Indonesia's Moratorium on Palm Oil Expansion from Natural Forest: Economy-Wide Impact and the Role of International Transfers

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Indonesia's moratorium on palm oil expansion from natural forest: Economy-wide impact and the role of international transfers

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Abstract

Palm oil has become increasingly important in Indonesian export. Indonesian economic growth, particularly in forest-rich regions of the country depends on the expansion of palm oil production. On the other hand, Indonesian government is committed to reduce carbon emissions from land use change from which the conversion from natural forest to palm oil has greatly contributed. Indonesia introduced a moratorium of conversion from natural forest to palm oil land. Using a dynamic, bottom-up inter-regional computable general equilibrium of the Indonesian economy, we assess several scenarios of the moratorium and discuss its impact on the national as well as regional economy. The results suggest that moratorium reduces Indonesian economic growth, and other macroeconomic indicators, but international transfers ($10/tCO2 emissions avoided) can more than compensate the welfare loss. However, the impact varies across regions. Sumatera which is highly-dependent on oil palm; of which its economy is less broad-based and its carbon stock of its forest is no longer high, receive fewer transfers and suffer a great economic loss. In the meantime, Kalimantan which is relatively less dependent on oil palm than Sumatera and its forest's carbon stock is still high, receive more transfers and get greater benefit. This result suggest that additional policy measures anticipating the unbalanced impact of the transfers is required if the trade-off between conservation and reducing inter-regional economic disparity needs to be reconciled.

Keywords: palm oil, carbon emissions, computable general equilibrium, Indonesia

JEL code: R10, R11, R13

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1 Introduction

The United Nations Reduction of Emissions from Deforestation and forest degradation (REDD) programme seeks to reduce forest emissions and enhance carbon stocks in forests while contributing to national sustainable development (UN, 2015). REDD supports developing countries in their efforts to mitigate climate change through the implementation of several activities (UN-REDD Program, 2015). For example, financial mechanisms have been implemented to reduce deforestation, and therefore CO2 emissions by compensating countries and land owners for actions taken that prevent forest loss or degradation.

Deforestation and forest degradation have been estimated to contribute about 20 per cent of global CO2 emissions (Van der Werf et al, 2009). The main reason for deforestation is the conversion of forest to agricultural land for commercial and subsistence farming. Hosonuma et al., finds that overall, agricultural production contributes about 80 per cent of deforestation worldwide, followed by mining and urban expansion (Hosonuma et al, 2012). In Latin America the main cause for deforestation is the expansion of cropland and pasture. From 2001 to 2013, it is estimated that 17 percent of new cropland and 57 percent of new pasture area was created by converting forest area (Gaesser et al, 2015; De Sy et al, 2015). In Sub-Saharan Africa (SSA), deforestation is mainly driven by the high demand for crop commodities such as cocoa and oil palm (Ordway et al, 2017). Other determinants of the rates of deforestation in SSA include population growth and the discovery of extractive resources such as oil and gas (Rudel, 2013). In South-East Asia deforestation is driven by the growth in consumption of vegetable oil, such as palm oil, which is used in food and biodiesel. Within South-East Asia, Indonesia contributes significantly to CO2 emissions. Over the period 1990 to 2010 the forest cover in the peatland of Peninsular Malaysia, Sumatra and Borneo fell from 77 per cent to 36 per cent. Sumatra now only has 28 per cent of its historical forested peatlands left after years of deforestation (Miettinen et al., 2012a).

Several studies have been conducted to evaluate the economic viability of an incentive payment to reduce deforestation and CO2 emissions. The viability and effectiveness of incentive payments depends on the profitability of alternative land uses (Butler et al, 2009) and the price of CO2 per ton (Sandker et al, 2010). For example, Sandker et al (2010) developed a systems dynamics model for a cocoa agroforest landscape in southwestern Ghana to explore whether REDD payments are like to promote forest conservation and what the economic implications would be. They find that in the short term, REDD is likely to be preferred by farmers, especially if a large annual up-front payment is planned and when the policy only focuses on payments that ends deforestation of old-growth forests. However, soon after the payment, there may be an incentive to break the contract due to the higher rental returns from cocoa production. REDD may not be effective when also avoiding deforestation of degraded forests since this is the land required for the expansion of cocoa production. If cocoa prices increase, the carbon prices should be even more than US$ 55 per ton CO2 to stop deforestation of old-growth forests (Sandker et al., 2010). Butler et al., (2009) model and compare the profitability of converting forest to oil palm against conserving forests for a payment. They find that converting a hectare of forest to palm oil production is more profitable to land owners than preserving it for carbon credits. They suggest that giving REDD credits price parity with carbon credits traded would boost the profitability of avoiding deforestation (Butler et al., 2009). Bellassen and Gitz (2008) calculate the break-even price of carbon, which yields comparable revenue for preserving forests or shifting cultivation in Cameroon. They calculate a break-even price of $2.85/t of CO2 would generate similar revenue values. They suggest that at the current CO2 prices it could be more profitable to preserve the primary forest rather converting it to crops (Bellasen and Gitz, 2008). In general, it seems to be difficult to provide a framework for REDD, which is based on long-term contracts, given the fluctuation in agricultural commodity prices in the short run.

In this paper we develop and apply a regional dynamic computable general equilibrium (CGE) model for Indonesia to investigate two scenarios regarding the moratorium placed on the conversion of Managed and Natural Forest are to oil palm plantations. In the first scenario we model the moratorium in the absence of a once-off REDD payment. In the second scenario we model the moratorium on land conversion and the role of a once-off REDD payment, assuming a price of $10/t CO2 emissions.

2 Development of the palm oil sector in Indonesia

Indonesian economic growth has been highly dependent on its resource-based sectors. [1] However, in recent years, the palm oil sector has become one of the country's leading economic sectors and an important export-oriented industry. Palm oil is extracted from the bunches of plum-sized fruit borne by oil palm trees, which grow mostly in Malaysia or Indonesia[2]. Output has grown rapidly since the 1960s and it is now the world's highest-volume vegetable oil, used for food, fuel and other industrial purposes.

2.1.1 Global view

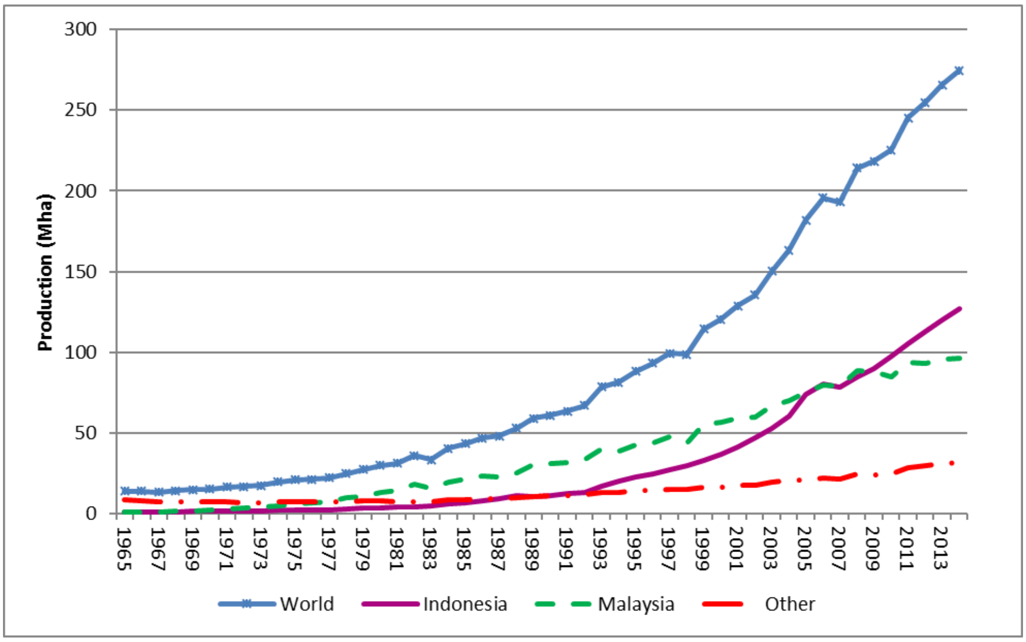
The development of the Indonesian palm oil sector in goes back to the early 1960's with 70 thousand hectares area harvested for the oil palm. With an average productivity of 13.36 Tons / Ha, Indonesia was able to produce approximately 936 thousand tons of palm oil (FOA, Data). Rapid developments in this sector occurred in 1980, when the government changed the plantation scheme of which was only occupied by *Perkebunan Besar Negara* (PBN, State-own Plantation Company) to be also done

[1] Indonesia has significant natural resource reserves. It is a leading exporter of steam coal, tin, nickel, gold, bauxite, lead, copper and zinc. In recent years, over 40 per cent of exports are mineral and petroleum products (Dutu, 2015; Natural Resource Governance Institute). Globally, Indonesia is also the main palm oil producer and exporter. They are also the second-largest exporter of rubber, robusta coffee and fish products (Dutu, 2015).

[2] See http://www.palmoilworld.org/about_malaysian-industry.html

by *Perkebunan Besar Swasta* (PBS, Private Plantation), *Perkebunan Rakyat* (PR-smallholder plantation). The immediate impact of this policy was an increase in plantation area to 204,000 hectares with a production of 3.4 million tons in 1980. In 2014, Indonesia was the largest producer of oil palm with 7.4 million ha of planation area with a production capacity of 126.7 million tons (FAO, Database). Figure 1 shows the world production of palm oil, which is dominated by Indonesia and Malaysia. Other countries include Cameroon, Colombia, Ghana, Nigeria and Thailand and collectively produce less than 15 percent of the world production.

Figure 1. Global production of oil palm (1965-2014)

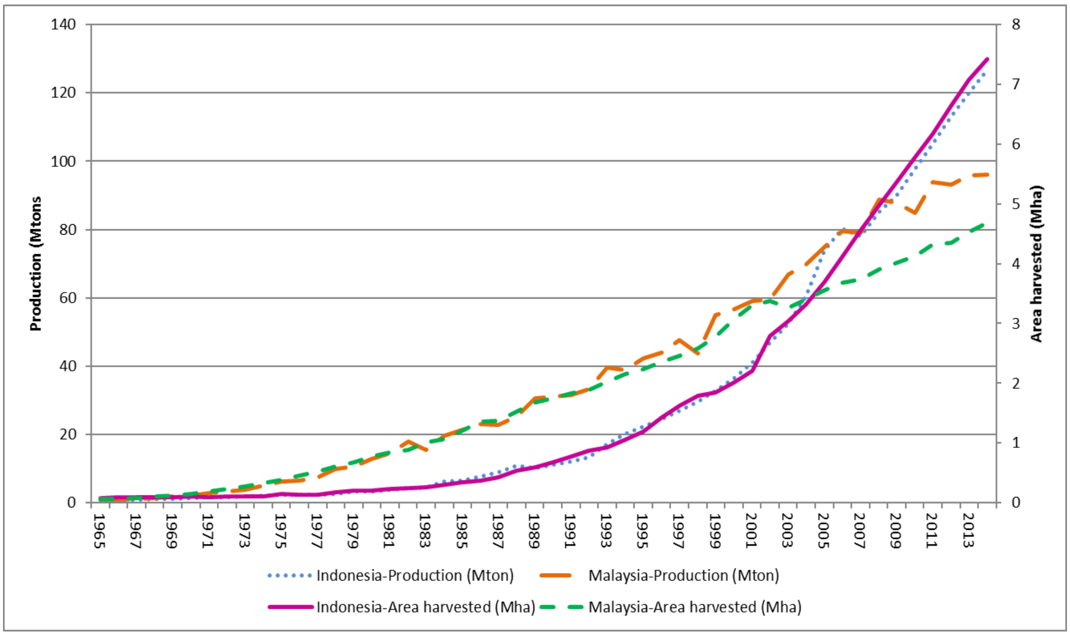


Source: FAO Database

2.1.2 National view

Figure 2 shows the production and harvest area of oil palm **in Indonesia** and Malaysia from 1965 to 2014. With little improvement in productivity, the increase in production is driven by transforming natural forest into plantation land. Data from the Food and Agricultural Organization of the United Nations (FAO) shows an increase of the area harvested from 204 thousand hectares in 1980 to 7.4 million hectares in 2014 with hardly changes in productivity (Figure 2). The productivity from oil palm planation in Indonesia increased from approximately 11.1 tons/ha in 1965 to an average of 17 tons/ha in 2014. We note that over the last two decades there has been little productivity improvement in Indonesia.

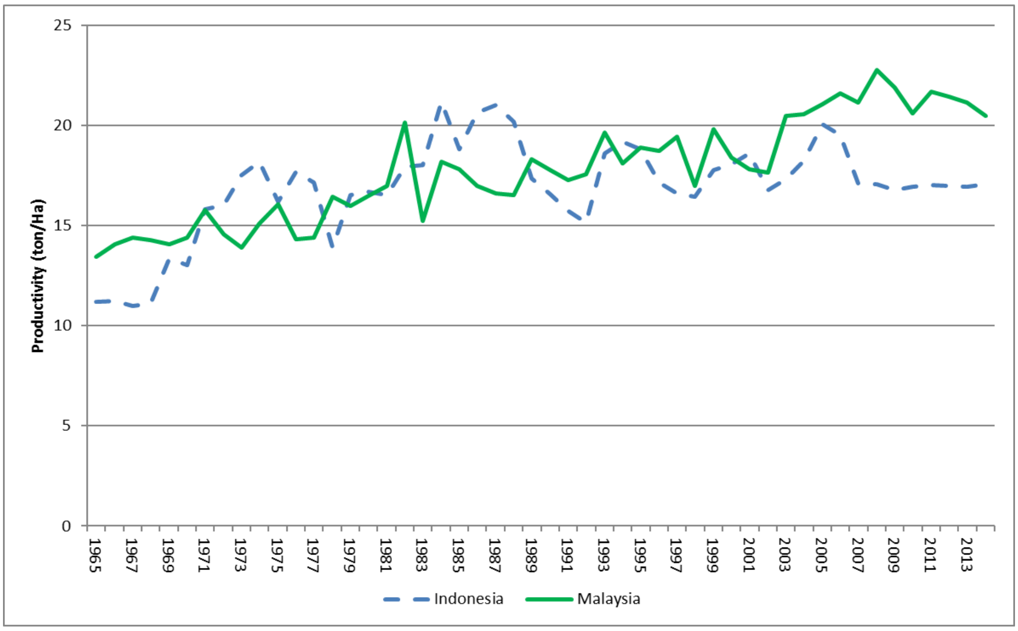
Figure 2. Area harvested and production of palm oil plantation, Indonesia and Malaysia (1965 – 2014)



Source: FAO Database

In contrast, Malaysia has a well developed palm oil sector. Not only did Malaysia increase their production area, they also focused on increasing productivity (Figure 3). A contributing factor to the low Indonesian productivity is the involvement of small-scale palm oil producers. In 2010, 42% of total palm oil plantation holders were small-scale producers (Burke & Resosudarmo, 2012). On one hand, the small-scale producers increase community involvement and provide economic benefits to rural communities, especially those in Sumatra and Kalimantan (Burke & Resosudarmo, 2012). However, in reality, small-scale plantation owners typically have below-average productivity (Burke & Resosudarmo, 2012; Rudel, Defries, Asner, & Laurance, 2009).

Figure 3. Palm oil productivity for Indonesia and Malaysia (1965 – 2014)



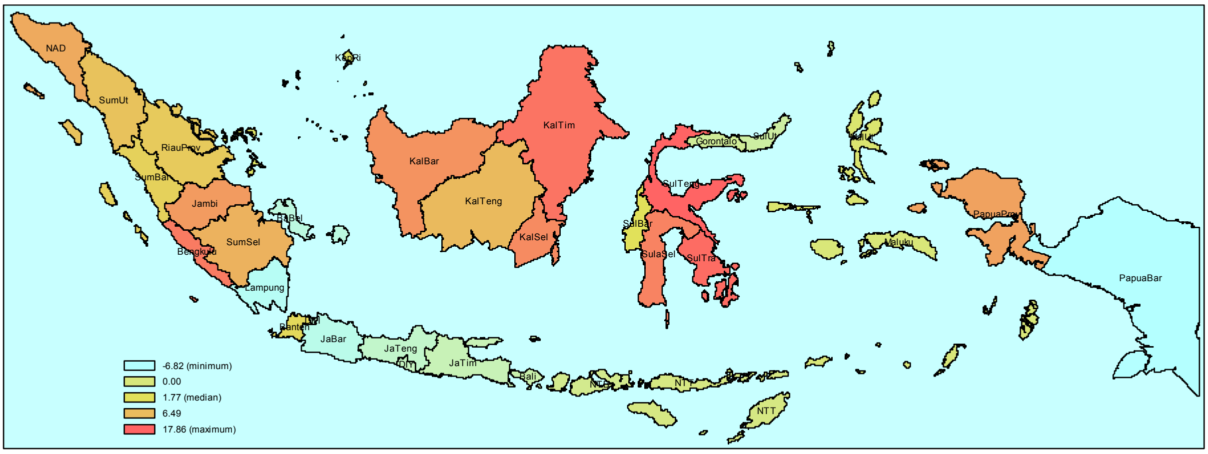
Source: FAO Database

Palm oil production is an important driver of Indonesian growth. Indonesia is also the world's largest exporter of palm oil (Burke & Resosudarmo, 2012). In 2013, exports of Indonesian palm oil products reached 20.53 million tonnes or about 17 billion US$ (FAO, 2015).

The global demand for oil palm and palm oil related products is mainly driven by the fact that (1) palm oil is very cheap to produce; (2) oil palm is more productive per acre than other oils such as soy oil and (3) countries such as China and India, use palm oil in processed foods as well as cooking oil (**Earth Island Journal**). There has also been an increase in demand for oil palm from the USA and Europe, mainly because of their avoidance of genetically modified foods (GMO) and trans fats as well as an attempt to replace petroleum. With research showing a link between trans fats and health risks, some countries require nutrition labels on food commodities to show the amount of trans fatty acids. The EU, in its aim to reduce greenhouse gas emissions, is committed to replace some of the transport fuels with biofuel made from vegetable oil. (**Earth Island Journal, European Union (Renewable energy)**). Despite its potential as a source of foreign and domestic revenue, the development of the oil palm sector hold environmental consequences.

Production of palm oil in Indonesia is mainly located on the **Sumatra Island and Kalimantan**. In 2012, Sumatra contributed approximately 73 per cent to the national production of palm oil. Within Sumatra, Riau is the province with the greatest planted area and production. This province has 1.9 million ha of the national oil palm plantation area and produces 5.8 million tons of palm oil. Kalimantan (Borneo) contributes approximately 23 per cent to palm oil production. Most recently, the government has also promoted oil palm production in the eastern part of Indonesia. Over the last five years, oil palm plantations in Central Sulawesi and Southeast Sulawesi grew by 17.8 per cent and 15.4 per cent annually.

Figure 4. Regional distribution of oil palm plantations in Indonesia (2014)



Source: INDOTERM model

2.2 Indonesian oil palm sector and carbon emissions

Indonesia contributes significantly to the deforestation in South East Asia via the conversion of peat swamp forests and into commercial use. Over the period 1990 to 2010, the proportion of forest cover in the peatlands of Malaysia, Sumatra and Borneo fell from 77 per cent to 36 per cent (Miettinen et al, 2012a). Miettinen et al (2012) suggests that if current levels of peatland deforestation is allowed, then Southeast Asian peat swamp forests will disappear by 2030. This conversion will have serious consequences for the environment, by releasing greenhouse gases and damaging forest ecosystems as well as communities that rely on the forests for survival (Miettinene et al, 2012; Burke & Resosudarmo, 2012; Carlson et al., 2012; Rudel et al., 2009; Tan et al., 2009).

Focusing on Indonesia, Mitten et al (2012b) historic analysis shows that 70 per cent of all industrial plantations have been established since 2000 while only 4 per cent of the current plantation area existed in 1990. They estimate that if future conversion rates is similar to historic conversion rates, between 6 and 9 Mha of peatland in insular SouthEast Asia may be converted to plantations by 2020. The annual carbon emission could increase between 380 and 920 Mt CO2 by 2020. Mietten et al (2011) further presents a time-series of peatland conversion and degradation in the Air Hitam Laut peatland in the Jambi Province located in Sumatra. They use high-resolution satellite imagery to map land cover and degradation status between 1970 and 2009. They find that forest covers declined from 90 per cent to 43 percent over the study area. Within the Berbak National Park, forest area fell from 95 per cent to 73 per cent and outside the national park from 86 per cent to 25 per cent. They find that large-scale oil palm plantations and small-holder producers accounted for 21 and 8 per cent respectively of the conversion (Mietten et al, 2011).

Abood et al (2014) compares the magnitude of forest and carbon loss, and forest and carbon stocks remaining within four main industries, namely oil palm plantation, logging, fiber plantation and coal mining. They find that the four industries accounted for 44.7 per cent of forest loss in Kalimantan, Sumatra, Papua, Sulawesi and Moluccas between 2000 and 2010. In their study, they rank the oil palm industry third in terms of deforestation and second in terms of CO2 emissions (Abood et al, 2015).

A recent study by Carlson et al., found that the 2010 – 2020 net cumulative GHG emission from palm oil plantation is projected to reach 1.52 Gt CO2 (Carlson et al., 2012). They also projected that during the same period, the carbon emission from oil palm plantation in Kalimantan would rise by 284 per cent contributing 27 per cent of Indonesia's projected 2020 land-based emission. This contradicts the Government effort to reduce GHG emission by 26 per cent relative to business as usual scenario by 2020. Considering the whole plantation area, the emission from oil palm alone would prevent reaching the 2020 target by 2020.

3 Modelling the moratorium on land conversion in return for a payment

Capturing the regional impact of a moratorium on land conversion in return for a payment requires a detailed regional multi-sector model of Indonesia that accounts for changes in land availability and CO2 emissions detail. For this paper, we use INDOTERM, a multi-regional, recursive dynamic general equilibrium model based on the well-known TERM model developed by Horridge (2011). This section provides a more detailed description of the INDOTERM model and the modelling of land supply used in palm oil production.

3.1 Overview of the core model

While the complete model is too large to describe in this paper, a comprehensive description is contained in Horridge (2011) and Horridge et al. (2005). The TERM model was created for Australia (Horridge et al, 2005, Wittwer, 2012) and adopted for South Africa (Stofberg and Van Heerden, 2015), Poland (Zawalinska et al. 2013) , Brazil (Ferreira-Filho et al. 2010), China (Horridge and Wittwer, 2008) and Indonesia (Pambudi et al. 2006). As the theory of the TERM model and data structures are well documented, for this paper we provide an overview only.

INDOTERM consists of three inter-dependent modules. The first module describes the region-specific behaviour of producers, investors, households, government and exporters at a regional level.

Producers in each region are assumed to minimize production costs subject to a nested constant-returns-to-scale (CRS) production technology. In this nested structure, each regional industry's inputs of primary factors are modelled as a constant elasticity of substitution (CES) aggregate of labour, capital and land inputs. Commodity-specific intermediate inputs to each regional industry are modelled as CES composites of foreign and domestic varieties of the commodity. Labour inputs used by each regional industry are distinguished by occupation, with substitution possibilities over occupation-specific labour described via CES functions specific to each regional industry. In each region, the representative households are assumed to choose composite commodities to maximise a Klein-Rubin utility function. Households and firms consume composite commodities that are assumed to be CES aggregations of domestic and imported varieties of each commodity. The allocation of investment across regional industries is guided by relative rates of return on capital. For each region-specific industry, new units of physical capital are constructed from domestic/imported composite commodities in a cost-minimising fashion, subject to CRS production technologies. Region-specific export demands for each commodity are modelled via constant elasticity demand schedules which link export volumes from each region to region-specific foreign currency export prices. Regional demands for commodities for public consumption purposes are modelled exogenously, or are linked to regional private consumption. For a detailed description of the input-output structure see Appendix A.

As mentioned above, the core section includes equations determining the demand for factor inputs by industry. Typically, we model the demand for primary factors via the following optimisation problem:

Each industry in all regions

choose XPRIM(i,d) to minimise total primary cost $\sum_i XPRIM(i,d) * PPRIM(i,d)$

subject to XPRIM(i,d) = CES(LAB(i,d), CAP(i,d), LND(i,d)) (E.1)

where LAB, CAP, LND are the overall labour, capital and land demand. Pprim is the primary factor price in industry i. The percentage-change form of the optimisation problem yields the following demand equation for land:

$$xlnd(i,d) = xprim(i,d) - \sigma^{lnd}(i)\left[plnd(i,d) - pprim(i,d)\right] \quad \text{(E.2)}$$

Equation (E.2) implies that in the absence of any price changes the demand for land moves in proportion to the overall demand for primary factors. The second term on the RHS shows the price induced substitution effect between the primary factors. An increase in the price of land relative to the cost-weighted-average of all three factors, leads to substitution away from land in favour of the others. The magnitude of the change depends on the elasticity of substitution. It is common in CGE models to assume that the total quantity of land available for agricultural purposes are fixed.

The core model includes two dynamic mechanisms, namely, capital accumulation and labour market adjustment. In each region, industry-specific capital is linked to industry-specific investment. Industry-specific investments are linked to changes in industry-specific rates of return. The labour market mechanism guides the labour market from a short-run environment (sticky real wages, flexible labour) to a long-run environment (flexible wage, fix employment). Therefore, in the short run, positive (negative) outcomes are reflected in positive (negative) changes in employment (with no change in real wage) and in the long run reflected as positive (negative) changes in real wage (with employment unchanged).

3.2 Treatment of land-use change, emissions and REDD payment

IndoTERM identifies 5 land uses, namely, Crops, Estate Crops, Oil Palm plantation, Managed Forest and Natural Forest. Below we specify a set of core equations that allow for the conversion of land-use, emissions and REDD payment. Specifically model (i) the conversion of natural forest to palm oil plantation and (ii) the REDD payment, which is a once-off payment for the promise of not converting natural forest to palm oil plantations.

In this module we do not explicitly model the supply of land available for agricultural purposes as a function of land rents. In other words, we do not model a supply-curve. Instead, we take the quantity of total land available as exogenous and change the allocation of land between uses of land.

Our module begins with an equation that determines the change in land area, measured in thousands of hectares (t/ha), by industry and region as:

$$\triangle AREA_{(i,d)} = \left[LNDAREA_{(i,d)} \big/ 100 \right] * xlnd_{(i,d)} \text{ for } d \in REG,\ i \in \text{land using IND} \qquad \text{(E.3)}$$

where

- $\triangle AREA_{(i,d)}$ is the change in the amount of land available by industry i and region d.[3]
- $LNDAREA_{(i,d)}$ is the initial amount of the land available by industry i and region d.
- $xlnd_{(i,d)}$ is the percentage change in the land rental value by industry i and region r (See E.2).

Land may be used for either commercial purposes such as the cultivation of *Crops*, *Estate Crops*, *Oil Palm*, *Managed Forests* or classified as *Natural Forests*, which is defined as undisturbed forests free of commercial activity.

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[3] A percentage change for the variable called *x* is defined as $x = \frac{\Delta X}{X} * 100$ where ΔX is the change in X and X is the initial value. The ordinary change in X can therefore be written as $\Delta X = (x * X) * 0.01$.

Equation (E.4) determines the change in CO2 emissions due to land-use change (LUC) by region.[4] CO2 intensity is measured as tonnes of CO2 emissions per hectare. This equation states that the total change in CO2 intensity by region is the sum of the product of the change in land area allocated to various land-using industries including Natural Forest, multiplied with the CO2 intensity for each of these activities.

$$\triangle CO2_{(d)} = \sum_{i \in IND} CO2INT_{(i,d)} * \triangle AREA_{(i,d)} + CO2INTNF_{(d)} * \triangle \text{NFAREA}_{(d)} \qquad \text{(E.4)}$$

for $d \in REG$, $i \in$ land using IND

where

- $\triangle CO2_{(d)}$ is the total change in CO2 emissions by region.
- $CO2INT_{(i,d)}$ is the total CO2 intensity measured tonnes of emission per hectare for all industries using land.
- $CO2INTNF_{(d)}$ is the CO2 intensity measured as tonnes of emissions per hectare of Natural Forest.
- $\triangle \text{NFAREA}_{(d)}$ is the ordinary change in the natural forest area by region r.

Equations (E.5) and (E.6) allows us to impose two rules to simulate the different land conversion scenarios. The first rule (E.5), states that half of the area allocated to palm oil plantation is from Managed Forests. For example, if the land area for palm oil production increases by 2 ha, 1 ha of land will come from the Managed Forest area. The remaining 1 ha comes from the conversion of Natural Forest to palm oil production. When this equation is operational in the business as usual scenario, we assume that both Natural and Managed forests contribute, in equal share, to the oil palm plantation.

$$\triangle AREA_{(\text{"Forestry"},d)} = -0.5 * \triangle AREA_{(\text{"}OilPalm\text{"},d)} + f\_rule1_{(d)} \text{ for } d \in REG \qquad \text{(E.5)}$$

The second rule is shown in Equation (E.6). This equation states that an increase in the land allocated to palm oil production comes from only Managed forests. When this rule is activated in the policy simulation, we place a moratorium on the areas converted from forest to palm oil production, allowing only the conversion from Managed forests to palm oil production while conserving Natural forests.

$$\triangle AREA_{(\text{"Forestry"},d)} = -\triangle AREA_{(\text{"}OilPalm\text{"},d)} + f\_rule2_{(d)} \text{ for } d \in REG \qquad \text{(E.6)}$$

where

[4] As explained in Section 4.2, converting land cover from one use (i.e. forest) to another (i.e. oil palm plantation) causes the volume of CO2 stored (/emitted) in the land cover to change. For example, natural forests store more CO2 than, say plantations. If Natural Forest is transformed to oil palm, which stores less CO2 than Forests, more (less) CO2 is then emitted (stored) into the atmosphere.

- $\triangle AREA$ is the change in the land area allocated to Managed Forestry and Oil Palm plantations by region.
- f_rule1 and f_rule2 are shift variables, used to activate or deactivate the respective equations.

Equation (E.7) calculates the change in the REDD payment by region as the difference between the REDD payment between two consecutive years.

$$\triangle REDD_{(d)} = REDD^{t}_{(d)} - REDD^{t-1}_{(d)} \text{ for } d \in REG \qquad \text{(E.7)}$$

where

- $\triangle REDD$ is the change in the REDD payment between years t and t-1 by region d.
- $REDD^{t}_{(d)}$ and $REDD^{t-1}_{(d)}$ is the REDD payment in two consecutive years by region d.

Equation (E.8) determines the REDD payment in year t as the carbon price per tonne of CO2 emission multiplied by the fall in the CO2 emissions for that year. BaseEmit captures the baseline level of CO2 emissions and is determined via (E.9). Equation (E.8) is activated in the policy simulation and states that as long as CO2 emissions, is above the baseline level of emissions, the change in REDD payment will fall. Alternatively, if the CO2 emissions falls in the policy simulation relative to the base level of emissions, then the REDD payment will increase. If the emissions in the policy simulation is fixed at the base level of emissions, the change in the REDD payment is zero.

$$REDD^{t}_{(d)} = CO2PRICE * \left[-\triangle CO2_{(d)} + BaseEmit_{(d)} \right] \text{ for } d \in REG \qquad \text{(E.8)}$$

where

- $CO2PRICE$ is the carbon price per tonne of CO2 emission.
- $\triangle CO2$ is the change in CO2 emission from changing the use of land and is determined in (E.2).
- *BaseEmit* is the level of CO2 emissions in the baseline simulation and determined via (E.9).

Equation (E.9) is operational only in the base simulation and determines the base level of CO2 emissions. Base emissions by region are determined by the ordinary change in CO2 emissions in the business as usual simulation (determined in (E.4)) and a shift variable.

$$BaseEmit_{(d)} = \triangle CO2_{(d)} + f\_BaseEmit_{(d)} \text{ for } d \in REG \qquad \text{(E.9)}$$

where

- *BaseEmit* is the base level of CO2 emissions by region.
- *f_BaseEmit* is a shift variable used to activate or deactivate the equation.

In the baseline simulation, the shift variable is exogenous and *BaseEmit* is endogenous. In the policy simulation this equation is inoperative with the shift variable set endogenously and *BaseEmit* set exogenously.

In our theory, the REDD payment is directly paid to households in each region. Equation (E.10) determines the value of household income by regions as the sum of labour income and the REDD payment. This equation also includes two exogenous shift variables that allows for uniform or region-specific changes to household income to be imposed.

$$HOUTOT_{(d)} = WAGE_{(d)} + f\_HOU_{(d)} + f\_HOU\_D + \triangle REDD_{(d)} \qquad \text{for } d \in REG \qquad \text{(E.10)}$$

review this equation – wrongly written

where

- $WAGE$ is the wage income by region.
- $\triangle REDD$ is the ordinary change in the REDD payment by regions as determined in (E.7).
- f_HOU by region and f_HOU_D are naturally exogenous shift variables which can be used to impose uniform or region-specific changes to household income.

The REDD payment is a payment to Indonesian households from a foreign donor and therefore we include the REDD payment with other net transfers from the rest of the world[5]. The final equation shows that the share of the nominal change in the balance of trade (BOT) and REDD payment to GDP.

$$SHRBOTGDP = \frac{[\Delta BOT + \triangle NTROW]}{GDP} \qquad \text{(E.11)}$$

where

- $SHRBOTGDP$ is the share of the sum of BOT and NTROW to GDP.
- ΔBOT is the nominal change in the balance of trade as defined as exports minus imports.
- $\triangle NTROW$ is the change in net transfers abroad which is the sum of net remittances and the REDD payment.
- GDP is nominal GDP.

In the policy simulations, we hold the SHRBOTGDP exogenous. This captures the idea that on a national level, Indonesia faces an external balance constraint. We also note that assuming there is no change in GDP or SHRBOTGDP, an increase in the NTROW implies a fall in the nominal BOT.

[5] Net transfers from the rest of the world includes payments received such as remittance and aid as well as payment from Indonesia to the rest of the world .

4 Description of the database

Two large databases form the initial solution to the INDOTERM model. The base year is 2005.

4.1 The core database

The core TERM database is calibrated using various sources. These sources include:

(i) Indonesian national Input Output Table 2005,

(ii) Indonesian Inter-regional Input Output Table 2005,

(iii) Regional share of production for each commodities for various years,

(iv) Indonesian Social Accounting Matrix (SAM) 2005.

The process of the construction of the IndoTERM database can be found in Horridge et al. (2005) and Horridge & Wittwer (2006). The regional database consists of a set of matrices, capturing the 2005 structure of the Indonesian economy. We begin by creating a USE matrix valued at producers' price. This matrix shows the flow of commodity c, from source s to user u. Values at producers' price is the sum of the flows of commodity c, from source s to user u at basic price and the associated indirect tax. We also have a matrix capturing the margins which facilitates the flow of commodities. Value added matrices which are: labour payments by industry and occupation, capital and land rentals by industry and production taxes by industry. The database is balanced in that the costs equal sales for each sector. From the national database we create regional input-output data and inter-regional flows of commodities. Detailed regional data is not available in the required format. We use regional output shares to inform us on regional distribution of inputs and outputs. We then construct inter-regional trade matrices which show the trade of commodities between regions. Our task is made easier by assuming that industry-specific technologies are similar across regions. Given these assumptions we ensure that regional data is consistent with national data. Land-use and CO2 database. For a detailed description of the TERM database see Horridge (2011).

4.2 Land-use and CO2 database

In parameterising the Land-Use module, we require data on:

(i) the land area, measured in hectares, used for commercial purposes by region;

(ii) the land area, measured in hectares, identified as Natural Forest by region; and

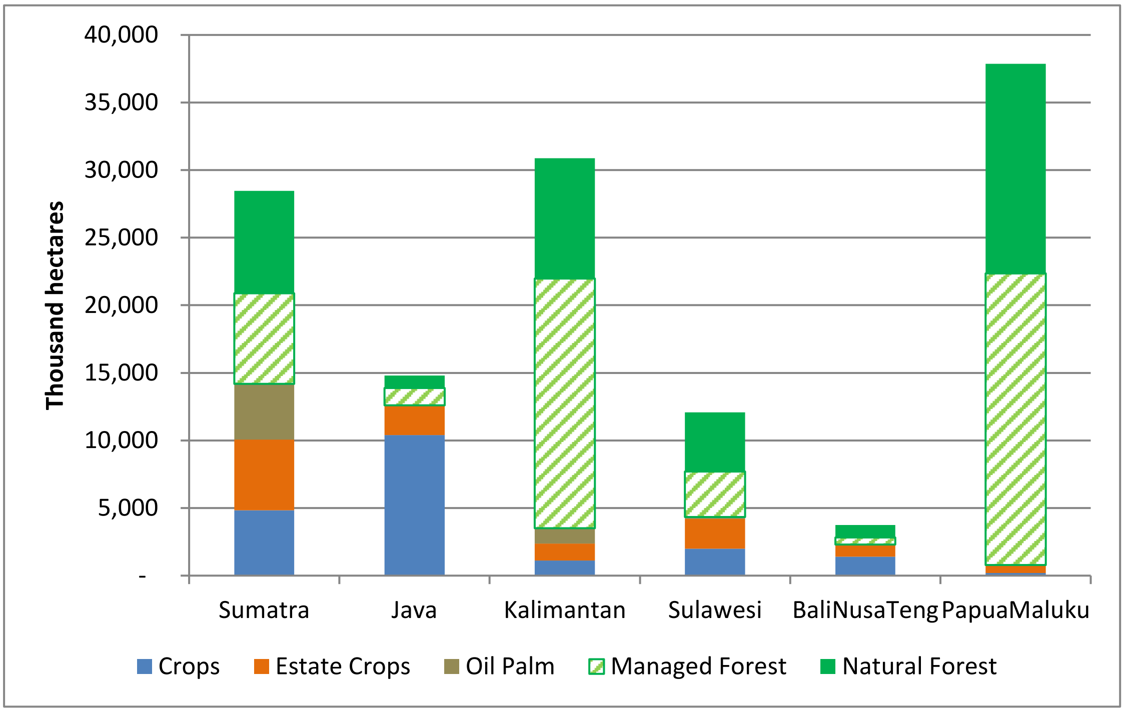
(iii) the CO2 intensities per hectare (CO2/ha) by land-use and region.

As mentioned before, land is used for either, commercial purposes (Crops, Estate Crops, Oil Palm, Managed Forests) or classified as Natural Forests, which is defined as undisturbed forests free of commercial activity. Figure 5 shows the land area by use and region.[6] Figure 5 shows that the land area and land-use differs across regions. Regions such as Kalimantan and Papua/Maluku have the

[6] In the database we distinguish between 12 regions. For descriptive purposes we focus on the main regions.

largest area of Managed and Natural Forests. They are followed by Sumatra and Sulawesi. Java has the lowest level of forests and the highest level of land allocated to the cultivation of Crops.

Figure 5. Land use by region (000 hectares), 2005



Source: Database

For this study it is important to know the initial carbon stock stored in different land-use activities (e.g. crops, oil palm and primary forests). Drawing on literature, carbon dioxide is stored in plant biomass and soil. Angus et al., (2009) describes the carbon stored in various biomass and soils. They note that the amount of carbon stored in plant biomass and soil varies by region and depends on climate, soil fertility and land-use (Angus et al., 2009: 120).

For *mineral land* carbon is mainly stored in plant biomass (e.g. root), necromass (dead and non-decomposed plant parts) and below ground (soil). Carbon stored in *plant biomass* is difficult to measure as it varies between land-use and the stage of plant growth.[7] Generally, primary forests stored more carbon than say oil palm plantations and oil palm plantations store more carbon that coffee, tea and sugar plantations (Angus et al., 2009). Carbon stored in *soil* depends mostly on organic materials. Inorganic carbon consists of mineral forms such as calcium and magnesium. Inorganic soil carbon is limited to calcareous soils. The amount of organic carbon in soil depends on the soil type, climate change as it regulates plant production and soil management (Carson, unknown). The process

[7] Carbon stock in plant biomass is expressed in terms of time average. Time average is the carbon content stored in a plant with respect to age of the plants. This is a useful method of measurement and allows for areas with different plant and tree growth and harvesting to be compared in terms of carbon storage.

of above ground biomass carbon stock in *peatland*[8] is similar to that of mineral land. In general, it is assumed to be a bit lower than mineral land because the values of biomass carbon stock are lower in peatland than mineral soil. The largest stock of carbon is stored below the ground itself. Angus et al., (2009) states that one meter of peatland stores more than double the carbon stock of plant biomass.

The amount of carbon stock stored in biomass depends on where carbon is stored and the growth stage (i.e. oil palm), soil fertility, climate conditions, elevation and drainage, and land use (Angus et al., 2009). CO2 emissions occur when there is a change in land use. The amount of CO2 emission depends on the carbon stock of the biomass of the initial land before land conversion takes place. For example, converting peatland, which stores high level of carbon, to palm oil plantations will cause more green-house gas, especially CO2, to be emitted into the atmosphere.

We do not have data on the CO2 intensities per hectare by land-use and region. To infer the CO2 intensities per hectare and region, we use the following data:

1. Carbon stock map (Figure 6), and
2. Land use map (Figure 7)

to estimate the carbon intensity (CO2 /ha) by land-using sector (agriculture) and natural-forest (forest area that is not used by any of industries). To do that using Geographic Information System (GIS) software we overlay the two map and calculate the average of carbon intensity. Here, we don't distinguish between peat or other type of land, as whether the land is peat or not-peat has implicitly been accounted for in the carbon stock map. This step resulted in the carbon-intensity table as shown below in Figure 8.

We define the carbon intensity as c_i where *i* is land-using industry.

From other data source we obtain the land-area (in ha) used in 2008 (the year of database of the model). We define it as l_i.

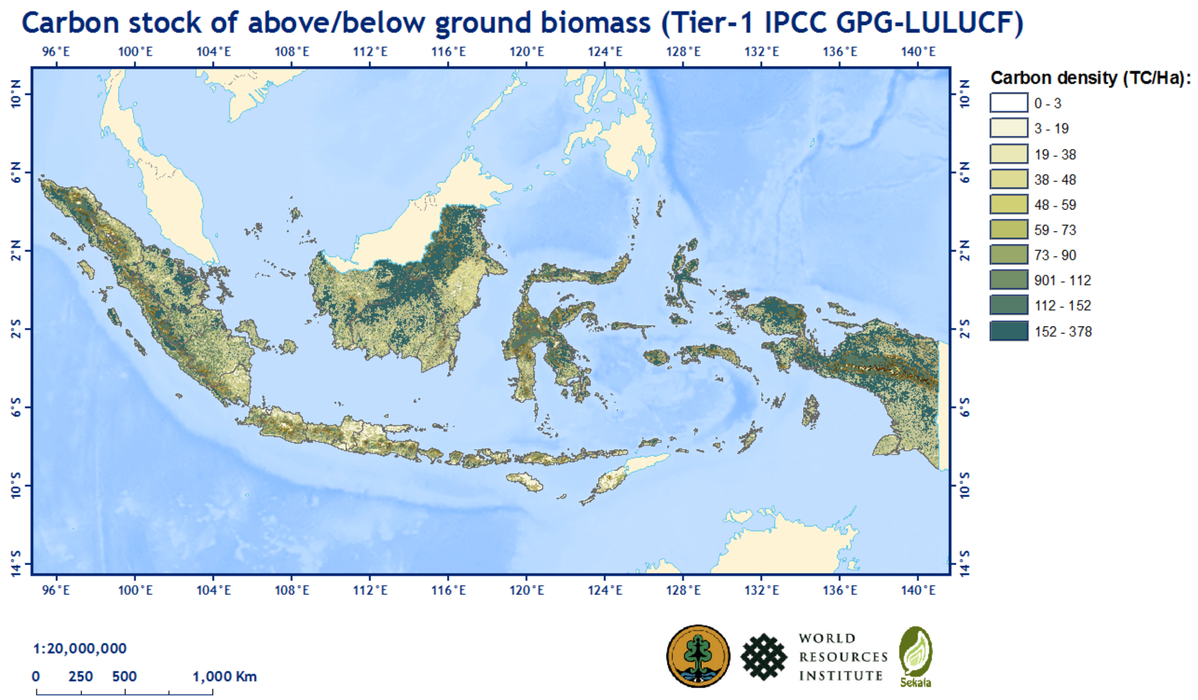
A carbon-dioxide emission is then calculated with the following equation:

$$e = -\left(c_n \Delta n + \sum_i c_i \Delta l_i\right)$$

Where Δl_i is the change in land use of industry *i* and Δn is the change in the area of natural forest.

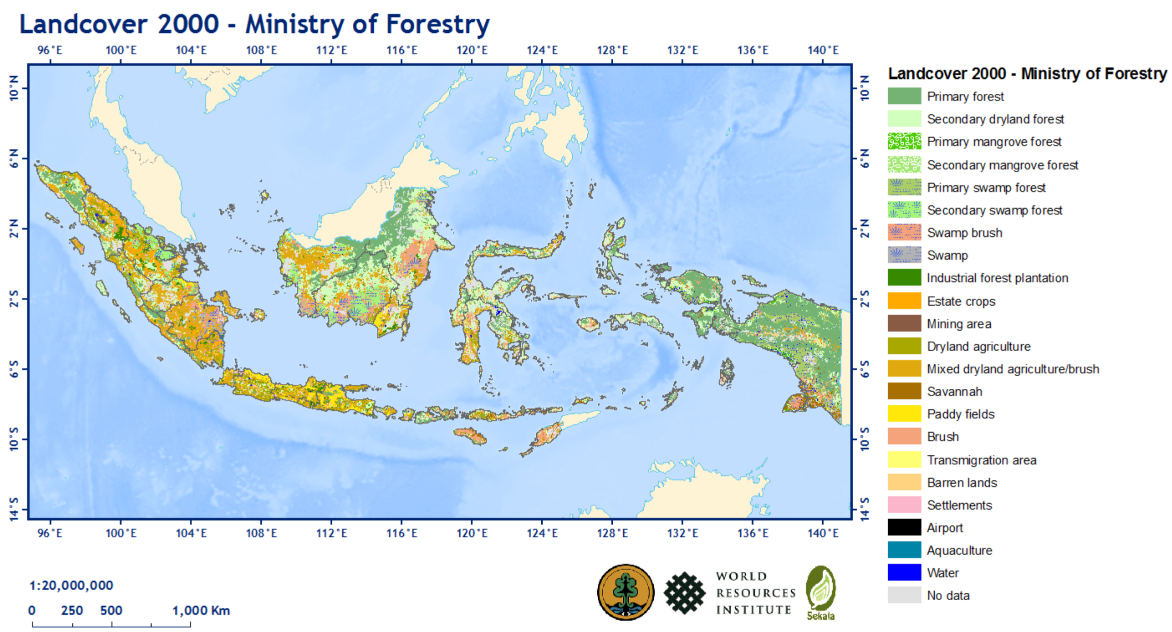
[8] Peat swamps occur when a dead tree, especially the roots, is in the process of decomposing. The incomplete decomposition of the tree in permanently saturated soil conditions leads to the accumulation of organic material over millennia leading to a high carbon density (Page, et al. 2011: 14).

Figure 6. Carbon stock of above/below ground biomass



Source: Ministry of Forestry

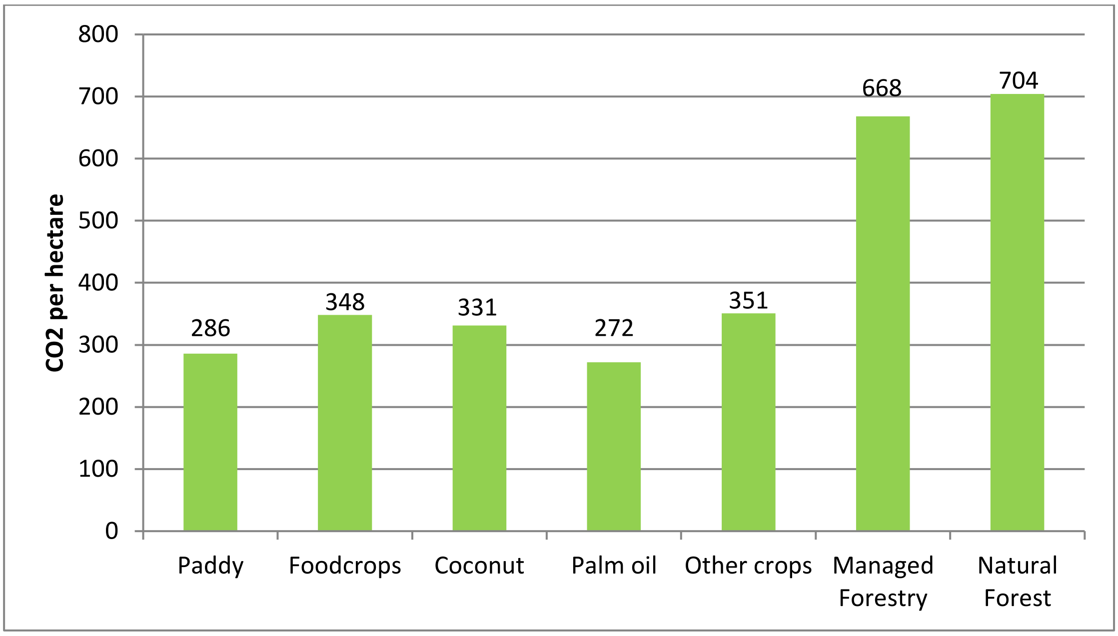
Figure 7. Land cover of Indonesia



Source: Ministry of Forestry

Figure 8 shows the average carbon stock per hectare for selected land-use activities. The data suggests that the average carbon stock given land cover types, is the lowest for Oil Palm plantations and the highest for Managed and Natural forests. Identifying the land cover types and their carbon intensity is consistent with Carson (XX) and Angus et al (2009).

Figure 8. Average carbon intensity by land use (CO2 per hectare)



Source: Author's calculation

5 Simulation design: BAU, moratorium and REDD payment

We run three simulations with the INDOTERM-L model:

(i) SIM0 – the baseline simulation
This simulation which shows the growth of the Indonesian economy in the absence of the moratorium and REDD scheme. We assume that oil palm land grow between 3-8 percent per annum depending on the regions toward 2030. We use regional land oil palm data to come up with this scenarios. Higher growth regions are provinces in Kalimantan and rather low growth regions are in Sumatera. We assume that half the oil palm land is originated from natural forest and the other half from production forest. This is roughly based on Carlson et al (2013).

(ii) SIM1 – Moratorium without international transfers
This simulation reproduces the growth paths of (i) but without further conversion of natural forest to palm oil. We assume that oil palm land still grows but from the conversion from managed forest.

(iii) SIM2 – Moratorium with international transfers
reproduces the growth paths of (ii) but with a REDD payment proportional to the emissions saved by (ii). Therefore, in this simulation we convert the avoided deforestation into avoided carbon emissions and translate it into international transfers by

multiplying the avoided emissions with the price of carbon (see E.4 and E.8). We used $10/tCO2e. We distribute the transfers to the regions according to their magnitude of emissions reduction. The transfers is given directly to representative households who will spend the money received as consumption spending (E.10).

5.1 SIM0: Baseline simulation

5.1.1 Assumptions

The base simulation is designed to serve as a plausible business-as-usual (BAU) scenario for the future path of the Indonesian economy in the absence of the REDD scheme, i.e. in the absence of additional efforts to curb deforestation and carbon emissions. This baseline is used as a benchmark against which the economic impacts of reduced forest clearing with and without a REDD payment is measured.

Our baseline forecast is driven by projected changes in population, labour force, productivity, and foreign demands that are roughly consistent with Indonesia's recent annual GDP growth rates of 6 per cent per annum. We impose the following exogenous changes for each year of the base simulation:

(i) The labour force and population grow respectively at 2.5 and 1.5 per cent per annum. over the entire simulation period. The higher growth rate for labour force reflects (a) the relative youth of Indonesians, and (b) the idea that over time workers will migrate from informal to formal sectors, becoming more productive.

(ii) There is a continued increase in foreign demand for Indonesian commodities, including edible oils.

(iii) Labour productivity improves for all service industries by 3 per cent p.a. and for non-service industries by 6 per cent p.a.

Of special importance in our simulations are our assumptions regarding natural resource endowment and productivity. Natural resources not only refer to "Land" as defined in Section XXX, but also include ore bodies, fish stocks and other water activities. We assume that:

(iv) Land productivity rises by 3 per cent per annum. in all Agricultural sectors. The Agricultural sectors include *Crops*, *Estate Crops*, *Oil Palm* and *Managed Forests*. Improved land productivity is another way of increasing output in, for example, the palm oil sector.

(v) Land productivity in all extractive sectors except for Oil and Gas, rises by 2 per cent per annum. The assumption of no land productivity in the Oil and Gas sector reflects our view that Indonesian oil reserves offer little scope for output increase.

(vi) For all land-using sectors, except the Palm Oil sector, we assume that the land area under cultivation is fixed. Although the current Indonesian policy is not to allocate more land to the Palm Oil sector, we increase the land allocated to this sector. This is because there are still substantial Natural Forest areas previously allocated for Palm Oil, that have not actually yet been converted. This (and perhaps flouting of the policy) allows palm area to rise. We assume that the land area for Palm Oil increases by 8 per cent in Kalimantan and Papua, 4 per cent in East Sumatra and Sulawesi and 3 per cent in West Sumatra.

Below we focus on selected baseline results. For a detailed description and analysis of the baseline results, see Appendix B.

Figure 9 shows the accumulated change in regional growth. All regions expand during the simulation period but at different growth rates. Regional performance is dependent on the type of economic activity that is dominant in that region. For example, palm oil production is mainly located on Sumatra (78.5 per cent) and Kalimantan (17.5 per cent). Therefore, any changes, such as a moratorium on the expansion of palm oil plantations, will affect the regional growth of Sumatra and Kalimantan. The extent of this impact depends on these regions dependence on oil palm production and related sectors such as the edible oil industry (palm oil is used as an input into the production of edible oils). Kalimantan's economy is less palm oil dependent whereas Sumatra has a higher dependency on oil palm and related industries such as edible oil industry. Kalimantan for example has a higher share of mining (20 per cent) and manufacturing other than edible oils (28 per cent) as part of their economy.

Another difference between Sumatra and Kalimantan is the amount of CO2 t/ha stock that is stored in their forests. As mentioned in Section 4.2, the CO2 stock stored in the Kalimantan forests are much higher than in Sumatra. This does not have a direct impact on economic growth, but as we shall see in the policy simulations, will affect the REDD payment to Sumatra and Kalimantan and, alter welfare via changes in household income. We surmise that if Kalimantan converts fewer forests into palm oil plantations, more carbon is stored in Kalimantan forests. With a higher carbon intensity, the level of CO2 emissions are lower and the transfer payment to Kalimantan households higher. Sumatran households will benefit from REDD transfers, but not at the same level as Kalimantan, as the carbon intensity of Sumatran forests are slightly lower.

Our baseline simulation results show that Java is more than three time larger, in 2030 than in 2005 while PapuaMaluku doubled in size. Java has the highest growth rate over the period because this region hosts the majority of manufacturing and service industries. These industries show strong growth over the simulation period whereas in Papua and Maluku, which grows at a lower rate, mainly produce output that does not benefit greatly from the employment and productivity improvements.

Figure 9. Regional GDP (cumulative change)

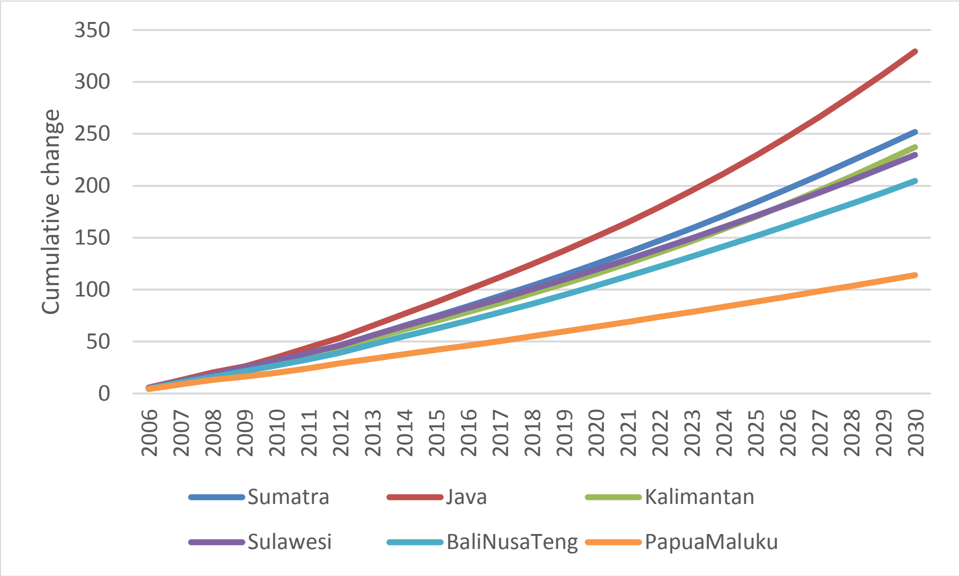
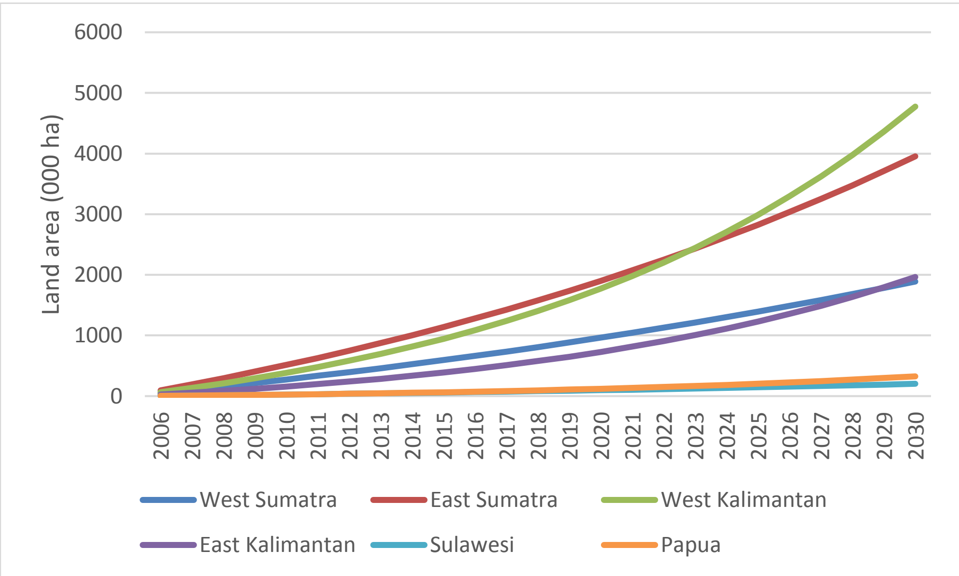


Figure 10 shows the cumulative increase in land area for palm oil over the simulation period by region. Kalimantan and Sumatra shows the highest levels of land-use conversion from Forests to Palm Oil plantations. Papua and Sulawesi shows the lowest level of land conversion. The increase in the land area designated for Palm Oil implies a loss of Managed and Natural Forest Area. With the change in land use, we expect a change in the level of CO2 emissions. The change in CO2 emissions follows a similar path to the change in palm oil land area (Figure 10). Based on the carbon stock of natural forests, the level of CO2 emissions is the highest in Kalimantan and Sumatra. Regions with the lowest CO2 emissions are Papua and Sulawesi.

Figure 10. Palm Oil land area by region (cumulative change)



The new growth paths of the economic indicators, generated in Sim1 and Sim2, move away from the baseline, making it possible to evaluate the impact of the policy. Policy effects are reported as percent deviations from the base forecast.

6 Consequences of the moratorium and REDD payment

6.1 Sim1: Imposing a land moratorium in the absence of REDD

In the first policy simulation we simulate the economic impact of the moratorium on converting Natural Forests to Palm Oil plantation in the absence of a once-off REDD payment. The features of the policy simulation are the same as the baseline but now we assume that from 2015 all land conversion from forests to palm oil come from Managed Forests only – no land will be allocated from Natural Forests. Following normal practice, we report policy results as differences from the base scenario.

Because land for palm oil is now sourced from Managed forests only, palm oil grows half as fast as in the base simulation. Thus, the differences between the base and policy simulations are that:

(i) there is one less hectare of land converted to palm oil;
(ii) the converted land only comes from Managed forests;
(iii) no Natural forest is converted to palm oil, avoiding deforestation and conserving this area;
(iv) there is a fall in CO_2 emissions; and
(v) there are varied regional economic impacts.

Figure 11 shows that the total area converted to palm oil is lower than in the baseline while Figure 12 shows the Natural forest area, which is not converted to palm oil land, as higher in the SIM1 than in the baseline. By the end of the simulation period, approximately 5 million ha of forests have been conserved, with the bulk of these forests located on Kalimantan and Sumatra.

Figure 11. Palm Oil land area by region (000 ha) (ordinary cumulative deviation from baseline)

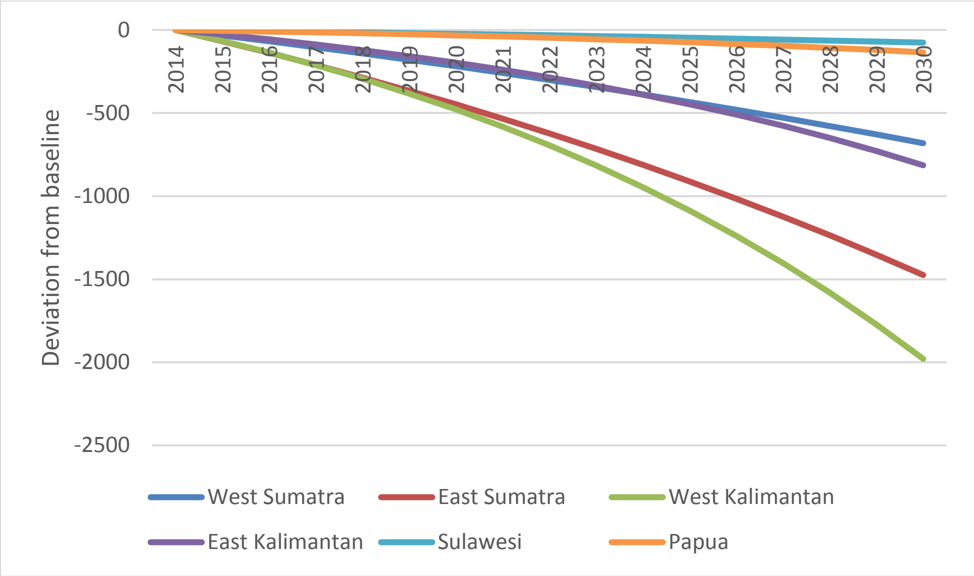


Figure 12 Natural Forest by land area and region (000 ha) (ordinary change from baseline)

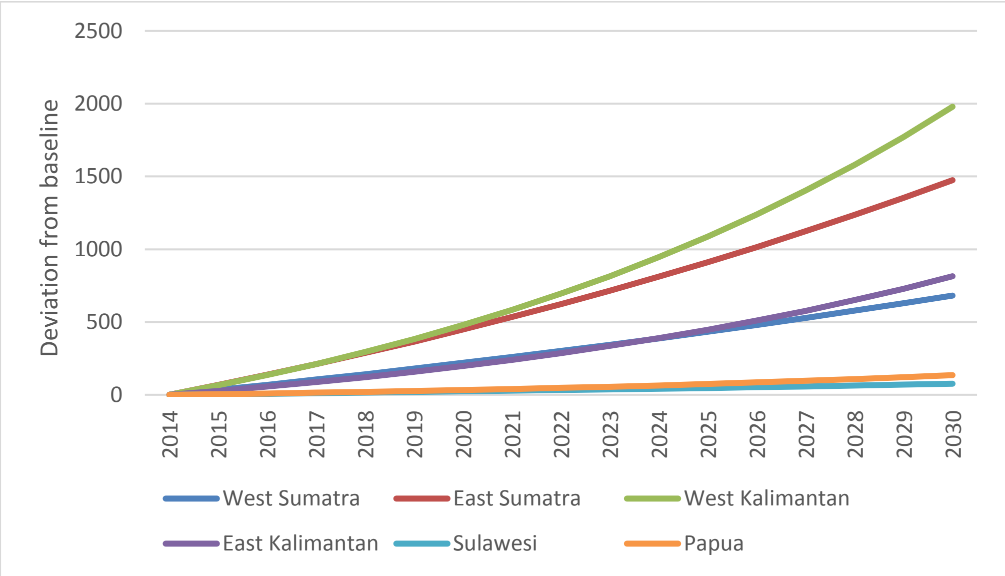


Table 1 presents figures that help explain Figure 11 and 12. Table 1 shows the cumulative deviation away from baseline in in land use for 2015 and 2030 for selected regions. This table shows that in 2015 the change in the land area used for Palm Oil plantations in West Kalimantan is 33.8 thousand hectares below the baseline level (Table 1, row 1, column 1). This fall implies that there must be an increase in the land area allocated to the forest are. By assumption we see that the land are for Natural Forests increase by the same area as the fall in palm oil. We see this confirmed in columns 2 and 3 where the land area allocated to Managed and Natural Forests both fall by 473 thousand hectares. Columns 4 to 6 are for 2030 and can be interpreted in the same way.

Table 1. Land area change by selected region (ordinary deviation away from base)

		1	2	3	4	5	6
	Year	2015			2030		
	Land use / Region	Oil Palm	Managed forest	Natural forest	Oil Palm	Managed forest	Natural forest
1	West Sumatra	-33.8	0.0	33.8	-681.4	0.0	681.4
2	East Sumatra	-67.6	0.0	67.6	-1474.6	0.0	1,474.6
3	West Kalimantan	-65.3	0.0	65.3	-1979.2	0.0	1,979.2
4	East Kalimantan	-26.9	0.0	26.9	-814.4	0.0	814.4
5	Sulawesi	-3.5	0.0	3.5	-76.0	0.0	76.0
6	Papua	-4.4	0.0	4.4	-134.9	0.0	134.9
7	Total	-201.4	0.0	201.4	-5160.5	0.0	5160.5

Another way of representing the results is to compare the actual values generated in the policy simulation with results generated in the baseline simulation. For example, Figure 14 shows the total land area used for palm oil production. In the baseline, this land area grows to 18,564 thousand hectares in 2030 while in the policy simulation this are grows to 13,403.9. The difference of 5,160 is the Natural Forest area that was conserved due to the moratorium. Therefore, instead on the palm oil are growing at an annual average of 4.89 per cent as in the baseline, the palm oil land area grows at an average rate of 2.9 per cent per annum.

Figure 13. Total land area for palm oil in the baseline and policy simulation (thousands hectare)

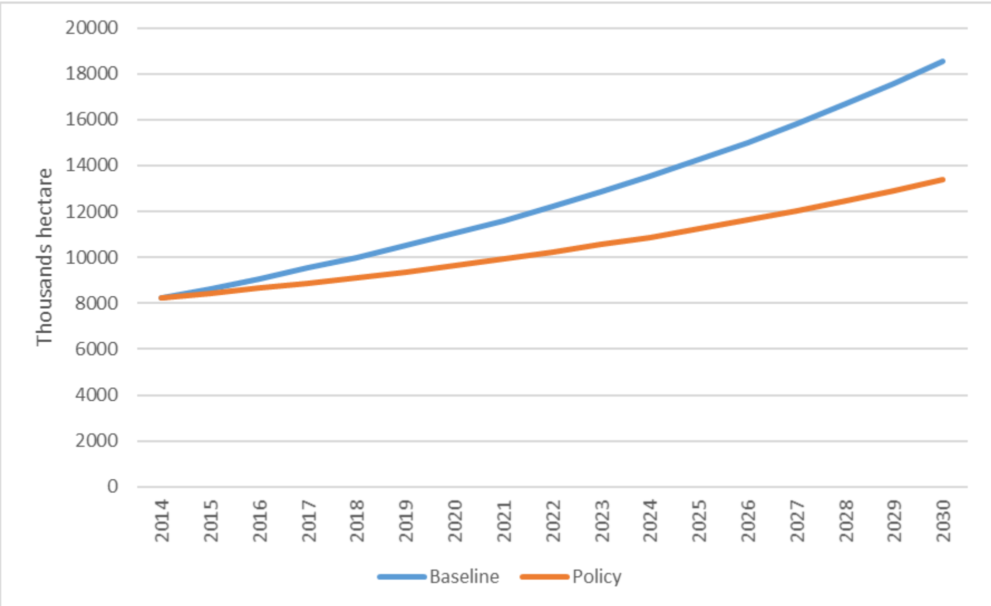


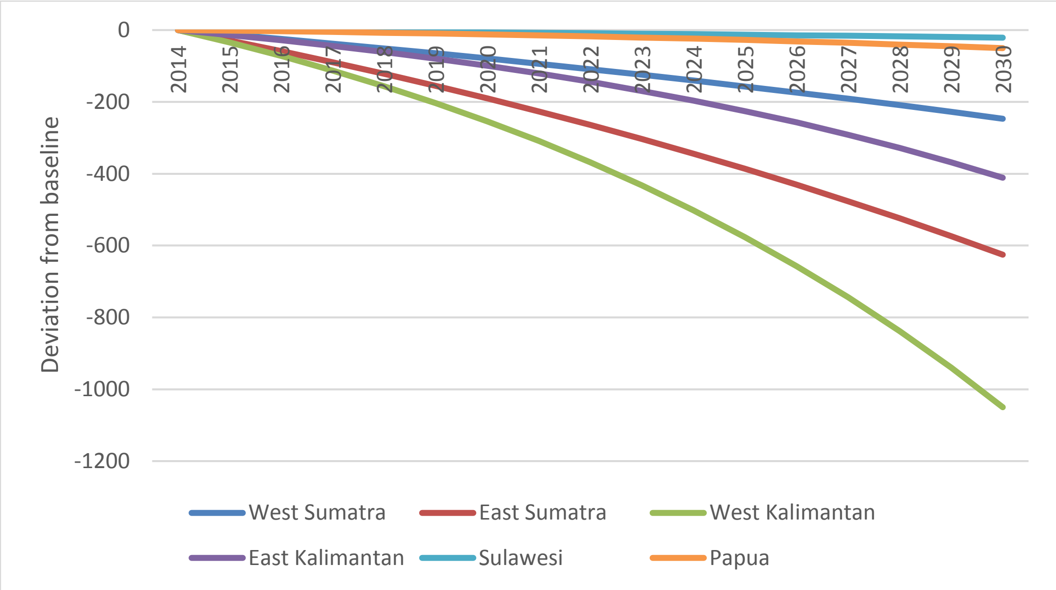
Figure 14 shows that due to the conservation of Natural forests (Figure 12), CO_2 emission fall relative to the baseline in all regions (although at different levels). The change in the level of CO_2 emissions depends on the carbons stock intensity of each land use (See Section 4.2). This is because Natural forests stores more carbon stock than palm oil plantations. CO2 emissions fall the most in West Kalimantan followed by East Sumatra. These figures depend on:

(i) the hectares of natural forests saved from deforestation; and

(ii) the carbon stock stored in Natural forests in the different regions.

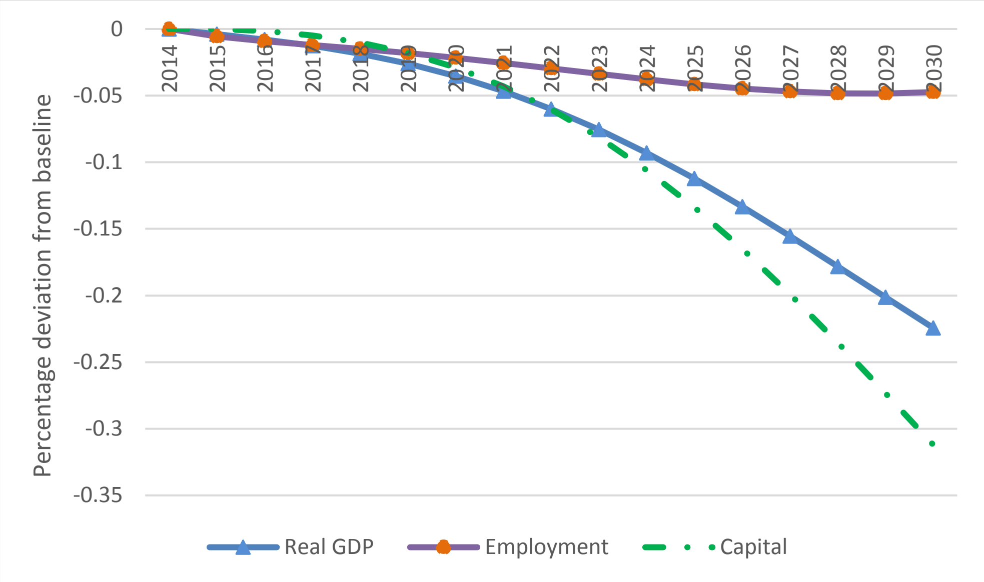
Our initial setting of CO2 intensities show that the carbon stored in natural forests are the highest for West Kalimantan at 800 tons per hectare.

Figure 14. CO2 emission by region (t/ha) (ordinary change from baseline)



On a macro level the impact of a moratorium on land conversion, seem small. However, as we shall see there are regional disparities, which are significant especially in Kalimantan and Sumatra. We shortly focus on the main macroeconomic variables before moving on to the regional impact of the moratorium. Figure 15 shows the results for the GDP components from the income side. The results show that capital and GDP falls in the long run and is 0.3 and 0.23 below base respectively. Our assumption is that employment is fixed in long run. With employment effectively unchanged and with no productivity improvement, capital adjusts given fixed rates of returns.

Figure 15. GDP from the income side (percentage deviation from baseline)



The percentage of GDP calculated as the share weighted sum of capital and palm oil land.

$$gdp = SHRlab * xlab + SHRcap * xcap + SHRlnd * xlnd + a \quad \text{(E.12)}$$

where

gpd, *xlab*, *xcap*, *xlnd* and *a* are the percentage change in real GDP, labour, capital, land and productivity. SHRlab, SHRcap and SHRlnd is the share of labour, capital and land in GDP. With *xlab* and *a* fixed the percentage change is depended on the share capital and land and the percentage change in capital and land, specifically palm oil land.

$$gdp = SHRcap * xcap + SHRlnd * xlnd \quad \text{(E.13)}$$

$$gdp = 0.45 * -0.31 + 0.003 * -21 \quad \text{(E.14)}$$

$$gdp = -0.21 \quad \text{(E.15)}$$

We note that the percentage change in capital contributes the most to the change in GDP. For each $1 of land lost, $2 of capital is lost, given that capital is mobile and adjust to fixed rate of return.

A point to note is that even though the long-run change in national employment is negligible, this does not mean that employment at the individual industry level remains close to baseline values. In most industries, there are permanent employment responses to the moratorium. Figure 16 and 17 shows the percentage change in employment for the main industries and regional employment. In the long-run, employment in the edible oil industry falls by 10 percent from the baseline. This result is explained by the underlying input-output linkages captured in the database, which shows that palm oil is mainly used as an input in the edible oils industry. With the change in aggregate employ negligible, the fall in employment in the edible oils industry and palm oil industry, implies an increase in employment in other industries such as the manufacturing industries. In terms of regional employment, Sumatra shows the largest negative deviation due to the prominence of palm oil and edible oil sectors in this region.

Figure 16. Employment by main industry (percentage deviation from baseline)

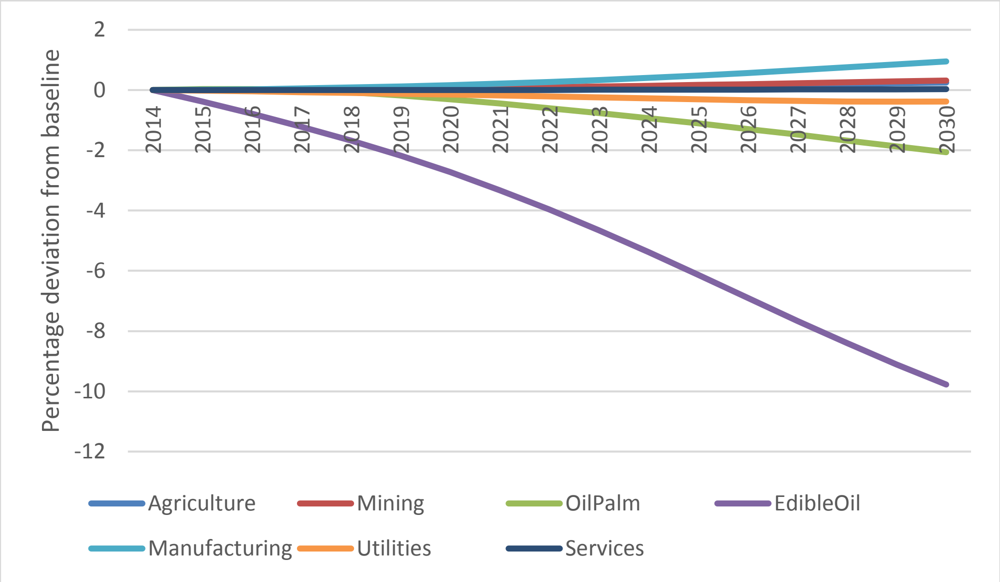


Figure 17. Employment by region (percentage deviation from baseline)

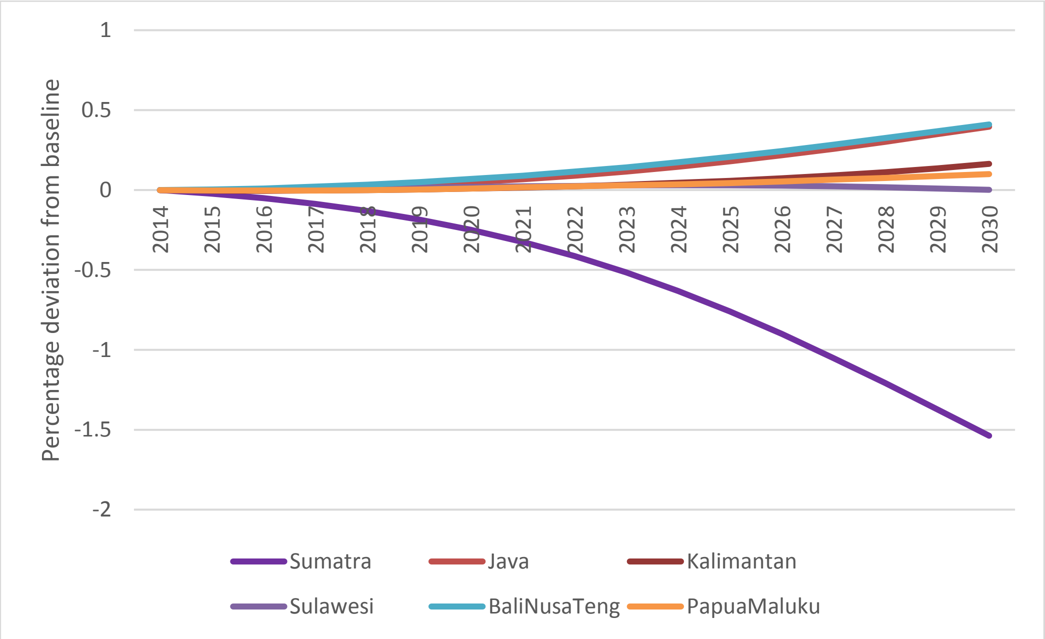


Figure 18. GDP from the expenditure side (percentage deviation from baseline)

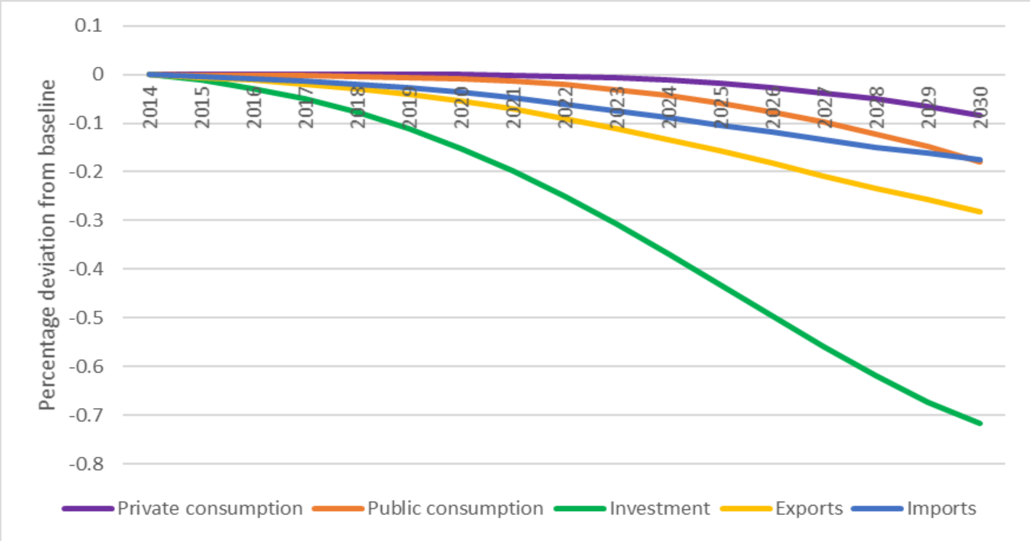


Figure 18 shows the percentage deviation from baseline for the GDP components from the expenditure side. In the long-run, investments falls by 0.7 per cent in the long run. Investment adjust to fixed rates of return and fall in-line with the fall in capital (Figure 17). At region level, real public consumption follows real household consumption – this tends then to be the case nationally. Both public and private consumption adjust by a uniform national amount to ensure that the BOT/GDP remains at base levels. Note that it is the nominal BOT/GDP that is held fix. Export prices rise implying a TOT gain. With the foreign demand for Indonesian commodities facing downward sloping demand curves, the increase in the price of exports causes the demand for Indonesian commodities to fall.

Figure 19 shows the percentage deviation from baseline for the main industries. Not surprisingly, the oil palm and edible oil industries shows the strongest decline in industry output. Regions that rely on palm oil production and related industries (such as edible oil sector) for employment and economic growth, show the strongest decline in regional employment and output (See Figure 9 and adjacent description).

Figure 19. Output of main industries (percentage deviation from baseline)

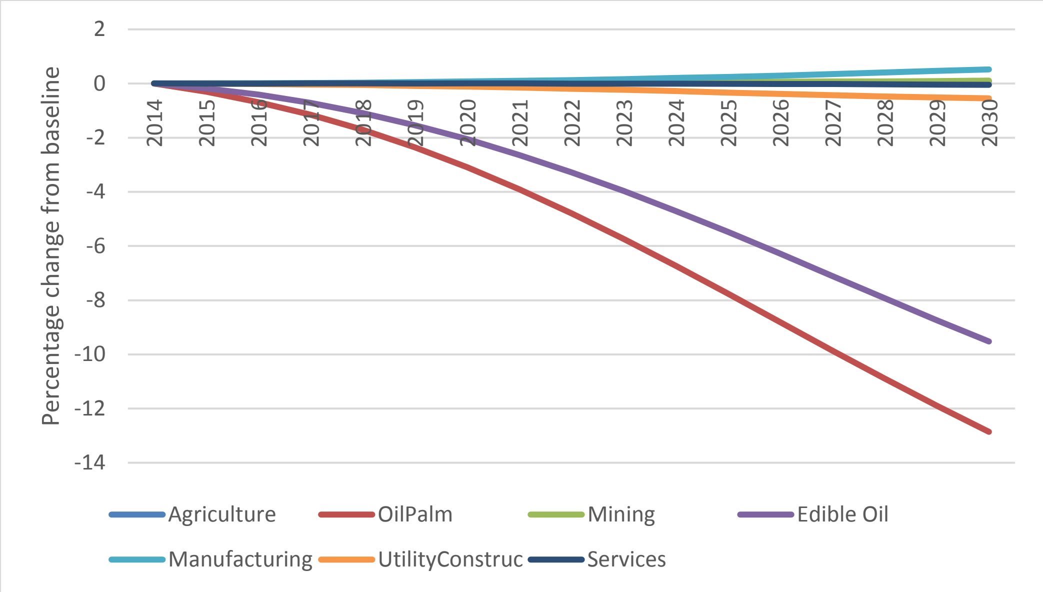
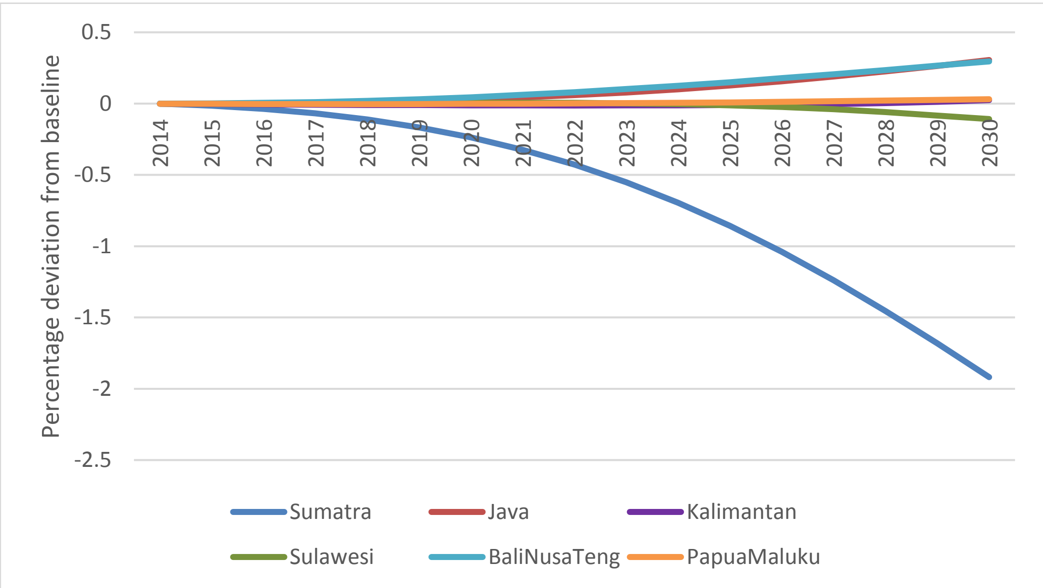


Figure 20. GDP by region (percentage deviation from baseline)

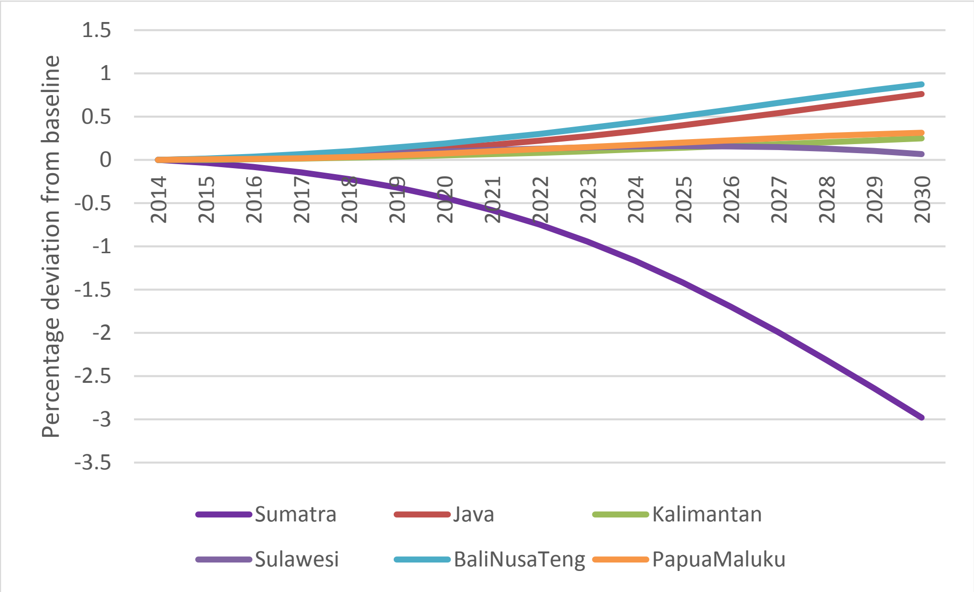


In our simulation, wages adjust to hit target employment rate (by 4 OCC) while holding national employment fixed at base levels (see Figure 15). Therefore, the loss of jobs in palm-oil areas means gains elsewhere. Regions gaining probably do not produce much palm oil and produce for example other manufacturing commodities (e.g. Java). As mentioned before, most palm oil plantations and edible oils industries are located in Sumatra and Kalimantan. It is therefore not surprising that Sumatra growth is below baseline throughout the simulation period. Kalimantan however shows little change in regional growth. This is because Kalimantan is less dependent than Sumatra on oil palm production, is more diversified in their productive activities and can therefore better adjust to the land moratorium.

Our final discussion point is regional welfare. With the moratorium placed on land conversion, smallholders are likely to be impacted the most, risking their livelihood. We use household consumption as a measure of welfare. In our simulations, nominal consumption is linked to wage income and the REDD payment (E10). In the absence of a once-off REDD payment, consumption follows nominal wage payments. As mentioned above, employment in the long-run remains unchanged. Therefore, where industries or regions experience a loss in employment, other regions and industries will show a gain in employment (Figures 16 and 17). Broadly, we expect the impact on welfare to follow the change in employment.

Figure 21 shows the deviation from baseline in nominal consumption. Sumatra is the only region with a fall in welfare, measured as a fall in nominal consumption. This is consistent with the change in regional employment (Figure 17).

Figure 21. Consumption by region (percentage deviation from baseline)



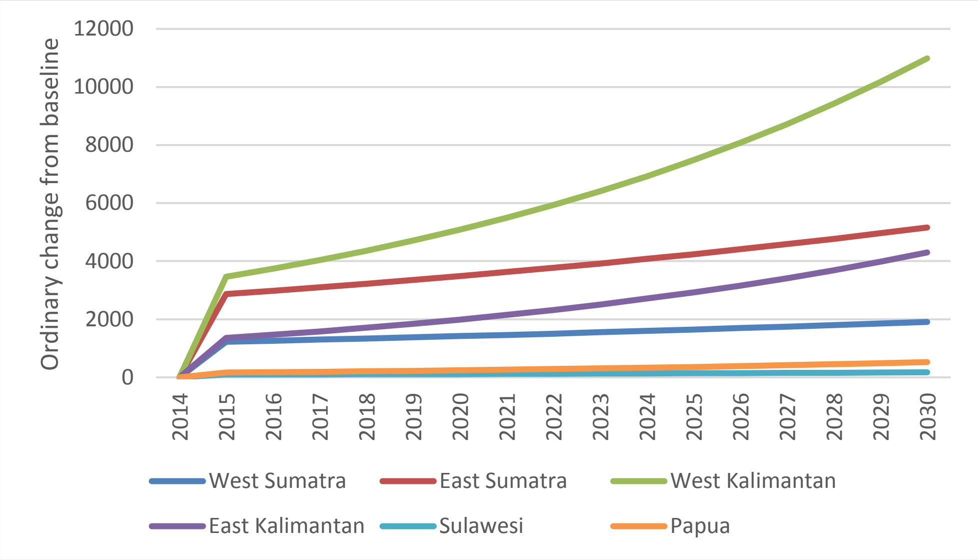
In the next simulation, we translate the moratorium on land conversion into a monetary reward to those regions with lower CO2 levels.

6.2 Sim 2: Imposing a land moratorium in return of a REDD payment

In this simulation we evaluate the impact of a moratorium on the land used for palm oil, similar to Sim1, but now it is accompanied with a gift of foreign exchange (REDD payment) in return for lower CO2 emissions. The payment is directly awarded to households in region *r* (See E.10).

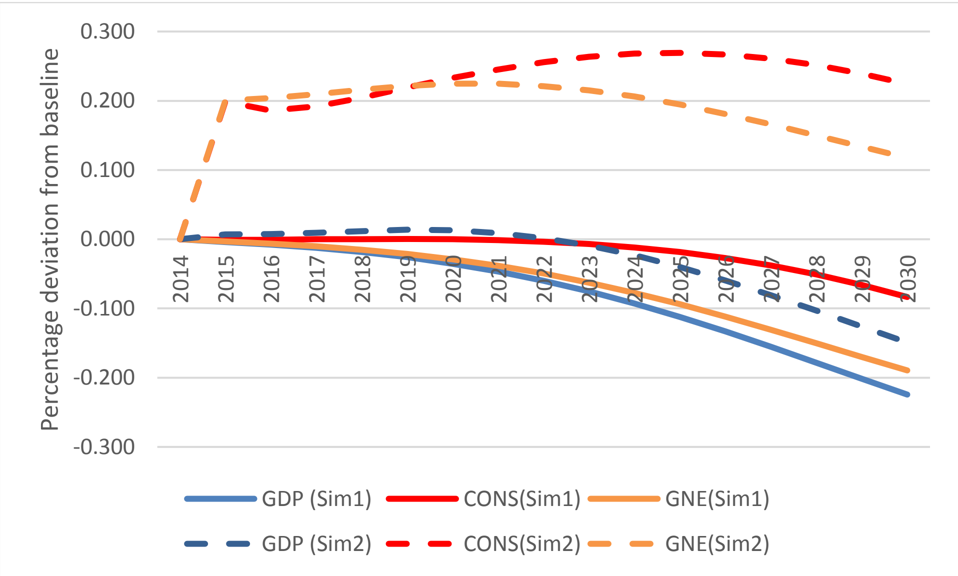
As previously explained (Figure 14), West Kalimantan and East Sumatra shows the largest reductions in CO2 emissions. Therefore, it is not surprising that the largest REDD payment is to West Kalimantan followed by East Sumatra. West Kalimantan receives the highest REDD payment because of (1) the high level of CO2 reduction and (2) the carbon storage per tonne in natural forests are also the highest in West Kalimantan (see Section 4.2).

Figure 22. REDD payment by region (ordinary change from baseline)



As shown by the Figure 23, the moratorium reduces Indonesian economic growth, and other macroeconomic indicators such as GNE and welfare, but international transfers ($10/tCO2 emissions avoided) can more than compensate the welfare loss as mesured by consumption or GNE. However, fall in GDP due to the moratorium cannot fully be compensated. In this context, however, GNE or consumption is a better measure of welfare as the international transfer impact the current account deficit (see Appendix C).

Figure 23. GDP, GNE and consumption (percentage deviation from baseline)



The impact of the moratorium with international transfers varies across regions. Kalimantan wins, Sumatera losses (Figure 24 and 25). Sumatera is highly-dependent on oil palm and its economy is less broad-based. The carbon stock of its forest is no longer high compared to the past. Consequently it receive less transfers than Kalimantan. Kalimantan, on the other hand, is not yet too dependent on oil palm, as its economy is more broad base. In addition, the carbon stock of its forest is still high, therefore receiving more transfers.

Figure 24. Consumption for Sumatra and Kalimantan (percentage deviation from baseline)

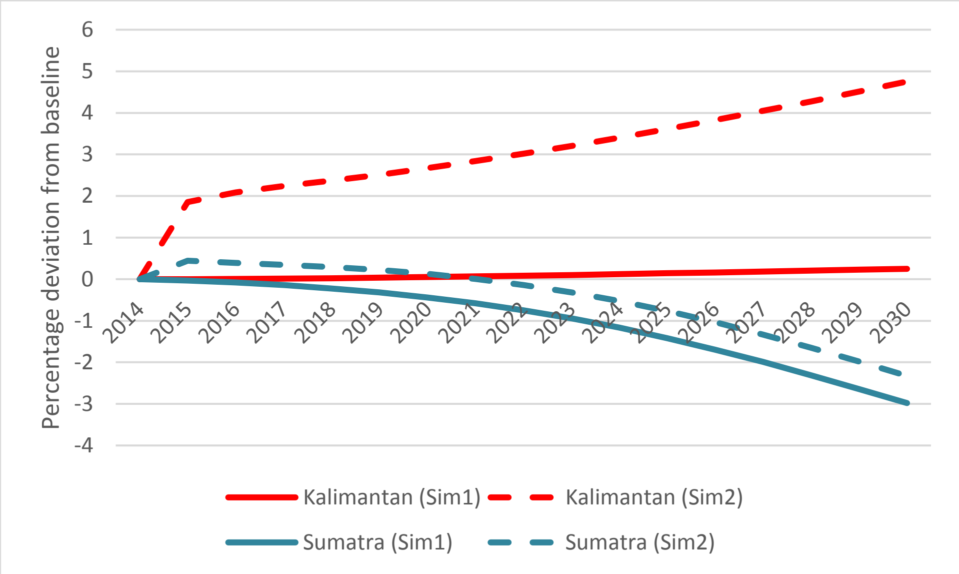
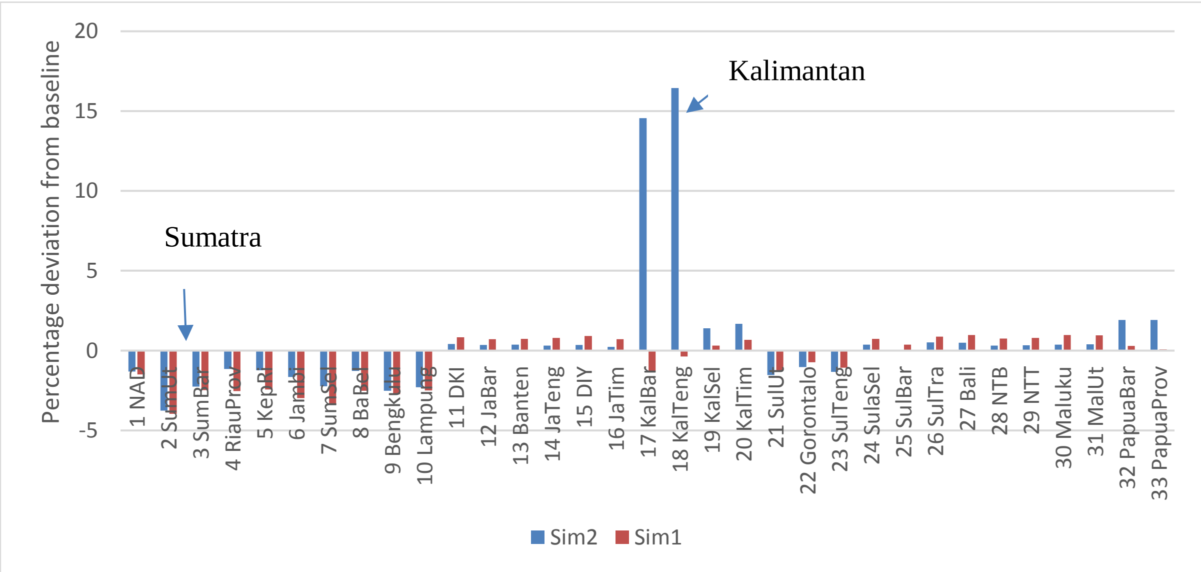


Figure 25. Household consumption by province in 2013 (percentage deviation from baseline)



7 Conclusion

This objectives of this paper is (1) to see the macroeconomic effect of the moratorium on the Indonesian economy including how the effect is distributed across different regions in the country (2) to see to what extent international transfers, which is a payment for ecosystem services (PES) where international community pays the avoided deforestation or the additioanl carbon storage services can mitigate the effect of the moratorium.

To do this we use the IndoTERM model, a bottom-up multi-regions computable general equilibrium model. Bottom-up means that the national economy is an aggregation of sub-national economies. Unlike the other kind of multi-regional model namely top-down multi-regional CGE, with the bottom-up model, each commodities has different market clearing equations for each regions. Therefore, prices for each commodity will be differentiated across regions. With this kind of model, region-specific shocks can be easily formulated with the model.

We use IndoTERM model to conduct three experiments. The first simulation is the business-as-usual simulation where we model the growth of the Indonesian economy in the absence of a moratorium and REDD payment. In the baseline simulation we assume that both Natural and Managed forests are converted to palm oil plantations. We then use this model to evaluate alternative growth paths where we simulate a moratorium on converting forest area to oil palm plantation in (1) the absence of a REDD payment and (2) return for a REDD payment which is proportional to the fall in CO2 emissions.

Our results show that in the baseline, by 2030, 13,110 thousand hectare of Forest land is converted to palm oil. Of the total land converted, half comes from Managed forest and the other half from Natural forest.

The results suggest that moratorium reduces Indonesian economic growth, and other macroeconomic indicators, but international transfers ($10/tCO2 emissions avoided) can more than compensate the welfare loss. However, the impact varies across regions. Sumatera which is highly-dependent on oil palm; of which its economy is less broad-based and its carbon stock of its forest is no longer high, receive less transfers and suffer a great economic loss. In the meantime, Kalimantan which is relatively less dependent on oil palm than Sumatera, and its forest's carbon stock is still high, receive more transfers and get greater benefit. This result suggest that additional policy measures anticipating the imbalanced impact of the transfers is required if the trade-off between conservation and reducing inter-regional economic disparity needs to be reconciled.

In future, it may be useful to run several scenarios simulating different levels of REDD payments, i.e. different CO2 prices. In this paper we do not improve palm oil productivity in the policy simulations. It would be interesting to see the regional and national impact if productivity in the palm oil sector is the same as that in Malaysia.

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Appendix A. The core TERM model

Figure A1 represents the model's input-output structure[9]. The rectangles indicate matrices of flows. Core matrices contained in the database are printed in bold while other matrices may be calculated from the core matrices. The dimensions of the matrices are indicated by indices corresponding to the sets listed at top right.

The matrices on the left-hand side of the diagram resemble (for each region) a conventional single-region input-output database.[10] For example, the matrix USE at top left shows the delivered value of demand for each good (c in COM) whether domestic or imported (s in SRC) in each destination region (DST) for each user (USER, comprising the industries, IND, and 4 final demanders: households, investment, government, and exports). Some typical elements of USE might show:

- USE("OilPalm","dom","EdibleOil","Sumatra"): domestically-produced OilPalm used by the EdibleOil industry in Sumatra.
- USE("OilGas","dom","EXP","Kalimantan") : domestically-produced OilGas exported from a port in Kalimantan.

The TAX matrix of commodity tax revenues contains elements corresponding to each element of USE. Together with matrices of primary factor costs and production taxes, these add to the costs of production (or value of output) of each regional industry.

The MAKE matrix at the bottom of Figure B1 shows the value of output of each commodity by each industry in each region. A subtotal of MAKE, MAKE_I, shows the total production of each commodity *c* each region *d*.

The right hand side of Figure A1 shows the regional sourcing mechanism. The key matrix is TRADE, which shows the value of inter-regional trade by sources (*r* in ORG) and destinations (*d* in DST) for each good (*c* in COM) whether domestic or imported (*s* in SRC). The diagonal of this matrix (r=d) shows the value of local usage which is sourced locally. For foreign goods (*s*="imp") the regional source subscript *r* (in ORG) denotes the port of entry. The matrix IMPORT, showing total entry of imports at each port, is simply an add-up (over *d* in DST) of the imported part of TRADE.

[9] This and the next subsection draw from Horridge et al. (2003).

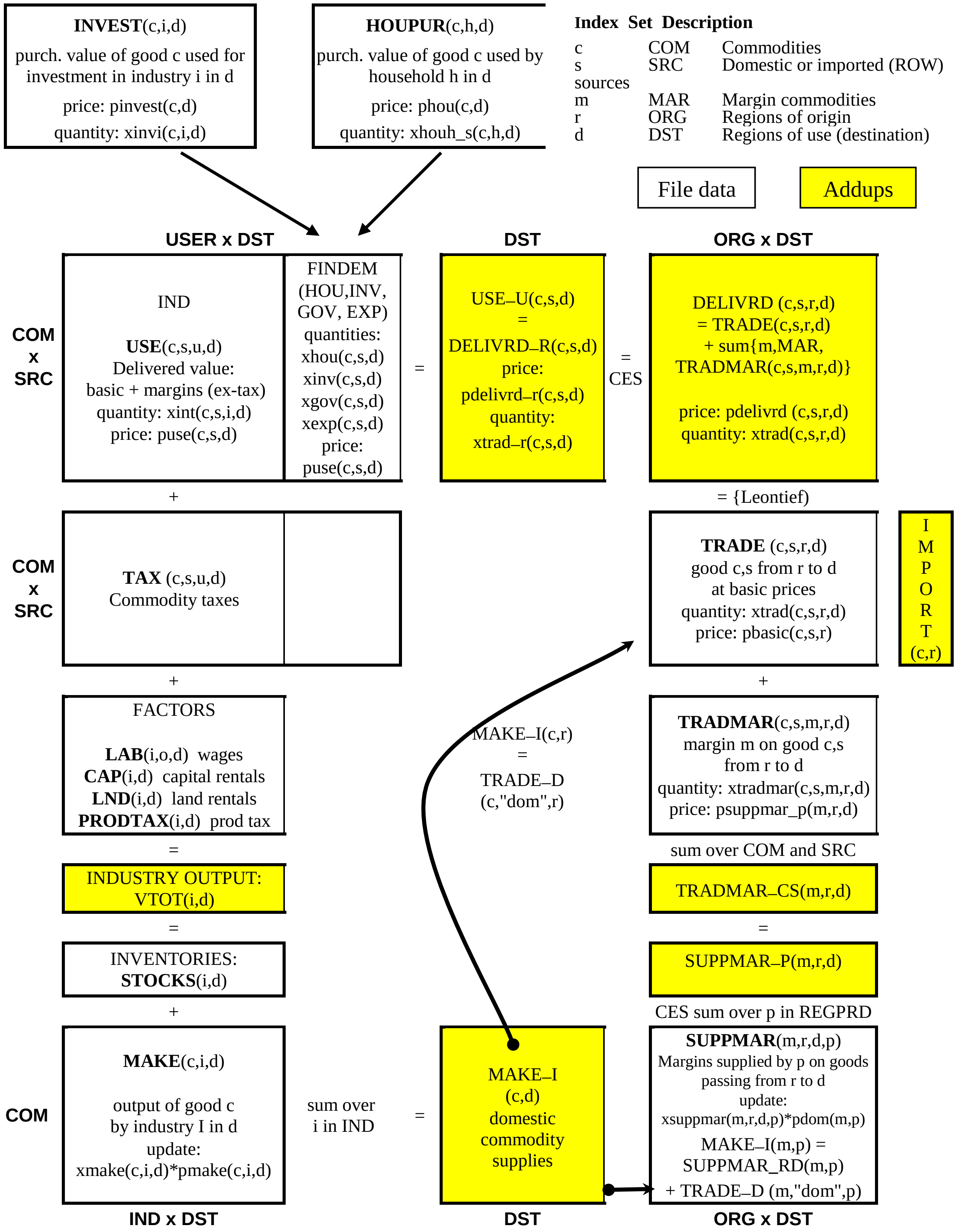
[10] The matrices in Figure 2 show the value of flows valued according to 3 methods:

1) Basic values = Output prices (for domestically-produced goods), or CIF prices (for imports)

2) Delivered values = Basic + Margins

3) Purchasers' values = Basic + Margins + Tax = Delivered + Tax

Figure A1: INDOTERM flows database



The TRADMAR matrix shows, for each cell of the TRADE matrix the value of margin good *m* (*m* in MAR) which is required to facilitate that flow. Adding together the TRADE and TRADMAR matrix gives DELIVRD, the delivered (basic + margins) value of all flows of goods within and between regions. Note that TRADMAR makes no assumption about where a margin flow is produced (the *r* subscript refers to the source of the underlying basic flow).

Matrix SUPPMAR shows where margins are produced (*p* in PRD). It lacks the good-specific subscripts *c* (COM) and s (SRC), indicating that, for all usage of margin good *m* used to transport any goods from region *r* to region *d*, the same proportion of *m* is produced in region *p*. Summation of SUPPMAR over the *p* (in PRD) subscript yields the matrix SUPPMAR_P which should be identical to the subtotal of TRADMAR (over *c* in COM and *s* in SRC), TRADMAR_CS. In the model, TRADMAR_CS is a CES aggregation of SUPPMAR: margins (for a given good and route) are sourced according to the price of that margin in the various regions (p in PRD).

IndoTERM assumes that all users of a given good (*c,s*) in a given region (*d*) have the same sourcing (*r*) mix. In effect, for each good (*c,s*) and region of use (*d*) there is a broker who decides for all users in d whence supplies will be obtained. Armington sourcing is assumed: the matrix DELIVRD_R is a CES composite (over *r* in ORG) of the DELIVRD matrix.

A balancing requirement of the IndoTERM database is that the sum over user of USE, USE_U, shall be equal to the sum over regional sources of the DELIVRD matrix, DELIVRD_R.

It remains to reconcile demand and supply for domestically-produced goods. In Figure 2 the connection is made by arrows linking the MAKE_I matrix with the TRADE and SUPPMAR matrices. For non-margin goods, the domestic part of the TRADE matrix must sum (over d in DST) to the corresponding element in the MAKE_I matrix of commodity supplies. For margin goods, we must take into account both the margins requirement SUPPMAR_RD and direct demands TRADE_D.

(a) At the moment, IndoTERM distinguishes only 4 final demanders in each region:
(b) HOU: the representative household
(c) INV: capital formation, distinguished by sector of use
(d) GOV: government demand
(e) EXP: export demand.

Figure A2 illustrates the details of the IndoTERM system of demand sourcing. Note that this figure covers only the demand for a single commodity (Vegetables) by a single user (Households) in a single region (Sumatra). The same diagram would apply to other commodities, users and regions. The diagram depicts a series of 'nests' indicating the various substitution possibilities allowed by the model. Down the left side of the figure, boxes with dotted borders show in upper case the value flows associated with each level of the nesting system. These value flows may also be located in **Error! R**

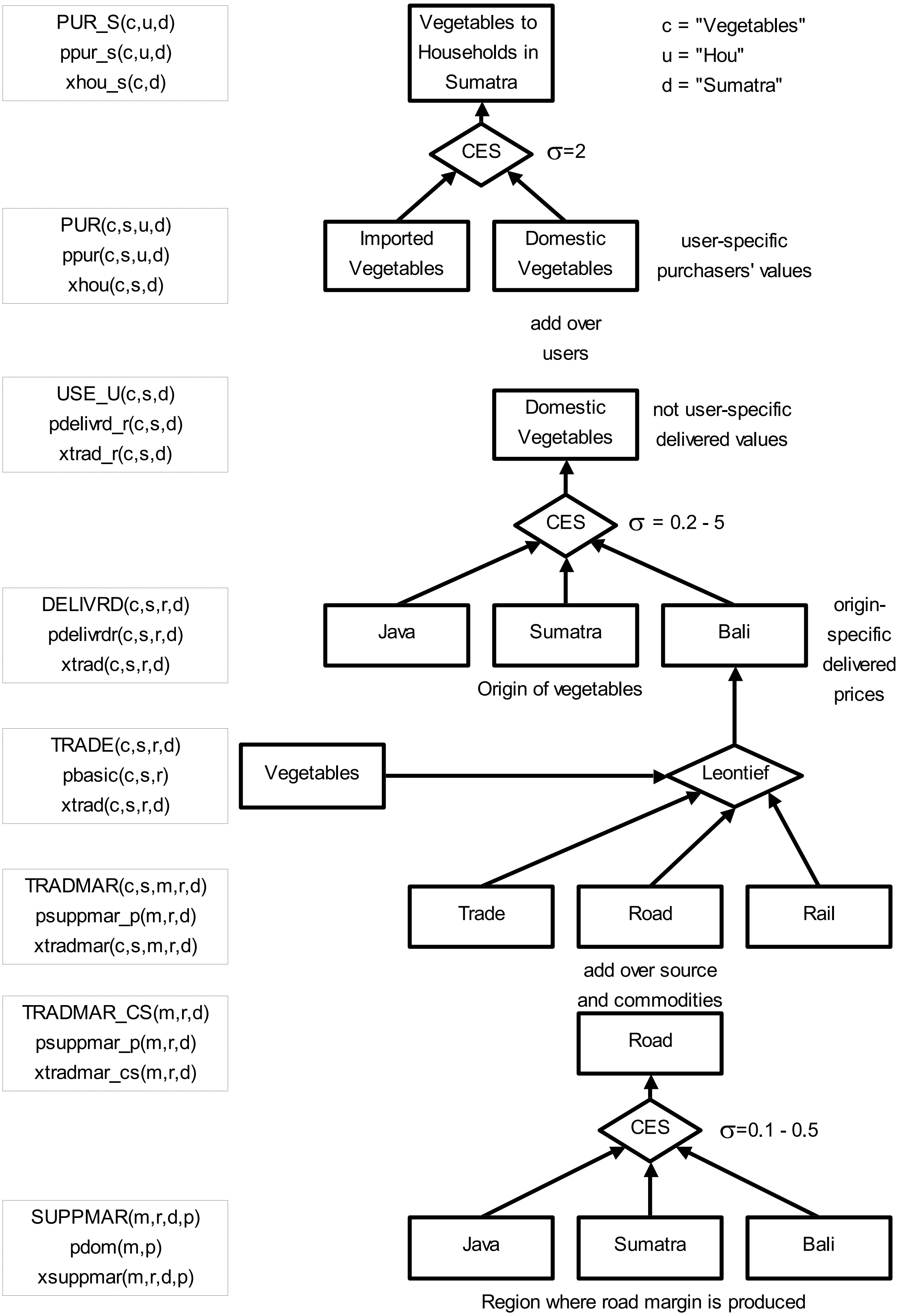
eference source not found.. The same boxes show in lower case the price (p....) and quantity (x....) variables associated with each flow. The dimensions of these variables are critical both to the usefulness of the model and to its computational tractability; they are indicated by subscripts c, s, m, r, d and p, as explained at top right of **Error! Reference source not found.**A1. Most key features of I ndoTERM could be reconstructed from Figure A1 and **Error! Reference source not found.**.

At the top level, households choose between imported (from another country) and domestic vegetables. A CES or Armington specification describes their choice—as pioneered by ORANI and adopted by most later CGE models. Demands are guided by user-specific purchasers' prices (the purchasers' values matrix PUR is found by summing the TAX and USE matrices of Figure A2).

Demands for domestic vegetables in a region are summed (over users) to give total value USE_U (the "_U" suffix indicates summation over the user index u). The USE_U matrix is measured in "delivered" values—which include basic values and margins (trade and transport), but not the user-specific commodity taxes.

The next level treats the sourcing of USE_U between the various domestic regions. The matrix DELIVRD shows how USE_U is split between origin regions *r*. Again a CES specification controls the allocation; substitution elasticities range from 5 (merchandise) to 0.2 (services). The CES implies that regions which lower production costs more than other regions will tend to increase their market share. The sourcing decision is made on the basis of delivered prices—which include transport and other margin costs. Hence, even with growers' prices fixed, changes in transport costs will affect regional market shares. Notice that variables at this level lack a user (*u*) subscript—the decision is made on an all-user basis (as if wholesalers, not final users, decided where to source vegetables). The implication is that, in Sumatra, the proportion of vegetables which come from Bali is the same for households, intermediate, and all other users.

Figure A2: IndoTERM sourcing mechanisms



The next level shows how a "delivered" vegetable from, say, Bali, is a Leontief composite of basic vegetables and the various margin goods. The share of each margin in the delivered price is specific to a particular combination of origin, destination, commodity and source. For example, we should expect transport costs to form a larger share for region pairs which are far apart, or for heavy or bulky goods. The number of margin goods will depend on how aggregated is the model database. Under the Leontief specification we preclude substitution between Road and Retail margins, as well as between Road and Rail. For some purposes it might be worthwhile to construct a more elaborate nesting which accommodated Road/Rail switching.

The bottom part of the nesting structure shows that margins on vegetables passing to Sumatra from Bali could be produced in different regions. The figure shows the sourcing mechanism for the road margin. We might expect this to be drawn more or less equally from the origin (Bali), the destination (Sumatra) and regions between (Java). There would be some scope ($\sigma = 0.5$) for substitution, since trucking firms can relocate depots to cheaper regions. For retail margins, on the other hand, a larger share would be drawn from the destination region, and scope for substitution would be less ($\sigma = 0.1$). Once again, this substitution decision takes place at an aggregated level. The assumption is that the share of Java in providing Road margins on trips from Bali to Sumatra, is the same whatever good is being transported.

Although not shown in Figure A2, a parallel system of sourcing is also modelled for imported vegetables, tracing them back to port of entry instead of region of production.

Appendix B. Baseline simulation assumptions and results

Assumptions

The base simulation is designed to serve as a plausible business-as-usual (BAU) scenario for the future path of the Indonesian economy in the absence of the REDD scheme, i.e. in the absence of additional efforts to curb deforestation and carbon emissions. This baseline is used as a benchmark against which the economic impacts of reduced forest clearing with and without a REDD payment is measured.

Our baseline forecast is driven by projected changes in population, labour force, productivity, and foreign demands that are roughly consistent with Indonesia's recent annual GDP growth rates of 6 per cent per annum. We impose the following exogenous changes for each year of the base simulation:

(vii) The labour force and population grow respectively at 2.5 and 1.5 per cent per annum. over the entire simulation period. The higher growth rate for labour force reflects (a) the relative youth of Indonesians, and (b) the idea that over time workers will migrate from informal to formal sectors, becoming more productive.

(viii) There is a continued increase in foreign demand for Indonesian commodities, including edible oils.

(ix) Labour productivity improves for all service industries by 3 per cent p.a. and for non-service industries by 6 per cent p.a.

Of special importance in our simulations are our assumptions regarding natural resource endowment and productivity. Natural resources not only refer to "Land", but also include ore bodies, fish stocks and other water activities. We assume that:

(x) Land productivity rises by 3 per cent per annum in all Agricultural sectors. The Agricultural sectors include *Crops*, *Estate Crops*, *Oil Palm* and *Managed Forests*. Improved land productivity is another way of increasing output in, for example, the palm oil sector.

(xi) Land productivity in all extractive sectors except for Oil and Gas, rises by 2 per cent per annum. The assumption of no land productivity in the Oil and Gas sector reflects our view that Indonesian oil reserves offer little scope for output increase.

(xii) For all land-using sectors, except the Palm Oil sector, we assume that the land area under cultivation is fixed. Although the current Indonesian policy is not to allocate more land to the Palm Oil sector, we increase the land allocated to this sector. This is because there are still substantial Natural Forest areas previously allocated for Palm Oil, that have not actually yet been converted. This (and perhaps flouting of the policy) allows palm area to rise. We assume that the land area for Palm Oil increases by 8 per cent in Kalimantan and Papua, 4 per cent in East Sumatra and Sulawesi and 3 per cent in West Sumatra.

Macro results

Our simulation results show an increase in GDP and population growth, implying an increase in demand for manufacturing services including edible and palm oil products.

Real GDP growth slowly decelerates over the 25 year period from 5.5 per cent 4.8 per cent per annum. Over this period, real GDP nearly triples. This implies an average annual growth rate of 5.5 per cent per annum over the period 2006 -2030. There are three main drivers to explain the growth in GDP. Firstly, our choice of shocks explained above governs our view about the growth path of the Indonesian economy. The gradual decline in GDP is partly due to the increase in the factor share of total land use. Land-use as a share of factor use increase from approximately 3.4 per cent in 2005 to 11.4 per cent in 2030. This increase in the factor share combined with the land productivity shocks partly explains this decline.[11]

Secondly, there is a shift towards the use of services. In the base simulation, GDP per capita increases leading to an increase in spending on services.[12]

Finally, the share of resource-based products in exports declines and is replaced by manufacturing. In 2005 the share of mining in exports is approximately 20 per cent and manufacturing 67 percent. In 2030, the share of mining falls to 4.5 per cent and manufacturing increases to 83 per cent.

Employment grows at a slower pace, at an annual average rate of 2.4 % p.a.. Recall from our baseline shocks that labour productivity in service industries, which employs approximately 56 per cent of those employed, increases by less that the productivity in non-service industries, which employs 44 per cent of all labour. The share of labour in value added falls from 48 per cent in 2005 to 43 per cent in 2030. Capital stock grows at an annual average rate of about 5.3 % p.a. The capital share in value added decrease slightly from 48 per cent to 46 per cent over the simulation period.

National household and government consumption adjusts so that the ratio (Balance of trade/GDP) is held fixed. Over the simulation period there is very little change in the share of the expenditure components in GDP. There is a slight change in the share of investment and public spending between 2005 and 2030. The investment share falls slightly from 21.7 per cent to 18.6 per cent and the share of public spending increases from 7 to 8.1 per cent. All the expenditure components show strong annual average growth, similar to that of GDP growth.

[11] The marginal contribution of additional labour and capital to GDP reduces as the labour/land ratio increases given that GDP = COB(Lab,Land,Cap). There is a diminishing return of labour because labour increases by 6 per cent and land at 3 per cent.

[12] The spending by households is influenced by the expenditure elasticities. Expenditure elasticities are typically set low for food and higher for services. Thus, as people become richer, they spend more on service and manufactured goods.

Figure B1. GDP component from the income side (year-on-year percentage change)

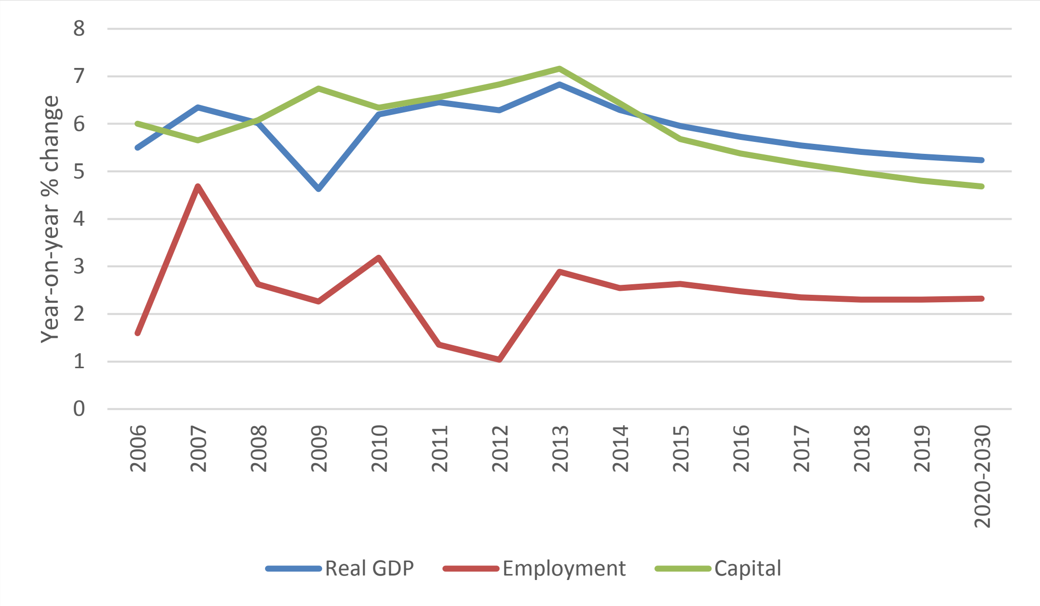
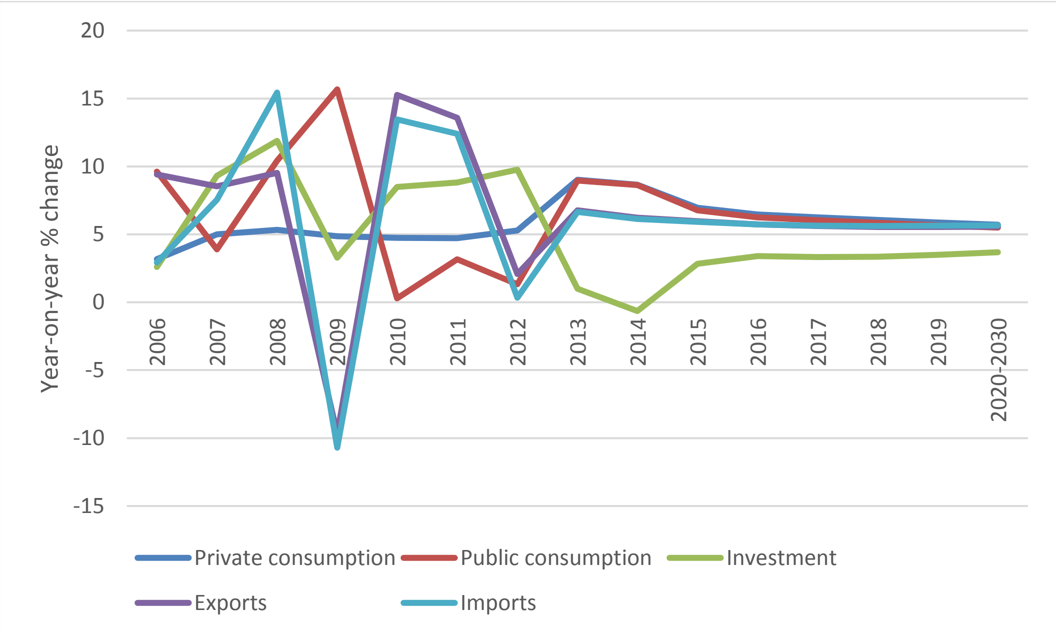


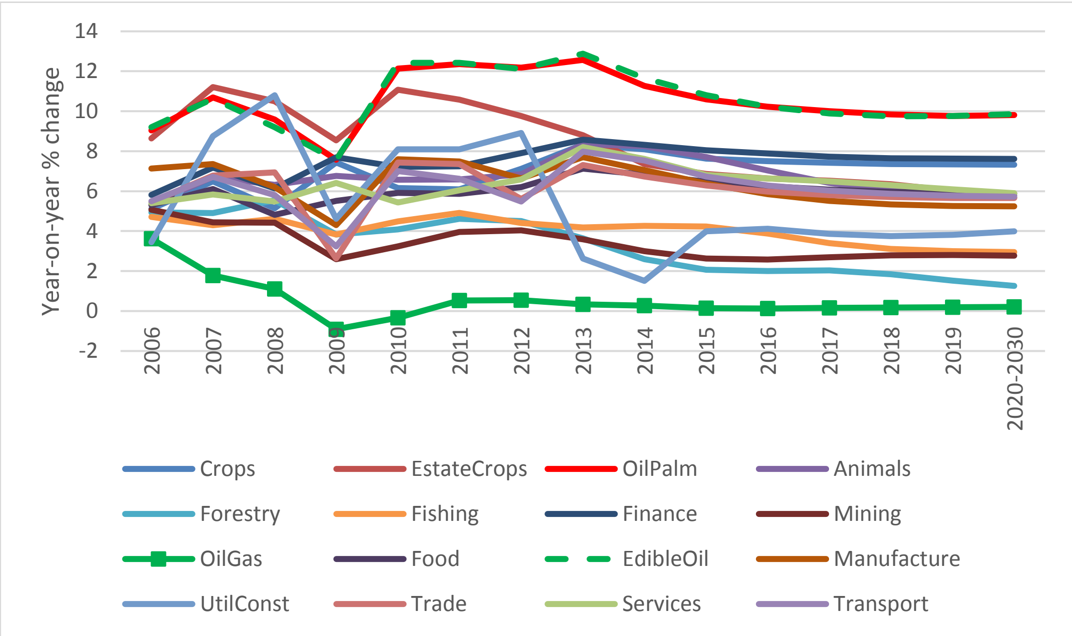
Figure B2. GDP component from the expenditure side (year-on-year percentage change)



Industry results

All sectors grow but at different rates. The Oil and Gas industry shows the lowest growth rates, averaging 0.4 per cent over the period 2006-2030. The main reason for the poor growth is our assumption that Indonesia's capacity to extract oil is fixed. Less than 10 per cent of this industry's factor cost is labour, and therefore this sector benefits little from labour productivity. The Oil and Gas sector is followed by the Fishing, Forestry and Mining industries. These sectors are also resource-constrained industries but they benefit from both the labour and land productivity improvement. The average growth rates of these industries range between 2 and 3.4 per cent. The industries that performed the best are the Palm Oil and Edible Oil industries growing annually at 10 and 10.15 per cent respectively. Although the Palm Oil industry is a land-using industry, their share of labour in total factor cost is more than 75 per cent. They therefore not only benefit from land productivity but also from an increase in labour productivity. Agricultural processing closely follow the output change of their primary input. For example, the Edible Oil industry is a fast growing industry with an annual average growth rate of 10 per cent. A major input to this industry is Palm Oil which also grows strongly throughout the simulation period.

Figure B3. Growth in industry output (year-on-year percentage change)



Regional results

Regional performance is dependent on the type of economic activity that is dominant in that region. Our baseline simulation results (Figure B4 and Table B1) show that Java grows that fastest at an annual average of 5.9 per cent per annum and the PapuaMaluku region the lowest at an annual average of 3.3 per cent per annum. Java has the highest growth rate over the period because this region hosts the majority of manufacturing and service industries. These industries show strong growth over the simulation period whereas in Papua and Maluku, which grows at a lower rate, mainly produce output that does not benefit greatly from the employment and productivity improvements.

Figure B4. GDP growth rates by region (year-on-year percentage change)

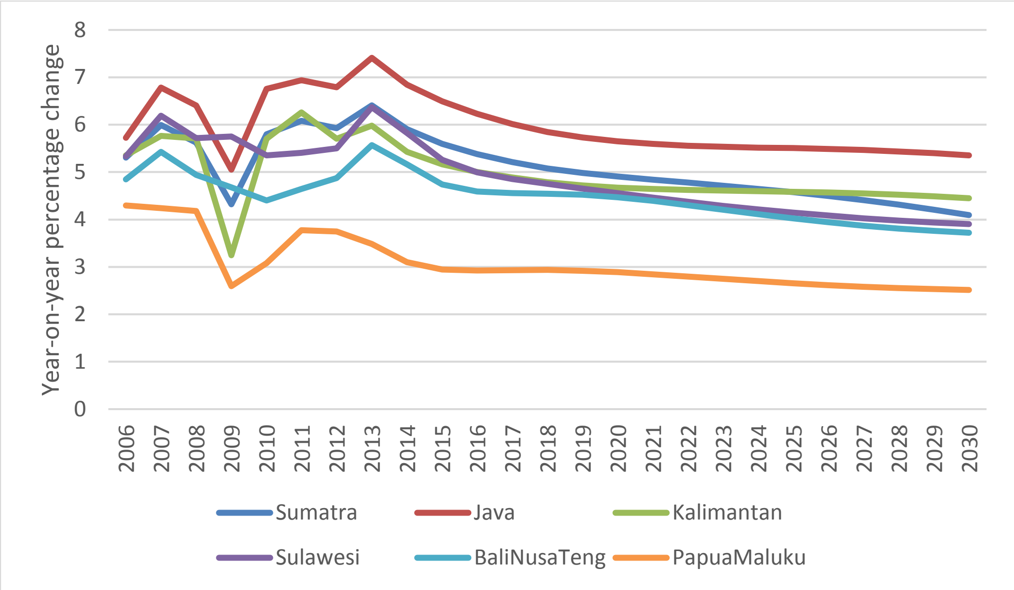
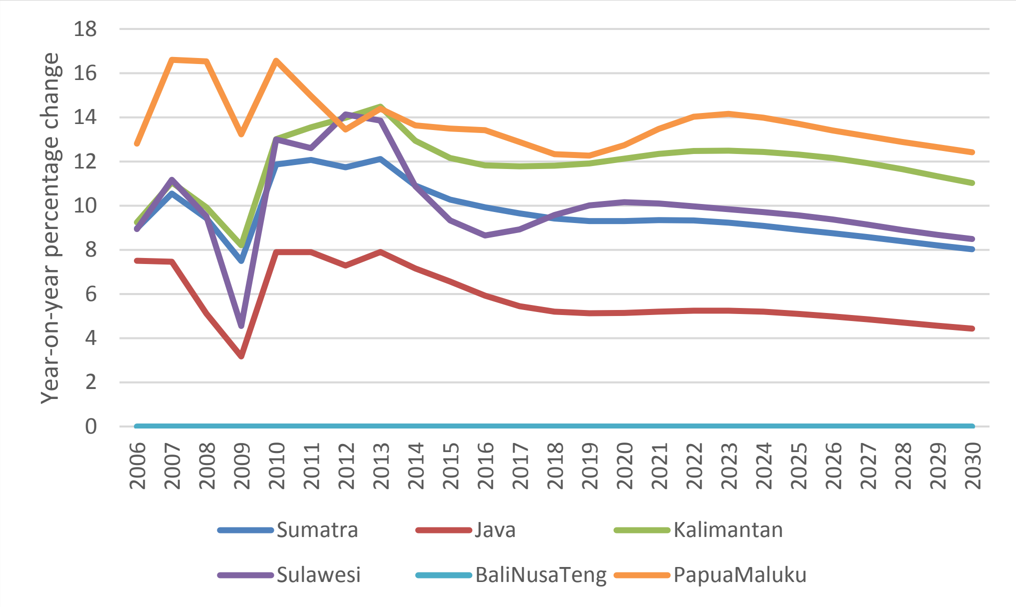


Table B1. Annual per cent growth rates by main region (percentage)

		2010	2015	2020	2025	2030	Average
1	Sumatra	5.4	6.0	5.1	4.7	4.3	5.1
2	Java	6.1	6.8	5.8	5.4	5.2	5.9
3	Kalimantan	5.5	6.0	5.0	4.7	4.5	5.1
4	Sulawesi	5.7	5.7	4.8	4.3	4.0	4.9
5	BaliTeng	5.0	5.2	4.7	4.3	3.9	4.6
6	PapuaMaluku	4.2	3.9	3.1	2.8	2.5	3.3

Figure B5 shows that the growth paths for oil palm production is grouped into 3 groups based on annual growth rates. Regions with the highest palm oil growth rates includes Papua at approximately 13 per cent per annum. This reflects the governments' effort to extend palm oil plantations to the eastern regions of Indonesia. This region is followed by Kalimantan. The second group includes, Sulawesi and Sumatra with growth rates at just below 10 per cent over the medium and long run. The regions with the lowest growth rates for Palm Oil include Java at approximately 5 per cent. We assume in this simulation that there is little scope for expansion in Java and therefore the growth in land allocated to palm oil cultivation is set to zero. The growth rate is mainly due to land and labour productivity shocks. Bali and NusaTeng do not have any palm oil plantations and therefore the growth in these regions is zero.

Figure B5. Palm Oil sector growth rates by region (percentage change)



Land area and CO2 emissions

For our study, an important feature in the BAU simulation is the growth path of land-use area and CO2 emissions. In the baseline simulation, we hold land available for Crops and Estate crops fixed and only allow for the conversion of Forest area to Palm Oil plantations. We assume that half of the land converted to Palm Oil plantations comes from Managed Forest and the other half from Natural Forestry. We accommodate this simulation by activating equation (E.4) in the baseline simulation.

Figure B6 shows the accumulated increase in land area for Palm oil over the simulation period by selected regions. West Kalimantan and East Sumatra shows the highest levels of land-use conversion from Forests to Palm Oil plantations, followed by West Sumatra and East Kalimantan. Papua and Sulawesi shows the lowest level of land conversion.

The increase in the land area designated for Palm Oil implies a loss of Managed and Natural Forest Area. As mentioned above, half of the land converted to Palm Oil plantations comes from Managed Forest and the other half from Natural Forestry. Figure B7 shows that loss of Managed Forest area over the simulation period contributes half of the increase in palm oil plantation land (Figure B6). The other half is the loss of Managed Forest area and the graph would be similar to Figure B7.

Figure B6. Palm Oil area by region (cumulative ordinary change)

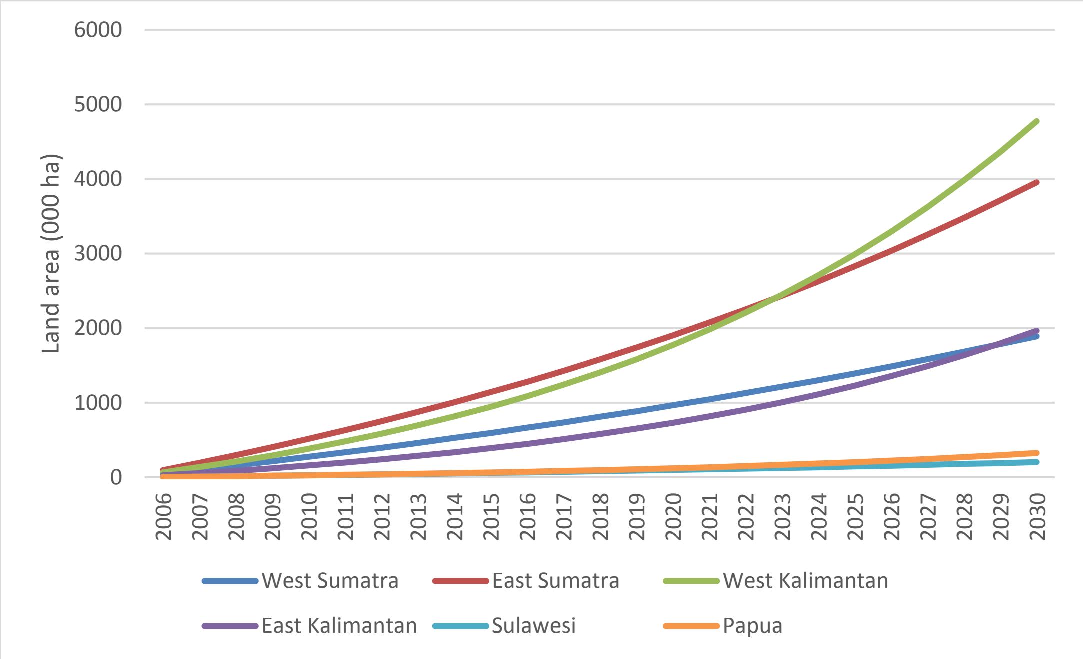


Figure B7. Loss of Natural Forest area by region (cumulative ordinary change)

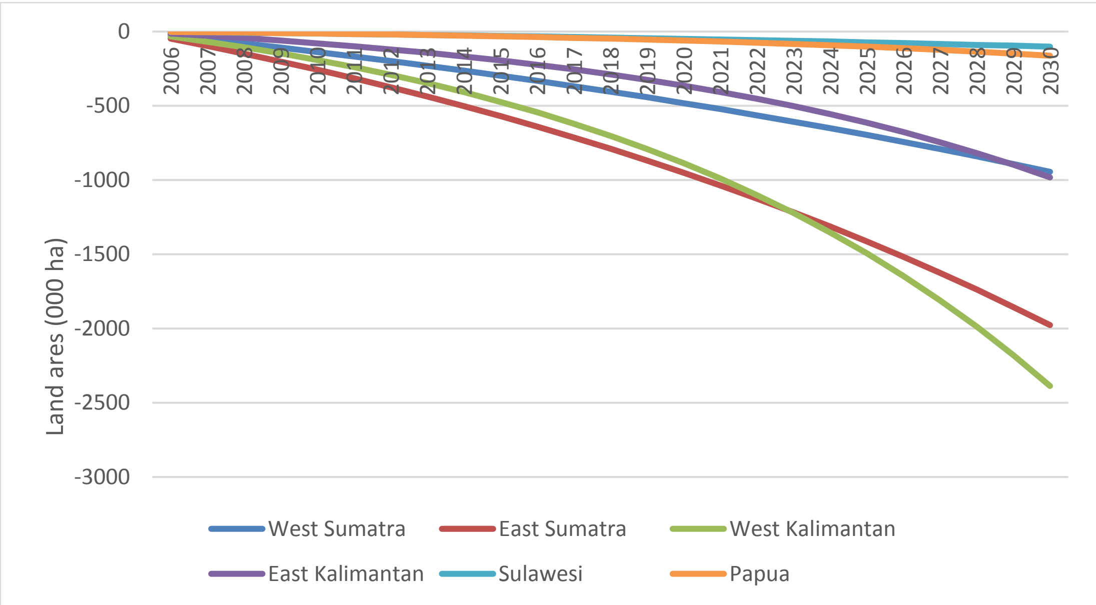


Table B2 shows the cumulative change in land use for 2015 and 2030 for selected regions. For example, in 2015 the change in the land area used for Palm Oil plantations in West Kalimantan increased by 946 thousand hectares (Table B2, row 1, column 1). This increase implies that there must be a fall in the land area allocated to Managed and Natural Forests. We see this confirmed in columns 2 and 3 where the land area allocated to Managed and Natural Forests both fall by 473 thousand hectares. Columns 4 to 6 are for 2030 and can be interpreted in the same way.

Table B2. Land area change by selected region (cumulative change)

		1	2	3	4	5	6
	Year	2015			2030		
	Land use / Region	Oil Palm	Managed forest	Natural forest	Oil Palm	Managed forest	Natural forest
1	West Kalimantan	946.0	-473.0	-473.0	4,773.9	-2,387.0	-2,387.0
2	East Sumatra	1,139.9	-570.0	-570.0	3,954.0	-1,977.0	-1,977.0
3	East Kalimantan	389.2	-194.6	-194.6	1,964.3	-982.1	-982.1
4	West Sumatra	594.1	-297.0	-297.0	1,889.3	-944.7	-944.7
5	Papua	64.5	-32.2	-32.2	325.4	-162.7	-162.7
6	Sulawesi	58.7	-29.4	-29.4	203.7	-101.9	-101.9

In our baseline simulation CO2 emissions are set to increase (see E.3). This increase is due to our assumption that more land is allocated to Palm Oil by decreasing Managed and Natural Forests. Although palm oil plantations do hold some CO2, it stores less than Forests (see Section about the database). Therefore, given deforestation, more CO2 is emitted over time.

Figure B8. CO2 emissions tonnes by hectare (ordinary cumulative change)

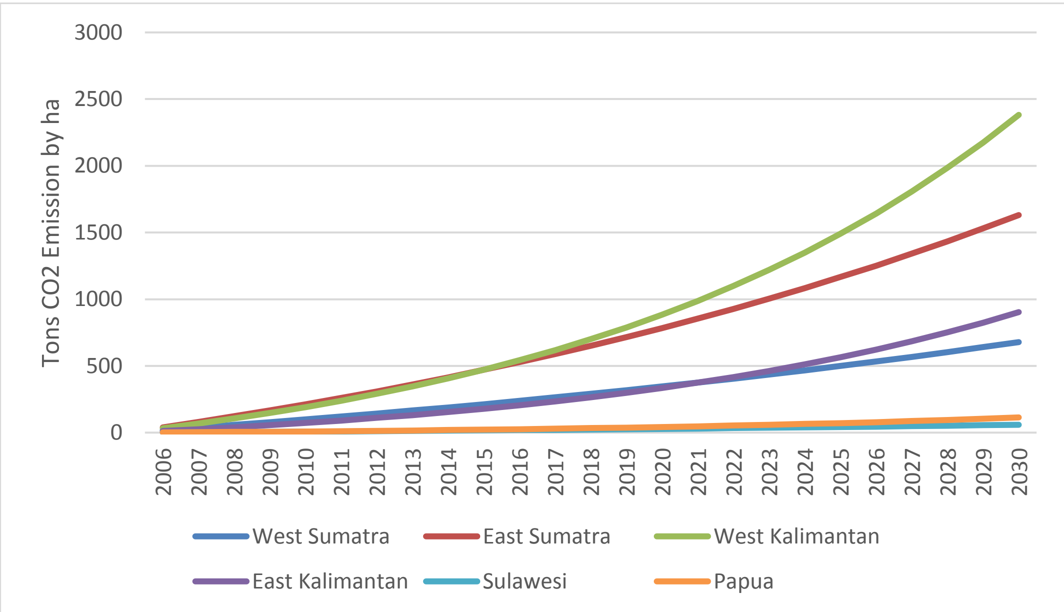


Figure B8 shows the regional emission of tonnes of CO2 by hectare. The regions emitting the most CO2 is West Kalimantan and East Sumatra followed by East Kalimantan and West Sumatra. Papua and Sulawesi are the regions with the lowest emission levels. This graph corresponds with Figure B6 showing that the regions with the highest levels of CO2 emissions are also the regions with the highest levels of deforestation.

Appendix C. Impact of a REDD payment on net exports

The main difference between Simulation 1 and 2 is the REDD payment and the impact on the balance of trade. Below we present a set of equations to show the impact of an external payment of the BOT. Our discussion begins with the basic GDP identity from the expenditure side.

$$GDP = C + I + G + (X - M) \qquad \text{(E.1)}$$

C and G refer to private and public consumption and I is aggregate investment. (X-M) refers to the trade balance.

Gross national product (GNP) from the expenditure and income side is defined in (E.2) and (E.3).

$$GNP = GDP + NTROW \qquad \text{(E.2)}$$

$$GNP = C + G + S \qquad \text{(E.3)}$$

where NTROW is the net transfers from the rest of the word and S refers to domestic savings. Rewritting (E.2) and (E.3) yields,

$$C + G + S = C + I + G + (X - M) + NTROW \qquad \text{(E.4)}$$

Simplifying (E.19) yields,

$$S = I + (X - M) + NTROW \quad \text{or} \qquad \text{(E.5)}$$

$$S - I = (X - M) + NTROW \qquad \text{(E.6)}$$

On a national level, the country faces external balance of payments constraint. Generally speaking, gifts increase GNP (E.2) and may reduce GDP. The reason is that the balance of trade (X-M) can fall by the size of the gift.