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Connecting the fragmented habitat of endangered mammals in the landscape of Riau–Jambi–Sumatera Barat (RIMBA), central Sumatra, Indonesia (connecting the fragmented habitat due to road development)

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A B S T R A C T

The trend of wildlife habitat fragmentation worldwide continues as a result of anthropogenic activities on development of a linear infrastructure and land use changes, which is often implemented as part of spatial planning policies. In this paper we expand upon an existing approach to design wildlife corridors through habitat quality assessment. We used models of Habitat Quality of Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) and Corridor Design tools. The habitat quality model of InVEST provides a rapid approach to assess status and change of biodiversity, and can contribute to enhanced corridor design of fragmented wildlife habitat. We conducted an assessment of habitat quality of the RIMBA corridor landscape, which is part of Riau, Jambi and West Sumatra provinces of central Sumatra Island. The result of the habitat quality model was used as the main input to evaluate habitat connectivity and assess the target segment of roads that cross the modelled corridor. We found 20 wildland blocks, the total area of the corridor modelled including wildland blocks was calculated as about 0.77 million hectares. We have obtained accurate quantitative measurement of the length of roads crossing the corridor, with a total of 417.78 km (artery 10.31 km; collector 19.52 km; and local 1987.9 km roads). This method can be replicated as an approach in valuing the quality of habitat as part of the implementation of the presidential decree of Sumatra Island Spatial Planning. This may also be applied to the spatial planning of other major islands in Indonesia and elsewhere.

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1. Introduction

The impact of anthropogenic activities on land use worldwide includes accelerated deforestation and habitat fragmentation caused by conversion for other land use purposes and infrastructure development, further contributing to declining local biodiversity (Newbold et al., 2015). A global study on road impact showed that considering the location of human and environmental systems such as agricultural areas and natural forest when developing roads can help to avoid environmental costs of habitat fragmentation and maximize the human benefit from roads, especially in the case of agriculture (Laurance et al., 2014). However, further effort is required to conduct these types of analyses at the national and sub-national level—especially in high biodiversity areas like Indonesia and Madagascar. This will help define optimal strategies for road zone development, including improving cost effectiveness of road design and networks for countries, provinces and districts (Laurance et al., 2014; Mustapha et al., 2012).

Efforts to rehabilitate the connectivity of habitats are strategically conducted from region to local levels. Habitat connectivity maintains the home range of viable populations, and provides the opportunity for enhanced genetic flow of plants and wildlife. Reviews of habitat connectivity from different regions (such as Europe, Latin America, Asia, the Pacific, and Africa) conclude that conservation planning approaches improve preservation of biodiversity at the level of ecosystem, eco-region, and landscape. Moreover, the habitat connectivity approach can be integrated into regional development plans; this would change the paradigm from current protected areas "as islands" to analysing connectivity as a network system and a part of local, national, regional and international systems (Bennett and Mulongoy, 2006). Furthermore, several studies have used this lens to emphasize the impact of construction – including roads, railways, and other linear infrastructure—at the local level on wildlife habitat, such as birds and large mammals, including deer in California and Arizona (Beier et al., 2006), jaguars in Mexico (Colchero et al., 2011) and pandas in China (Wang et al., 2014). According to the existing literature, several ways exist to restore fragmented habitats, including forest restoration (Bhagabati et al., 2014) and by creating artificial connectivity (Liu et al., 2005), such as animal bridges or eco-road construction. The idea of eco-roads is to replace conventional road construction, which includes tactics like cut off mountains and filling valleys. Eco-roads involve adopting the ecological principle of connectivity—in essence, the road is not a barrier, but it can allow movement of animals from one side to the other without an accident and minimize human disturbance (Morelli et al., 2014; Wang et al., 2014; Corlatti et al., 2009; Beier et al., 2006).

The main challenge of biodiversity conservation efforts is maintaining habitat quality and connectivity in the face of anthropogenic disturbance (Wang et al., 2014). Road development can be a main factor in triggering a snowball effect of habitat degradation. Several studies have demonstrated the negative impact of roads, such as habitat loss due to conversion, increased human disturbance including encroachment due to ease of access, mortality caused by traffic accidents, and roads acting as barriers to species movement) (Morelli et al., 2014; Basille et al., 2013; Gaveau et al., 2009). Therefore, crossings for animals are required to reduce accidents, including ecoducts (wildlife bridges) and tunnels (Beben, 2012; Bennett and Mulongoy, 2006). Although road network density in Indonesia is low compared to China, India, Malaysia, Thailand and the Philippines, the investment for road development is still growing, which is expected to continue in the future. The total of the current road network (km) distribution in Indonesia is 60% in Sumatra and Java Islands. Sumatra has the highest road network density compared with major island groups in Indonesia (Java-Bali, Kalimantan, Sulawesi, Maluku, Papua and Nusa Tenggara) (Mustapha et al., 2012).

In Indonesia, many conservation areas are inclined to be discrete locations, and there is poor access to connect one location to another due to linear infrastructure, mainly roads development. Although there are efforts to avoid deforestation and fragmentation, these are not sufficient to prevent the tendency towards isolated protected areas in a matrix of road networks. Furthermore, local strategies to determine scenarios for sustainable land use and eco-friendly infrastructure development for preserving biodiversity and connectivity of wildlife habitat are unclear. A comprehensive study on forest cover loss mapping in Indonesia estimated 6 million ha (hectare) of primary forest loss from 2010 to 2012, and in Sumatra about 2.86 million ha (Margono et al., 2014). One consequence of this deforestation is that species dispersal ability can be disturbed, which negatively affects gene flow (Leblond et al., 2013; Proctor et al., 2012).

The importance of the island of Sumatra is highlighted by its classification as a priority place of global biodiversity. The 2015 Global Living Planet Report released by World Wildlife Fund (WWF) mentions that infrastructure development is projected to be one of the drivers of future deforestation in Sumatra. Therefore, road development should be designed to properly reduce deforestation risk and the resulting threats to remaining biodiversity areas and habitat connectivity (Taylor et al., 2015). Because Sumatra faces these multiple challenges of deforestation and other forms of anthropogenic disturbance but currently has a primarily isolated protected area network, it is crucial to promote novel approaches for regional development that are effective in minimizing the impacts of road and other linear infrastructure on wildlife habitat quality (Laurance et al., 2014; Leblond et al., 2013; Schuster et al., 2013; Pagnucco et al., 2012). To preserve the remaining Sumatra ecosystem, Indonesia's government has developed island spatial planning regulation and recognized corridor ecosystems as critical for connecting protected areas and homeranges for large mammals (such as tigers and elephants) and birds. The corridor RIMBA (**Ri**au, Ja**m**bi and Sumatera **Ba**rat provinces) has been designated as one of five such corridors within Presidential Decree No 13/2012 in the Sumatra Island spatial plan (article 48). This study can help inform the adjustment of the RIMBA corridor boundary that has been delineated by the provincial government; the corridor boundary has never been previously evaluated.

In this study, we used three models. First, the habitat quality model of integrated valuation of ecosystem services and trade-offs (InVEST), which is a tool to spatially describe habitat sensitivities and threats of anthropogenic disturbance (land