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Young Scientists Summer Program

Global trade and socio-economic and environmental trade-offs: A study on the future of Indonesia palm oil

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Approved by:

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This report represents the work completed by the author during the IIASA Young Scientists Summer Program (YSSP) with approval from the YSSP supervisor.

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Supervisor signature:

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Abstract

Indonesian oil palm production has doubled in the last decade, driven by increasing consumption at national and global scales. Oil palm plantations are associated in Indonesia with increased value added and employment, but also land expansion, leading to GHG emissions and biodiversity loss. Models and scenarios are often used to investigate potential future development and options to mitigate socioeconomic and environmental trade-offs, yet no model is able to adequately cover most relevant dynamic processes across spatial scales (from global to local) and disciplines (socioeconomics vs. environmental aspects). To close this gap, this study develops a coupling method to link Indonesia-tailored versions of the GLOBIOM partial equilibrium model and the MRIO input-output model, and use it to analyze the potential future developments of Indonesian oil palm. This study shows that from 2010 to 2030, the global economic output is estimated to increase by 100.1 billion Euro. This will increase to 120.9-141.3 billion Euro due to increasing global oil palm demand, depending on the amplitude of global demand. Indonesia economic output will expand from 38.2 billion Euro baseline to 45.2-52.1 billion Euro, occurring primarily in Sumatra and Kalimantan. Compare to 2010, national employment baseline will increase by 2.1 million jobs. With increasing global oil palm demand, it will rise to 2.5-2.9 million jobs. Sumatra GHG emission baseline will increase by 20.47 million tons CO_2e, and rise to 24.2-27.8 million tons CO_2e with increasing global demand. Under increasing global demand, Kalimantan land use will increase by 1.5-1.7 million ha and by 1.3-1.6 million ha with land-use intensification program. The Sumatra lowland rain forest will increase its potential species loss from 494 to 587-677 species for mammals if there Is increasing global demand on oil palm. With land-use intensification program, this potential species loss decline to 535-618 species. Other species taxa also are under threat due to the high global demand on oil palm. This study demonstrates the trade-off between socioeconomic and environmental consequences Land intensification reduces the pressure for land expansion and biodiversity loss. This study highlights the important to control global demand on oil palm to protect habitats with high biodiversity. The application and its limitation of this coupling method are also highlighted in this paper.

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About the authors

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Introduction

Global demand refers to the demand for products originating mainly from distant locations (opposite to local demand). It generates production in other parts of the world to meet global consumption, which has socioeconomic and environmental effects on the producing country, such as economic output, value added and employment, as well as greenhouse gas (GHG) emission, land use change, and biodiversity. Global trade contributes to create disparity between where the products are produced, and where socioeconomic and environmental impacts occur. High-income countries tend to consume a range of products, whilst middle and low-income countries often bear the environmental impact. We need a deeper understanding of the relationship between socioeconomic and environmental linkage in order to make better decision on adaptation and mitigation of climate change.

Some agriculture products are related with extensive land use. The effect of overproduction put pressure on the environmental in production area. Global demand of oil palm is a good example of how global consumption influences global environmental problems. To now, oil palm production was only concentrated in Indonesia and Malaysia. These two countries produced around 80% of the global production but only used 20% of the global consumption. Indonesian oil palm production has doubled in the last decade, driven by increasing consumption at national and global scales. Oil palm plantations are associated with land expansion, leading to large greenhouse gas emissions and biodiversity loss. This exemplifies recent trend in domestic resource exploitation in tropical countries for global markets, with domestic socioeconomic improvements but detrimental climate and biodiversity consequences.

Models and scenarios are often used to investigate potential future development and options to mitigate these trade-offs, yet no model is able to adequately cover most relevant dynamic processes across spatial scales (from global to local) and disciplines (socioeconomic vs. environmental aspects). There is a need for coupling method to evaluate the range of socioeconomic and environmental impacts of global demand at the local, regional and global levels. Environmental extended Multi-Regional Input Output (MRIO) has been used widely to examine the impact of consumption on land use needs and greenhouse gas (GHG) emissions. However, MRIO has limitation to capture global supply constraints. A global supply bottom-up model such as GLOBIOM is also capable of analyzing the impact of consumption on land use needs and GHG emissions, taking into account the land constraint. However, GLOBIOM is limited on capturing socioeconomic impacts at provincial level. Linking MRIO with GLOBIOM will create possibility to have better and comprehensive analysis.
This study aims to develop a coupling method to link GLOBIOM with environmental extended MRIO and then use it to analyze the potential future developments of Indonesian oil palm and inform socioeconomic and environmental aspects while covering global (e.g., trade) to local (e.g., employment, land use and GHG emission) interdependencies.

Literature Review

For many years, Indonesian palm oil production has expanded, from 21.9 million tons CPO in 2010 to 40.6 million tons in 2018 (FAO, 2022). Rising domestic consumption of oil palm, from 5.7 million tons CPO in 2010 to 12.6 million tons in 2018, and global consumption of oil palm, from 44.4 million tons to 70.7 million tons CPO, are the main drivers of increasing oil palm production in Indonesia. As the world's main producer of oil palm, Indonesia accounts around half of global production. However, its contribution to global consumption is less than a quarter. This illustrates that the majority of Indonesian oil palm production is for export (i.e., 74.2% in 2010 and 68.7% in 2018). Global demand has driven global trade, which has impact on national oil palm production, particularly in provincial level. This significant global demand is attributable to the characteristics of oil palm in the context of vegetable oil: high yield, low inputs, high production and a substance rich in fatty acids that serves as a raw material for all daily products. Other vegetable oil crops with the same inputs yields less than oil palm (Meijaard et al., 2020; Parsons et al., 2020).

Oil palm plantation is associated with the process of land use extensification. In Indonesia, the harvested are of fresh fruit bunch (FFB) is growing from 8.3 million ha in 2010 to 14.3 million ha in 2018 (FAO, 2022). The productivity of FFB production in Indonesia is lower or unchanged in the last decade compare to other countries, failing from 17.2 ton/ha in 2010 to 17.1 ton/ha in 2018. Reasons for Indonesia's lower yield include high input costs and low producer price. Land use extensification has been a quick solution to increase oil palm production in order to fulfill global demand.

Extensification has been associated with land use and land use change. In the last decade, oil palm production in Indonesia has driven deforestation (Carlson et al., 2013; Koh & Wilcove, 2008). Now recent studies show that the proportion of oil palm plantations driving deforestation has declined (Gaveau et al., 2016; Vijay et al., 2016). The government has implemented national and regional regulations to reduce deforestation, including from oil palm plantations under Presidential Decree No. 32/1990 and No. 41/2004. A moratorium on new oil palm plantation has also been implemented for forest and peatland areas under Presidential Instruction No. 6/2013. A national sustainable palm oil certificate has also been implemented to promote sustainable production under Presidential Regulation No. 44/2020. Although the governments have tried to put in place policies that are good for the environment, it is still not clear how these policies can lead to sustainable consumption and production.

Biodiversity can be impacted by land use and land use change. Indonesia is located in the tropical area and contains ecoregions with high biodiversity indicators (Raven et al., 2020). Tropical countries are the habitat for many species, showing high species richness in the ecoregions. Land use and land use change in Indonesia will have a higher impact on biodiversity. More species will be endangered as a result of habitat loss for massive monoculture plantations. Global trade has driven biodiversity treats in developing countries, and Indonesia has become the world's highest exporter of biodiversity threat in the world, by degrading habitat and endangering biodiversity to produce exports (Lenzen et al., 2012).

Input-output model captures global trade by showing transaction flows from one sector in one region to other sectors in other regions. In addition to intraregional trade flows, it also captures interregional trade flows and factor inputs used to produce a product in the region. Factor inputs can include internal input such as product inputs and employment, and also from external input such as GHG emissions and land use. In this model, however, it is assumed that demand can create more supply without any constraint. On the other hand, there is a supply-driven model called GLOBIOM which can show how land resource across region should be allocated to meet global demand. However, this model cannot capture the impact of other non-agricultural sectors, both on economic output and employment. In this study, we link GLOBIOM and MRIO-Indonesia to analyze the impact of increasing global demand for Indonesian oil palm.

Method

Model

We use two different models. The first model is GLOBIOM, developed by International Institute for Applied System Analysis (IIASA) (Havlík et al., 2014). It is a global partial equilibrium model for agriculture, forestry and bioenergy sectors (a gridded global model covering trade dynamics in the oil palm sector and refined for Indonesia). The model has detailed coverage on land use-based sectors, with explicit production technology, geo-location of land cover and land use using bottom-up approach for Indonesian provinces. The second model MRIO, well explained by Isard (1951). It is a multi-regional input-output that connect regional economies on full sectoral coverage, from agriculture to services.

GLOBIOM-Indonesia will be used in this study. Some of the differences in this model includes 34 Indonesian provincial coverage, 50x50 km resolution, more important tree crops, separating large and smallholder oil palm plantations. This model covers global and subnational coverage, from EU28 and 25 other countries and regions with 34 provinces in Indonesia. This model is a recursive dynamic model, with time frame from 2000 to 2030 (5-year time step), where the solution of the equilibrium in period t depends on starting condition from the previous period $t-1$. The demand side is represented by single agent per region and per good, and his decision depends only on the price of this good. The model uses total surplus maximization subject to market balance constraints. The model is therefore used to address issues affecting land use-based sectors, and consider ceteris paribus. However, there is no feedback from these sectors to the rest of the economy and labor and capital market is not represented.

MSRIO-Indonesia will be used in this study. This model has global and subnational coverage, from 34 provinces and 43 countries and 5 rest of continents. This model is constructed from EXIOBASE (Stadler et al., 2018; Wood et al., 2015) and INDOTERM (Horridge, 2012; Yusuf et al., 2018). This model is a static model, only represents the economies year 2010, where the total input and output for each sector and region is set equal. The model has detailed transaction flow from and to each sector and region. The model uses fix technological coefficient, which means the level of technological progress remains constant. The model is therefore used to address issues affecting trade-related sectors under market equilibrium. However, the model does not incorporate the existence of supply constraints.

Coupling method

In this study, we start from GLOBIOM-Indonesia to capture the implications of increasing global demand of palm oil in the future. Because this model optimized the country's economy surplus with subject to supply constraints, it creates a different response in global consumption and trade. We capture the dynamic change in consumption and import of palm oil from all countries. These outputs are used as inputs in MSRIO-Indonesia to look how these change affect to socioeconomic indicators, such as economic output, value added and employment in all sectors for Indonesian provinces and other countries.

We link GLOBIOM-Indonesia into MSRIO-Indonesia using a comparative static assessment which focus on a certain year. We start from GLOBIOM to capture production, consumption and trade (import-export) quantity by region by product due to the exogenous changes. In this study, we impose a global demand shift on palm oil, from 2010-2030. We look at the deviation (in %) from baseline on global consumption and import quantity in year 2030, compare to year 2010. We then implement the deviation from GLOBIOM into the MSRIO as the final demand change (in M Euro). Finally, we analyze the economic output, value added and employment of Indonesian provinces, as well as other countries.
The simulation run from 2000 to 2030 with 5-year time step, and demand shift starts from 2010 to 2030. Along with other impacts, we find the potential impact on oil palm consumption C^r and net export $\sum_{d=1}^{D}\left(EX^{r,d} - IM^{d,r}\right)$ in region r. Since MRIO is a comparative static analysis, we can only link GLOBIOM and MRIO on a single year. We decided to use year 2030 in our study. The change in global consumption and net trade of oil palm from GLOBIOM are translated into the change in global palm oil demand Δy^r in MRIO as follows

$$\Delta y^r = \Delta y_C^r + \Delta y_{EX}^r$$

$$\Delta y_C^r = \left(\frac{\alpha C_P^r}{\alpha C_B^r} - 1\right) \times \delta^r \times \bar{C}^r$$

$$\Delta y_{EX}^r = \left(\frac{\sum_d \alpha EX_P^{r,d}}{\sum_d \alpha EX_B^{r,d}} - 1\right) \times \gamma^r \times \overline{EX}^r$$

where $\bar{C}^r$ is the total consumption value of vegetable oil (from all user and origin) in region r, taken from MRIO; δ^r is the share of palm oil to vegetable oil consumption in region r, based on FAO; αC_P^r (αC_B^r) is the consumption level of palm oil in region r under policy (baseline) simulation P (B), taken from GLOBIOM; α is the conversion rate from oil palm to palm oil. Next, $\overline{EX}^r$ is the total export value of vegetable oil (to all user and destination) in region r, taken from MRIO; γ^r is the share of palm oil to vegetable oil export in region r, based on UN Comtrade; αEX_P^r (αEX_B^r) is the export level of palm oil in region r under policy (baseline) simulation, taken from GLOBIOM.

Biodiversity Impact of land use

We calculate biodiversity impact from land use change. The biodiversity indicator is based on characterization factors for each taxon and each ecoregion (Chaudhary et al., 2018). We only focus on the characterization factors on crop land use. We used middle technology use for five different taxa, i.e., mammals, birds, amphibians, reptiles, and plants. We link land use change in each province with the characterization factor for each ecoregion. We calculate the potential unit species loss for each land use and province in Indonesia for each scenario.

The change of land use input associated with the change of total output can be expressed by

$$\Delta F = S^L \Delta X$$

where S^L is the land use coefficient. We aggregate this land use change over the sector for each region, such that

$$\Delta F_{l,r} = \sum_n^N \Delta F(l,n,r)$$

where l is the land use type, n is sector, and r is region. Next, we create a correspondent matrix M from administrative region r to terrestrial ecoregion er, such that

$$M_{r,er} = \frac{L_{r,er}}{\sum_{er} L_r}$$

$$M_r = \sum_{er}^{ER} M_{r,er} = 1$$

where $L_{r,er}$ is the total land use by region and ecoregion. Then, we calculate the biodiversity impact of land use ΔB, using the formula below

$$\Delta B_{l,t} = \Delta F_{l,r} \cdot M_{r,er} \cdot CF_{er,t}$$

where $CF_{er,t}$ is the characterization factor matrix of land occupation from ecoregion er and taxa t, developed by Chaudhary et al. (2018).

Developing scenario

We run baseline and policy scenarios from 2010 to 2030, with a 5-year time optimization step. We begin in 2010 with the baseline and policy scenario at the same level. We design and analyze six scenarios to explore the future impact that global consumption for palm oil can have on economic output, value added and employment as well as related land use change, emission and biodiversity consequences. For all scenarios, population and GHG projections were based on the shared socioeconomic pathway 2 (SSP2), the middle of the road scenario framework. An outline of the scenario combinations can be found in Table 1.

Table 1. Scenario development. Source: Authors

Policy: global demand \ intensification	Baseline	Land use intensification program
Baseline	BS-BS	BS-IN
Medium increase in global oil palm demand	MD-BS	MD-IN
High increase in global oil palm demand	HG-BS	HG-IN

Note: BS=baseline, MD=medium, HG=high, IN=intensification.

For global palm oil demand, we have two policy scenarios, (1) we increase by 10% in global oil palm demand compared to baseline in 2020 and 2030, and (2) we increase by 20%, doubling the shock of first scenario. We impose this demand shift to all countries. In addition, we also compare with land use intensification program, where we increase 10% in large scale and smallholder oil palm yields in 2025 and 15% in 2030.
Since this is a comparative static analysis, we analyze "what if" there is a policy implementation taking place in the economy. We will use the year 2030 for the year analysis to understand the future. We will use the baseline and policy results from GLOBIOM in 2010 and 2030 and calculate the percentage change for each country (Appendix A). The results we are looking at are consumption and export-import variables by country for oil palm product. Since we use the percentage change, it will not affect to the conversion from oil palm to palm oil. We calculate the change of consumption and import of oil palm from each country using MRIO

baseline and the percentage change from GLOBIOM. We impose additional change of consumption and global import for each country in MRIO. For Indonesia, we allocate the changes for each province using the share to national palm oil output. We apply these scenarios and measure the change by sector and region in output, value added, employment, GHG emission and land use. The outcomes are presented in monetary and physical terms.

Results

Baseline projection

The baseline for global oil palm consumption, exports, and imports generated from GLOBIOM are shown in Figure 1. According to this projection, China, Malaysia, and Asia Pacific countries are the top three countries with regards to oil palm usage. Malaysia previously consumed less oil palm than Indonesia, but after 2015, Malaysia overtook Indonesia. In 2030, Indonesia will export twice as much oil palm as Malaysia, playing a significant role in the global trade. China, India, Asia Pacific and Western Africa countries continue to be the main importers. In 2030 we will see a 2.5-fold increase in global consumption on oil palm compare to 2010, but the growth of global imports will exceed global consumption by 3.5 times. It shows that in the baseline projection, global consumption of oil palm will be more dependent on exporting countries in the future.

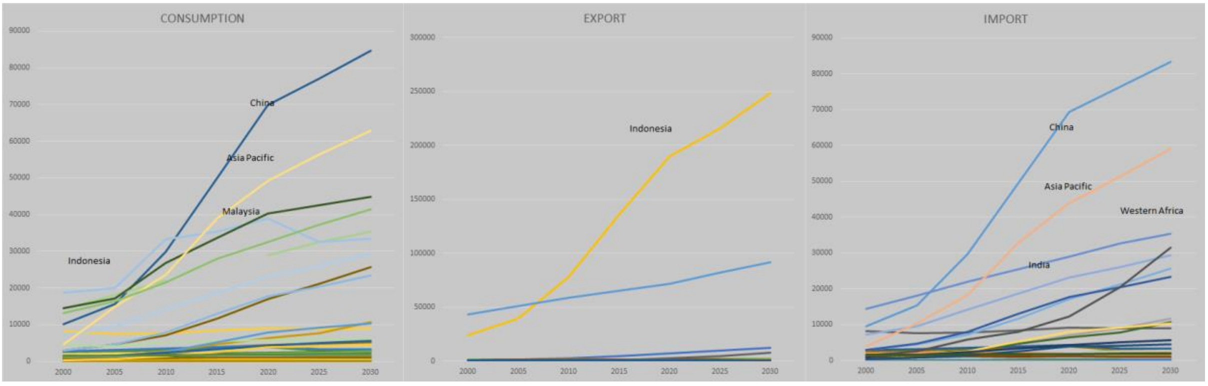

Figure 1. Baseline for global consumption, export and import of oil palm (1000 ton). Source: Authors calculation.

Change in global economic output

Table 2 shows the change in global economic output across six different scenarios. The change is the different between year 2010 and 2030. In the baseline projection, global economic output in 2030 increases by 100.3 billion Euro compare to 2010. And specific for Indonesia, their economic output increases by 38.1 billion Euro. With higher global demand, Indonesia experiences more production by 45.2 and 52.1 billion Euro, under medium and high global scenarios respectively. These economic outputs increase more with the

implementation of land-use intensification program in Indonesia. This country experiences an increase of 40.2, 47.2, and 54.5 billion Euro of economic output under baseline, medium and high global demand.
In the global context, Indonesia experiences the highest impact from increasing global demand. For comparison, the Asia Pacific countries, the second highest rank region, only sees less changes, around 14.2-16.4 billion Euro in 2030 compare to 2010, under medium and high global demand. Middle East countries are showing high increase in their economic output, around 12.5-14.1 billion Euro. Africa countries in this period also increase by 9.1-11.1 billion Euro, under medium-high global demand. These results highlight that the increasing global demand on oil palm will affect mostly to the Indonesian economy.

Table 2. Change in global economic output (M Euro) under 6 scenarios. Source: Authors calculation

Country	BS-BS	MD-BS	HG-BS	BS-IN	MD-IN	HG-IN	dMD	dHG	dMD-IN	dHG-IN
Australia	653	805	961	664	809	966	152	308	145	302
Brazil	1,749	2,072	2,382	1,760	2,072	2,400	323	633	312	640
Canada	563	683	804	570	684	807	120	241	114	237
China	5,148	5,997	6,810	5,194	6,013	6,880	849	1,662	819	1,686
EU Baltic	19	25	31	19	25	31	6	12	6	12
EU Central East	24	112	202	26	115	207	88	178	89	181
EU Mid West	1,817	2,471	3,140	1,825	2,458	3,129	654	1,323	633	1,304
EU North	569	782	997	578	787	1,005	213	428	209	427
EU South	403	1,060	1,720	381	1,032	1,691	657	1,317	651	1,310
India	9,081	11,423	13,635	9,181	11,526	13,778	2,342	4,554	2,345	4,597
Indonesia	38,185	45,286	52,027	40,282	47,189	54,548	7,101	13,842	6,907	14,266
Japan	666	869	1,076	681	877	1,087	203	410	196	406
Mexico	79	110	141	79	109	140	31	62	30	61
Middle East	11,104	12,511	14,099	11,172	12,519	14,109	1,407	2,995	1,347	2,937
Africa	7,186	9,095	11,044	7,243	9,189	11,139	1,909	3,858	1,946	3,896
America	1,252	1,887	2,584	1,215	1,846	2,554	635	1,332	631	1,339
Asia Pacific	12,230	14,261	16,429	12,427	14,264	16,399	2,031	4,199	1,837	3,972
Europe	996	1,165	1,335	1,003	1,169	1,342	169	339	166	339
Russia	3,705	4,221	4,735	3,729	4,233	4,759	516	1,030	504	1,030
South Africa	363	489	605	370	490	612	126	242	120	242
South Korea	490	610	733	500	615	739	120	243	115	239
Turkey	372	513	658	362	505	651	141	286	143	289
US	3,708	4,444	5,160	3,734	4,448	5,199	736	1,452	714	1,465
Global	100,362	120,891	141,308	102,995	122,974	144,172	20,529	40,946	19,979	41,177

Note: BS-BS is the baseline scenario, global demand of oil palm follows the SSP2 scenario, MD-BS is the medium increase of global palm oil demand, HG-BS is the high increase of global palm oil demand. The BS-IN, MD-IN, HG-IN scenarios correspond to the previous scenarios and with addition on the land use intensification program, and the last four columns are calculated from dMD_BS=(MD-BS)-(BS-BS), dHG_BS=(HG-BS)-(BS-BS), dMD-IN=(MD-IN)-(BS-IN), dHG-IN=(HG_IN)-(BS-IN).

Change in provincial economic output

We can look deeper into Indonesian economic output at the provincial level in 2030 as shown in Table 3. Riau, North Sumatra and Lampung, which are all in the Sumatra Island, are the three provinces with the highest change in economic output due to the future of global demand for oil palm. In Kalimantan Island, the remaining three provinces with high change are South Kalimantan, Central Kalimantan and East Kalimantan. This indicates that among the Indonesian islands, Sumatra and Kalimantan have the highest impact on economic output as a result of the increasing global demand for oil palm. Sumatra contributes around 80% and Kalimantan around 12.5% to the total national economic output change.

In 2030, under baseline projection, Riau province experiences increasing economic output by 16.8 billion Euro compare to 2010. With higher global demand, their output increases more by 19.8-22.8 billion Euro under medium-high global demand scenario. With land-use intensification program, this province produces more output, with 20.6-23.8 billion Euro increase, respectively. North Sumatra and Lampung also experience higher increase with the intensification program, i.e., by 10.1-11.7 and 3.8-4.5 billion Euro, respectively.

Table 3. Change in provincial economic output (M Euro) under 6 scenarios. Source: Authors calculation

Province	BS-BS	MD-BS	HG-BS	BS-IN	MD-IN	HG-IN	dMD	dHG	dMD-IN	dHG-IN
Aceh	226	272	315	241	286	334	46	89	45	93
North Sumatra	8,299	9,794	11,223	8,721	10,182	11,728	1,495	2,924	1,461	3,007
West Sumatra	560	664	763	591	692	800	104	203	101	209
Riau	16,829	19,881	22,796	17,700	20,680	23,840	3,052	5,967	2,980	6,140
Riau Islands	255	300	343	267	311	357	45	88	44	90
Jambi	639	762	878	677	797	925	123	239	120	248
South Sumatra	734	879	1,014	780	919	1,069	145	280	139	289
Bangka Belitung	126	152	176	135	160	187	26	50	25	52
Bengkulu	157	192	224	170	203	240	35	67	33	70
Lampung	3,075	3,675	4,238	3,265	3,846	4,470	600	1,163	581	1,205
Jakarta	370	441	508	391	460	533	71	138	69	142
West Java	376	462	540	407	488	578	86	164	81	171
Banten	127	152	175	134	158	183	25	48	24	49
Central Java	131	160	186	141	168	198	29	55	27	57
Yogyakarta	6	7	8	6	8	9	1	2	2	3
East Java	284	343	399	303	360	422	59	115	57	119
West Kalimantan	766	936	1,091	828	990	1,168	170	325	162	340
Central Kalimantan	1,284	1,528	1,757	1,358	1,594	1,847	244	473	236	489
South Kalimantan	1,538	1,812	2,074	1,614	1,881	2,164	274	536	267	550
East Kalimantan	1,130	1,346	1,551	1,195	1,405	1,630	216	421	210	435
North Kalimantan	90	107	124	95	112	130	17	34	17	35
North Sulawesi	552	653	749	581	679	784	101	197	98	203
Gorontalo	20	24	27	21	25	29	4	7	4	8
Central Sulawesi	202	247	289	219	262	310	45	87	43	91
South Sulawesi	85	102	117	90	106	123	17	32	16	33
West Sulawesi	63	81	97	71	88	108	18	34	17	37
Southeast Sulawesi	16	19	22	17	20	24	3	6	3	7
Bali	42	50	57	44	52	60	8	15	8	16
West Nusa Tenggara	20	23	27	21	25	28	3	7	4	7
East Nusa Tenggara	16	19	22	17	20	23	3	6	3	6
Maluku	17	21	25	19	22	26	4	8	3	7
North Maluku	80	95	110	85	100	117	15	30	15	32
West Papua	35	42	48	37	43	50	7	13	6	13
Papua	36	44	51	39	46	54	8	15	7	15
National	38,150	45,241	51,973	40,241	47,142	54,494	7,091	13,823	6,901	14,253

Change in regional GDP

Table 4 shows the change in Gross Domestic Product (GDP) of Indonesian regions. Under baseline projection 2010-2030, Indonesia's GDP increases by 18.5 billion Euro. And with land-use intensification program, the baseline GDP projection changes to 19.6 billion Euro. With higher global demand, Indonesia experience higher GDP change, around 22.1-22.5 billion Euro under medium-high global demand scenario.

At the regional level, Sumatra dominantly contributes to this change. Due to the higher global demand on oil palm, they experience the highest shift in GDP, around 17.6-20.2 billion Euro, which account for more than 80% of the change in national GDP. Other Indonesian regions, in contrast, only way modest change in GDP. Kalimantan increases by 2.8-3.2 billion Euro. Java, most developed region in Indonesia, only experiences an increase around 0.7-0.8 billion Euro due to medium-high global demand.

Under land-use intensification program, Sumatra experiences the most benefit. The change in GDP increases from 17.6-20.2 to 18.4-21.2 billion Euro under medium-high global demand scenario. These results highlight that increasing global demand on oil palm affects positively to the regional GDP change in Indonesia, especially in Sumatra region.

Table 4. Change in regional GDP (M Euro) under 6 scenarios. Source: Authors calculation

Region	BS-BS	MD-BS	HG-BS	BS-IN	MD-IN	HG-IN	dMD	dHG	dMD-IN	dHG-IN
Sumatra	14,940	17,682	20,294	15,738	18,410	21,251	2,742	5,354	2,672	5,513
Java	615	743	859	656	776	906	128	244	120	250
Kalimantan	2,392	2,850	3,283	2,533	2,976	3,453	458	891	443	920
Sulawesi	481	577	668	512	605	707	96	187	93	195
Eastern Indonesia	168	203	233	178	210	245	35	65	32	67
National	18,596	22,055	25,337	19,617	22,977	26,562	3,459	6,741	3,360	6,945

Change in regional employment

Table 5 shows the regional employment change in Indonesia. Under baseline projection 2010-2030, national employment increases by 2.1 million jobs and by 2.2 million jobs intensification program. With higher global demand on oil palm, employment in 2030 rises by 2.5-2.9 million jobs compare to 2010, under medium-high global demand respectively. The land-use intensification program brings an addition to 2.6-3.1 million jobs to this region. Java, as the most populated region, experiences the least impact on their employment. Higher global demand only increases employment in Java by 104 and 120 thousand jobs.

Table 6 shows how the global demand for oil palm changes the number of jobs in each sector. Under baseline projection, most of the jobs created are in oilseed sector. In Riau province, for example, around 79% of employment change happens in oilseed sector. The service sector in Riau only experiences small change in their employment compare to what in Lampung. In contrast, Jakarta province experience most of the employment change on service sector, around 71% of total new jobs happens in this sector. Manufacture sector contributes most of the employment change in West Java and East Java.

Table 5. Change in regional employment (1000 people) under 6 scenarios. Source: Authors calculation

Region	BS-BS	MD-BS	HG-BS	BS-IN	MD-IN	HG-IN	dMD	dHG	dMD-IN	dHG-IN
Sumatra	1,598	1,894	2,175	1,685	1,973	2,280	296	577	288	595
Java	87	104	120	92	108	126	17	33	16	34
Kalimantan	275	329	379	292	344	400	54	104	52	107
Sulawesi	95	115	133	102	120	141	20	38	19	39
Eastern Indonesia	87	105	122	93	110	129	18	34	17	36
National	2,142	2,546	2,928	2,264	2,656	3,075	404	786	392	811

Table 6. Contribution of total employment change by sector under baseline scenario. Source: Authors calculation

Province	FoodProds	OilSeeds	OtherAgri	OthManufact	OthServices	Transport	VegOilsFats
Riau	0.02%	79.10%	0.69%	0.19%	11.35%	0.77%	7.65%
North Sumatra	0.10%	78.17%	2.01%	0.47%	13.40%	0.56%	4.76%
Lampung	0.73%	55.53%	8.13%	1.41%	22.34%	1.04%	10.29%
South Kalimantan	0.09%	78.73%	3.15%	0.94%	14.16%	0.56%	1.56%
Central Kalimantan	0.01%	84.05%	1.51%	0.22%	10.60%	0.33%	2.49%
East Kalimantan	0.03%	86.78%	0.72%	0.63%	8.27%	0.71%	1.84%
South Sumatra	0.05%	71.73%	6.26%	1.01%	14.03%	1.19%	4.90%
Jambi	0.02%	84.04%	2.09%	0.36%	8.32%	0.34%	4.31%
West Kalimantan	0.06%	82.94%	3.96%	0.45%	9.73%	0.50%	1.62%
West Sumatra	0.11%	71.98%	4.71%	2.09%	12.62%	0.90%	6.69%
North Sulawesi	0.16%	63.25%	2.37%	0.40%	14.09%	1.10%	17.85%
Jakarta	0.58%	0.85%	0.07%	10.95%	70.70%	5.06%	7.92%
West Java	1.67%	5.00%	9.07%	25.59%	42.53%	9.74%	2.05%
Aceh	0.05%	81.40%	3.69%	1.21%	10.11%	0.61%	2.22%
East Java	2.12%	3.89%	23.42%	19.75%	29.38%	7.30%	9.58%

Note: Only 7 of 12 sectors and 15 of 34 provinces with the highest change in their GDP change are presented in this table. FoodProds is food processing sector, Oilseed is oil seed related sector, OtherAgri is other agriculture sector, OthManufact is other manufacture sector, OthServices is other service sector, Transport is transportation sector, and VegOilsFats is vegetable oil sector.

Change in regional GHG emission

Changes in GHG emission in Indonesian regions are shown in Table 7. Under baseline projection, Indonesia in 2030 experiences increase in GHG emission by 25.3 million tons CO_2e compare to 2010 and with land-use intensification program, it becomes 26.7 million tons CO_2e. With higher global demand on oil palm, Indonesia will experience a rise in GHG emission by 30.1-34.5 million tons CO_2e under medium-high global demand scenario.

At the regional level, Sumatra experiences an increase of 24.2-27.8 million tons CO_2e under medium-high global demand. And with additional intensification program, this leads to a rise of 25.23-29.12 million tons CO_2e, which make the region with the most environmental impact. Kalimantan experiences an increase by 4-4.6 and 4.2-4.8 million tons CO_2e with intensification program. Java experiences higher GHG emission compare to rest of the regions.

Table 7. Change in regional emission (million tons CO_2e) under 6 scenarios. Source: Authors calculation

Region	BS-BS	MD-BS	HG-BS	BS-IN	MD-IN	HG-IN	dMD	dHG	dMD-IN	dHG-IN
Sumatra	20.5	24.2	27.8	21.6	25.2	29.1	3.8	7.3	3.7	7.6
Java	0.8	0.9	1.1	0.8	1.0	1.1	0.2	0.3	0.2	0.3
Kalimantan	3.4	4.0	4.6	3.6	4.2	4.9	0.7	1.3	0.6	1.3
Sulawesi	0.6	0.7	0.8	0.6	0.7	0.9	0.1	0.2	0.1	0.2
Eastern Indonesia	0.2	0.2	0.2	0.2	0.2	0.3	0.0	0.1	0.0	0.1
National	25.4	30.1	34.6	26.8	31.4	36.2	4.7	9.2	4.6	9.5

Table 8. Change in regional land use (1000 ha) under 6 scenarios. Source: Authors calculation

Region	BS-BS	MD-BS	HG-BS	BS-IN	MD-IN	HG-IN	dMD	dHG	dMD_IN	dHG_IN
Sumatra	3,450	4,098	4,723	3,183	3,735	4,314	648	1273	552	1131
Java	9	10	12	9	11	12	1	3	2	3
Kalimantan	1,274	1,522	1,756	1,184	1,394	1,615	248	482	210	431
Sulawesi	37	47	53	35	44	50	10	16	9	15
Eastern Indonesia	26	31	36	28	31	37	5	10	3	9
National	4,796	5,708	6,580	4,439	5,215	6,028	912	1784	776	1589

Change in regional land use

Changes in land use in Indonesian regions are shown in Table 8. Under baseline projection, Indonesia will increase their land use in 2030 by 4.7 million ha, compare to 2010. While with land-use intensification program, it increases by 4.4 million ha. With higher global demand on oil palm, Indonesia experiences increase in land use by 5.7-6.6 million ha under medium-high global demand scenario. With intensification program, land use change is declining to 5.2-6.1 million ha. At the regional level, Sumatra experiences the most land use change, i.e., 4.1-4.9 million ha under medium-high global demand and 3.7-4.3 million ha with land-use intensification. Land use change in Kalimantan reaches 1.5-1.7 million ha and 1.3-1.6 with intensification program, respectively.

Change in ecoregional biodiversity

Table 9 displays the trend in regional biodiversity change in Indonesia. Under baseline projection, the average number of potential species loss due land use change in 2010-2030 in Sumatra lowland rain forest are 494 mammals, 504 birds, 310 amphibians, 313 reptiles, and 5,067 plants. Under higher global demand, the number of potential species loss for mammals increases to 587.5-677.2 species under medium-high global demand scenario.

The risk of extinction can be mitigated by implementing this intensification program. Under land-use intensification program, these numbers of potential species loss are decreasing. For example, the number of potential species loss for mammals increase to 535.5-618.6 species under medium-high global demand in Sumatra lowland rain forest. Increasing global demand is having an effect not only on this ecoregion, but also on other ecoregions in Sumatra, such as Sumatra montane rain forest, Mentawai islands rain forest, and Sumatra peat swamp forests. Borneo lowland rain forest gets the highest biodiversity loss in Kalimantan.

Table 9. Change in potential species loss under 6 scenarios. Source: Authors calculation

Ecoregion	Mammals	Birds	Amphibians	Reptiles	Plants	Mammals	Birds	Amphibians	Reptiles	Plants
Scenario	**BS-BS**					**BS-IN**				
Sumatran lowland rain forests	494.40	504.64	310.78	313.34	5067.15	456.39	465.84	286.89	289.25	4677.54
Sumatran montane rain forests	323.95	323.98	373.67	225.34	2128.02	299.01	299.04	344.90	207.99	1964.18
Borneo lowland rain forests	248.71	189.25	289.21	79.99	1704.77	231.03	175.80	268.65	74.31	1583.59
Mentawai Islands rain forests	215.89	20.12	11.76	11.20	675.08	199.77	18.61	10.89	10.36	624.67
Sumatran peat swamp forests	119.96	225.87	88.80	80.45	1984.39	110.59	208.22	81.86	74.16	1829.33
Sunda Shelf mangroves	46.11	47.59	0.55	30.50	122.70	42.54	43.90	0.51	28.13	113.18
Sumatran freshwater swamp forests	42.56	52.46	16.51	14.14	1769.81	39.21	48.33	15.21	13.03	1630.46
Borneo montane rain forests	38.48	31.94	60.05	11.66	259.58	36.07	29.94	56.29	10.93	243.31
Sundaland heath forests	35.16	36.25	23.56	22.56	357.24	32.69	33.71	21.91	20.97	332.17
Sulawesi montane rain forests	33.14	13.21	3.29	0.99	37.40	31.77	12.66	3.16	0.95	35.85
Scenario	**MD-BS**					**MD-IN**				
Sumatran lowland rain forests	587.53	599.69	369.32	372.36	6021.60	535.50	546.58	336.61	339.39	5488.33
Sumatran montane rain forests	384.82	384.85	443.87	267.68	2527.85	350.75	350.77	404.57	243.98	2304.01
Borneo lowland rain forests	296.86	225.89	345.21	95.48	2034.82	271.88	206.89	316.16	87.45	1863.62
Mentawai Islands rain forests	256.92	23.94	14.00	13.33	803.36	234.62	21.86	12.79	12.17	733.64
Sumatran peat swamp forests	142.45	268.21	105.45	95.53	2356.37	129.69	244.18	96.00	86.97	2145.30
Sunda Shelf mangroves	54.76	56.52	0.66	36.21	145.70	49.88	51.48	0.60	32.99	132.73
Sumatran freshwater swamp forests	50.48	62.22	19.59	16.78	2099.34	45.95	56.63	17.83	15.27	1910.70
Borneo montane rain forests	46.24	38.37	72.15	14.01	311.89	42.64	35.38	66.53	12.92	287.60
Sundaland heath forests	41.93	43.24	28.10	26.90	426.05	38.45	39.65	25.76	24.67	390.68
Sulawesi montane rain forests	40.27	16.05	4.00	1.20	45.44	37.82	15.07	3.76	1.13	42.68
Scenario	**HG-BS**					**HG-IN**				
Sumatran lowland rain forests	677.17	691.19	425.67	429.18	6940.33	618.58	631.38	388.84	392.04	6339.81
Sumatran montane rain forests	443.44	443.48	511.49	308.46	2912.95	405.05	405.08	467.20	281.75	2660.73
Borneo lowland rain forests	342.88	260.92	398.73	110.28	2350.31	315.05	239.74	366.36	101.33	2159.53
Mentawai Islands rain forests	296.32	27.61	16.15	15.37	926.57	271.30	25.28	14.78	14.08	848.32
Sumatran peat swamp forests	164.12	309.02	121.49	110.06	2714.89	149.73	281.91	110.84	100.41	2476.77
Sunda Shelf mangroves	63.09	65.11	0.76	41.72	167.87	57.59	59.44	0.69	38.09	153.24
Sumatran freshwater swamp forests	58.13	71.65	22.56	19.32	2417.46	53.01	65.34	20.57	17.62	2204.27
Borneo montane rain forests	53.58	44.47	83.61	16.24	361.41	49.64	41.19	77.45	15.04	334.80
Sundaland heath forests	48.41	49.92	32.44	31.06	491.89	44.53	45.92	29.84	28.57	452.46
Sulawesi montane rain forests	46.92	18.69	4.66	1.40	52.94	44.37	17.68	4.41	1.32	50.07

Note: Only 10 ecoregions with the highest biodiversity impact of 38 ecoregions in Indonesia are presented in this table.

Discussion

Coupling Method

In this study, we propose a simple coupling method to link GLOBIOM with MRIO. There are some points that we can highlight from this coupling method:

A. We use a one-way approach, which mean we only use outputs from GLOBIOM and use them as inputs for MRIO. Thus, there no feedbacks from MRIO that is used for GLOBIOM
B. GLOBIOM is a dynamic model while MRIO is a static model. When we use outputs from GLOBIOM, we only look at the final year results, called T, we ignore the dynamic change within the period. However, the final results in GLOBIOM are cumulative results thus any change happens within the period will still be reflected in the final results. This approach is used to accommodate static process in the MRIO.
C. Since MRIO is only for a certain year, called t, then outputs from GLOBIOM at year T will be calculated relative to time t (refer as the baseline). This process makes outputs from GLOBIOM become compatible for MRIO.
D. Outputs from GLOBIOM that we can use for MRIO are only related to final demand (consumption, export, and import) and land productivity (yield).
E. Since outputs from GLOBIOM can be differ across regions, we can accommodate different impulse across regions in MRIO according to GLOBIOM. It gives more dynamic inputs across regions in MRIO.
F. The output from MRIO will always refer to baseline. Any change in GDP, for example, it will refer to the change from t to T.

For this study, this method has the drawback of using the economic structure from the year 2010. We project the future of Indonesian oil palm in term of socioeconomic and environmental impacts in 2030, and assume the there is no change in Indonesian economic structure during 2010 and 2030. If there is change in economic structure during the period, then the results will be misleading.

Application

In this study, we analyze the impact of future global demand by relating two global demands for oil palm (medium and high) with the efficiency of land use using intensification program. This study shows that increasing global demand improves regional economies but declines environmental qualities. Regional economies are represented by sectoral economic output, gross domestic product (GDP), and employment at the provincial and global level. And environmental qualities are represented by GHG emissions, land use, and biodiversity. The connection between global demand and biodiversity loss can be explored by showing the correlation between GDP, land use, and the potential species loss, shown in Figure 1. In this study, we explain how increasing global demand for oil palm can create value added to producing countries but at the same time be compensated by environmental loss.

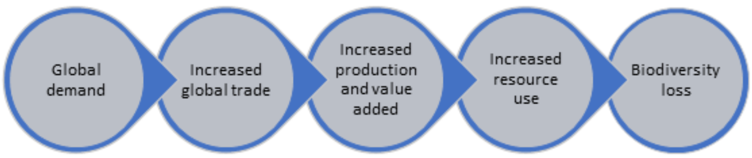

Figure 1. How global demand contributes to biodiversity loss. Source: Authors.

The results show that global economic output increase on top of baseline projection as well as Indonesia provincial outputs. This increasing economic output in global and subnational level has been attributed to high demand for palm oil and all of its derivatives. The global import on oil palm is projected to increase until 2030. This trend is correlated with global consumption. Increases in Indonesian exports of oil palm are closely correlate with high global demand for oil palm, which further increases production of oil palm in the provinces. Production is also related with value added and employment. National GDP and employment increase because of increasing global demand for oil palm. This global demand creates positive impacts to Indonesian economy. Since oil palm production is related to land occupation, only two regions in Indonesia experience the majority of this economic gains, i.e., Sumatra and Kalimantan. However, there are increasing GHG emission, land use, and biodiversity loss in these regions.

This study also assesses how land-use intensification program can help to reduce environmental consequences. With additional land-use intensification, the impacts on national GDP, employment are higher. The national land use changes also decline due to higher yields on small and large-scale monoculture plantations. The potential species loss also declines because of fewer land use change.

Conclusion

Increases in the efficiency of land use through land use intensification could enable the decoupling of an increase in national GDP with a reduction in environmental consequences. This study demonstrates that increased economic output and GDP in Indonesia as a result of global demand has not led to a decline in the land use of oil palm. This decoupling can be achieved in the future by reducing the global demand for oil palm. The consequences of land use change are likely to create high pressure on habitat loss and increase the potential species loss.

We show that there are trade-offs between increasing global demand and biodiversity conservations. Allowing the growth of global demand for oil palm generally results in an increased regional economy in terms of economic output, value added, and employment, not only in provinces where production rises, but also in other trade-related provinces. However, this study shows that increased economic output could take place in many provinces that are valuable for biodiversity conservation. From a socioeconomic point of view, the highest value added and employment take place in Sumatra, particularly in Riau, North Sumatra, and Lampung provinces. From a conservation point of view, considering that these provinces also have a high biophysical potential for land use expansion as well as relatively high species richness, they represent valuable regions but with the highest pressure for land use change. Land use intensification reduces the pressure for land expansion and biodiversity loss, but this study shows it is less significant to generate better trade-offs. Trade-offs between socioeconomic and environmental impacts are driven by the future global consumption that arises at both global and national scales. This study highlights the importance of controlling global demand to protect habitats with high biodiversity.

Further exploration on developing better scenarios will be useful to accurately measure the impacts of increasing global demand for oil palm. To be able to capture the dynamic change within the period, the dynamic CGE model can be used in the coupling method.

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Appendix

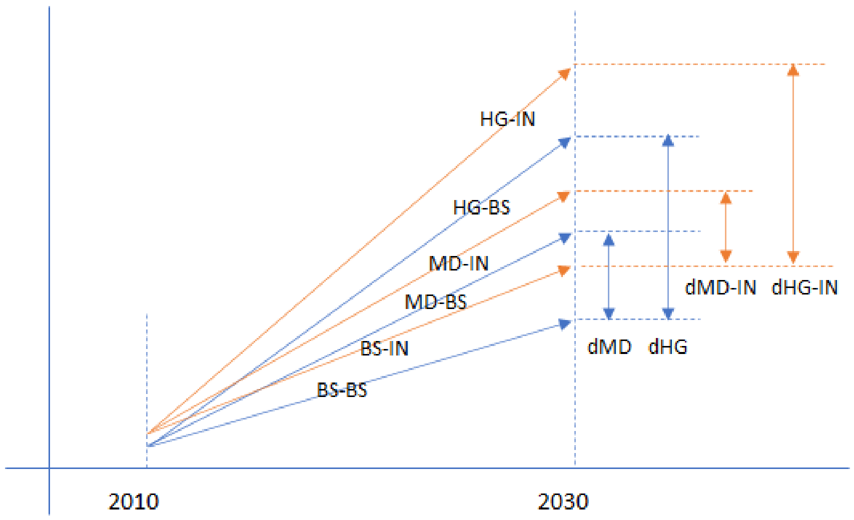

Figure A1. Deviation among six different scenarios between 2010 and 2030. Source: Authors