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SAVi Sustainable Asset Valuation

SIMULATIONS

What-If SAVi Simulations on a Sustainable Recovery 2020

Are Investments in Road Infrastructure on Borneo a Sustainable Recovery Strategy for Malaysia?

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The Rationale for the What-If Sustainable Asset Valuation (SAVi) Simulations

Planning a sustainable recovery requires that we look ahead and forecast how spending today will play out in the national and global economy in the years to come. It is also important that the ongoing, unprecedented wave of public spending triggers a sustainable recovery, one that has the environment, climate, and social cohesion at its core. The What-If simulations based on the Sustainable Asset Valuation (SAVi) methodology are designed to inform this debate. We use the SAVi simulation to run "What-if" scenarios to understand the economic and societal benefits that can be realized when public spending is targeted at sustainable infrastructure. Simulations are inspired by ongoing recovery plans and are based on authoritative data and real science.

Section 1: About This What-If Simulation

This simulation forecasts the outcomes of recovery spending on new road infrastructure in Malaysia. We examine the costs and benefits of the planned Pan Borneo Highway. The implementation of this large-scale highway project has commenced and is set for completion in 2023 (Povera & Yunus, 2020). The highway is planned to cut through the Heart of Borneo (HoB), one of the world's most biodiverse regions, in an effort to connect the markets of the Malaysian provinces of Sabah and Sarawak, and to increase tourism in the area. The HoB is a vast area that stretches along the borders of Brunei Darussalam, Malaysia, and Indonesia. It hosts around 6% of the world's biodiversity, providing essential ecosystem services to an area of 54 million hectares (ha), serving more than 11 million people (van Paddenburg et al., 2012).

Investing in road infrastructure is often considered an attractive recovery option to create employment opportunities and stimulate economic growth. Its benefits include job creation, increased mobility, increased speed of travel, and improved access to markets.

On the other hand, roads require a considerable amount of upfront investment for construction as well as annual operation and maintenance costs. Building a road is not a trivial exercise: it requires complex engineering and advanced project financing. In light of climate change and the increasing frequency of extreme weather events, greater levels of damage to infrastructure are anticipated to increase the necessary operational budget for such infrastructure projects. Further, roads that cut through biodiverse forests generate costs to society that are typically unaccounted for in project assessments. Road construction and improved access to land imply direct and indirect deforestation which will lead, among others, to loss of carbon sequestration and habitat quality. It will also lead to the reduction of other ecosystem goods and services that local populations rely on for their livelihoods.

This simulation will assess the costs, benefits, and trade-offs (adverse impacts) of the Pan Borneo Highway currently being built and address the questions: What-if the Malaysian government considers the highway as a recovery project? And What-if the Government would not only promote the highway project but also provide recovery spending for mitigating and offsetting adverse environmental impacts caused by this infrastructure project? Can the highway project in either of these instances be considered a worthwhile project for achieving a sustainable recovery in the Malaysian part of Borneo?

Section 2: The SAVi Simulation Results

Overview

This SAVi assessment consists of:

- A valuation of the capital and operational costs and benefits of the Pan Borneo Highway
- Spatial analysis of land cover change and resulting ecosystem services deterioration caused by the road construction on Borneo
- A valuation of the trade-offs associated with the highway
- A reassessment of the costs and benefits of the Pan Borneo Highway if measures to mitigate and offset some of the trade-offs are included in the project's cost

Table 1 presents the costs, benefits, trade-offs, and mitigation measures that are included in this simulation.

Table 1. Factors valued in this SAVi simulation

Costs	• Construction costs of Pan Borneo Highway • Operation and maintenance (O&M) costs
Benefits	• Wage generation from jobs indirectly created through the new highway • Value of travel time reductions • Value of increased tourism
Trade-offs valued	• Carbon emissions caused by deforestation, valued as the social cost of carbon (SCC) • Increased spending on flood damages because of deforestation • Cost of biodiversity-related services lost • Carbon emissions caused by the production of Portland cement (used as road surface material), valued as SCC
Costs for mitigation & offsetting measures	• Cost of flood control • Cost of reforestation to replace forested area lost from road construction • Investments in solar energy generation to replace coal power generation as a means to indirectly offset carbon emissions caused by Portland cement production and deforestation • Cost for wildlife crossings

Table 2 provides an overview of the What-if simulation results. The presence of direct and indirect costs of road construction calls for a careful assessment of its economic viability and societal value. We estimate that the Pan Borneo Highway will generate a return of USD 1.06 per USD 1 invested when considering conventional costs and benefits only, but when accounting for negative environmental impacts (trade-offs), this declines to below USD 1 per USD 1 invested. Therefore, the return on investment turns negative, suggesting that the highway project cannot be considered worthwhile from a societal point of view.

Table 2 also presents results of the simulation if measures are taken to mitigate and offset some of the highway's negative environmental impacts. As indicated above, the return on investment for road construction varies depending on cost positions and negative externalities (trade-offs) included in the assessment. Depending on the location and the related magnitude of negative environmental impacts, the return on investment can even become negative. Some negative environmental impacts and associated costs, especially those caused by carbon emissions and deforestation, can be offset or mitigated in various ways. However, some other adverse impacts, such as biodiversity and habitat loss, can never be fully recovered or appropriately offset.

With 13.3% of Malaysia's GDP relying on ecotourism (Knoema.com, 2018), and this being one of the most relevant growth areas in the future, recovery efforts need to account for the protection of forest landscapes, biodiversity, and climate change mitigation. Aside from environmental benefits, investing in restoring ecosystems will improve the livelihoods of local communities, will increase their self-sufficiency (for income, food), and reduce issues like the rural-to-urban transition.

When mitigating or offsetting some of the negative impacts, the net value of a road project can improve and could appear more positive from a societal point of view. Therefore, two mitigation options are proposed and assessed in this What-if simulation. Both options serve to offset the carbon emissions caused by deforestation and mitigate some of the adverse impacts caused by habitat fragmentation due to the new highway. These options are as follows:

- **Option 1**: Reforestation to replace forested area lost due to the highway construction and operation; and constructing wildlife crossings to mitigate habitat fragmentation caused by the highway.
- **Option 2**: Investments in solar energy generation to replace coal-fired power plants as a way to offset carbon emissions caused by deforestation and cement production, plus constructing wildlife crossings to mitigate habitat fragmentation. Option 2 includes a low-end and high-end calculation to capture the varying estimates of carbon emissions caused by deforestation.

The results for the two offsetting options suggest that if the highway is constructed with the additional measures included in Option 1, for every USD 1 invested, USD 1.04 will be returned. If instead Option 2 is implemented, for every USD 1 invested USD 1.05 will be returned assuming either high- or low-end estimates of the emissions caused by deforestation.

Table 2. Overview of the SAVi simulation results for the Pan Borneo Highway (undiscounted)

	Annual value (USD)	Cumulative value, 25 years (USD)
Project costs	296,638,000	7,415,946,000
Benefits	313,305,000	7,832,635,000
Benefit per USD 1 invested: [benefits/costs]	**1.056**	**1.056**
Trade-offs (emissions from deforestation and cement production, flood damages, wildlife fragmentation)		
Low-end estimate	17,818,000	445,438,000
High-end estimate	26,620,000	665,503,000
Benefit per USD 1 invested, including the costs of trade-offs		
Highway & trade-offs (low end)	**0.996**	**0.996**
Highway & trade-offs (high end)	**0.969**	**0.969**
Mitigation and offsetting options		
Option 1: Costs for reforestation and wildlife crossings	3,420,000	85,510,000
Option 2 – low end: Costs for solar energy and wildlife crossings	17,869,700	40,959,300
Option 2 – high end: Costs for solar energy and wildlife crossings	26,436,286	49,525,887
Benefit per USD 1 invested, including costs for mitigation and offsetting		
Highway & offsetting Option 1	**1.040**	**1.040**
Highway & offsetting Option 2 (low end)	**0.995**	**1.049**
Highway & offsetting Option 2 (high end)	**0.968**	**1.048**

A Closer Look at the Simulation Results for the Pan Borneo Highway

Assessment of Conventional Project Costs and Benefits

Table 3 offers the results of the simulation for the project costs and benefits. First, the estimated capital costs of the Pan Borneo Highway, as reported by Kanyakumari (2019), total USD 6.48 billion. Next, assuming an annual O&M cost of USD 37.44 million, the results suggest that the Pan Borneo Highway will cost USD 935.95 million to maintain over the course of 25 years. Cumulatively, the direct costs of the highway will be USD 7.416 billion.

Second, the results suggest that the indirect jobs created by the newly available highway will generate USD 138.24 million in additional wages annually. This will total USD 3.446 billion over 25 years.

The new road will also reduce commuter's time spent on travel. According to Kanyakumari (2019), "it used to take 19 hours to travel from Sematan to Miri but with Pan Borneo, the travel time will be reduced by half." Avoided travel time can be calculated in economic terms as the avoided opportunity cost of commuting. Based on the average hourly wage in Malaysia, the avoided commuting time is estimated at USD 86.06 million annually and USD 2.15 billion over the course of 25 years.

In addition, the highway is expected to improve economic opportunities for ecotourism, as it will increase accessibility to diverse parts of the island's forest. Assuming the newly available highway increases the duration of tourist stays in the region by 10%, the annual economic benefit is estimated at USD 89 million. Increased tourism spending will provide a benefit of USD 2.225 billion over 25 years.

The benefits of the highway total USD 7.83 billion over a 25-year time span. As a result, for every USD 1 invested over the project's timeline, USD 1.06 will be returned. Thus, direct costs (capital and O&M costs) and the benefits of the highway are of similar magnitude. Considering that, aside from tourism, we do not estimate the economic value created by providing additional access to markets, the construction of the road seems appealing from an economic standpoint. However, these estimates fail to account for the adverse effects, such as negative environmental impacts, that are also associated with road construction.

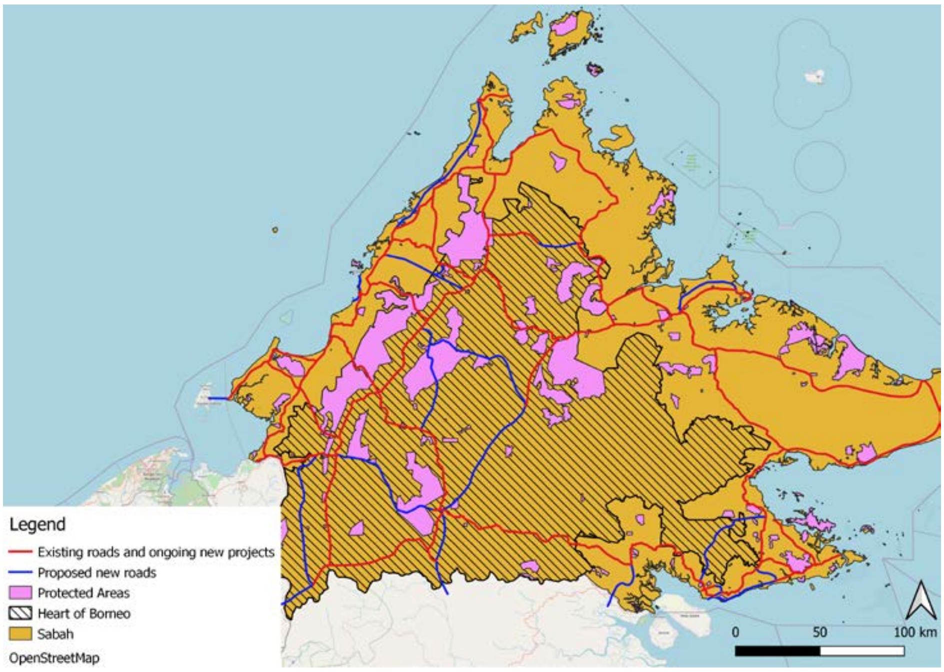
Table 3. Cost and benefits of the Pan Borneo Highway – Overview of the SAVi simulation results (undiscounted)

	Annual value (USD)	Cumulative value, 25 years (USD)
Traditional project costs		
Total capital cost	259,200,000.00	6,480,000,000
Total O&M cost	37,438,000	935,946,000
Total costs:	**296,638,000**	**7,415,946,000**
Project benefits		
Wage creation	138,240,000	3,456,000,000
Value of travel time reductions	86,058,000	2,151,447,000
Value of increased tourism	89,008,000	2,225,188,000
Total benefits	**313,305,397.29**	**7,832,634,932.18**
Benefit per USD 1 invested [benefits/costs]	**1.056**	**1.056**

The Costs of Trade-offs

When estimating the long-term costs of the road, the indirect costs associated with negative environmental impacts need to be accounted for. Road construction leads to deforestation, which depletes carbon sequestration and storage, reduces flood control, reduces biodiversity, and causes CO_2 emissions from the manufacturing of construction materials. These trade-offs imply a societal cost, especially in biodiversity hotspots such as the rainforests of Malaysia. While this simulation estimates the costs of the Pan Borneo Highway, other road networks are simultaneously being planned on the island of Borneo and several more in Southeast Asia. By using the InVEST family of models (Sharp et al., 2020), it was possible to assess the environmental damage caused by roads. The proposed road networks and protected areas in the region are presented in Figure 1, and the simulation results for the costs of trade-offs caused by the Pan Borneo Highway are presented in Table 4.

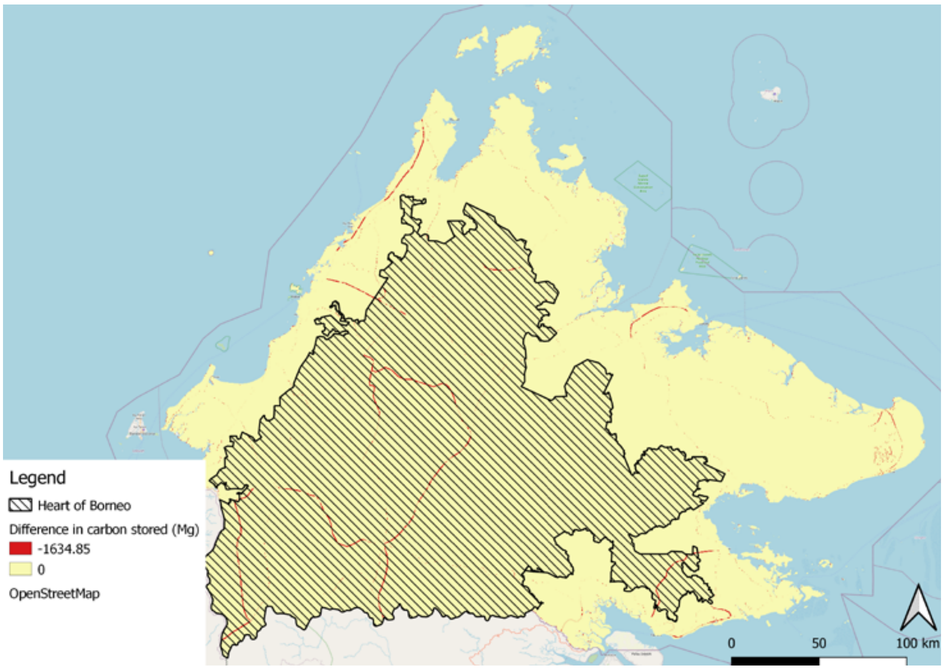
Figure 1. Proposed road developments and protected areas in Sabah (Malaysia)



Source: Author diagram

First, forests store valuable amounts of CO_2 above ground, below ground, in organic matter, and soil. Road construction requires deforestation, which depletes these carbon stocks. The expected amount of carbon stock that will be lost from the construction of Malaysia's proposed roads is presented in Figure 2. Carbon emissions caused by deforestation for the construction of the Pan Borneo Highway can be valued as societal costs by estimating the SCC. The SCC is a measure of the loss of human welfare that is caused by emitting one additional ton of CO_{2eq}. emissions (Nordhaus, 2017). Deforestation caused by the highway's construction is expected to generate emissions in the range of 13.9 million tons (low end) and 23.2 million tons of CO_2 (high end). Applying an amount of USD 30 per ton of CO_2 yields a total SCC of between USD 416.96 million and USD 637.03 million, depending on the exact level of carbon emissions caused by deforestation.

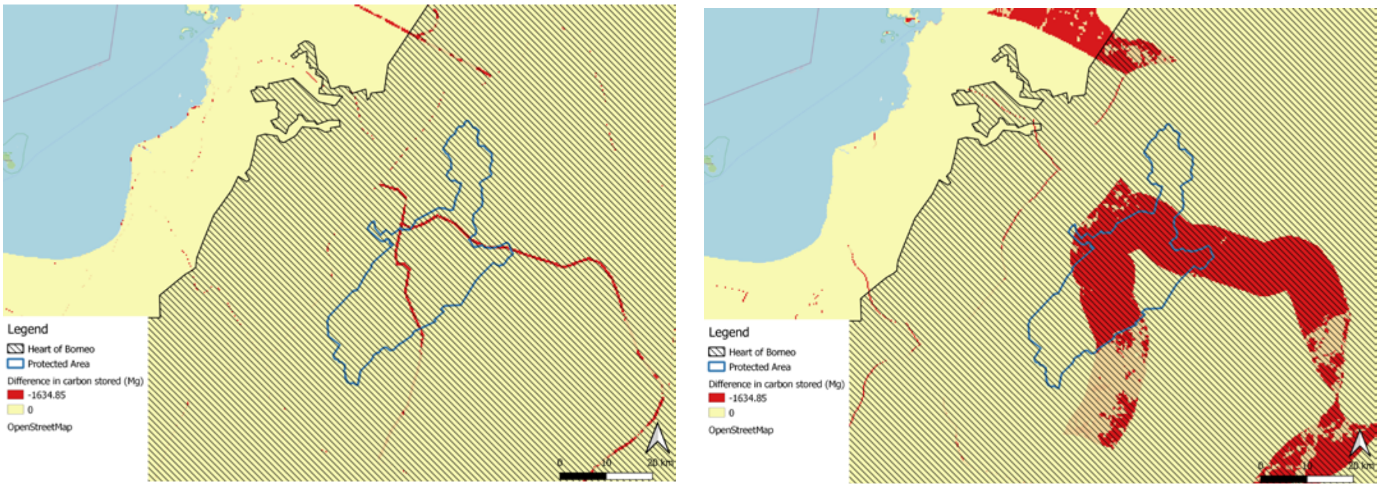
Figure 2. Difference in carbon stored in megagrams (Mg) between the current and proposed road scenario – no buffer around the roads



Source: Author diagram

It is worth noting that constructing and operating the new highway will affect protected areas, as presented in Figure 3. The improved accessibility and new economic opportunities will draw additional people to the area to establish new settlements. This will lead to deforestation and loss of carbon storage (possibly well beyond the area covered by the road, see Figure 3, right).

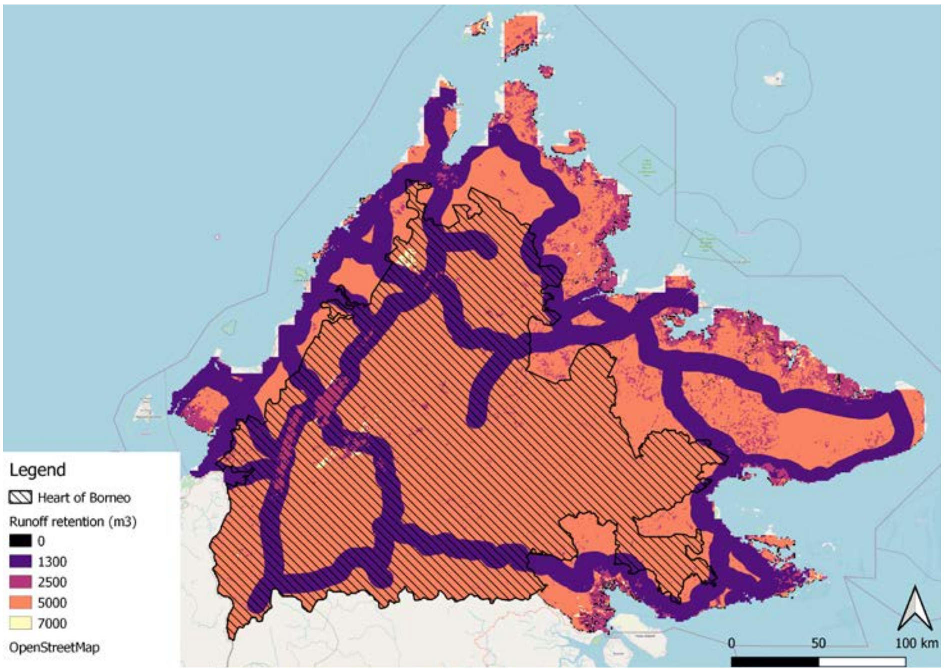
Figure 3. Difference in carbon stored in megagrams (Mg) between the current and proposed road scenario in one protected area – without (left) and with buffer around the road (right).



Source: Author diagram

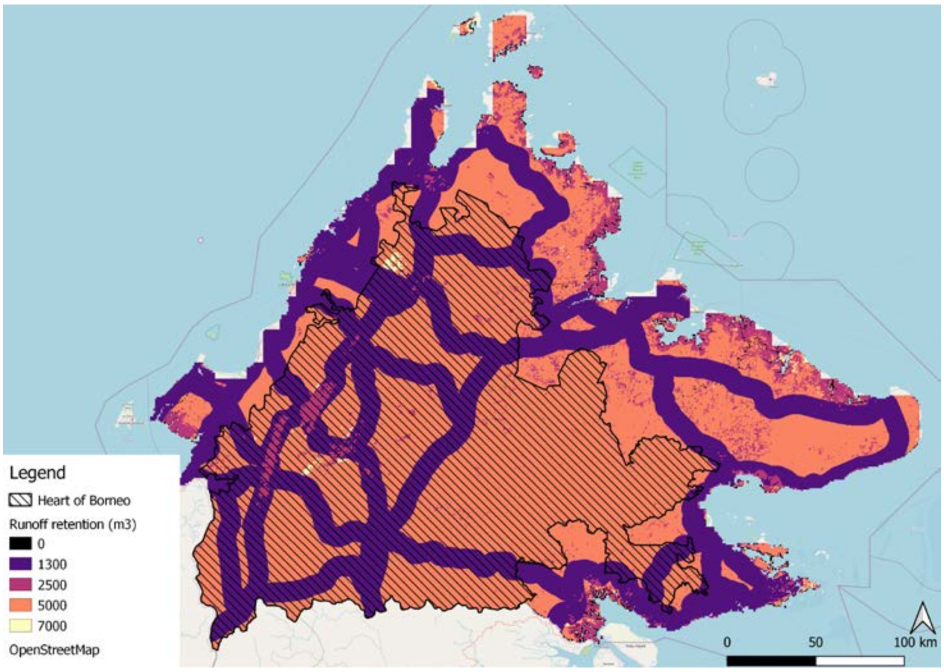
Forests deliver ecosystem services and according economic benefits to society, including water regulation and flood control. Constructing road networks and deforestation will increase the area of impervious surface and lead to more flood events and flood damage down the line, possibly resulting in costs for many small villages. The expected change in runoff retention caused by the proposed roads is presented in Figure 4 and Figure 5. The simulation highlights the fact that the Pan Borneo Highway will reduce runoff retention and result in increased flood damages costing USD 7,922 annually, totalling USD 198,039 over 25 years.

Figure 4. Runoff retention (m^3) – current road scenario with deforestation



Source: Author diagram

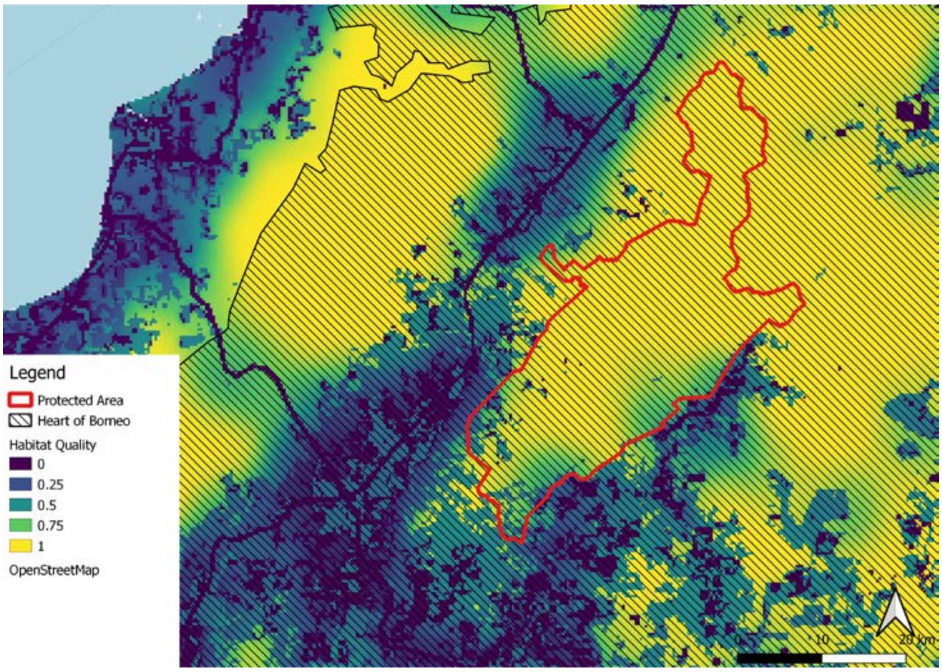
Figure 5. Runoff retention (m^3) – proposed road scenario with deforestation



Source: Author diagram

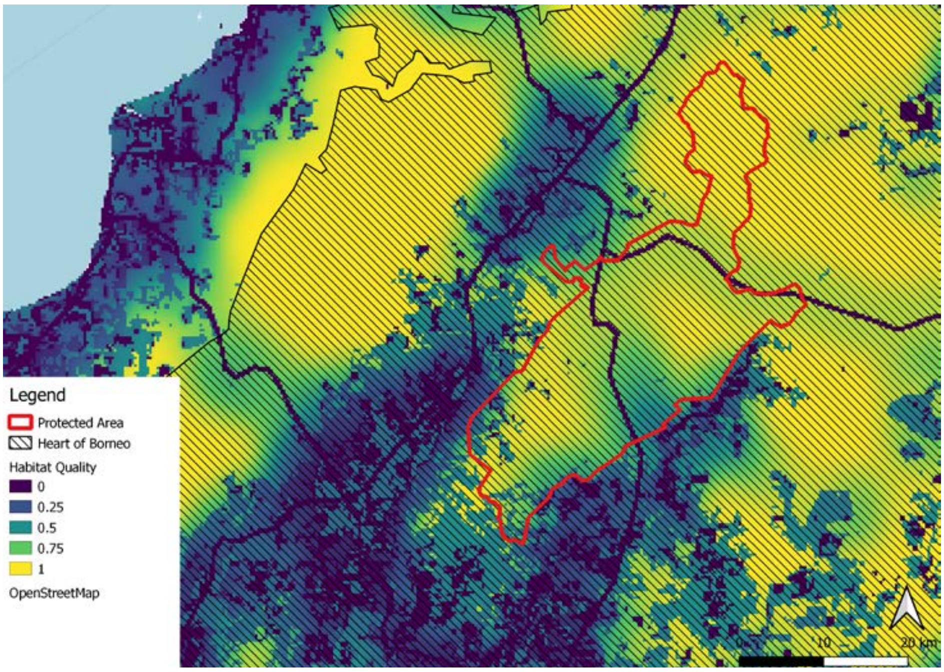
Changes in habitat quality caused by the proposed highway cutting through a protected area on the island of Borneo are presented in Figure 6 and Figure 7. The simulation estimates that the loss of habitat quality caused by the Pan Borneo Highway will present a societal cost of USD 436,000 annually and USD 10.9 million after 25 years.

Figure 6. Habitat quality in a selected protected area (current scenario)



Source: Author diagram

Figure 7. Habitat quality in a selected protected area (proposed scenario)



Source: Author diagram

Finally, the manufacturing of road construction materials, in particular cement, emits harmful CO_2 into the atmosphere. This can again be valued by estimating the SCC. Considering the emissions that are associated with producing the amount of Portland cement required to construct the Pan Borneo Highway, society will eventually bear a cost of USD 17.37 million.

We find that the negative environmental impacts caused by the Pan Borneo Highway add up to a cost in the range of USD 445.44 million and USD 665.5 million over the course of 25 years, depending on the amount of emissions that the deforestation from road construction will finally cause. When accounting for the costs of these trade-offs, the construction of the highway is less appealing to society. We estimate that after 25 years, for every USD 1 invested in the highway's construction, about USD 1 will be returned in the low-end estimate of emissions from deforestation, and USD 0.97 will be returned, assuming the high-end estimate of emissions.

Table 4. Trade-offs of the Pan Borneo Highway – Results of the simulation (undiscounted)

Trade-offs	Annual value (USD)	Cumulative value, 25 years (USD)
Cost of carbon from deforestation (low-end estimate)	16,678,570	416,964,000
Cost of carbon from deforestation (high-end estimate)	25,481,148	637,029,000
Increased spending on flood damages because of deforestation	7,922	198,000
Cost of biodiversity-related services lost	436,000	10,905,000
SCC from CO_2 emissions caused by manufacturing of Portland cement	695,000	17,371,000
Total value of trade-offs		
Low-end estimate	17,818,000	445,438,000
High-end estimate	26,620,000	665,503,000
Benefit per USD 1 invested, including the costs of trade-offs		
Low-end estimate	0.996	0.996
High-end estimate	0.969	0.969

Costs and Benefits of Mitigation and Offsetting Options

In addition to estimating the costs of trade-offs associated with the Pan Borneo Highway, this simulation estimates the potential costs and benefits of mitigating and offsetting some of the adverse effects.

The results, presented in Table 5, demonstrate that costs associated with mitigation measures to address expected flood damages from decreased runoff retention amount to more than USD 2.9 billion over 25 years (see details in Table 6 on flood-mitigation measures assessed). Implementing flood-mitigation measures in combination with constructing the road is significantly more expensive than tolerating the cost of flood damages estimate over the course of 25 years. Therefore, the investment in flood-mitigation measures cannot be justified economically and will not be included in our defined mitigation and offsetting scenarios.

Trade-offs that can be addressed are the forested area lost from deforestation as well as carbon emissions caused by deforestation and cement production. Moreover, measures can be taken to mitigate some of the adverse effects caused by the road's habitat fragmentation. The average annual cost and the total cost over a period of 25 years for each singular measure proposed are indicated in Table 5. Based on that, three combined mitigation and offsetting options are analyzed.

Option 1 entails investing in reforestation to restore exactly the size of forest cover cleared for the highway project. Moreover, the option includes the installation of wildlife crossings. While crossings will not prevent the loss of habitat quality and related ecosystem services due to the newly constructed highway, they are useful to reduce habitat fragmentation. Option 2 aims at offsetting the amount of carbon emissions caused by deforestation and cement production, as well as the installation of wildlife crossings. As the carbon emissions estimates caused by deforestation vary (see Table 6), Option 2 distinguishes between a low-end and high-end offsetting scenario. In both cases, the offsetting is achieved by investing in solar energy generation capacity to replace carbon-emitting coal-powered energy generation to the extent that offsets the low- and high-end estimates caused by deforestation, respectively.

For Option 1, the costs of reforestation are USD 67,564,000 (which includes the cost of constructing wildlife crossings). Option 1 costs a total of USD 85.6 million over 25 years. We estimate that after 25 years, for every USD 1 invested in the highway's construction and mitigation measures (as proposed in Option 1) USD 1.04 will be returned. This return on investment is more appealing than the integrated results for the highway when not investing in any mitigation and offsetting measures. While spending on reforestation appears worthwhile and will help rebuild wildlife habitat—and restore forest-related ecosystem services—the reforested area will not be able to offset and restore the same degree of pristine habitat and biodiversity that will be lost due to deforesting primary forest landscapes for the highway project.

For Option 2, the costs of implementing solar energy production to replace coal-fired power to exactly offset emissions caused by cement production and deforestation range from USD 23.013 million to USD 31.58 million. This range depends on the high- and low-end estimates of emissions caused by deforestation. When further accounting for the cost of wildlife crossings to mitigate wildlife fragmentation, the costs of Option 2 range from roughly USD 40 million to USD 49.5 million. This amount is significantly lower than the SCC caused by deforestation and Portland cement production, which cumulatively ranges from USD 434.3 million to USD 654.4 million. It thus appears economically worthwhile to invest in carbon offsetting. Considering the total investment volume, we estimate that for every USD 1 invested in the highway's construction and offsetting measures proposed in Option 2, approximately USD 1.05 will be returned. It should be noted that these calculations consider only offsetting the costs associated with harmful carbon emissions and include some mitigation measures to reduce the adverse effects of habitat fragmentation. Costs associated with biodiversity loss and loss of other forest ecosystem services are not captured by this offsetting option. Such costs will occur if the highway is constructed.

In summary it can be concluded that the Pan Borneo Highway would yield a higher societal return if some trade-offs caused during construction and operation are mitigated and offset. From the point of view of the Malaysian government, it would hence be reasonable to provide recovery spending for such mitigation and offsetting measures. However, even though the societal return improves under these offsetting scenarios, the project still yields a low societal return on investment. This generally sheds doubt on whether constructing this highway on Borneo can be considered a worthwhile infrastructure project from a societal point of view.

Table 5. Costs and benefits of offsetting – Results of the simulation (undiscounted)

Offsetting and mitigation measures	Annual value (USD)	Cumulative value, 25 years (USD)
Cost of flood-mitigation techniques (reduce expected flood damages)	1,624,898,000	2,905,888,000
Total reforestation cost (reforest area expected to be deforested from road construction)	2,703,000	67,564,000
Solar energy generation (offset low-end carbon emission estimate caused by deforestation and cement production)	17,151,855	23,013,168
Solar energy generation (offset high-end carbon emission estimate caused by deforestation and cement production)	25,718,000	31,580,000
Cost for wildlife crossings (reduce habitat fragmentation)	718,000	17,946,000
Total costs (low end)	**1,645,470,000**	**3,014,411,000**
Total costs (high end)	**1,654,037,000**	**3,022,977,000**
Mitigation and offsetting options		
Option 1: Costs for reforestation and wildlife crossings	3,420,000	85,510,000
Option 2 – low end: Costs for solar energy and wildlife crossings	17,869,700	40,959,300
Option 2 – high end: Costs for solar energy and wildlife crossings	26,436,286	49,525,887
Benefit per USD 1 invested, including costs for mitigation and offsetting		
Highway & offsetting Option 1	**1.040**	**1.040**
Highway & offsetting Option 2 (low end)	**0.995**	**1.049**
Highway & offsetting Option 2 (high end)	**0.968**	**1.048**

Section 3: Using the Results of This Simulation

The results of this What-if simulation provide insights about the costs and benefits of investing in the Pan Borneo Highway as well as cost and benefit implications when mitigating and offsetting some of the negative environmental impacts caused by implementing this road infrastructure in a pristine and biologically rich environment.

In light of economic downturns caused by the COVID-19 pandemic and considerations of policy-makers to invest in public infrastructure to create jobs and boost economic activity, it is important to determine which projects would contribute to a sustainable recovery and which projects are rather shortsighted and imply undesirable trade-offs. Malaysian policy-makers and infrastructure planners who are seeking sustainable recovery strategies will hence appreciate the results of this What-if simulation. The results point to the socioeconomic benefits associated with the Pan Borneo Highway but also highlight the monetary value of the significant trade-offs caused by environmental degradation and carbon emissions. If accounting for the costs of these trade-offs, the Pan Borneo Highway will yield a negative return on investment from a societal standpoint. This highlights how road infrastructure can turn from an investment opportunity to a liability for society.

The net results of the project improve when investing in the assessed mitigation and offsetting options, but the project's overall societal return remains unappealing. Even when investing in reforestation or carbon offsetting, there will be an irreversible loss of habitat quality, biodiversity, and ecosystem services given that pristine primary forests will be cut and large areas of habitat degraded. The loss of these forests will also imply adverse impacts for rural communities, impede the achievement of climate change mitigation and adaptation targets, and counteract economic prospects of establishing Borneo as an ecotourism destination. Consequently, the Pan Borneo Highway cannot be considered a project of choice for recovery efforts when Malaysian policy-makers envision realizing a sustainable recovery. If the highway's construction is still pursued by the Malaysian government, it is essential to provide recovery spending for mitigation and offsetting measures in order to at least avoid an overall negative societal return on investment.

Section 4: The Design of the Simulation

Table 6. Explanation of the simulation's design

Total capital cost	Total construction costs are estimated at MYR 27 billion (~ USD 6,480,000,000) (Kanyakumari, 2019).
Total O&M cost	Using O&M costs per 0.5 acres of conventional pavement over 25 years as estimated by Terhell et al. (2015), we assumed a total paved area of 8,405 acres considering the four-lane, 2,325 km long highway, as reported by the Borneo Post ("Govt will continue," 2017), and assuming an average lane width of 3.66 meters. We estimate O&M costs will be USD 935,946,000 over 25 years.
Wage creation (cumulative total over 25 years)	Wage creation was calculated using an estimate from the Borneo Post ("Govt will continue," 2017) that the highway is expected to create 400,000 indirect jobs. PayScale's (n.d.) estimate of the average annual wage in Kota Kinabalu, the capital of Sabah, Malaysia, is MYR 36,000; we estimate the benefit in terms of wage creation is USD 138,240,000 annually, totalling USD 3,456,000,000 over 25 years.
Value of travel time reductions	Kanyakumari (2019) reports that the highway's construction will reduce travel time from Miri to Semetan, an 816.6 km route, by 9.5 hours. The Star (2018) estimates that the highway will improve road safety for 3.74 million people. This value also uses an estimate from the Department of Transportation (2018) that the average person travels 13,476 miles per year. Assuming 1% of the distance driven by the people impacted by the highway's construction is spent on the path between Semetan to Miri, we estimate that 9,436,172 hours of travel will be saved annually. Assuming an average hourly wage in Malaysia of RM38, as estimated by SalaryExplorer, we estimate that the avoided opportunity cost of time spent in travel to be USD 86,058,000 annually. This totals USD 2,151,447,000 over the course of 25 years.
Value of increased tourism	Based on statistics provided by Sabah Tourism (2020), there were 1,469,475 international tourists and 2,726,428 domestic tourists in Sabah in 2019. Additionally, a report by the Sabah Development Corridor (2007) estimates that international tourists spend eight nights in Sabah on average, and domestic tourists spend three nights. An article by Budget Your Trip suggests that the average amount spent per night on a trip to Kota Kinabalu is USD 44. Assuming that the highway's construction will increase the length of tourist stays by 10%, and assuming that daily spending stays constant, we estimate the amount of increased revenue generated from increased tourism totals USD 89,008,000 annually. This will total USD 2,225,188,000 over 25 years.

Cost of carbon from deforestation	The cost of carbon is calculated by assuming that most deforestation will occur within 5.5 km of the highway based on the analysis of Barber et al. (2014). Additionally, a study by Alamgir et al. (2020) estimates that the highway will cut through 161 km of pristine forests. This suggests that 885.5 km2 of forested area will be affected. Barber et al. (2014) suggest that 43.6% of the forests in the area within 5.5 km of the highway will be lost; thus, 386.1 km2 of forests will be affected. Strand (2017) estimates that between 100 and 160 tons of carbon (and thus between 360 and 550 tons of CO_2) are released per hectare of deforested area. Considering an SCC of USD 30/ton of CO_2, the societal cost of deforestation can be estimated in the range of USD 13,898,808 annually, and between USD 347,470,000 and USD 530,857,250 after 25 years.
Increased spending on flood damages because of deforestation	To estimate the additional amount spent on flood damages if the highway is constructed, we use the fact that there are 45,392 km2 of intact forests on the island of Borneo, as suggested by Bryan et al. (2013). Using the result from the cost of carbon calculation that 386.1 km2 of forests will be deforested, thus 0.85% of forests on the island of Borneo will be lost. Bradshaw et al. (2007) estimate that there will be a 1.6% increase in flood frequency per 1% loss of forest cover. Thus, flood frequency will increase by 0.01361%. Considering annual spending on flood damage is USD 24.3 million in Sabah and USD 33.8 million in Sarawak, as reported by Che Ros et al. (2017), annual spending on flood damage can be expected to increase by USD 7,921 annually, totalling USD 198,038 over the course of 25 years.
Cost of biodiversity-related services lost	Using the Environmental Service Valuation Database, biological control of forests provides an ecosystem service worth USD 19.7/ha, maintenance of life cycles of migratory species provides a service worth USD 26.83/ha and the maintenance of genetic diversity offers an ecosystem service of USD 9.88/ha. Again, assuming that 386.1 km2 of land is deforested, the biodiversity-related services lost will total USD 436,000 annually, or USD 10,905,000 over 25 years.
Cost of carbon caused by manufacturing Portland cement for road surface	To estimate the cost of emissions due to the production of the concrete to construct the road, we use an estimate from Singh et al. (2020) that Portland cement emits 225,930 $kgCO_2$/km. Considering the highway is 2,325 km long, and using the estimate of Nordhaus (2017) that the SCC is USD 30, the societal cost of the emissions caused by cement manufacturing total USD 17,371,000.
Total reforestation cost (offset carbon lost from deforestation)	We assumed a cost of USD 1,750/ha, based on cost estimates from the Friends of the National Parks Foundation. Again, assuming that 386.1 km2 is deforested, the cost to reforest totals USD 67,564,000.

Solar energy generation (offset carbon lost from deforestation)	We found that between 13,898,808 and 21,234,290 tons of CO_2 are emitted from deforestation. Additionally, an estimated 579,029 tons of CO_2 will be emitted from Portland cement production. Based on US Energy Information Administration data, coal energy generation leads to 2.07 pounds of CO_2 emissions per kWh. As a result, to offset the emissions from deforestation and cement production, somewhere in the range of 13,429 GWh and 21,075 GWh of coal energy generation needs to be replaced with solar. This requires a solar capacity in the range of 9.02 GW and 14.15 GW. Assuming the capital cost of solar energy generation in USD 1,800 per MW and O&M costs are USD 26/yr/MW, the total cost ranges from USD 23,013,000 to USD 31,580,000 over 25 years.
Cost for wildlife crossings (intended to reduce habitat fragmentation)	Based on an article by Chung (2014), it typically costs about USD 2 million to construct a wildlife crossing. Clevenger and Huijser (2011) suggest building one crossing per 15 km of road. This results in a cost of USD 17,946,000.
Combination of flood-mitigation techniques (offset expected increase in flood damages)	Based on an article by Stormwater Report (2015), the capital cost of managing a hectare of impervious surface is USD 462,000. Additionally, the report calculates that the O&M cost of bioretention is USD 1,750/yr/acre of impervious surface, the O&M cost of tree infiltration trenches is USD 2,600/yr/acre of impervious surface, and the O&M cost of porous pavement is USD 2,000/yr/acre of impervious surface. Considering the surface area of the highway is expected to be 8,405 acres, the total cost of flood mitigation amounts to USD 2,905,888,000 after 25 years.

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