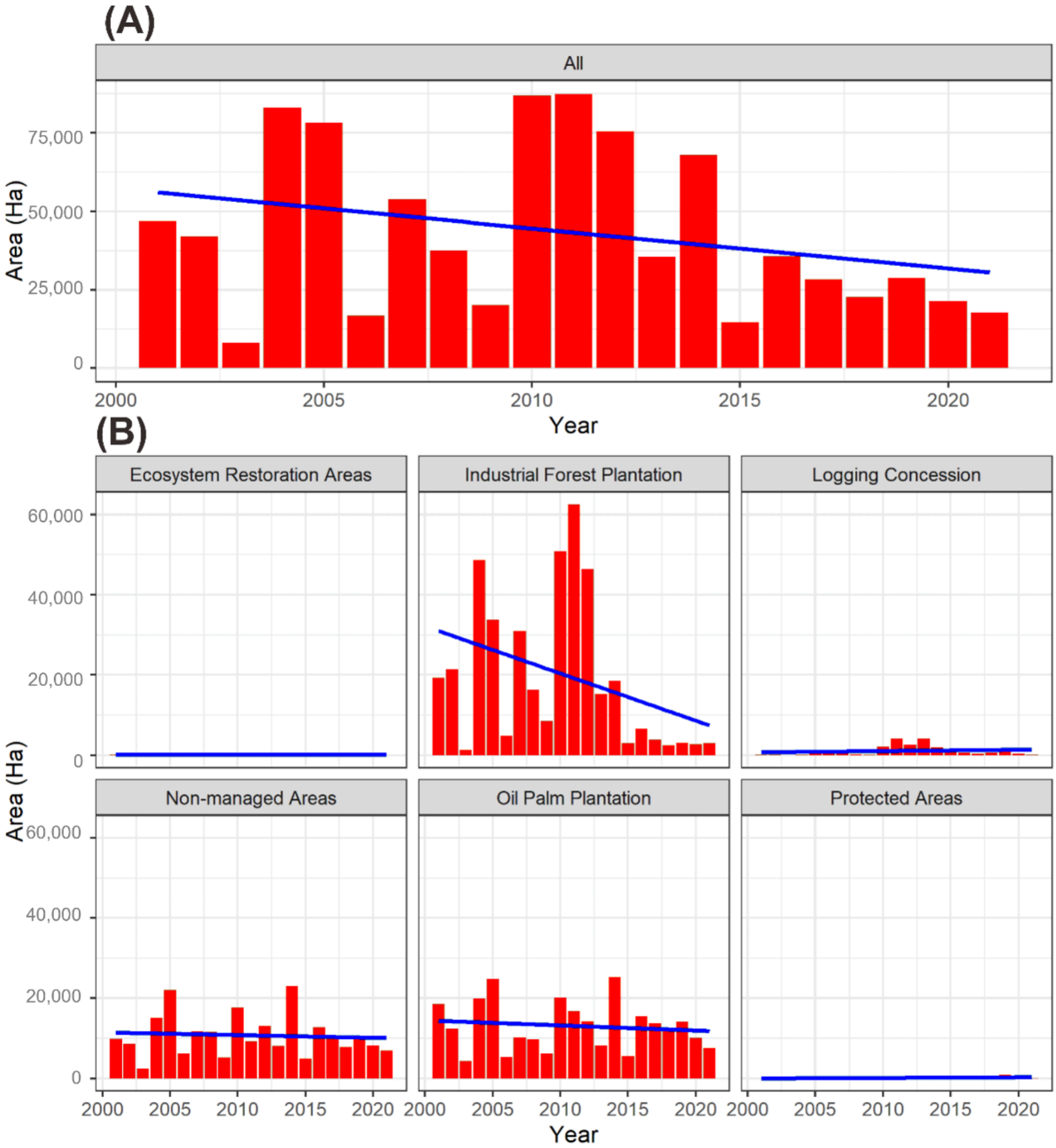

Figure 3 Historical deforestation over 2001–2021 in whole landscape (A) and each landscape designation (B) (the red bars indicate annual forest loss in hectares and the blue lines depict historical deforestation trends over the period)

Forest Carbon Dynamics

The results found that the overall landscape of Kampar Kerumutan's carbon net flux was 29.38 Tg CO_2eq per year, with a total carbon emission of 46.92 Tg CO_2eq per year and –17.54 Tg CO_2eq per year carbon removal. Only two of the designated areas were carbon net sinks, which are the PA and ERA, with total sinks of –113,786.75 and –188,946.12 Mg CO_2eq per year. The highest net carbon flux comes from IFP with a total amount of 21.04 Tg CO_2eq per year with carbon emission and removal of 29.91 Tg CO_2eq per year and –8.86 Tg CO_2eq per year. OP area releases 6.36 Tg CO_2eq per year with a total carbon emission of 7.94 Tg CO_2eq per year and –1.57 Tg CO_2eq per year carbon removal. The non-managed areas release 2.16 Tg CO_2eq per year with a total carbon emission of 8.85 Tg CO_2eq per year and –6.69 Tg CO_2eq per year carbon removal, while LC releases 1.02 Tg CO_2eq per year with a total carbon emission of 1.24 Tg CO_2eq per year and –222,267.07 Mg CO_2eq per year carbon removal (Figure 4).

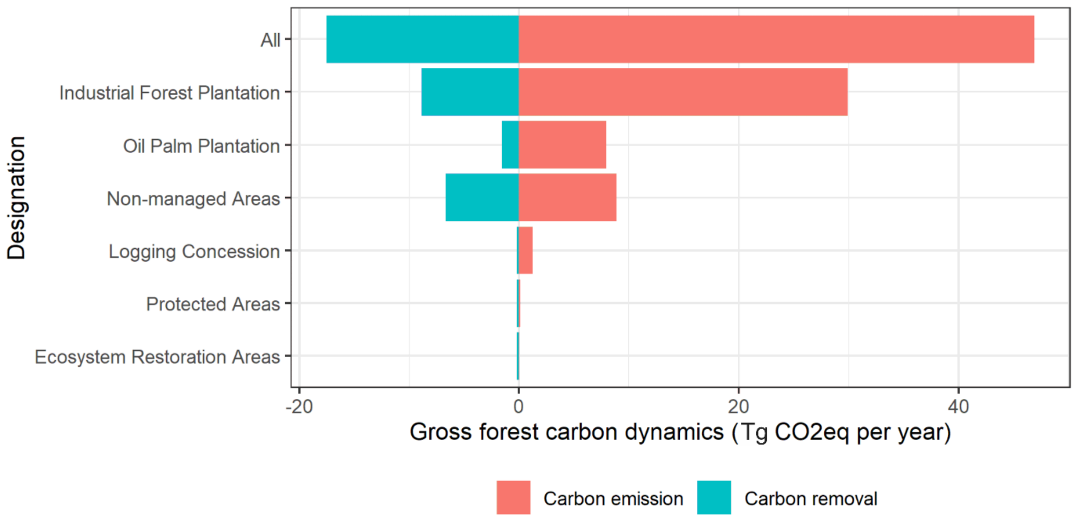

Figure 4 Forest carbon balance for 2001–2021 across the multi-designated landscape of KKL

Conservation Vulnerability

In this study, we divided vulnerability classification into five categories (Figure 5): i) less important areas, ii) potential conservation areas, iii) potential restoration areas, iv) high-risk areas, and v) very high-risk areas. This study found approximately 177,083 ha (~9%) of high-risk and very high-risk areas for conservation within all landscapes, with the most vulnerable areas occurring in industrial forest plantations (101,238 ha). We proposed potential conservation areas within a landscape of approximately 205,747 ha (~10%), with the majority found in non-managed areas (54,262 ha). The potential restoration has the highest area in the landscape (~53%), that is, 1,076,579 ha. Industrial forest plantations were also considered the highest area for potential restoration, with a total area of approximately 379,715 ha.

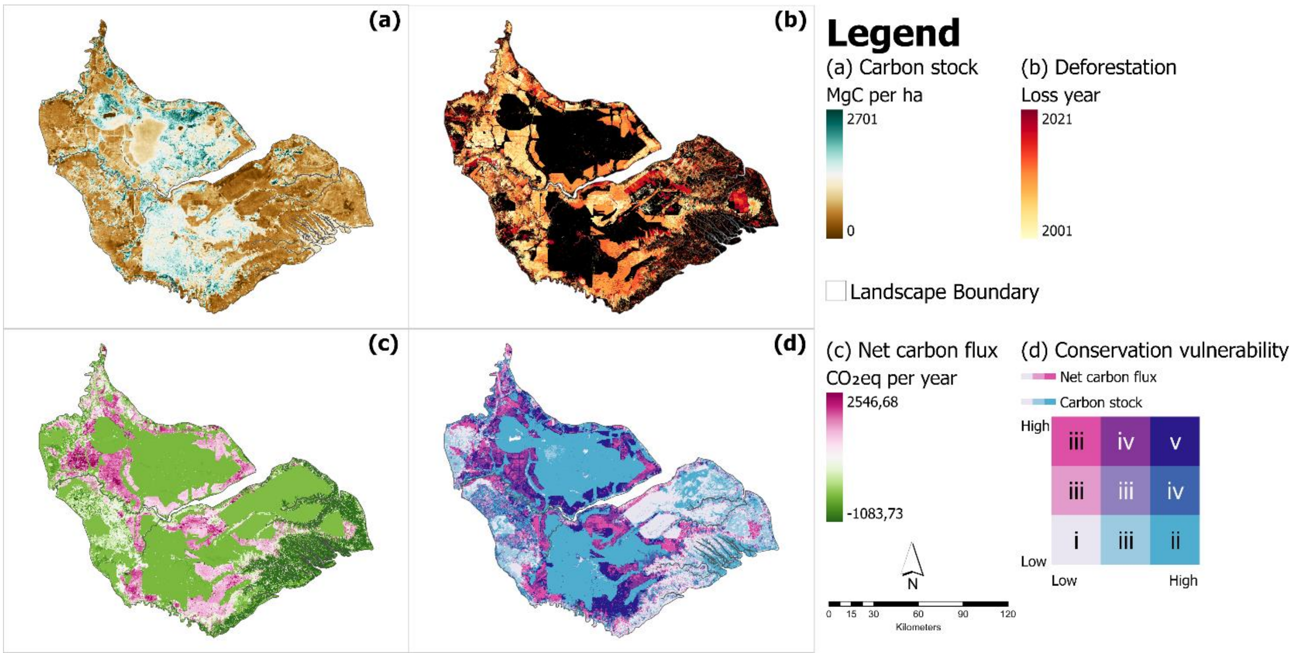

Figure 5 Spatial assessment of conservation vulnerability based on carbon pool and flux carbon dimensions; (a) Carbon stock, (b) annual deforestation, (c) net carbon flux, and (d) vulnerability bivariate map: i) less important areas, ii) potential conservation areas, iii) potential restoration areas, iv) high-risk areas, and v) very high-risk areas

Corridor Analysis for Sumatran Tiger

The least-cost path analysis revealed that wildlife corridors could be constructed predominantly in industrial forest plantations (28.47%). This study found that 26.66% of the proposed wildlife corridors could be developed in protected areas. Non-managed areas also made a relatively high contribution to wildlife corridor development (13.97%). Figure 6 depicts the explicit location of the wildlife corridor throughout the landscape. As a top predator in tropical rainforest ecosystems, Sumatran tigers can maintain the stability of the food chain from producers to species with a lower trophic level. Therefore, conserving this species will support its conservation and maintain ecological processes within their habitats (WRI 2016).

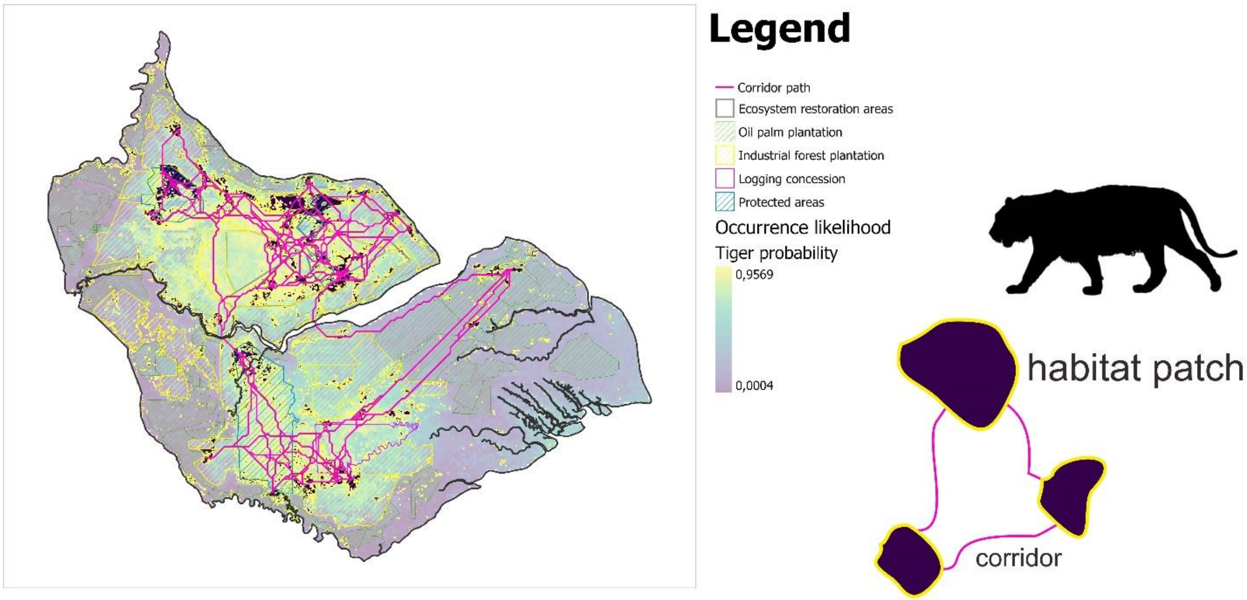

Figure 6 Landscape connectivity of Sumatran tigers as an umbrella species of KKL

DISCUSSION

KKL is an essential landscape in the Sumatera region that has suffered multifaceted disturbances due to large-scale cultivation activities (Margono et al. 2012). This study provides novel insights to support the national conservation agenda to strengthen sustainable management and conservation planning at the landscape level. The results showed that KKL has a large potential carbon pool, contributing approximately 1.4% of the world's irrecoverable carbon (Noon et al. 2021). The results indicated that the protected areas functioned effectively for carbon sequestration. This corresponds closely with other previous studies in Sumatra conducted by Condro et al. (2022) in Leuser PA and 39 other PAs (Gaveau et al. 2009). In addition, this landscape also harbors many endangered species within high carbon stock areas, so large carbon pools provide co-benefits for biodiversity (Deere et al. 2018).

The negative consequences of environmental disturbance, such as deforestation within the tropical ecosystem, are long-term and far-reaching, and include the biodiversity crisis, impairment of water regulation services, and greenhouse gas emissions (Foley et al. 2011). This study revealed that deforestation within KKL was relatively high, with an average national deforestation rate of 9% in Indonesia. This study indicated that the expansion of timber, oil palm plantations, and other anthropogenic activities (e.g., illegal logging and encroachment) were the main drivers of deforestation in the KKL, which is strongly related to the high demand for timber of all types and other resources from Riau and its neighboring provinces. Industrial plantation forests have potential commercial and ecological benefits. Ecologically, it helps maintain biomass and carbon dioxide while reducing carbon dioxide emissions, while economically, it serves as the primary source of raw materials for several industries (Primahardasni et al. 2022).

A previous study also showed that palm oil plantations caused large deforestation in the Sumatran landscape (Austin et al. 2019), whereas another study showed the expansion of industrial timber plantations (Margono et al. 2012). Our study also suggests that protected and ecosystem restoration areas were effectively used to safeguard biodiversity from deforestation. These results are also aligned with those a of previous study by Gaveau et al. (2009), which revealed that the protected areas could effectively reduce deforestation in Sumatra. We also found that historical deforestation continues to decline from to 2001–2021 within the landscape owing to sustainable management regulations at the regional and national levels (Gaveau et al. 2019), which can create a higher price of palm oil that can be harmful to society (Gaveau et al. 2022). Although we found relatively high carbon removal activities within industrial forest plantations, palm oil plantations, and non-managed areas, our findings showed that the net carbon flux was still positive, indicating that most areas were responsible for the carbon source.

Many previous studies have suggested that agricultural concessions need areas with high conservation values to support their native species (Bugalho et al. 2016; Scriven et al. 2015). Our study provides potential areas for conservation within the landscape for all designations. This result suggests that ~10% of the landscape, particularly in non-managed areas, should be considered new areas with conservation outcomes. OECMs are considerably effective for conservation, are ecologically representative, and are integrated into a broader landscape (Donald et al. 2019). The recognition of areas that are not part of a formal protected area network could empower multi-stakeholder interactions and increase their responsibility for maintaining sustainable management (Alves-Pinto et al. 2021). The Directorate General of Nature Resources and Ecosystem Conservation under the Ministry of Environment and Forestry of Indonesia (MoEF) has recognized OECMs as the essential ecosystem area (EEA) (Tropenbos 2019). Therefore, our study also identifies potential areas that can be recognized as EEA.

In addition, our findings suggest that more than 50% of the landscape should potentially function as a restoration area. More than 100 million hectare of restoration commitments have been pledged globally, and Indonesia has contributed to 20% of the global restoration target (Brancalion et al. 2019). The success of landscape restoration relies on multiple parameters, such as land tenure security, local disturbance, and legal instruments (Barlow et al. 2016), to address climate and biodiversity crises. Focusing restoration investments on landscapes with high benefits and feasibility would leverage the potential to reduce anthropogenic impacts and increase the well-being of society (Dinerstein et al. 2020). In addition, improving the connectivity of habitat through wildlife corridors is also crucial for enhancing biodiversity protection, whereas most conservation plans fail to deal with corridors or connectivity (Dinerstein et al. 2017). Our findings suggest that more than 50% of the potential corridors should have thrived in KKL. The most fragmented forest patches that require extensive restoration as wildlife corridors to achieve connectivity are industrial forest plantations, ecosystem restoration, and non-managed areas. However, guidance documents and tools to assist stakeholders in managing their land as wildlife corridors should be created (Gregory et al. 2021). The Indonesian government has a strong commitment to reducing greenhouse gases from the forestry and land use sector through the FOLU Net Sink 2030 program (MoEF 2022). Our findings can be useful for fulfilling the FOLU Net Sink agenda for specific conservation targets, particularly: i) assessment of essential ecosystems (OECMs) through natural mechanisms and rehabilitation/restoration based on its vulnerability level; ii) providing a holistic approach to create landscape connectivity for biodiversity; and iii) providing an insight from historical carbon net flux data to obtain baseline values on carbon emission and removal to support FOLU Net Sink 2030 monitoring and evaluation.

Based on the guidelines for recognizing and reporting OECM by IUCN (WCPA 2019), KKL is dominated by ancillary conservation, which refers to areas that provide in-situ conservation from management activities, such as commercial timber supply. Although providing spatially explicit information regarding how to fulfill conservation targets at the landscape level is critical, further studies related to the challenges for the human-biodiversity nexus should be addressed, and all areas that have been assessed should be screened to meet the specific case; for example, socioeconomic factors, including government and stakeholder assessment, should be conducted at the local level for a finer understanding of conservation management and planning, particularly in the landscape to meet the OECM criteria.

CONCLUSION

In this study, we examined where the conservation of a multi designated landscape could be mapped to support biodiversity. This study provides comprehensive information in a 'bird-eye view' to capture landscape vulnerability towards conservation and how to deal with the multifaceted threats through connectivity under the multi-designated landscape of Kampar Kerumutan, Riau, Indonesia. Most KKLs were categorized as potential restoration areas (~53% of the landscape). Industrial forest plantations had the highest risk for conservation based on carbon pool and activity perspective (carbon emission rate: 29.91 Tg CO2eq per year). Besides, our findings showed that ~28% and ~27% of wildlife corridors could be potentially developed inside industrial plantation areas and protected areas, respectively. To connect the potentially highly conserved areas within KKL for species mobility, restoration projects (particularly in the IFP, Protected Areas, and Non-managed areas) should be conducted to achieve human and natural balance in the KKL.

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