

# Development Corridors and Remnant-Forest Conservation in Sumatra, Indonesia

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Sean Sloan<sup>1</sup> , Mohammed Alamgir<sup>1</sup>, Mason J. Campbell<sup>1</sup>,  
Titiek Setyawati<sup>2</sup>, and William F. Laurance<sup>1</sup>

## Abstract

Road-infrastructure development in Southeast Asia is opening new resource frontiers but also consolidating earlier investments in agriculture and trade, as illustrated by the 2,700-km Trans-Sumatra Highway planned for Sumatra, Indonesia. In contrast to earlier broadscale forest losses in Sumatra, driven historically in Sumatra infrastructure and agricultural expansion, the Trans-Sumatra Highway would largely affect remnant forests. We identify Kerinci Seblat National Park and its surrounds, the Leuser Ecosystem, and the Batang Toru area as three remnant-forest areas critical to Sumatra's ecological integrity and facing conservation challenges that would be significantly aggravated by the Trans-Sumatra Highway. If completed as planned, the highway will promote human incursions into the fringes of these areas. New Indonesian regulations concerning road developments in forests are unlikely to prevent such outcomes. The regulations afford weaker protections to ungazetted and *noncore* protected forests, which typify remnant-forest areas threatened by infrastructure expansion and are often critical for species conservation. We urge that ungazetted protected forests be given equal priority to gazetted protected forests in regard to conservation planning for road development, and also that gazetted forests be expanded in the Leuser Ecosystem and Batang Toru area to hedge against further incursions. Without such provisions, recent legal challenges to road developments in Sumatra's remnant forests have often been unsuccessful. The Trans-Sumatra Highway may conceivably promote an effective legal alliance between conservationists and agricultural communities threatened with land expropriation, given that nearly half of the highway's route remains pending contentious land-acquisition processes.

## Keywords

Sumatra, infrastructure, roads, corridor, conservation, development, remnant forest

## Introduction

Road-infrastructure expansion is a major factor in conservation and development planning across the Global South (Infra Eco Network Europe, 2014; Selva, Switalski, Kreft, & Ibisch, 2015; Venter et al., 2016). Road length is projected to increase ~20% to 60% globally by 2050, largely in developing countries (Laurance et al., 2014; Meijer, Huijbregts, Schotten, & Schipper, 2018). Such trends reflect the proliferation of infrastructure mega-projects to open sparsely populated areas (Ascensão et al., 2018; Laurance, Sloan, Weng, & Sayer, 2015; Sloan, Bertzky, & Laurance, 2016) but also the consolidation of agricultural developments in more settled regions. These two thrusts converge in Southeast Asia, as illustrated by elements of the Chinese Belt and Road Initiative (Ascensão et al., 2018;

Laurance, 2018; Lechner, Chan, & Campos-Arceiz, 2018) and various economic-development corridors across Indonesia, Malaysia, and Papua New Guinea (Alamgir, Campbell, Sloan, Suhardiman, & Laurance, 2019; Alamgir, Sloan, Campbell, Engert, & Laurance,

<sup>1</sup>Centre for Tropical Environmental and Sustainability Science, College of Science and Engineering, James Cook University, Cairns, Australia

<sup>2</sup>Wildlife Conservation Society, Bogor, Indonesia

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### Corresponding Author:

Sean Sloan, Centre for Tropical Environmental and Sustainability Science, College of Science and Engineering, James Cook University, Cairns, Queensland 4870, Australia.  
Email: sean.sloan@jcu.edu.au

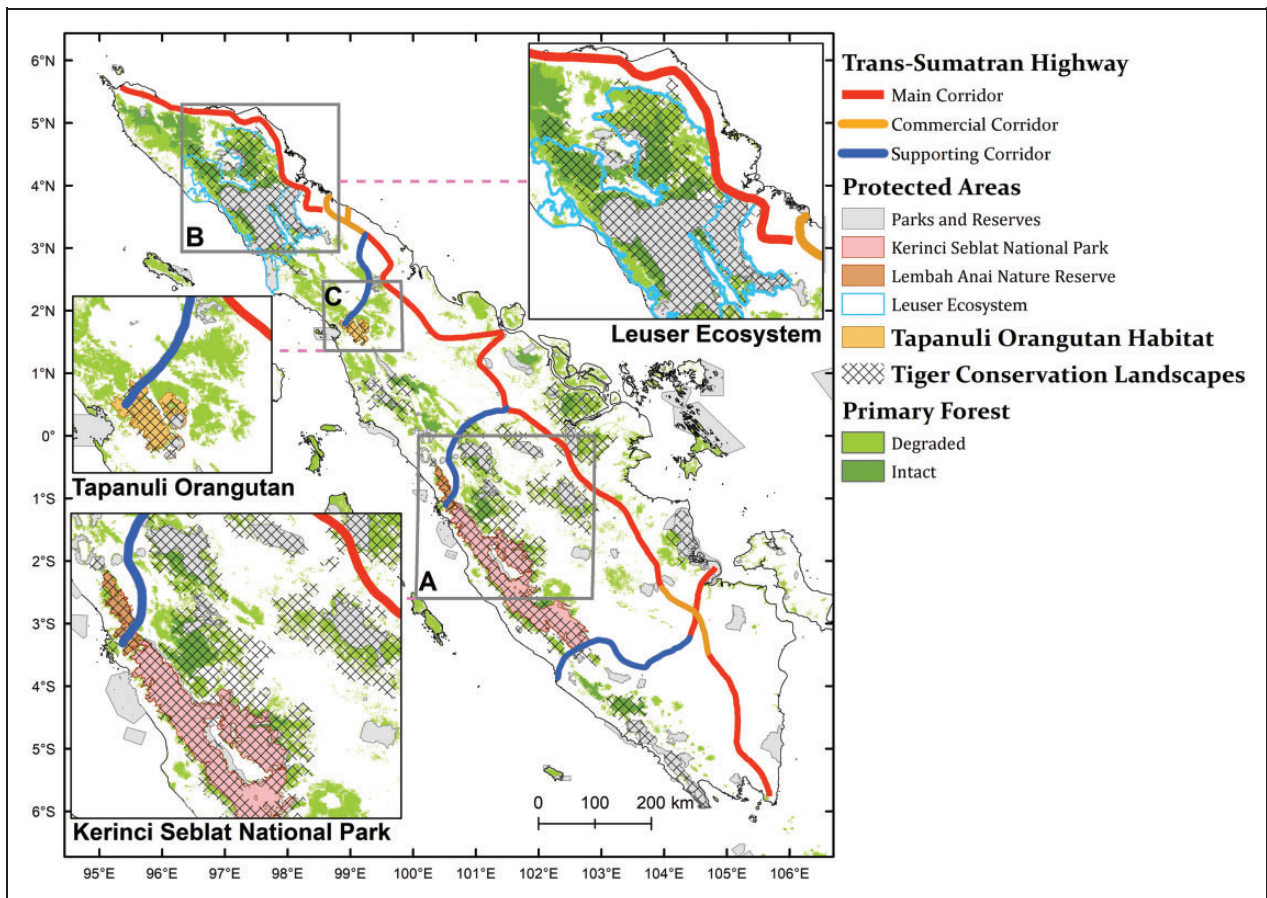


2019; Coordinating Ministry for Economic Affairs, 2011; Sloan, Campbell, Alamgir, Engert, et al., 2019; Sloan, Campbell, et al., 2018; Sloan, Campbell, Alamgir, Lechner, et al., 2019). Here, we assess the conservation implications of major road expansion plans for Sumatra, Indonesia, considering the legacy of prior road developments and related conservation challenges.

Indonesia is rapidly expanding economic-development corridors across its major islands in a bid to boost economic growth (Coordinating Ministry for Economic Affairs, 2011). Differences among the economic and environmental contexts of Indonesia's islands preclude a generalized conservation strategy in relation to these corridors. For instance, whereas the Trans-Papuan corridor would open remote forest areas to

historically limited agro-industrial development in the Papuan region of eastern Indonesia (Sloan, Campbell, Alamgir, Engert, et al., 2019), the Trans-Sumatran corridor would integrate decades of prior agricultural, mining, and road developments to boost commodity exports from Sumatra.

The Trans-Sumatran corridor, hereafter the Trans-Sumatran Highway (Figure 1), thus represents a *second wave* of agro-economic development and conservation planning. Much as is occurring in Papua today, the original Sumatran highway of the 1980s shifted road networks and land-use patterns away from riverine swidden cultivation and toward new agricultural concessions and transmigration settlements (Fearnside, 1997; Miyamoto, 2006; Murdiyarso, Van Noordwijk,



**Figure 1.** The proposed Trans-Sumatra Highway and priority remnant-forest areas for conservation and development planning. The status of primary forests within the colored forest areas of sites A, B, and C is generally *intact*, that is, not previously exploited. Primary forests were classified using Landsat satellite imagery by Margono, Potapov, Turbanova, Stolle, and Hansen (2014) for 2000–2012 and reflect official forest designations relevant to forest licensing and agricultural development. Orangutan habitat at site C is the sole range of the Tapanuli orangutan (*Pongo tapanuliensis*) according to Nater et al. (2017). Tiger conservation landscapes are estimated tiger ranges according to Dinerstein et al. (2007). Protected areas are according to The World Database on Protected Areas (International Union for Conservation of Nature & UN Environment Programme-World Conservation Monitoring Centre, 2015). Note that the Leuser Ecosystem is not a gazetted protected area but rather holds a lesser status as a National Strategic Area for ecosystem-service protection (Sloan, Campbell, et al., 2018). The highway is according to a 1:7 million-scale map produced by the Executive Office of the Indonesian President such that its actual local alignment may vary slightly to that shown.

Wasrin, Tomich, & Gillison, 2002). Rapid broadscale forest loss resulted, underlying Sumatra's position as global epicenter of tropical deforestation, fires, and air pollution. Also as is occurring in Papua today, prior conservation planning in Sumatra sought to establish new protected areas and improve the licensing transparency of agricultural, timber, and mining concessions. In contrast, much of the proposed 2,700 km Trans-Sumatran Highway will traverse previously cleared lands and thus is less likely to provoke broadscale deforestation and associated conservation strategies (Rudel, 1996; Rudel, DeFries, Asner, & Laurance, 2009).

In Sumatra, current schemes for infrastructure development are more likely to increase pressures on remnant forests and promote spontaneous agricultural incursions (Gaveau et al., 2009; Sloan, Campbell, et al., 2018). Maintaining the legal and physical integrity of remnant forests is therefore likely to figure prominently in conservation strategies surrounding the Trans-Sumatra Highway. The planned highway entails segments crossing the last major domain of remnant forest along the island's central uplands (Figure 1). Remnant forests in Sumatra have recently been degraded or lost following nearby road developments (Clements et al., 2014; Linkie, Smith, & Leader-Williams, 2004; Wich et al., 2016), including in national parks (Poor, Frimpong, Imron, & Kelly, 2019; Poor, Jati, Imron, & Kelly, 2019), and we presume this trend will continue. Here, we highlight three remnant forest areas that are critical to Sumatra's ecological integrity and which face conservation challenges that the Trans-Sumatra Highway would aggravate (Figure 1). In this context, we emphasize that remnant-forest conservation will require a more inclusive view of protected forests and a greater focus on local governments and agricultural communities.

## Conservation and Development in Priority Remnant Forests

### *Development Pressures in Kerinci Seblat National Park*

Kerinci Seblat National Park is Indonesia's second-largest terrestrial protected area, the largest habitat for the endangered Sumatran tiger, elephant, and tapir (Karyadi, Pratiwi, Danis, Suyanto, & Hedrayadi, 2018; Wibisono et al., 2011), and the largest element of the Tropical Rainforest Heritage of Sumatra World Heritage Site (Figure 1A).<sup>1</sup> Local district governments have long been discontented by the park's large expanse and restrictions on road development. Such districts complain particularly of economic isolation from eastern Sumatra and of having to endure the burdens of conservation without commensurate benefits or compensation.

Since Indonesia's political decentralization in 2001, local district governments have leveraged such frustrations and proposed 30 road projects throughout the park (Bettinger, 2014). Small-scale, individual encroachments prior to decentralization gave way to political-economic coalitions pursuing grander expansions of road networks and economic opportunities (Bettinger, 2014).

By 2011, the Tropical Rainforest Heritage of Sumatra World Heritage Site was formally listed as *in danger* due to *serious and specific* threats of infrastructure development and human encroachment (Government of the Republic of Indonesia, 2017). A recent assessment of 12 road-development proposals<sup>2</sup> within Kerinci Seblat National Park by the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Committee concluded that these roads would "create a physical habitat barrier preventing interactions between animal populations that may affect genetic changes and population survival" and that such "widespread impacts clearly indicate an unacceptable impact on the [region's] attributes of outstanding universal value and integrity" (UNESCO, 2017).

In response, in 2017, the Government of Indonesia assured UNESCO that there are no "currently new road developments nor any requests for [road developments]" within the World Heritage Site (Government of the Republic of Indonesia, 2017). However, ongoing road developments, including road upgrades, are apparently still being advanced in the name of equitable economic development (Jong, 2017). The precise status of ongoing developments in the park remains fluid and unclear. In 2018, UNESCO critiqued two road upgrades within the park for inappropriate environmental impact assessments (UNESCO, 2018), though these roads were reportedly atypical urgent responses to natural disasters (Government of the Republic of Indonesia, 2019).

The Trans-Sumatran Highway initiative would entail a major highway along the northern boundary of Kerinci Seblat National Park (Figure 1A). This highway is a compromise in many respects. On the one hand, its current route is superior to one that would bisect the park. On the other hand, the highway still would separate the park from the adjacent Lembah Anai Nature Reserve and possibly fragment this reserve, depending on the degree to which the highway follows existing roads.

At a minimum, the new highway is likely to reduce the range of critically endangered Sumatran tigers, given their aversion to roads (Linkie, Chapron, Martyr, Holden, & Leader-Williams, 2006), their vulnerability to poaching (Gray et al., 2018), and the pending isolation of the 950 km<sup>2</sup> Lembah Anai reserve. Such an impact would be notable, considering the importance of the park and surrounds for tiger survival

(Dinerstein et al., 2007; Wibisono et al., 2011; Wikramanayake et al., 2011).

Synergies between the highway and 12 current road proposals across Kerinci Seblat National Park are more fluid. Presently, the Infrastructure Development Agency of the Indonesian Ministry of Public Works is collaborating with the Ministry of Environment and Forestry and Indonesian nongovernmental organizations to assess which planned roadways might be permitted, amended, or cancelled. Another priority is to formulate policies for future infrastructure across the World Heritage Site, possibly including compensation schemes for local communities and districts (e.g., conditional cash transfers; Ministry of Environment and Forestry, 2019a). Such considerations do not extend to the highway itself, however, as it would pass just outside the park's official boundaries.

### *Incursions Into the Leuser Ecosystem*

The Leuser Ecosystem includes the Gunung Leuser National Park (Figure 1B)—the second-largest element of the Tropical Rainforest Heritage of Sumatra World Heritage Site—and is the last common habitat for endangered elephants, orangutans, tigers, and rhinoceros. As a National Strategic Area for ecosystem-service protection, the Leuser Ecosystem should legally restrict road developments within and around its extent to prevent agricultural incursions (Sloan, Campbell, et al., 2018). In practice, redundancies in its legal protections and a related fluidity of its status have meant that actual protections have varied with local governments and legal rulings. Indeed, a recent legal challenge to a proposed highway that would have violated the Leuser Ecosystem's National Strategic Area status was stayed, ironically, in part because other, generic forest protections would in theory still prevail (GeRAM, 2016). Although the highway failed to materialize, numerous smaller road developments and agricultural incursions have still penetrated the Leuser Ecosystem, despite such generic protections (Gaveau et al., 2009; Sloan, Campbell, et al., 2018; Wich et al., 2016). Only 78% of the Leuser Ecosystem remains unroaded forest, with nearly one third of this extent comprised of forest corridors, smaller forest patches (typically  $<10\text{ km}^2$ ), and the edges of larger fragments (typically  $\sim 200\text{--}300\text{ km}^2$ ) (Sloan, Campbell, et al., 2018).

The Trans-Sumatra Highway would pass the northeast flank of the Leuser Ecosystem (Figure 1B), where earlier road developments and agricultural activities have expanded into formerly intact forests (Sloan, Campbell, et al., 2018). Without additional local conservation, the highway would likely further expand and consolidate such incursions, primarily as oil-palm plantations, which already exist in the northeast Leuser

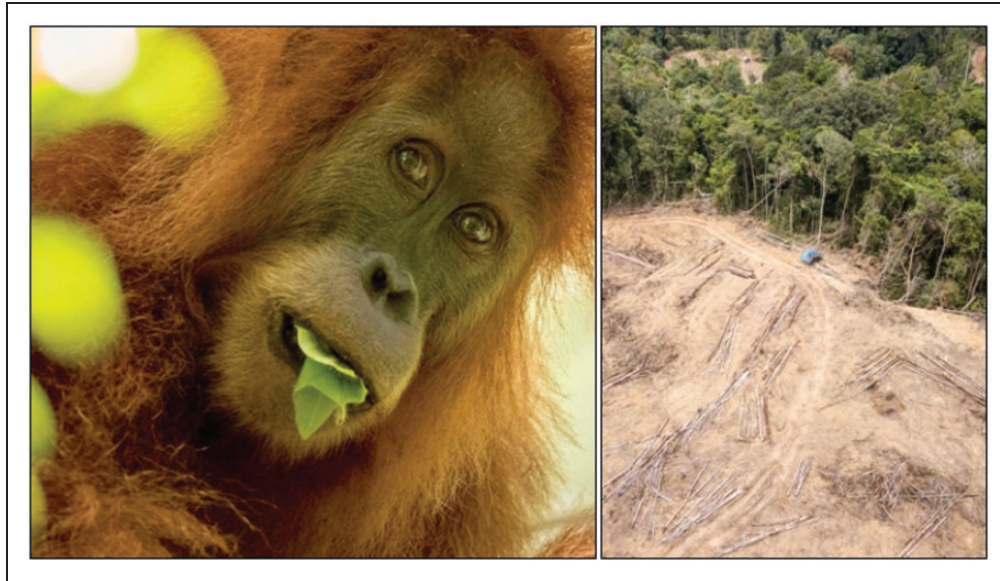
Ecosystem and are extensive in its southeast (Sloan, Campbell, et al., 2018). National moratoria on new oil-palm concessions and primary-forest conversion (Jong, 2019; Sloan, 2014; Sloan, Edwards, & Laurance, 2012; Wijedasa et al., 2018) have not stemmed related deforestation in the Leuser Ecosystem. In its northeast, forest clearing occurred in eight of nine oil-palm concessions in 2019 (Leuser Watch, 2019a, 2019b). Beyond this, smallholders (who do not apply for concessions) probably account for most incursions and deforestation generally, and their activities are strongly affected by road expansion.

### *Habitat Loss in the Batang Toru Region*

Remnant forests in the Batang Toru region are the last refuge of the critically endangered Tapanuli orangutan (*Pongo tapanuliensis*) and would be intersected by a highway and hydroelectric developments (Figure 1C). Although most local forests are nominally protected, their conservation status and utility as habitat are increasingly tenuous and would be jeopardized by these developments (Sloan, Supriatna, Campbell, Alamgir, & Laurance, 2018; Wich, Fredriksson, Usher, Kühl, & Nowak, 2019).

The loss of nearby habitat and ongoing deforestation in Batang Toru (Wich, Riswan, Refisch, & Nellemann, 2011) has reduced the Tapanuli orangutan to  $\sim 800$  individuals confined to three forest fragments. Notably, 15% of these forests remain eligible for agricultural conversion (Wich et al., 2019), including one fifth of the large *East Block* fragment. Small-scale agriculture occurs within protected forests along the fringes of all three fragments as well as within the interior of the East Block to a limited degree (Sloan, Supriatna, et al., 2018). Given the experience of the nearby Leuser Ecosystem, which similarly hosts the endangered Sumatran orangutan (*Pongo abelii*), new highway development is likely to extend, and even regularize, such piecemeal incursions.

The primary threat to the Batang Toru area is, however, posed by a hydroelectric project entailing 20 km of roadways, a 13-km hydrotunnel, and transmission lines among the remnant forest fragments (Figure 2). Although the World Bank's International Finance Corporation and the Asian Development Bank declined to finance these developments given environmental concerns, the Bank of China may finance them under China's Belt and Road Initiative, with which the planned highway and Chinese Sinohydro corporation align. Project construction is proceeding toward a 2022 completion date (Leahy, 2019) following failed legal challenges by scientists and conservationists (Gunawan & Kahfi, 2019). Although opportunities for orangutan habitat reintegration exist (Sloan, Campbell, et al., 2018),



**Figure 2.** The critically endangered Tapanuli orangutan and the clearing of its habitat in preparation for the Batang Toru hydroelectric project in northern Sumatra. Photo credit: Sumatran Orangutan Conservation Programme.

they are largely incompatible with this project. Infrastructure development and flooding would isolate ~25% of the species into nonviable communities and destroy prime habitat of the sole viable community in the *West Block* fragment (Wich et al., 2019).

### Implications for Remnant-Forest Conservation in Sumatra

The aforementioned case studies exhibit several common attributes relevant to remnant-forest conservation amidst second-wave infrastructure development in Sumatra. First, though the Trans-Sumatran Highway is a national initiative, many of the conservation issues it provokes are driven by local economic grievances couched in terms of economic equity (Jong, 2017). Effective conservation has therefore often leveraged local, rather than national, interests and regulations, often preemptively.

Second, remnant forest protections are frequently more fluid than their nominal legal statuses would suggest, once tested. There is a need to legally reinforce the status of such forests, perhaps especially those that are degraded. Legal challenges by scientists and conservationists to this end have often been unsuccessful when reacting to development pressures (see Hanafiah, 2019 for a recent exception in the Leuser Ecosystem). Critiques of Indonesia's management of ungazetted but still protected forests (e.g., Batang Toru and parts of the Leuser Ecosystem) have had only modest effects, relative to critiques relating to World Heritage Sites and national

parks, suggesting the importance of legal status and management jurisdiction.

Third, incursions into ungazetted protected forests promote conditions in which a range of de facto land uses become implicitly tolerated despite departing from officially zoned forest uses. This may in turn facilitate more incursions still, if simply by reducing the nominal conservation value of the forest. Ultimately, such synergies have facilitated the contraction of truly protected forests.

Indonesia recently decreed new environmental regulations for road development in forest areas, recognizing their growing relevance to nature conservation (Ministry of Environment and Forestry, 2019b). The case studies here would recommend certain refinements and recommendations, however.

Foremost is that ungazetted protected forests should be considered on equal terms to forests gazetted for conservation. Although the new regulations discourage road construction in most conservation forests, they do so only for *core* areas within ungazetted protected forests. This fails to recognize the degree to which ungazetted forests also support biodiversity, particularly in remnant-forest landscapes such as Batang Toru, where core forest areas are few and small. The new regulations would thus seemingly channel developments toward fringe, noncore areas of remnant forests, which may undermine forest integrity generally, as is evident for the Leuser Ecosystem. Regardless of any revisions to the regulations, the ungazetted, protected, noncore forests in Batang Toru and the Leuser Ecosystem should be gazetted to hedge against further encroachments, given

their global ecological significance. Such an outcome would directly challenge ongoing developments in Batang Toru.

In addition, whereas the new regulations apply narrowly to *nationally strategic roads* developed by the central government, they should also encompass local road proposals implicitly aligned with these strategic roads. The case of Kerinci Seblat National Park underscores the potential for synergies and trade-offs between highways and local road proposals in and around gazetted forests, which the new regulations would overlook. Again, the Leuser Ecosystem demonstrates the perils of overlooking such synergies.

It is noteworthy that the new regulations endorse alternative routes to road proposals as a mitigative measure to avoid gazetted forests and flagship species, namely orangutans, tigers, elephants, rhinos, and monitor lizards. Considering the foreseeable impacts of the highway developments in question on the integrity of gazetted and high-conservation priority forests and their endangered flagship species, we vociferously advocate for selective rerouting as a warranted and efficacious conservation measure. In particular, the corridor to Padang City in West Sumatra Province (Figure 1A) should be rerouted around the northern edge of Lembah Anai Nature Reserve, rather than separate the reserve from the southerly Kerinci Seblat National Park. Such a detour would take advantage of existing forest roads (near Padang Panjang City) and entail only an additional ~60 km of travel from Pandang north-eastward to the currently planned route. Such a detour would increase the impetus behind local road proposals further south in Kerinci Seblat National Park; hence the prior recommendation that local road proposals be scrutinized alongside related nationally strategic roads. The corridor to Sibolga City of North Sumatra Province in the Batang Toru region (Figure 1C) may similarly be rerouted ~130 km around the south of the Tanapuli orangutan habitat from just east of Tartung City to Sibolga. The existing ~40 km of forest road between Sibolga and Tartung may still afford ready highway access eastward from Sibolga. Meaningfully rerouting the corridor alongside the Leuser Ecosystem further eastward (Figure 1B) may not be possible due to the tight geographic confines imposed by coastal urban networks between Medan City and Langsa City. Instead, the revival of enhanced, semi-independent management of the Leuser Ecosystem may be attached to any ultimate highway development to prevent encroachment—a condition likely requiring the cooperation of Aceh province.

The Trans-Sumatra Highway is optimistically scheduled for completion by 2024. As of May 2019, just 10% (278 km) of its planned routes were *operational*, whereas 8% (225 km) were *functional* (Prabowo, 2019).

Furthermore, ~40% of lands required for the Highway have yet to be acquired because of conflicts with agricultural communities (Handayani, 2019). These conflicts provide an impetus to consider alternative routes but also adaptive conservation strategies. In particular, agricultural communities facing land expropriation could become new legal allies of conservationists, who have generally been unsuccessful in challenging developers on the basis of planning regulations. Joint litigation over land expropriation might prove more successful because the Trans-Sumatran Highway seeks public–private partnerships to meet its development targets (Negara, 2016) but such partnerships have been limited in part because of the economic risks posed by land expropriation (DG Highways, 2013; Negara, 2016). Indeed, land-acquisition conflicts along the Trans-Java Highway delayed the completion of that project for over two decades. The capacity of Indonesian environmental advocates to engage in such joint litigation is not negligible, as they have previously dealt with parallel issues, such as indigenous land claims (Sulistiyawan et al., 2018).

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### ORCID iD

Sean Sloan  <https://orcid.org/0000-0002-7834-0203>

### Notes

1. This World Heritage Site is comprised of the Kerinci Seblat National Park, Gunung Leuser National Park within the Leuser Ecosystem in northern Sumatra (discussed later), and Bukit Barisan Selatan National Park in southern Sumatra.
2. Collectively, these proposed roadways would span 1,360 km. They largely entail road upgrades (e.g., paving and widening), though a new road is also proposed. See Jong (2017) for a summary and UNESCO (2017) for details.

## References

- Alamgir, M., Campbell, M. J., Sloan, S., Suhardiman, A., & Laurance, W. F. (2019). High-risk infrastructure projects pose imminent threats to forests in Indonesian Borneo. *Scientific Reports*, 9, 140.
- Alamgir, M., Sloan, S., Campbell, M. J., Engert, J., & Laurance, W. F. (2019). Infrastructure expansion projects undermine sustainable development and forest conservation in Papua New Guinea. *PLoS One*, 4(7), e0219408.
- Ascensão, F., Fahrig, L., Clevenger, A. P., Corlett, R. T., Jaeger, J. A. G., Laurance, W. F., & Pereira, H. M. (2018). Environmental challenges for the belt and road initiative. *Nature Sustainability*, 1(5), 206–209.
- Bettinger, K. (2014). Death by 1,000 cuts: Road politics at Sumatra's Kerinci Seblat National Park. *Conservation and Society*, 12(3), 280–293.
- Clements, G. R., Lynam, A. J., Gaveau, D. L. A., Wei, L. Y., Lhota, S., Goosem, M., . . . Laurance, W. F. (2014). Where and how are roads endangering mammals in Southeast Asia's forests? *PLoS One*, 9(12), 25.
- Coordinating Ministry for Economic Affairs. (2011). *Master plan: Acceleration and expansion of Indonesia economic development, 2011-2025*. Jakarta: Author.
- DG Highways. (2013). *Current progress on high grade highway eastern corridor of Sumatera 2013*. Jakarta, Indonesia: Director General of Highways, Ministry of Public Works, Government of Indonesia. Workshop Presentation. Retrieved from [https://www.unescap.org/sites/default/files/Indonesia\\_1.pdf](https://www.unescap.org/sites/default/files/Indonesia_1.pdf)
- Dinerstein, E., Loucks, C., Wikramanayake, E., Ginsberg, J., Sanderson, E., Seidensticker, J., . . . Klenzendorf, S. (2007). The fate of wild tigers. *AIBS Bulletin*, 57(6), 508–514.
- Fearnside, P. M. (1997). Transmigration in Indonesia: Lessons from its environmental and social impacts. *Environmental Management*, 21(4), 553–570.
- Gaveau, D. L. A., Wich, S., Epting, J., Juhn, D., Kanninen, M., & Leader-Williams, N. (2009). The future of forests and orangutans (*Pongo abelii*) in Sumatra: Predicting impacts of oil palm plantations, road construction, and mechanisms for reducing carbon emissions from deforestation. *Environmental Research Letters*, 4(3), 034013.
- GeRAM. (2016, November 29). *Press Release: Aceh Citizen Lawsuit Movement to Appeal Judge's Decision* [Press release]. Retrieved from [http://www.haka.or.id/?page\\_id=2595](http://www.haka.or.id/?page_id=2595)
- Government of the Republic of Indonesia. (2017). *State of conservation status of the world heritage in Indonesia: World heritage property tropical rainforest heritage of Sumatra (N 1167)*. Jakarta, Indonesia: Author. Retrieved from <http://whc.unesco.org/en/list/1167/documents/>
- Government of the Republic of Indonesia. (2019). *State of conservation status of the world heritage in Indonesia: World heritage property tropical rainforest heritage of Sumatra (N 1167)*. Jakarta, Indonesia: Author. <https://whc.unesco.org/en/list/1167/documents/>
- Gray, T. N. E., Hughes, A. C., Laurance, W. F., Long, B., Lynam, A. J., O'Kelly, H., . . . Wilkinson, N. M. (2018). The wildlife snaring crisis: An insidious and pervasive threat to biodiversity in Southeast Asia. *Biodiversity and Conservation*, 27(4), 1031–1037.
- Gunawan, A., & Kahfi, K. (2019, March 4). Court rejects challenge to Batang Toru dam. *The Jakarta Post*. Retrieved from <https://www.thejakartapost.com/news/2019/03/04/court-rejects-challenge-to-batang-toru-dam.html>
- Hanafiah, J. (2019, August 29). Tok! Hakim Batalkan Izin Pakai Hutan Leuser untuk PLTA Tampur (Judge Canceled Permit to Use Leuser Forest for Tampur Hydropower). *Mongabay.com*. Retrieved from [https://www.mongabay.co.id/2019/08/29/tok-hakim-batalkan-izin-pakai-hutan-leuser-untuk-plta-tampur/?fbclid=IwAR3PGt hoO\\_rgAQeOvWh5Qx4ywpzpDVLjRRXx9KMP903dxKq qkbg627NimqY](https://www.mongabay.co.id/2019/08/29/tok-hakim-batalkan-izin-pakai-hutan-leuser-untuk-plta-tampur/?fbclid=IwAR3PGt hoO_rgAQeOvWh5Qx4ywpzpDVLjRRXx9KMP903dxKq qkbg627NimqY)
- Handayani, P. (2019, March 11). Tasting tran-Sumatra connectivity. *The Jakarta Post*. Retrieved from <https://www.thejakartapost.com/news/2019/03/10/tasting-transumatra-connectivity.html>
- Infra Eco Network Europe. (2014, September 16–19). *2014 Roadless Declaration, Infra Eco Network Europe International Conference "Life for a Greener Transport Infrastructure"*, Malmö, Sweden. Retrieved from <http://iene2014.iene.info/iene-2014-declaration/>; <https://conbio.org/policy/roadless-areas-initiative-gains-support>
- International Union for Conservation of Nature & UN Environment Programme-World Conservation Monitoring Centre. (2015). *The World Database on Protected Areas*. UNEP-WCMC. Retrieved from [www.protectedplanet.net](http://www.protectedplanet.net)
- Jong, H. N. (2017, August 7). Road projects threaten Sumatra's last great rainforests. *Mongabay.com*. Retrieved from <https://news.mongabay.com/2017/08/road-projects-threaten-sumatras-last-great-rainforests/>
- Jong, H. N. (2019, June 10). Indonesian ban on clearing new swaths of forest to be made permanent, Web Article. *Mongabay.com*. Retrieved from <https://news.mongabay.com/2019/06/indonesian-ban-on-clearing-new-swaths-of-forest-to-be-made-permanent/>
- Karyadi, H., Pratiwi, D. I., Danis, E. H., Suyanto, D. P., & Hedrayadi, S. (2018). *Taman Nasional Kerinci Seblat-Warisan Dunia Tanah Sumatra. Balai Besar Taman Nasional Kerinci Seblat* Direktorat Jenderal KSDAE, Kementerian LHK.
- Laurance, W. F. (2018). If you can't build well, then build nothing at all. *Nature*, 653, 295.
- Laurance, W. F., Clements, G. R., Sloan, S., O'Connell, C. S., Mueller, N. D., Goosem, M., . . . Arrea, I. B. (2014). A global strategy for road building. *Nature*, 513(7517), 229–232.
- Laurance, W. F., Sloan, S., Weng, L., & Sayer, J. (2015). Estimating the environmental costs of Africa's massive 'development corridors'. *Current Biology*, 25, 3202–3208.
- Leahy, S. (2019, March 4). Hydroelectric dam threatens to wipe out world's rarest ape. *National Geographic*. Retrieved from <https://www.nationalgeographic.com/animals/2018/08/tapanuli-orangutan-rarest-ape-threatened-dam-news/>
- Lechner, A. M., Chan, F. K. S., & Campos-Arceiz, A. (2018). Biodiversity conservation should be a core value of China's

- belt and road initiative. *Nature Ecology & Evolution*, 2(3), 408–409.
- Leuser Watch. (2019a, May 17). *Forest loss rises sharply in critical Leuser Ecosystem lowlands*. Retrieved from <https://www.ran.org/leuser-watch/forest-loss-rises-sharply-in-critical-leuser-ecosystem-lowlands/>
- Leuser Watch. (2019b, June 4). *Investigation underway into forest loss for palm oil in Leuser Ecosystem*. Retrieved from <https://www.ran.org/leuser-watch/investigation-underway-into-forest-loss-for-palm-oil/>
- Linkie, M., Chapron, G., Martyr, D. J., Holden, J., & Leader-Williams, N. (2006). Assessing the viability of tiger subpopulations in a fragmented landscape. *Journal of Applied Ecology*, 43(3), 576–586.
- Linkie, M., Smith, R. J., & Leader-Williams, N. (2004). Mapping and predicting deforestation patterns in the lowlands of Sumatra. *Biodiversity & Conservation*, 13(10), 1809–1818.
- Margono, B. A., Potapov, P. V., Turubanova, S., Stolle, F., & Hansen, M. C. (2014). Primary forest cover loss in Indonesia over 2000–2012. *Nature Climate Change*, 4(8), 730–735.
- Meijer, J. R., Huijbregts, M. A., Schotten, K. C., & Schipper, A. M. (2018). Global patterns of current and future road infrastructure. *Environmental Research Letters*, 13(6), 064006.
- Ministry of Environment and Forestry. (2019a, May 5). Aksi mengeluarkan TN Kerinci Seblat dari list terancam warisan duni (Action to remove Kerinci Seblat National Park from the list of threatened world heritage sites). *Top News*. Jakarta, Indonesia. Retrieved from <http://ksdae.menlhk.go.id/info/6431/aksi-mengeluarkan-tn-kerinci-seblat-dari-list-terancam-warisan-dunia.html>
- Ministry of Environment and Forestry. (2019b). *Regulation number P.23/Menlhk/Setjen/Kum.1/6/2019 concerning strategic roads in forest areas*. Jakarta, Indonesia. Retrieved from <http://jdih.menlhk.co.id/permenlhk>
- Miyamoto, M. (2006). Forest conversion to rubber around Sumatran villages in Indonesia: Comparing the impacts of road construction, transmigration projects and population. *Forest Policy and Economics*, 9(1), 1–12.
- Murdiyarto, D., Van Noordwijk, M., Wasrin, U. R., Tomich, T. P., & Gillison, A. N. (2002). Environmental benefits and sustainable land-use options in the Jambi transect, Sumatra. *Journal of Vegetation Science*, 13(3), 429–438.
- Nater, A., Mattle-Greminger, M. P., Nurcahyo, A., Nowak, M. G., de Manuel, M., Desai, T., ... Krützen, M. (2017). Morphometric, behavioral, and genomic evidence for a new orangutan species. *Current Biology*, 27(22), 3487–3498.e3410.
- Negara, S. D. (2016). Indonesia's infrastructure development under the Jokowi administration. In *Southeast Asian Affairs* (pp. 145–166). Singapore: ISEAS—Yusof Ishak Institute.
- Poor, E. E., Frimpong, E., Imron, M. A., & Kelly, M. J. (2019). Protected area effectiveness in a sea of palm oil: A Sumatran case study. *Biological Conservation*, 234, 123–130.
- Poor, E. E., Jati, V. I. M., Imron, M. A., & Kelly, M. J. (2019). The road to deforestation: Edge effects in an endemic ecosystem in Sumatra, Indonesia. *PLoS One*, 14(7), e0217540.
- Prabowo, D. (2019, April 5). 1.468 Kilometer Jalan Tol Trans Jawa dan Trans Sumatera Siap Dilintasi (1,468 Kilometers of Trans Java and Trans Sumatra Toll Roads Ready to Be Crossed). *Kompas.com*. Retrieved from <https://properti.kompas.com/read/2019/05/04/130000021/1.468-kilometer-jalan-tol-trans-jawa-dan-trans-sumatera-siap-dilintasi>
- Rudel, T. K. (1996). Shrinking tropical forests, human agents of change and conservation policy. *Conservation Biology*, 20(6), 1604–1609.
- Rudel, T. K., DeFries, R., Asner, G. P., & Laurance, W. F. (2009). Changing drivers of deforestation and new opportunities for conservation. *Conservation Biology*, 23(6), 1396–1405.
- Selva, N., Switalski, A., Kreft, S., & Ibsch, P. (2015). Why keep areas road-free? The importance of roadless areas. In R. van Der Ree, D. J. Smith, & C. Grilo (Eds.), *Handbook of road ecology* (1st ed., pp. 16–26). Hoboken, NJ: Wiley Blackwell.
- Sloan, S. (2014). Indonesia's moratorium on new forest licenses: An update. *Land Use Policy*, 38(May), 37–40.
- Sloan, S., Bertzky, B., & Laurance, W. F. (2016). African development corridors intersect key protected areas. *African Journal of Ecology*, 55, 731–737.
- Sloan, S., Campbell, M. J., Alamgir, M., Collier-Baker, E., Nowak, M., Usher, G., & Laurance, W. F. (2018). Infrastructure development and contested forest governance threaten the Leuser Ecosystem, Indonesia. *Land Use Policy*, 77, 298–309.
- Sloan, S., Campbell, M. J., Alamgir, M., Engert, J., Ishida, F. Y., Senn, N., ... Laurance, W. F. (2019). Hidden challenges for conservation and development along the Papuan economic corridor. *Environmental Science and Policy*, 92, 98–106.
- Sloan, S., Campbell, M. J., Alamgir, M., Lechner, A. M., Engert, J., & Laurance, W. F. (2019). Trans-national conservation and infrastructure development in the Heart of Borneo. *PLoS One*, 19(9), e0221947.
- Sloan, S., Edwards, D. P., & Laurance, W. F. (2012). Does Indonesia's REDD+ moratorium on new concessions spare imminently-threatened forests? *Conservation Letters*, 5(3), 222–231.
- Sloan, S., Supriatna, J., Campbell, M. J., Alamgir, M., & Laurance, W. F. (2018). Newly discovered orangutan species requires urgent habitat protection. *Current Biology*, 28(11), R650–R651.
- Sulistiyawan, B. S., Verweij, P. A., Boot, R. G. A., Purwanti, B., Rumbiak, W., Wattimena, M. C., ... Adzan, G. (2018). Integrating participatory GIS into spatial planning regulation: The case of Merauke District, Papua, Indonesia. *International Journal of the Commons*, 12(1), 26–59.
- United Nations Educational, Scientific and Cultural Organization. (2017). *Kajian Lingkungan Hidup Strategis (KLHS) Dampak Kumulatif Rencana Pembangunan Jalan di Pegunungan Bukit Barisan, Warisan Hutan Hujan Tropis Sumatra (Strategic Environmental Assessment (SEA) Cumulative Impact of Road Construction Plans in the Bukit Barisan Mountains, Sumatra's Tropical Rainforest Legacy)*. Jakarta, Indonesia: Author. Retrieved from



- Lingkungan-Hidup-Strategis-Hutan-hujan-tropis-Sumatera.pdf
- United Nations Educational, Scientific and Cultural Organization. (2018). State of Conservation 2018—Tropical Rainforest Heritage of Sumatra (Indonesia). *UNESCO World Heritage Committee*. Retrieved from <https://whc.unesco.org/en/soc/3804>
- Venter, O., Sanderson, E. W., Magrath, A., Allan, J. R., Beher, J., Jones, K. R.,...Watson, J. E. M. (2016). Sixteen years of change in the global terrestrial human footprint and implications for biodiversity conservation. *Nature Communications*, 7, 12558.
- Wibisono, H. T., Linkie, M., Guillera-Arroita, G., Smith, J. A., Sunarto, Pusparini, W...Zulfahmi, (2011). Population status of a cryptic top predator: An island-wide assessment of tigers in Sumatran rainforests. *PLoS One*, 6(11), e25931.
- Wich, S. A., Fredriksson, G., Usher, G., Kühl, H. S., & Nowak, M. G. (2019). The Tapanuli orangutan: Status, threats, and steps for improved conservation. *Conservation Science and Practice*, 1(6), e33.
- Wich, S. A., Riswan, J., Refisch, J., & Nellemann, C. (2011). Orangutans and the economics of sustainable forest management in Sumatra. *Birkeland Trykkeri, Norway*. Retrieved from <http://www.grida.no/publications/201>
- Wich, S. A., Singleton, I., Nowak, M. G., Atmoko, S. S. U., Nisam, G., Arif, S. M.,...Usher, G. (2016). Land-cover changes predict steep declines for the Sumatran orangutan (*Pongo abelii*). *Science Advances*, 2(3), e1500789.
- Wijedasa, L., Sloan, S., Page, S., Clements, G. R., Lapsco, M., & Evans, T. A. (2018). Carbon emissions from peat forests will continue to increase despite emission-reduction schemes. *Global Change Biology*, 24(10), 4598–4613.
- Wikramanayake, E., Dinerstein, E., Seidensticker, J., Lumpkin, S., Pandav, B., Shrestha, M.,...Than, U. (2011). A landscape-based conservation strategy to double the wild tiger population. *Conservation Letters*, 4(3), 219–227.