



## SECTORAL VENSIM MODELS (INTEGRATED IN IV2045)

Contract # 7189339

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### Accounting for Natural Capital in the Strategic Environmental Assessment of Indonesia: Carrying Capacity in the IV2045 Model

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This report for Contract #7189339 describes the models created for the IV2045 model, based on the prototype models and fully customized to Indonesia to complement the work done by other modeling teams working on the IV2045 for BAPPENAS.

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## 1. Model documentation

### 1.1. Land cover modules

#### 1.1.1. Land use

The land use module provides an overview of the aggregate land use in Indonesia. The model distinguishes between four different land use categories: forest land, agriculture land, urban and industrial land, and other land. The four stocks and with their corresponding flows are presented in Table 1.

Stock	Inflow(s)	Outflow(s)
Forest land	<ul style="list-style-type: none"> <li>• Agriculture to forest land rate</li> <li>• Urban industrial land to forest land rate</li> <li>• Other land to forest land rate</li> </ul>	<ul style="list-style-type: none"> <li>• Forest land to agriculture land rate</li> <li>• Forest land to urban industrial land rate</li> <li>• Forest land to other land rate</li> <li>• Forest land to other land due to mining rate</li> </ul>
Agriculture land	<ul style="list-style-type: none"> <li>• Forest land to agriculture land rate</li> <li>• Urban industrial land to agriculture land rate</li> <li>• Other land to agriculture land rate</li> </ul>	<ul style="list-style-type: none"> <li>• Agriculture to forest land rate</li> <li>• Agriculture land to urban industrial land rate</li> <li>• Agriculture land to other land rate</li> </ul>
Urban and industrial land	<ul style="list-style-type: none"> <li>• Forest land to urban industrial land rate</li> <li>• Agriculture land to urban industrial land rate</li> <li>• Other land to urban industrial land area</li> </ul>	<ul style="list-style-type: none"> <li>• Urban industrial land to forest land rate</li> <li>• Urban industrial land to agriculture land rate</li> <li>• Urban industrial land to other land rate</li> </ul>
Other land	<ul style="list-style-type: none"> <li>• Forest land to other land rate</li> <li>• Forest land to other land due to mining rate</li> <li>• Agriculture land to other land rate</li> <li>• Urban industrial land to other land rate</li> </ul>	<ul style="list-style-type: none"> <li>• Other land to forest land rate</li> <li>• Other land to agriculture land rate</li> <li>• Other land to urban industrial land area</li> </ul>

Table 1: Stocks in the land use module

The different flow values depend on the current and desired stock levels. The same approach for calculating the different stock values is used for all land use stocks. The stock of forest land agriculture land will serve for illustration purposes.

---


$$\begin{aligned}
 \text{Agriculture Land}_{t+1} = & \text{Agriculture Land}_{t0} + \text{forest land to agriculture land rate}_{t0} + \text{other land to agriculture} \\
 & \text{land rate}_{t0} + \text{urban industrial land to agriculture land rate}_{t0} - \text{agriculture land to other land rate}_{t0} \\
 & - \text{agriculture land to forest land rate}_{t0} - \text{agriculture land to urban industrial land rate}_{t0}
 \end{aligned}$$


---

Changes in land use are calculated based on the desired increase in the respective land types and a fraction that determines what amount of land is taken from which stock. Figure 1 illustrates the variables that affect agriculture land and flows related to agriculture land.

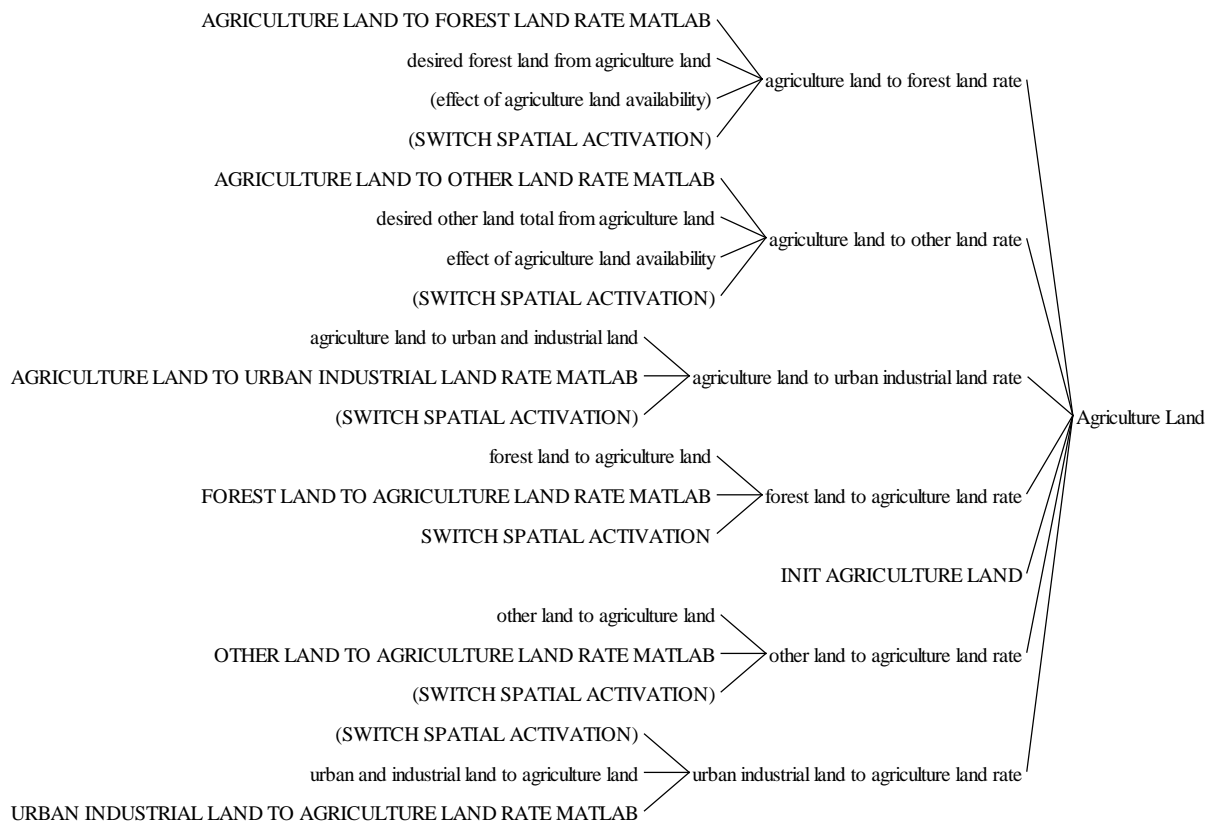


Figure 1: Causes tree agriculture land

The model allows for two different modes of simulating land use, with and without spatial activation. The Switch Spatial Activation is used to choose between the two different modes. If the switch is active, switch has a value of one ("1"), exogenous inputs obtained from MATLAB are used to drive the land use changes. If the switch is inactive, the model uses a more endogenous formulation which causes land conversion to slow down with decreasing stock levels (i.e. effect of agriculture land availability). In other words, this formulation captures the effects of land availability on land conversion rates, and land availability is determined by exogenous input. For example, the effect of agriculture land availability is formulated as an external time series function that indicates the availability of agriculture land for any point in time.

The flow equation for the flow of urban and industrial land to agriculture land is illustrated below.

---


$$\begin{aligned}
 & \text{Agriculture land to forest land} = \\
 & \text{IF THEN ELSE}(\text{SWITCH SPATIAL ACTIVATION}=0, \text{desired forest land from agriculture land} * \text{effect of} \\
 & \text{agriculture land availability, AGRICULTURE LAND TO FOREST LAND RATE MATLAB})
 \end{aligned}$$


---



Land use adjustments are modelled based on current and desired stock levels, and fractions that determine what land use stock is used for the conversion. The desired forest land from agriculture land is calculated by multiplying the stock level of agriculture land by the share of agriculture land to forest. The effect of agriculture land availability is determined based on a table function that uses the ratio between the current amount of agriculture land and the conserved amount of agriculture land as an input. The same approach is used for the calculation of the other land use stocks, based on variables described in the subsequent sections.

### 1.1.2. Agriculture

The agriculture module contains the variables that are used for calculating the land conversion to and from the agriculture land stock. The desired amount of agriculture land is calculated by multiplying total population by a per capita agriculture land multiplier.

The desired amount of agriculture land is estimated using an exogenous per capita demand and population. The trend is calibrated using historical data.

---

*Desired agriculture land = IF THEN ELSE(AB MODEL SWITCH = 1, total population \* Agriculture Land Per Capita 1, agriculture land desired va\*(1+trend agriculture land\*TIME TO INCREASE AGRICULTURE LAND))*

---

The desired amount of agriculture land is used to calculate the desired increase in agriculture land based on the following equation.

---

*desired agriculture increase =  
(IF THEN ELSE(policy switch land packages = 0, MAX(0, ((desired agriculture land actual – Agriculture Land) / TIME TO INCREASE AGRICULTURE LAND)) + total outrate agriculture land average,  
IF THEN ELSE(Time < 2015, MAX(0, ((desired agriculture land actual – Agriculture Land) / TIME TO INCREASE AGRICULTURE LAND)) + total outrate agriculture land average, MAX(0, ((desired agriculture land actual-Agriculture Land) / TIME TO INCREASE AGRICULTURE LAND)) + total outrate agriculture land average + actual agriculture land increase by policy)))*

---

The IF THEN ELSE function allows for simulating agriculture land use policies based on the variable actual agriculture land increase by policy. If the policy switch land packages is inactive, the adjustment takes place based on the difference between the current and desired level of agriculture land and the conversion time for agriculture land. The average outflow of the agriculture land stock, total outrate agriculture land average, is added to prevent a steady-state error and ensure that agriculture land is always adjusted to the desired level. A switch value of one (“1”) indicates that the policy based land use adjustment is active, starting from 2015. Before 2015, the same formulation outlined as in the baseline is used. After the year 2015, the time series policy increase in agriculture land is added to the formulation,



which increases or decreases the land use change in agriculture land. The desired increase in agriculture land is used to determine the three inflows to agriculture land indicated in Table 1.

### 1.1.3. Urban and industrial land

The urban and industrial land module is used to calculate the desired amount of urban and industrial land and the corresponding land conversion flows. The desired amount of urban and industrial land is calculated based on the desired urban and industrial land from population and the historical trend in urban and industrial land.

---


$$\text{desired urban and industrial land} = \text{desired urban and industrial land from population} * (1 + \text{trend urban and industrial land} * \text{TIME TO INCREASE URBAN AND INDUSTRIAL LAND})$$


---

The desired urban and industrial land from population is calculated by multiplying total population by the population to urban land ratio. This value is multiplied by one plus the trend in urban and industrial land, which is formulated as average annual per cent increase of urban land over the last 10 years, and by the time to increase urban and industrial land. The desired amount of urban and industrial land serves for the calculation of the desired urban and industrial land increase.

---


$$\text{desired urban and industrial land increase} = \text{MAX}(0, ((\text{desired urban and industrial land actual} - \text{Urban And Industrial Land}) / \text{TIME TO INCREASE URBAN AND INDUSTRIAL LAND})) + \text{total outflow urban and industrial land average}$$


---

The desired increase in urban and industrial land is distributed over the land conversion flows increasing urban and industrial land in the aggregate land use stock. The MAX function ensures that the land conversion values are either positive or zero and hence prevent the inflows from decreasing the stock. The sum of outflows, outflow urban and industrial land average, is added to the increase in urban area to ensure that the stock always adjusts to the desired level over time.

### 1.1.4. Forest

The forest module provides information about the current stock value of different forest types and the flows responsible for changes in forest composition. The land use stocks and corresponding flows of the forest module are presented in Table 2.

Stock	Inflow(s)	Outflow(s)
Primary forest	<ul style="list-style-type: none"> <li>None</li> </ul>	<ul style="list-style-type: none"> <li>Degraded Primary Forest to Secondary Forest</li> <li>Primary Forest Conversion to Plant Forest</li> </ul>



		<ul style="list-style-type: none"> <li>Degraded Primary Forest to Non Forest</li> </ul>
Secondary forest	<ul style="list-style-type: none"> <li>Degraded Primary Forest to Secondary Forest</li> <li>Planted Forest Conversion to Second Forest</li> <li>Land Restoration from Non Forest to Second Forest</li> </ul>	<ul style="list-style-type: none"> <li>Secondary Forest Conversion to Non Forest</li> <li>Secondary Forest Conversion to Plant Forest</li> </ul>
Planted forest	<ul style="list-style-type: none"> <li>Primary Forest Conversion to Plant Forest</li> <li>Secondary Forest Conversion to Plant Forest</li> <li>Land Restoration to Plant Forest</li> </ul>	<ul style="list-style-type: none"> <li>Planted Forest Conversion to Second Forest</li> <li>Plant Forest Conversion to Non Forest</li> </ul>
Non forest	<ul style="list-style-type: none"> <li>Degraded Primary Forest to Non Forest</li> <li>Secondary Forest Conversion to Non Forest</li> <li>Plant Forest Conversion to Non Forest</li> </ul>	<ul style="list-style-type: none"> <li>Land Restoration from Non Forest to Second Forest</li> <li>Land Restoration to Plant Forest</li> </ul>

Table 2: Stocks in the forest module

The flows in the forest cover module are partially determined based on exogenous time series functions (e.g. primary forest loss, based on trends from 2000 to 2014) and partially on the land deforestation and reforestation flows in the aggregate land used module (e.g. secondary forest loss to other uses, e.g. agriculture).

The degradation and conversion of primary forest to secondary and planted forest is calculated based on time series functions. The following equation is used to calculate the degradation of primary forest.

---


$$\text{Degraded Primary Forest to Secondary Forest} = \text{Primary Forest} * \text{share degraded primary forest to secondary forest}$$


---

The same approach is used to calculate the flow values for primary forest conversion to planted forest and the conversion of planted forest to secondary forest.

The conversion of forest land to non forest land is based on the variable forest to non forest and a fraction that distributes the change over its three inflows. Forest to non forest is the sum of outflows from the forest stock in the aggregate land use module.

---


$$\text{Forest to Non Forest} = \text{forest land to agriculture land rate} + \text{forest land to other land rate} + \text{forest land to other land due to mining rate} + \text{forest land to urban industrial land rate}$$


---

The same approach is used to attribute the decrease in non-forest land to the two reforestation flows, restoration of secondary forest and land restoration to planted forest. The land restoration to planted



forest is defined as the variable “non forest to planted forest”, which is calculated by the following equation.

$$\text{Non forest to planted forest} = \text{fraction non forest to planted forest} * \text{non forest to forest}$$

### 1.1.5. Biodiversity

The biodiversity module calculates the species carrying capacity. The carrying capacity defines the equilibrium or maximum sustainable species population. It is impacted by fertilization, biomass production, climate risk and land use change, as illustrated in Figure 2.

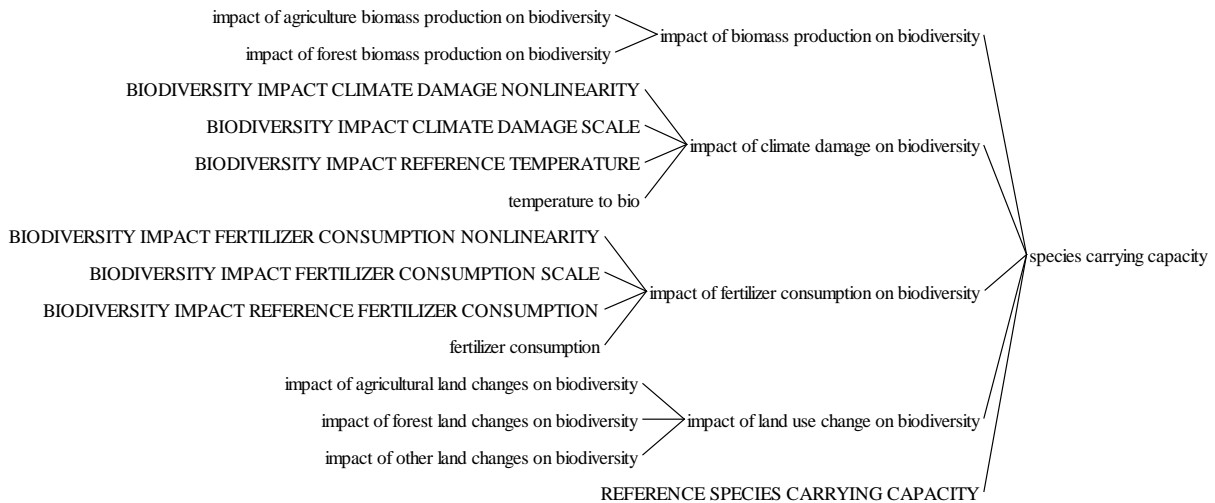


Figure 2: Causes tree species carrying capacity

The carrying capacity is an index that is calculated by multiplying the reference species carrying capacity by the impacts of biomass production, climate change, fertilizer consumption and land use change.

$$\text{species carrying capacity} = \text{REFERENCE SPECIES CARRYING CAPACITY} * \text{impact of biomass production on biodiversity} * \text{impact of climate damage on biodiversity} * \text{impact of fertilizer consumption on biodiversity} * \text{impact of land use change on biodiversity}$$

The four impact factors are based on the trend of the underlying variables, as illustrated in Figure 2, and an impact elasticity (e.g. worth noting that it is the same for other land and forest land) that determines the strength of the impact on carrying capacity. The relative value of the variables, which is calculated by





dividing the current value by a reference value from the year 2000, is used to determine whether impacts worsen and to what degree. The impact of fertilizer consumption on biodiversity is calculated by the following equation.

---

$$\text{impact of fertilizer consumption on biodiversity} = \frac{1}{(1 + \text{BIODIVERSITY IMPACT FERTILIZER CONSUMPTION SCALE} * (\text{fertilizer consumption} / \text{BIODIVERSITY IMPACT REFERENCE FERTILIZER CONSUMPTION}) ^ \text{BIODIVERSITY IMPACT FERTILIZER CONSUMPTION NONLINEARITY})}$$

---

The same underlying formulations are used to calculate the other impacts.

### **Biomass production**

Biomass production assumes that biomass is produced on forest land and agriculture land. The amount of land used for biomass production is calculated by dividing the total country biomass demand by the energy productivity per hectare of land. The impacts of agriculture- and forest biomass production are based on the ratio of area in use for biomass production on forest and agriculture land to total forest and total agriculture land. An elasticity is used to determine the impact that changes in this ratios have on biodiversity. The impact of agricultural biomass production on biodiversity is calculated by the following equation.

---

$$\text{impact of agriculture biomass production on biodiversity} = (1 - \text{agriculture biomass production land ratio}) ^ \text{AGRICULTURE BIOMASS PRODUCTION ON BIODIVERSITY ELASTICITY}$$

---

The impact of biomass production on forest is calculated using the same approach. The impact of biomass production on biodiversity is then calculated by multiplying the impact of forest biomass production on biodiversity by the impact of agriculture biomass production on biodiversity

---

$$\text{impact of biomass production on biodiversity} = \text{impact of agriculture biomass production on biodiversity} * \text{impact of forest biomass production on biodiversity}$$

---

### **Climate change**



The impacts of climate change consider the impacts of temperature changes on biodiversity, and are calculated as illustrated by the following equation.

---

$$\text{Impact of Climate Damage on Biodiversity} = \frac{1}{1 + \text{BIODIVERSITY IMPACT CLIMATE DAMAGE SCALE} * (\text{temperature to bio} / \text{BIODIVERSITY IMPACT REFERENCE TEMPERATURE}) ^ \text{BIODIVERSITY IMPACT CLIMATE DAMAGE NONLINEARITY}}$$

---

## Land use

The impact of land use change on biodiversity is calculated by the following equation. The respective impacts are defined as the relative value for each land use, calculated as current stock level divided by the initial stock level in the year 2000, to the power of an elasticity.

---

$$\text{Impact of Land Use Change on Biodiversity} = \text{impact of agricultural land changes on biodiversity} * \text{impact of forest land changes on biodiversity} * \text{impact of other land changes on biodiversity}$$

---

## 1.2. Agriculture and forestry modules

### 1.2.1. Agriculture production and value added

The agriculture module provides an overview of total agriculture production and value added. This module includes the factors that determine productivity and total production of the agriculture sector. Agriculture production depends on the average yield per hectare of agriculture land and the amount of agriculture land that is used for crop production. In addition, the model allows for simulating impacts of water shortages and floods on agriculture land and production. Figure 3 presents a causes tree illustrating the variables used to calculate total agriculture production.

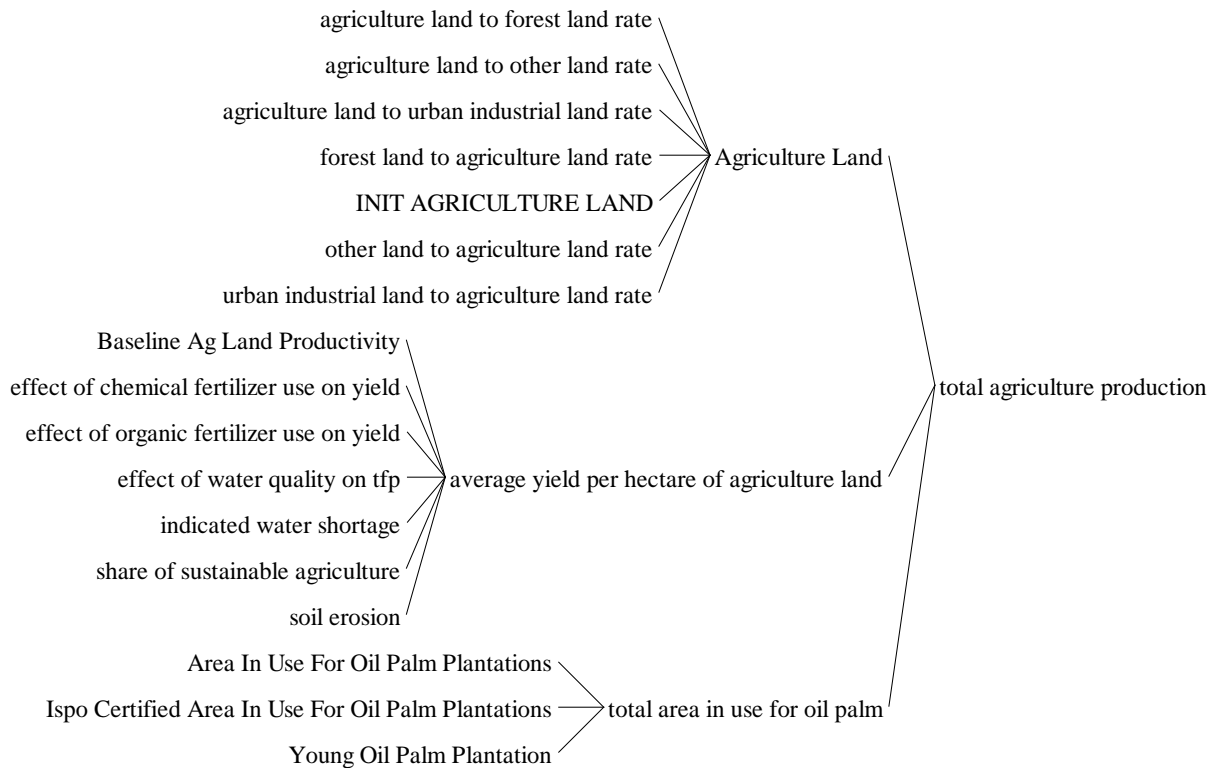


Figure 3: Causes tree total agriculture production

Agriculture land used for crop production is calculated by multiplying the stock of agriculture land, which includes pastures, cropland and plantations (including oil palm), by the share of agriculture land that is used for the production of crops (i.e. excluding oil palm, which is also agriculture land but not cropland). The productivity of agriculture land is determined based on a baseline productivity per hectare, fertilizer use (organic and inorganic), water availability and quality, soil erosion and the use of sustainable agriculture management practices.

The equation for calculating the average yield per hectare of agriculture land is:

---


$$\begin{aligned}
 & \text{Average yield per hectare of agriculture land} = \\
 & \text{Baseline Ag Land Productivity} * ((\text{effect of chemical fertilizer use on yield} * (1 - \text{share of sustainable} \\
 & \text{agriculture})) + (\text{effect of organic fertilizer use on yield} * \text{share of sustainable agriculture})) / \text{soil erosion} \\
 & * (1 - \text{indicated water shortage}) * \text{effect of water quality on tfp}
 \end{aligned}$$


---

The baseline productivity of agriculture land is modelled as a stock with an annual rate of change. The rate of change for the baseline productivity of agriculture land (in per cent per year) is used to model



historical changes in productivity caused by factors exogenous to this model or can serve to explore different productivity scenarios. Total agriculture production is calculated based on the amount of agriculture land used for crop production, calculated by subtracting the land used for palm oil from total agriculture land, by the average yield per hectare.

---

$$\text{total agriculture production} = (\text{Agriculture Land} - \text{total area in use for oil palm}) * \text{average yield per hectare of agriculture land}$$

---

A weighted average formulation is used to model the impact of fertilizer use on agriculture productivity. Fertilizer use in the model is based on a per hectare multiplier for chemical and organic fertilizer and the share of organic fertilizers applied. The share of organic fertilizers used is a policy variable that allows for exploring the impacts of different agriculture management scenarios. Fertilizer application rates are calculated by multiplying the amount of agriculture land used for crop production by the respective per hectare fertilizer application. Both the effect of organic and chemical fertilizers are calculated based on the relative application compared to the beginning of the simulation and an elasticity of yield to fertilizer use.

The impact of soil erosion in this model is calculated based on the relative use of chemical fertilizers and an elasticity of soil erosion to the use of chemical fertilizers.

Water shortages are determined based on the total agriculture water demand for irrigation and the availability of water for agriculture production. Irrigation water demand is calculated as the difference between monthly crop water requirements and monthly irrigation, multiplied by the total amount of cropland.

---

$$\text{Agriculture water demand for irrigation} = \text{MAX} ( 0, \text{crop water demand per hectare per month-seasonal precipitation} * \text{MONTHS PER YEAR} ) * \text{agriculture land used for crop production}$$

---

The water available for irrigation is assumed to be 10% of the total agriculture water demand for irrigation. The model calculates a per cent water shortage as soon as the water demand for irrigation is higher than the available water supply, represented by the variable indicated water shortage. Water shortages are indicated whenever water demand for irrigation is higher than available supply.

---

$$\text{indicated water shortage} = \text{ZIDZ}(\text{water available for irrigation, agriculture water demand for irrigation})$$

---



The indicated water shortage is calculated as water available for irrigation divided by the agriculture water demand for irrigation. The ZIDZ function is used to prevent an error if there is a division by zero.

The value added from agriculture production is calculated by multiplying total agriculture production by the average value per ton of agriculture produce. Baseline agriculture value added per ton is calculated based by multiplying the indicated agriculture value added per ton by the effect of roads on agriculture value added per ton. The effect of roads is defined as the relative kilometers of road to the power of the elasticity of agriculture value added to road infrastructure. The model contains a multiplier that allows to assume that the value added per ton of organic produce is higher or lower than the value added of conventional produce. The average value added per ton of produce is then calculated as a weighted average based on the share of sustainable agriculture and the value added for conventional and organic produce (see equation below).

---

$$\begin{aligned} \text{Average value per ton of agriculture produce} = \\ \text{agriculture value added per ton} * (1 - \text{share of sustainable agriculture}) \\ + \text{sustainable agriculture value added per ton} * \text{share of sustainable agriculture} \end{aligned}$$

---

### *Agriculture water demand*

For crop Irrigation requirements, an average monthly crop water demand is assumed. A customized application of the model to a local context allows to capture the water demand per hectare of agriculture depending on the local crop mix, the scheduling of irrigation events. The variable annual crop water demand is formulated as:

---

$$\begin{aligned} \text{crop water demand per hectare per month} = \\ \text{IF THEN ELSE (month counter modulo} = 1, 150, \\ \text{IF THEN ELSE (month counter modulo} = 2, 150, \\ \text{IF THEN ELSE (month counter modulo} = 3, 150, \\ \text{IF THEN ELSE (month counter modulo} = 4, 150, \\ \text{IF THEN ELSE (month counter modulo} = 5, 0, \\ \text{IF THEN ELSE (month counter modulo} = 6, 0, \\ \text{IF THEN ELSE (month counter modulo} = 7, 0, \\ \text{IF THEN ELSE (month counter modulo} = 8, 0, \\ \text{IF THEN ELSE (month counter modulo} = 9, 150, \\ \text{IF THEN ELSE (month counter modulo} = 10, 150, \\ \text{IF THEN ELSE (month counter modulo} = 11, 100, \\ \text{IF THEN ELSE (month counter modulo} = 12, 100,0 ))))))))))) \end{aligned}$$

---



The month counter modulo function divides each year into 12 time steps and is used to determine the water demand from crop land during each month. In order to determine the net water demand for irrigation per hectare, the monthly crop water demand is compared to monthly precipitation.

### 1.2.2. Forestry/Logging value added

Logging activities depend on the area under concession for logging. The stock Concessions for Logging contains the area that is available for legal logging activities. Concessions for logging are increased by the inflow issue of concessions for logging and decreased by the expiration of logging concessions. A pipeline delay is used to ensure that concessions expire once they reached the end of their lifetime, assuming that they will not be renewed.

Employment and production rate of logging concessions depend on the management practices that are employed for logging operations. The share of logging concessions managed under RIL (reduced impact logging) is used to calculate conventional and reduced impact logging areas. Reduced impact logging areas are calculated by multiplying concessions for logging by the share of logging concessions managed under RIL and conventional logging areas are calculated by multiplying Concessions for logging by one minus the share of concessions under RIL. To calculate the areas which are used for production each year, both variables are multiplied by the fraction of logging concession in production, resulting in the respective actual concession area in which logging takes place.

The production rate of conventional and RIL logging areas is calculated by multiplying the area under the respective management practices by the productivity of conventional logging and the productivity RIL respectively. The respective production rates are multiplied by the costs per m3 of timber and sales price per m3 of timber respectively, which yields the total turnover and costs for each management practices. Deducting the total costs of both practices from the total revenues of the respective practice yields the profits for each production practice. The sum of profits from conventional logging and RIL logging yields the logging GDP.

The employment from logging is the sum of *employment in conventional logging* and *employment in RIL*. Figure 4 provides an overview of the variables that are used to calculate employment for the two management practices.

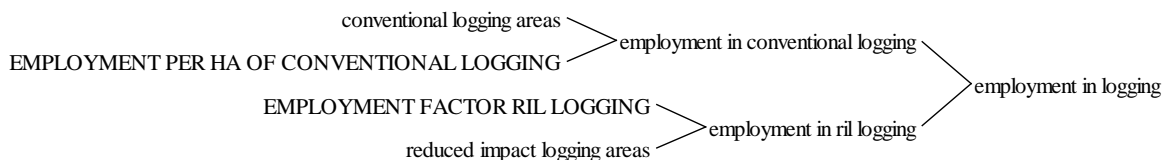


Figure 4. Causes tree employment in logging

The total costs for both logging practices are calculated by multiplying the total timber production rate by a costs per ton of timber produced. Labor costs are calculated by multiplying *employment in conventional logging* and *employment in RIL* by an *average salary per employee in logging*.



### 1.2.3. Palm oil – Area and production

The oil palm sector captures the dynamics that are driving the oil palm production and the expansion of land for oil palm. Several policy variables allow to evaluate the effects that different management and conservation policies have on oil palm development.

Name of variable	Type	Source for estimation
Concessions for oil palms	Initial	TNC, 2018
Issue of concession for oil palm	Policy	User input
Unused land under concession for oil palm plantation	Initial	Estimate
Young oil palm plantation	Initial	Estimate
Area in use for oil palm plantations	Initial	TNC, 2018
ISPO certified area in use for oil palm plantations	Initial	TNC, 2018
time to convert land for oil palms	Constant	Estimate
maturation time oil palm	Constant	Estimate
average annual palm oil yield per ha	Constant	TNC, 2018

Table 3 – Variables and sources used for the oil palm module

The behavior of oil palm plantations is driven by several balancing feedback loops that adjust the size of the plantation to the area that is under concession. The model assumes that land conversion starts as soon as a new concession is issued, and that the full amount of land under concession is converted. The process of legal conversion is driven by concessions. Concessions are issued and expire after their predefined duration. The stock Concessions for oil palms is an information stock that accumulates the area that is officially put under concession. It changes through the integration of the difference between the increase in concessions for oil palm plantations and the expiration of oil palm concessions.

---


$$\text{Concessions For Oil Palm}_{t+1} = \text{Concessions For Oil Palm}_{t0} + \text{increase in concessions for oil palm plantations}_{t0} - \text{Expiration Of Oil Palm Concessions}_{t0}$$


---

The increase in concessions for oil palm plantations is determined by the policy variable issue of concession for oil palm. This variable allows to simulate multiple scenarios, and to evaluate economic, social and environmental effects if different sizes in area that is made available for oil palm plantations though concessions. It is calculated by dividing the amount of land that is put under concession by the time it takes to issue concessions.

---


$$\text{increase in concessions for oil palm plantations} = \text{issue of concession for oil palm plantations} / \text{TIME TO ISSUE CONCESSIONS}$$


---



A pipeline delay is used for modeling the expiration of concessions, to ensure that the area that was under concession is removed from the stock after its useful lifetime.

---


$$\text{Expiration Of Oil Palm Concessions} = \text{Delay Fixed}(\text{increase in concessions for oil palm plantations}, \text{AVERAGE DURATION OF CONCESSIONS}, 0)$$


---

The area under concession for oil palms is the actual physical area that is under concession. It consists of a chain of four stocks with their respective in and outflows. The stocks and corresponding flows of the oil palm plantation module are listed in

Stock	Inflow(s)	Outflow(s)
Unused land under concession for oil palm plantation	<ul style="list-style-type: none"> <li>changes in unused land for oil palm plantation</li> </ul>	<ul style="list-style-type: none"> <li>changes in unused land for oil palm plantation</li> <li>land conversion for oil palm plantations</li> </ul>
Young oil palm plantation	<ul style="list-style-type: none"> <li>land conversion for oil palm plantations</li> </ul>	<ul style="list-style-type: none"> <li>maturation rate conventional oil palm plantations</li> <li>increase in ISPO certified oil palm plantations</li> </ul>
Area in use for conventional oil palm plantations	<ul style="list-style-type: none"> <li>maturation rate conventional oil palm plantations</li> </ul>	<ul style="list-style-type: none"> <li>ISPO certification of conventional plantations</li> </ul>
ISPO certified area in use for oil palm plantations	<ul style="list-style-type: none"> <li>increase in ISPO certified oil palm plantations</li> </ul>	<ul style="list-style-type: none"> <li>None</li> </ul>

Once a concession is issued, a goal seeking function ensures that the area under concessions is adjusted to the available concessions, by accumulating the difference between concessions for oil palms and area under concession for oil palms into Unused land under concession for oil palm plantation. The flow equation is

---


$$\text{changes in unused land for oil palm plantation} = \text{MAX}((\text{Concessions For Oil Palms} - \text{area under concession for oil palms}) / \text{TIME TO ISSUE CONCESSIONS}, 0)$$


---

Based on the assumption that the whole area under concession will be used for oil palm plantations, land conversion of unused land under concession continues, as long as there is Unused land under concession for oil palm plantations.



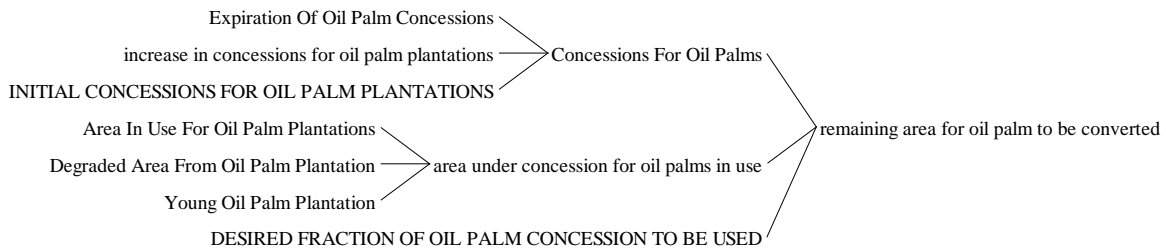


Figure 5: Causes tree remaining area for oil palm to be converted

The causes tree in Figure 5 shows the composition of the variable remaining area for oil palm to be converted. This area is determined by comparing the total area that is put under concession to the area in use, and is used for the calculation of the flow of land conversion for oil palm plantations. The conversion of unused land to young oil palm plantations is calculated by the equation

---

$$\text{land conversion for oil palms} = \text{MIN}(\text{remaining area for oil palm to be converted} / \text{TIME TO CONVERT LAND FOR OIL PALMS}, \text{Unused Land Under Concession For Oil Palm Plantation} / \text{TIME TO CONVERT LAND FOR OIL PALMS})$$

---

The MIN function ensures that the exact amount of land under concession that is yet to be converted is converted. Once the stock of available (unused) land is depleted, land conversion will stop.

The conversion of land accumulates in the stock Young palm oil plantations, which represents established plantations that are not productive yet. A pipeline delay of the land conversion flow is used to determine the inflow of productive plantations, for both conventional and ISPO certified (sustainable) oil palm plantations. The delay is nested in the variable 'maturation rate all oil palm' and is based on the maturation time of oil palm. The maturation rate all oil palm is then used to determine the amount of conventional and sustainable plantations that are established. The increase in ISPO certified oil palm plantations is calculated based on the maturation rate all oil palm and the current share of plantations that are ISPO certified.

---

$$\text{increase in ISPO certified oil palm plantations} = \text{Maturation Rate All Oil Palm} * \text{current share of plantations ISPO certified}$$

---

The maturation rate of conventional oil palm plantations is calculated as the difference between the maturation rate all oil palm and the increase in ISPO certified oil palm plantations.

The change in stock level of the Area in use for conventional oil palm plantations is calculated through the integration of the three flows:



---

*Area in use for conventional oil palm plantations<sub>t+1</sub> = Area in use for conventional oil palm plantations<sub>t0</sub> +  
Maturation Rate You Oil Palm Plantations<sub>t0</sub> - ISPO certification of plantations<sub>t0</sub>*

---

In addition to the outlined conversion process, the model allows for simulating the ISPO certification of conventional oil palm plantations, which allows for assessing the impacts of increasing the share of certified plantations.

---

*ISPO certification of conventional plantations =  
IF THEN ELSE ( Ispo Certified Area In Use For Oil Palm Plantations < (Total Area In Use For Oil Palm  
Plantations Proxy \* current share of plantations ispo certified),  
((Total Area In Use For Oil Palm Plantations Proxy \* current share of plantations ispo certified) – Ispo  
Certified Area In Use For Oil Palm Plantations) / TIME TO CERTIFY LAND FOR ISPO, 0)*

---

An IF THEN ELSE function is used to assess whether the ISPO certified area is equal to the desired ISPO certified oil palm area, which is calculated by multiplying the total area in use for oil palm plantations by the current share of plantations ISPO certified<sup>1</sup>. If the current and desired area under ISPO certification are equal, the flow value is zero. In case that the current and desired area are different, a goal seeking process compares the currently certified area to the desired certified area and adjusts the stock of ISPO certified plantations over the time it takes to certify plantations.

The area with mature plantations is considered the production area for oil palm, for both conventional and sustainable oil palm plantations. The model uses as yield the production of fresh fruit bunches (FFB) per hectare, therefore the production quantities are not directly given in crude palm oil (CPO). The production area for oil palm is used to calculate the production rate by multiplying it by the oil palm yield by plantation type by the respective plantation area. For conventional plantations, the FFB yield per hectare of oil palm is used to calculate total production, while a policy multiplier is applied to the yield for ISPO certified plantations.

---

*ISPO ffb yield per ha of oil palm =  
FFB YIELD PER HA OF OIL PALM \* ISPO IMPACT ON YIELD*

---

---

<sup>1</sup> A proxy stock that keeps track of the total area in use for oil palm in use is used for the calculation of the flow to ensure the consistency of the calculation.



The total FFB production rate is calculated as the sum of FFB production on conventional plantations and FFB production on ISPO certified plantations. The crude palm oil production rate is calculated by multiplying the total FFB production rate by the oil extraction ratio.

CO<sub>2</sub> emissions from the production of oil palm are determined based on the developed plantation area and a respective emission factor.

---

$$\text{CO}_2 \text{ emissions conventional oil palm} = \text{Area In Use For Conventional Oil Palm Plantations} * \text{CO}_2 \text{ EMISSIONS PER HECTARE CONVENTIONAL OIL PALM}$$

---

The same approach is used for the calculation of CO<sub>2</sub> emissions from ISPO certified plantations. Total area in use for each plantation type and the respective emission factor are used to determine the average emission factor of oil palm plantations.

---

$$\text{average emission factor oil palm} = (\text{co}_2 \text{ emissions conventional oil palm} + \text{co}_2 \text{ emissions ISPO oil palm}) / (\text{Area In Use For Conventional Oil Palm Plantations} + \text{ISPO Certified Area In Use For Oil Palm Plantations})$$

---

CO<sub>2</sub> emissions from conventional and ISPO certified plantations accumulate in separate stocks over time that indicate the total amount of emissions generated by each plantation type at any point in time. The sum of the two cumulative stocks presents the total cumulative CO<sub>2</sub> emission from oil palm, which can serve to assess the impacts of different plantation management strategies on total generated CO<sub>2</sub> emissions.

#### 1.2.4. Palm oil – Economics

The economics (or value added) module provides an overview over revenues and costs, and the employment generated by conventional and ISPO certified plantations. The same formulations are used for both plantation types. The costs are calculated by multiplying the current amount of land used by a management cost per hectare per year multiplier for each plantation type.

---

$$\text{costs conventional oil palm} = \text{Area In Use For Oil Palm Plantations} * \text{COSTS PER HA OF CONVENTIONAL OIL PALM}$$

---



The same formulation is used for ISPO certified plantations. Sales revenues are calculated by multiplying the respective production rates by the sales price per ton of FFB. The equation for revenues from conventional oil palm plantations serves for illustration purposes.

---


$$\text{revenues from conventional oil palm} = \text{ffb production conventional oil palm} * \text{AVERAGE PRICE PER TON OF FFB}$$


---

The profits from oil palm are calculated by deducting the production costs from sales revenues. The GDP generated by palm oil is the sum of profits generated from conventional and ISPO certified plantations, as illustrated in Figure 6.

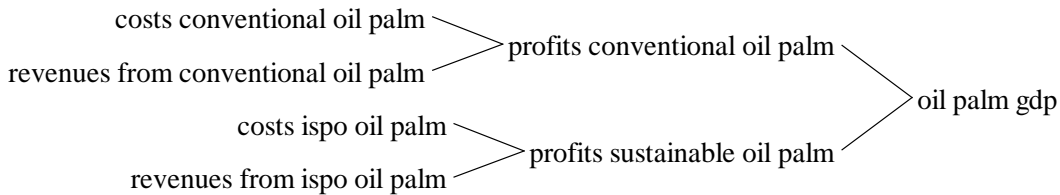


Figure 6: Causes tree oil palm GDP

Employment from oil palm plantations are calculated by multiplying the total amount of land used for each plantation type, defined as the sum of young and productive plantations, by an employment factor per hectare of oil palm on conventional and ISPO certified plantations.

---


$$\text{employment conventional oil palm} = (\text{Area In Use For Oil Palm Plantations} + (\text{Young Oil Palm Plantation} * (1 - \text{current share of plantations certified}))) * \text{EMPLOYMENT PER HA OF CONVENTIONAL OIL PALM}$$


---

The same approach is used to calculate the employment from ISPO certified plantation. The employment from each plantation type multiplied by an average salary for oil palm worker yields the respective labor income.

### 1.2.5. Forest plantations – Area and emissions

Forest production depends on the availability of concessions for forest plantations and the extent to which the concession area is used. The number of concessions changes based on the following equation:

---


$$\text{Concessions for Forest Plantations}_{t+1} = \text{Concessions for Forest Plantations}_{t0} + \text{increase in concessions for forest plantations}_{t0} - \text{expiration of concessions}_{t0}$$


---



The increase in concessions is a policy variable that allows for the simulation of different scenarios by defining a time series for the area to be put under concession at a given point in time. The expiration of concessions is modeled as a pipeline delay based on the lifetime of concessions.

---

$$\text{Expiration Of Concessions} = \text{Delay fixed}(\text{increase in concessions for forest plantations, AVERAGE DURATION OF CONCESSIONS, 0})$$

---

The fixed delay ensures that area that is put under concession remains in the concession stock for the full duration of concessions. Once the duration of the concession is over, the area is removed. The area under concession for forest plantations consists of the three stocks unused land under concession for forest plantation, area in use for forest plantations, and degraded area from forest plantations. It is calculated as the sum of the three stocks.

---

$$\begin{aligned} \text{Unused Land under Concession for Forest Plantations}_{t+1} = \\ \text{Unused Land under Concession for Forest plantations}_{t0} + \text{changes in unused land for} \\ \text{forest plantation}_{t0} - \text{land conversion for forest plantations}_{t0} \end{aligned}$$

---

The change in unused land for forest plantations is calculated by subtracting the total area under concession for forest plantations from the concessions for forest plantations. An increase in concessions will lead to an increase in unused land for plantations in the short term (before operations begin). Land conversion for forest plantations takes place once a concession is issued and is calculated by dividing the possible land conversion for forest plantations by the time to convert land for forest plantations.

The desired land conversion for forest plantations is estimated as the difference between unused land under concession for forest plantation and the remaining area for forest plantations to be converted. The remaining area for forest plantations to be converted is estimated using the following equation:

---

$$\begin{aligned} \text{remaining area for forest plantations to be converted} = \\ \text{MAX}(\text{Concessions For Forest Plantations} * \text{fractions of concessions in use} - \text{area under concession for} \\ \text{forest plantations in use, 0}) \end{aligned}$$

---

The area under concession for forest plantations in use is the sum of area in use for forest plantations and area in use for sustainable forest plantations. The MAX function ensures that the conversion stops once the sum of the area in use and degraded area are equal to the area under concession. The area in use for forest plantations, for both conventional and sustainable, changes based on the following equation:



$$\text{Area in use for Forest Plantations}_{t+1} = \text{Area in use for Forest Plantations}_{t0} + \text{land conversion for forest plantations}_{t0} - \text{certification of forest plantations}_{t0}$$

An increase in forest plantation is caused by the land conversion for forest plantations. The area in use for forest plantations decreases either through the expiration of concessions, or through the certification of forest plantations with a sustainability accreditation, which serves as an outflow of the area used for conventional plantations and an inflow for the stock of sustainable forest plantations.

The area in use for forest Plantations is used to calculate the production from forest plantations. The total timber production of forest plantations is calculated by multiplying the area in use for forest plantations by the forest plantation productivity.

#### 1.2.6. Forest plantations – Value added

The respective timber production rate, conventional and sustainable, is multiplied by the sales price per m<sup>3</sup> of timber, which yields the sales revenues from timber production. The costs of timber production are calculated as the sum of O&M costs, capital costs and labor costs for each plantation type. The costs for conventional forest plantations is calculated by the following equation.

$$\text{total cost conventional forest plantations} = \text{capital costs conventional forest plantations} + \text{labor cost conventional forest plantation} + \text{"o\&m and other cost conventional forest plantations"}$$

The same approach is used for sustainable forest plantations. The profits from timber production are calculated by deducting the costs of timber production from the revenues from timber production. The sum of profits from timber production yield the value added (GDP) by forest plantations. Figure 7 shows the variables that are used to calculate the forest plantations GDP.

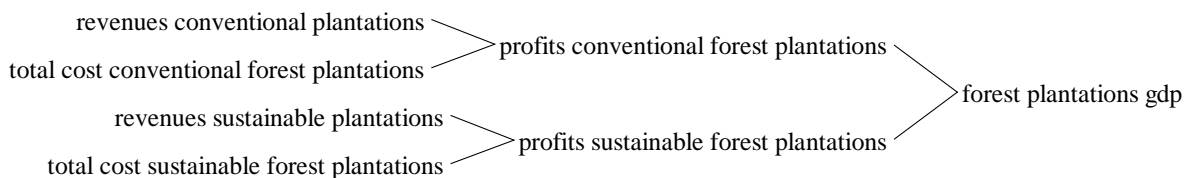


Figure 7. Causes tree forest plantations GDP

Employment from forest plantations is calculated by multiplying the area in use for each plantation type by a respective employment per hectare multiplier. The labor costs for forest plantations are calculated by multiplying the employment in forest plantations by the average salary for forest plantation workers. The same approach is used for emissions from forest plantations, which are calculated by multiplying the area in use by an emission factor per hectare of plantation.



## 1.2.7. Agroforestry

The agroforestry module estimates the area that is used to cultivate different crops and the respective production, costs, revenues, and resulting employment. The model uses a weighted average for each of the aforementioned variables based on data provided for maize, rubber, pineapple and jengkol are included in the model.

The area that is used for crop production is represented by a stock, in this case the stock area used for agroforestry, and is changed by one flow, the change in agroforestry area. A goal seeking function is used to calculate the changes in the area of the respective crop production system. The following equation illustrates the calculation of the change in area for agroforestry:

---

$$\text{change in Area used for Agroforestry} = \frac{(\text{desired maize area} - \text{Area used for Agroforestry})}{\text{TIME TO CONVERT LAND}}$$

---

The difference between the desired area used for agroforestry and the actual area used for agroforestry is divided by the time to convert land, and the integration of the result changes the stock of area used for agroforestry. The desired area used for agroforestry is a policy variable which allows for exploring the impacts of different ambition levels. The respective fractions are derived from the available data and are kept constant after 2015 for the remainder of the simulation.

The production rate is calculated by multiplying the yield by the area in use. The profits from agroforestry production are calculated by deducting the costs of agroforestry production from the revenues of agroforestry production. The costs of production are calculated by multiplying the area used for agroforestry by the costs per hectare of agroforestry, and the revenues by multiplying the agroforestry production rate by the sales price per ton.

The employment of the respective production systems is calculated by multiplying a weighted average employment per hectare factor across all crops. The labor income of the workforce in the respective crop system is calculated by multiplying the employment of the respective sector by the average annual salary that a person in the respective production sector earns.

## 1.2.8. Energy garden, ecotourism, green villages, NTFP and Ecosystem services business development

There are several modules in IV2045 that capture local, bottom up interventions. These are not linked to the macroeconomic performance of the country, due to the lack of policy interventions (or, suitable interventions were not identified at this stage, but could be found for work at the provincial level). These are energy garden, ecotourism, green villages and NTFP and ecosystem services business development. All sectors are driven by the land allocated for the specific activity. Energy gardens are presented as an example.



The energy garden module provides an overview of the amount of land that is assigned to communities for energy gardens. The stock area in use for energy gardens contains the area that is managed by communities, and is changed by the following equation:

---

$$\text{Area in use for energy gardens}_{t+1} = \text{Area in use for energy gardens}_{t0} + \text{change in area used for energy gardens}_{t0}$$

---

The change in area used for energy gardens is driven by a policy variable that allows for assessing the impacts of different ambitions. The change in area used for energy gardens is calculated by dividing the variable increase in land supervised by communities by the time to assign land. The production rate of energy gardens is multiplied by the yield per hectare and is used for the calculation of the revenues by multiplying total production by the sales price per ton. Costs and employment are calculated by multiplying the used for

### 1.3. Macroeconomy (aggregate) modules

#### 1.3.1. Industry and Services

The industry and services modules estimate value added for the secondary and tertiary sector of the economy. For both sectors, the same structural approach is used, with a supply side approach. The 'industry module' will serve as example to illustrate the variables and equations utilized.

Capital, labor and productivity are used to calculate the performance of the sector. The stock of capital for the industry sector changes based on the following flows:

---

$$\text{Industry Capital}_{t+1} = \text{Industry Capital}_{t0} + \text{gross capital formation industry}_{t0} - \text{depreciation of industry capital}_{t0}$$

---

Gross capital formation is calculated as nominal GDP multiplied by the fraction of GDP invested in industry. The depreciation of industry capital is calculated by dividing the current industry capital by the average lifetime of capital. The depreciation captures machinery that reaches the end of its lifetime. Relative industry capital, an index (using 2000 as base year) of how much industry capital has changed compared to the beginning of the simulation, is calculated by dividing the stock level of industry capital by its initial value.

The employment in industry is calculated by multiplying industry capital by an employment factor per unit of capital. Relative employment in the industry sector is calculated by dividing the employment in industry by its initial value.

Total factor productivity represents the combined impact of energy prices, infrastructure, technology, access to health care, level of education, water quality and air pollution.





---

$$\begin{aligned} & \text{total factor productivity industry} = \\ & \text{IF THEN ELSE}(\text{SWITCH EXTERNALITIES}=1, \text{Technology Effect On Productivity Industry} * \text{Effect Of Energy} \\ & \text{Price On Gdp Industry} * \text{effect of roads on gdp industry} * \text{effect of relative access to basic health care on} \\ & \text{industry productivity} * \text{effect of literacy on industry productivity} * \text{effect of water quality on tfp} * \text{relative} \\ & \text{effect of air pollution on tfp}, \\ & \text{Technology Effect On Productivity Industry} * \text{Effect Of Energy Price On Gdp Industry} * \text{effect of roads on} \\ & \text{gdp industry} * \text{effect of relative access to basic health care on industry productivity} * \text{effect of literacy on} \\ & \text{industry productivity}) \end{aligned}$$

---

The IF THEN ELSE function allows for turning the impacts of air and water quality on and off (considered externalities). If the policy is active (switch value equals one), the impacts of both air and water quality are added to the equation.

The impact of air pollution on productivity has been calibrated based on two sources: (1) current level of emissions and the social cost of carbon; (2) estimates of the health cost of air pollution (with the underlying assumption that air pollution will follow the same trend of emissions). It is worth noting that not all emissions are considered for the estimation of the impacts on productivity. Only emissions from energy and peat fires are taken into account (not emissions from land cover change), given that these emissions occur primarily in rural areas where emission concentration, and hence impacts on health are low. Practically, emphasis is put on areas with higher population density and energy intensity. The two methods (1 and 2) for cost estimation have been compared to GDP, resulting in a share of GDP of emissions costs in the range of 7% to 9% for 2015, calibrated to the cost estimated of the large peat fire of 2015. Finally, the impact of emissions is computed using a relative value, or an index, with base year 2018, to ensure compatibility with historical data and with the economic projections of the macroeconomic directorate (i.e. we focus on the estimation of the net impact of air and water pollution from 2018 on).

Development over time is assessed based on the relative values of each variable and an elasticity that determines the strength of the respective impact. In other words, if interventions are implemented to reduce emissions, the impact of air quality on productivity will be lower than the baseline.

The equation of the effect of roads on industry productivity serves for illustration purposes.

---

$$\begin{aligned} & \text{effect of roads on GDP industry} = \\ & \text{relative km of roads} \wedge \text{ELASTICITY OF GDP TO ROADS NETWORK} \end{aligned}$$

---

The same approach is used to calculate the other impacts used in the equation of total factor productivity.



Industry GDP represents the sectors' economic performance. It is calculated multiplying initial production industry, the industrial GDP of the beginning of the simulation, by relative capital, employment and productivity. The following formulation is used for the calculation of real industry GDP:

---

$$\text{Real GDP industry} = \text{INITIAL PRODUCTION INDUSTRY} * \text{relative production industry}$$

---

Figure 8 presents a causes tree that depicts the variables used for calculating real industry GDP and determining relative production industry. Relative production depends on the development of capital, employment and total factor productivity. The following equation is used for calculating Relative production in the industry sector.

---

$$\text{Relative production industry} = \text{relative capital industry} ^ \text{CAPITAL SHARE INDUSTRY} * \text{relative employment industry} ^ \text{labor share industry} * \text{total factor productivity industry}$$

---

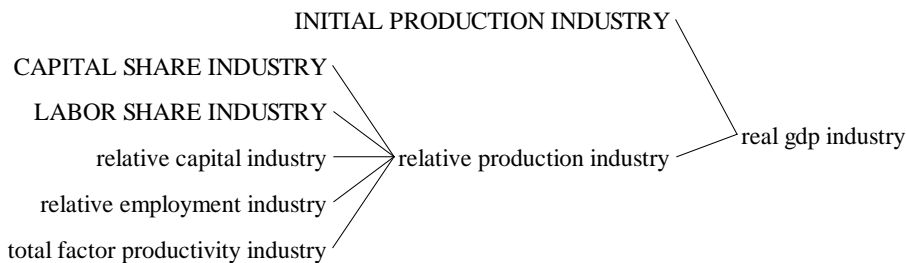


Figure 8: Causes tree real GDP industry

### 1.3.2. GDP

Total real GDP is calculated as the sum of sectoral GDPs of the agriculture real GDP (including crops, palm oil, forest plantations and logging, fisheries), Industry real GDP and Services real GDP.

---

$$\text{Real GDP} = \text{real gdp crop production} + \text{real gdp industry} + \text{real gdp services} + \text{forest plantation real gdp} + \text{logging real gdp} + \text{oil palm real gdp} + \text{fishery real gdp}$$

---



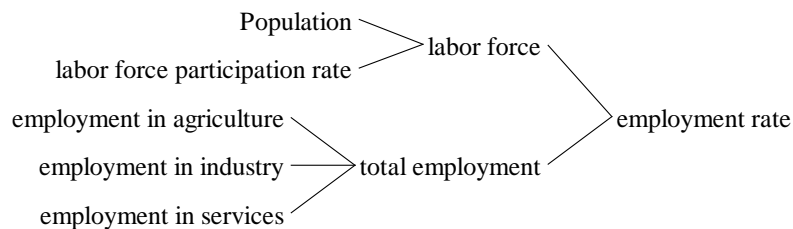
Real GDP is used for calculating the relative real GDP and the real GDP growth rate. The relative real GDP is calculated by dividing the current real GDP by its initial value. A TREND function is used to determine the real GDP growth rate based on total real GDP, the time horizon of measure GDP growth and the initial real GDP growth rate.

---

$$\text{Real GDP growth rate} = \text{TREND}(\text{real GDP}, \text{TIME HORIZON TO MEASURE GROWTH RATE}, \text{INITIAL REAL GDP GROWTH RATE})$$

---

Figure 9 illustrates the variables used for the calculation of the employment rate. The employment rate is calculated by dividing total employment by total labor force, whereby total employment is the sum of employment provided by the three production sectors (considering, for the primary sector, employment for crops, palm oil, forest plantations and logging, fisheries) .



*Figure 9: Causes tree employment rate*

The unemployment rate is calculated using the following formulation:

---

$$\text{Unemployment rate} = (1 - \text{employment rate})$$

---

### 1.3.3. Government accounts

The government accounts module captures government revenues and grants and provides information on total government consumption and investment. The government net balance is calculated based on government revenues and grants and government expenditure.

---

$$\text{Government net balance} = \text{revenue and grants} - \text{government expenditure}$$

---



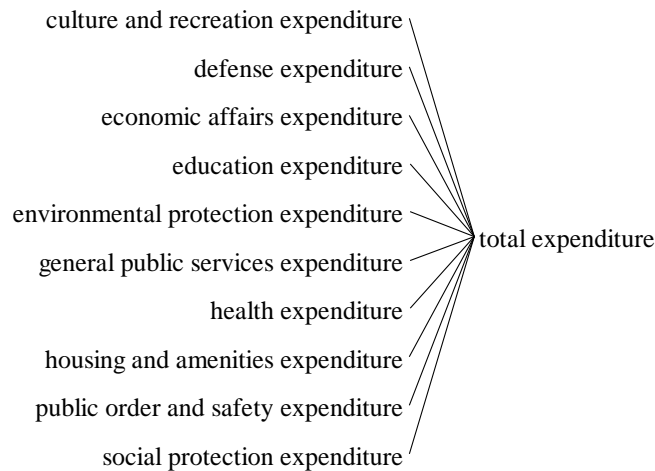
Revenues and grants is calculated by multiplying nominal GDP by a share of nominal GDP being revenues and grants.

---

$$\text{Revenue and grants} = \text{nominal gdp} * \text{revenue and grants as share of nominal gdp}$$

---

A causes tree representing all variables used to calculate public expenditure is depicted in Figure 10. Government expenditure is the sum of all public expenditures depicted in the causes tree.



*Figure 10: Causes tree total public expenditure*

Government investment is calculated as the difference between government purchases and government consumption. The causes tree in Figure 11 illustrates the variables used for determining government investments. Government consumption is calculated by multiplying government purchases by the fraction of government purchases used for consumption.

---

$$\text{Government consumption} = \text{government purchases} * \text{share of government consumption over total expenditure}$$

---

Government purchases is the difference between government expenditure and subsidies and transfers. A MAX function is used for government purchases to avoid negative values.



---

$$\text{Government purchases} = \text{MAX}(0, \text{government expenditure} - \text{subsidies and transfers})$$

---

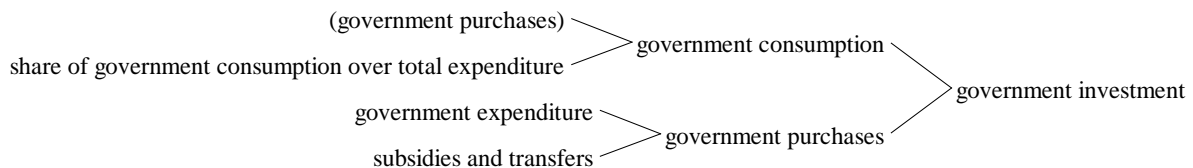


Figure 11: Causes tree government investment

#### 1.3.4. Household accounts

The household module contains household investment and consumption and provides an indication of the real disposable household income. Household revenues are calculated as the sum of nominal GDP, private and current transfers and government subsidies and transfers.

---

$$\text{Household revenues} = \text{nominal GDP} + \text{private current transfers} + \text{subsidies and transfers}$$

---

Household income less revenues and grants yields the total disposable income, which is used for the calculation of private savings and consumption, and real disposable per capita income. Real per capita income is calculated by dividing total disposable income by total population.

Private savings are calculated as disposable income multiplied by the propensity to save.

---

$$\text{Private savings} = \text{disposable income} * \text{propensity to save}$$

---

Propensity to save is a function of relative per capita income, calculated by dividing per capita income by its initial value in 2000, the initial propensity to save and the elasticity of savings to relative income, and an external table to approximates an increase of investments in the RPJMN scenarios relative to the baseline case.

A MIN function is used to ensure that the value does not go above 40% in the baseline scenario. The IF THEN ELSE function is used to include an additional impact from running the Moderate scenario.



$MIN(0.4, INITIAL PROPENSITY TO SAVE * relative pc real disposable income^{elasticity of propensity to save to income}) + IF THEN ELSE$

$(Time > 2018, MODERATE SCENARIO PROPENSITY TO SAVE TABLE(Time), 0) * MODERATE SCENARIO SWITCH$

Private consumption is calculated by subtracting private savings from total disposable income. The total domestic consumption expenditure is calculated as the sum of private and public consumption.

Private investments are determined based on private savings, multiplied by the investment share (assumed to be constant at 70% going forward) and private capital and financial transfers, whereby the latter one is exogenous.

$$Private investment = private saving * INVESTMENT SHARE + private capital and financial transfers$$

## 1.4. Fishery modules

### 1.4.1. Fishing capacity

Fishing capacity and fish catch depend on the fisheries capacity and the availability of fish. The capacity of Indonesia's fishery sector captures two different types of ships; vessels and fishing boats. The total size of the fleet is represented by the variable total boats and vessels, which is the sum of total vessels and the total number of small boats. Figure 12 shows the causes tree of the variable total boats and vessels, which illustrates the variables used to compute it.

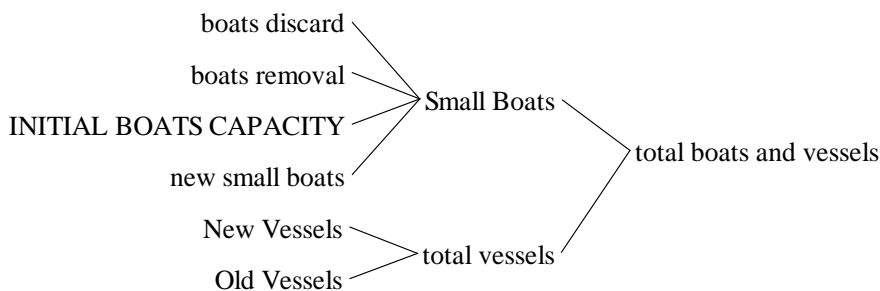


Figure 12: Causes tree total boats and vessels

The fishing capacity module has three stocks, old vessels, new vessels and small boats. The total number of vessels is the sum of new and old vessels, and the number of small boats depends on the balance between the purchase and discard of fishing boats. The equation used for the stock adjustment process



is similar for all three capacity types. The stock of small boats is changed by the three flows new small boat, boats discard and boats removal. The stock equation for small boat is described below for illustration purposes.

---

$$Small\ Boats_{t+1} = Small\ Boats_{t0} + new\ small\ boats_{t0} - boats\ discard_{t0} - boats\ removal_{t0}$$

---

The number of number of small boats depends on the boats acquisition rate, which is the sum of the desired number of boats to be purchase, the replacement rate of boats, represented by the variable boats discard, and the policy increase in boats resulting from the implementation of the national data platform. The desired number of boats to be purchased is calculated by multiplying small boats by the boats acquisition rate and dividing by the boats acquisition time. The following equation is used to calculate the number of new small boats

---

$$New\ small\ boats = boats\ discard + (boats\ acquisition\ rate * Small\ Boats) / BOATS\ ACQUISITION\ TIME + additional\ boats\ from\ national\ data\ platform / BOATS\ ACQUISITION\ TIME$$

---

The boat discard rate is calculated by dividing the number of small boats by the average life span of vessels.

### 1.4.2. Fisheries employment

Figure 13 illustrates the variables used for calculating the employment from capture fisheries, which is the sum of employment direct and indirect employment from capture fisheries. The direct employment from fisheries is the sum of employment on vessels and fishermen.

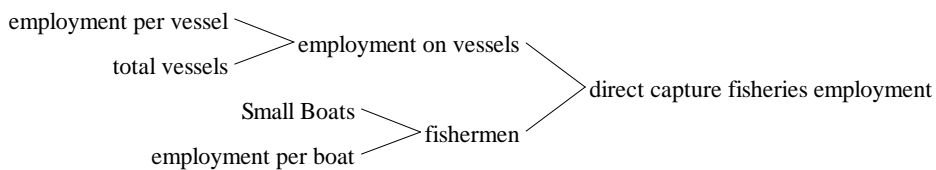


Figure 13: Causes tree direct capture fisheries employment

Employment on vessels and the number of fishermen are calculated by multiplying the respective number of ships with an employment factor per ship. Indirect employment from fisheries is calculated by multiplying total fish landings by an employment multiplier per ton of fish. The total employment in the fishery sector is the sum of direct and indirect employment from capture fisheries, employment in aquaculture and employment from seaweed production.



---

$$\text{total employment fisheries sector} = \text{total fisheries employment} + \text{employment seaweed production} + \text{employment in aquaculture}$$

---

The labor income of the fisheries sector is calculated by multiplying the respective employment variables by the average minimum salary provided by the ministry of manpower. In the baseline, total labor income from fisheries is the sum of labor income from capture fisheries, aquaculture, and seaweed. If a policy is active, then the labor income from active policy interventions is added to the total labor income from fisheries.

In addition, the model provides information about the direct employment that is generated from implementing interventions targeting the development of the fishery sector. The causes tree presented in FIGURE illustrates the variables that are used to calculate the total employment from fishery interventions.

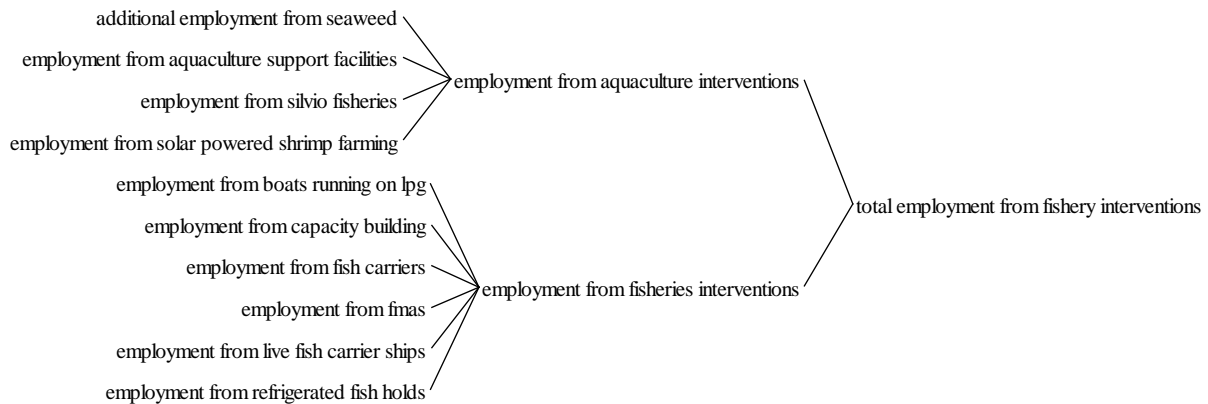


Figure 14: Causes tree of total employment from fishery interventions

### 1.4.3. Fish stock and catch

Fish catch in the fisheries model depends on the size of the fishing fleet and the available fish stock. The fish stock is affected by three flows, the inflow of juvenile fish and the two outflows natural death and fish harvest. The variables affecting the respective flows are presented in Figure 15.



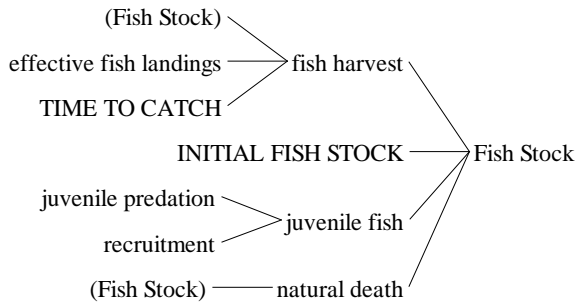


Figure 15: Causes tree fish stock

The catch per ship depends on the initial capacity of the respective ship, the fish density and the effect of technology on fish catch. The catch per vessel is calculated using the following equation.

---


$$\text{Catch per vessel} = \text{fishery vessel technology} * \text{effect of fish density} \wedge \text{ELASTICITY FISH DENSITY ON VESSEL CATCH}$$


---

The variable fishery vessel technology is calculated as a weighted average capacity for new and old vessels and the effect of fish density causes fish catch to decline if fish stocks decline and catch to go up if fish stocks recover beyond the initial value. Both, catch per vessel and catch per boat are used to calculate total fish landings.

---


$$\text{Total fish landings} = \text{MIN} (\text{Fish Stock} / \text{TIME TO CATCH}, (\text{catch per vessel} * \text{total vessels} + \text{catch per boat} * \text{Small Boats} * \text{productivity multiplier for boats from carrier ships} * \text{additional catch from fma multiplier}) * \text{impact of capacity building on fish catch} + \text{additional production from live carriers})$$


---

Total fish landings is calculated as a MIN function between the maximum available catch and the desired catch. The maximum available catch is calculated by dividing the fish stock by the time to catch fish. The desired fish catch is determined based on the current capacity and policy variables. The current capacity is calculated by multiplying the respective capacity value by the respective number of ships (i.e. catch per vessel \* total vessels). Policy multipliers such as the additional catch from FMA multiplier are used to capture the impacts of various different policies that are described in the assessment above. In the baseline scenario, without any policy being active, the multiplier have a value of “1”, to ensure that the total fish landings are only calculated based on the fishing fleet and the catch per ship.



#### 1.4.4. Fuel consumption and emissions from fisheries

The energy consumption from capture fisheries depends on the size of the fleet, the annual number of trips per ship, the and the energy use per ship. The diesel consumption from catchment fisheries is the sum of diesel consumption from small boats and vessels. The variables used to calculate the total diesel consumption are illustrated in the causes tree in Figure 16.

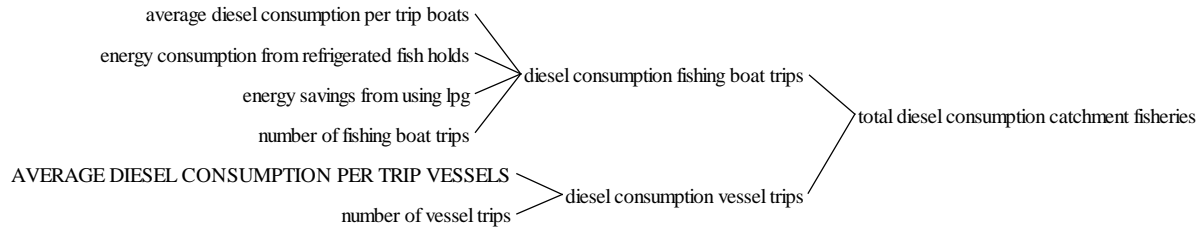


Figure 16: Causes tree total diesel consumption capture fisheries

The diesel consumption from fishing boat trips is affected by policy variables that aim at reducing the fuel consumption of small fishing boats. The following equation is used to calculate the diesel consumption from fishing boat trips.

---

$$\text{diesel consumption fishing boat trips} = \text{number of fishing boat trips} * \text{average diesel consumption per trip boats} + \text{energy consumption from refrigerated fish holds} - \text{energy savings from using lpg}$$

---

Diesel consumption from fishing vessels is calculated by multiplying the number of trips by the diesel consumption per vessel trip.

Emissions from capture fisheries depend on the amount and type of fuel used. Total CO<sub>2</sub> emissions from capture fisheries is the sum of CO<sub>2</sub> emissions from fishing boats, CO<sub>2</sub> emissions from vessels, and CO<sub>2</sub> emissions from LPG use on fishing boats. Figure 17 illustrates the variables used to calculate the respective emissions from boats, vessels and LPG use.

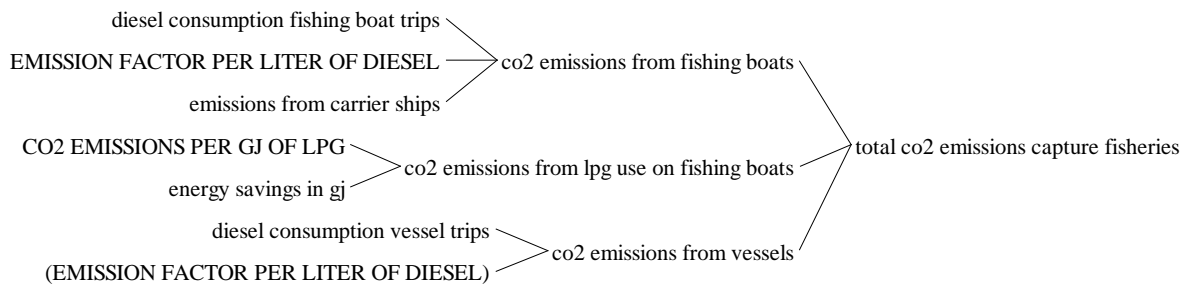


Figure 17: Causes tree total CO<sub>2</sub> emissions capture fisheries



CO2 emissions from aquaculture are calculated by multiplying the electricity consumption from aquaculture and seaweed by a grid emission factor. The total CO2 emissions from fisheries are calculated as the sum of CO2 emissions from capture fisheries and CO2 emissions from aquaculture.

### 1.4.5. Fishery GDP

The real GDP of the fishery sector is the sum of value added generated by the capture fishery and aquaculture sectors. Figure 18 illustrates the variables used to calculate the fishery real GDP.

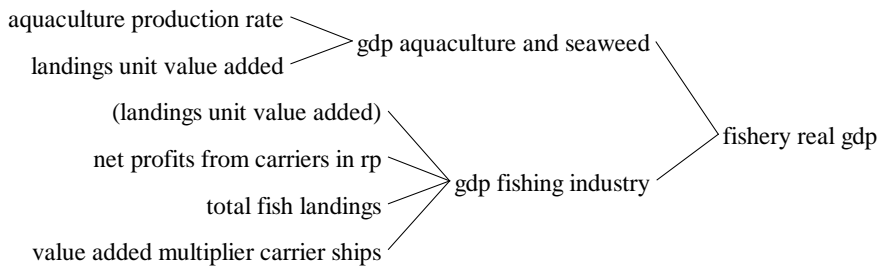


Figure 18: Causes tree of fishery real GDP

The production rates of the fishery and the aquaculture sector are multiplied by a value added per ton multiplier to calculate the respective GDP. In addition to multiplying total fish landings by the value added multiplier, value added from carriers is considered in the equation.

---


$$gdp\ fishing\ industry = total\ fish\ landings * landings\ unit\ value\ added * value\ added\ multiplier\ carrier\ ships + net\ profits\ from\ carriers\ in\ rp$$


---

The value added multiplier for carrier ships and the net profits from carriers are policy variables that affect the value added from capture fisheries if the respective policy is active.

### 1.4.6. Aquaculture and seaweed

The aquaculture contains two stocks, aquaculture capacity and seaweed production area. Seaweed is separated from the residual aquaculture sector to allow a more detailed assessment of policy impacts targeting the expansion of seaweed activities. The structure used for both aquaculture and seaweed production is similar, therefore the aquaculture sector will serve for illustration purposes.

The stock aquaculture capacity is changed by the flow change in aquaculture capacity. The change in aquaculture capacity is calculated by multiplying the current aquaculture capacity by the growth rate of aquaculture. The change in aquaculture capacity is a bi-flow, which means that it can both increase and decrease the stock level depending on the assumed growth rate. The uses tree displayed in Figure 19 provides an overview of the variables that are calculated based on the aquaculture capacity level and subsequent impacts.

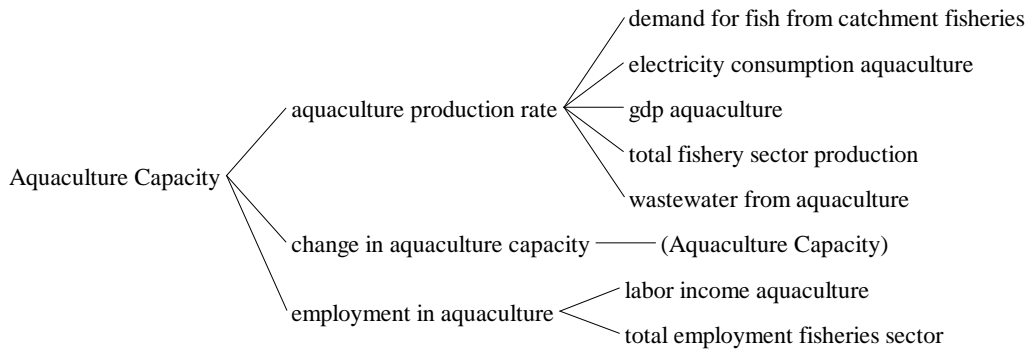


Figure 19: Uses tree aquaculture capacity

The aquaculture production rate is calculated by multiplying the current level of aquaculture capacity by the number of production intervals per year. To assess the impact of aquaculture related policy interventions (9A & 9B) on wastewater generation, electricity consumption and emissions, multiple policy variables area added to the described formulation. The following equation is used to calculate the aquaculture production rate.

---

$$\begin{aligned} \text{Aquaculture production rate} &= \text{Aquaculture Capacity} * \text{PRODUCTION INTERVAL PER YEAR} \\ &+ \text{additional production from silvio fisheries} + \text{additional production from supporting facilities} \\ &+ \text{additional production from seaweed} \end{aligned}$$

---

The aquaculture production rate is used for calculating wastewater loads and electricity consumption from aquaculture. Electricity use and wastewater from aquaculture is calculated by multiplying the aquaculture production rate by an electricity use per ton produced and wastewater per ton produced multiplier respectively. The electricity consumption from aquaculture is used to determine GHG emissions and electricity costs for the aquaculture sector.

Employment from aquaculture is calculated based on the current aquaculture production capacity and an employment per ton of aquaculture production multiplier.

## 1.5. Peat modules

### 1.5.1. Peat land

The peat module provides an overview of total peat land and the amount of various land use typologies that are on peat land. The variables used to calculate total peatland are illustrated in Figure 20.

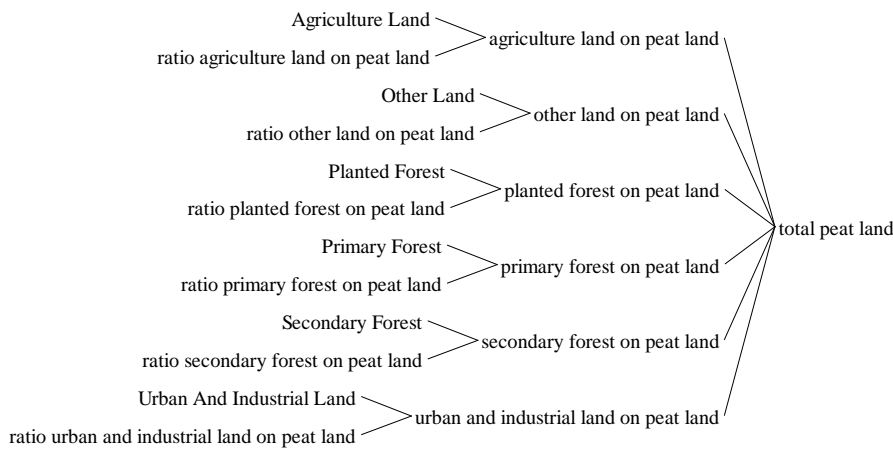


Figure 20: Causes tree of total peatland

### 1.5.2. Peat dynamics

The peat dynamics module is used to determine peatland affected by fires, the water level on productive peatland and total emission from fires and peat decomposition.

The amount of peatland affected by fires is calculated by multiplying the area affected by each fire by the fire frequency.

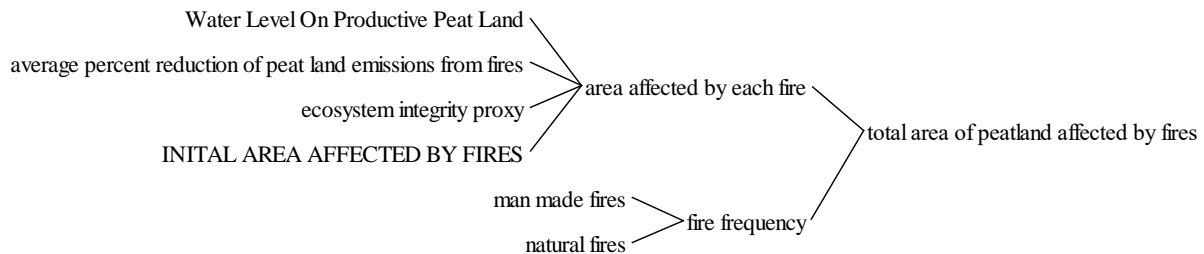


Figure 21: Causes tree for total area of peatland affected by fires

The area affected by each fire depends on the initial area affected by fires, the water level on productive peatland and the integrity of ecosystems.

---

$$\begin{aligned} \text{area affected by each fire} = \\ (\text{INITAL AREA AFFECTED BY FIRES} / \text{Water Level On Productive Peat Land} / \text{ecosystem integrity proxy}) \\ * (1 - \text{average percent reduction of peat land emissions from fires}) \end{aligned}$$

---



The fire frequency depends on the natural fire occurrence and man-made fires. The water level on productive peatland is affected by water drainage from peatland. The variable relative natural forest cover on peatland is used to determine the amount of water that is drained from peatland.

---

*water drainage =*

*BASELINE DRAINAGE / relative natural forest cover on peat \* (1-canal blocking ha share of peat land) \* (1 - "phasing out drainage-based agriculture ha share of peat land") \* (1 – average percent reduction of peat land decomposition emissions)*

---

Canal blocking and phasing out are policy multiplier that capture the impact of these interventions on water drainage from productive peat land. If the policies are inactive, these multipliers will have the value one and not affect the simulation results.

Total emissions from peatland is calculated as the sum of emissions from peat fires and emissions from peat decomposition. Emissions from peat decomposition are calculated by multiplying peat land by a per hectare decomposition multiplier. Peat emissions from fires depend on the area affected by each fire, the fire frequency and the emission factor of peat fires.

---

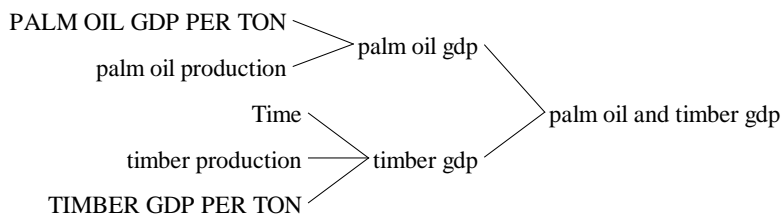
*emissions from peat fires =*

*PEAT FIRES EMISSION FACTOR \* fire frequency \* area affected by each fire*

---

### 1.5.3. Oil palm and timber on peat land

This module provides an overview of the GDP from timber and oil palm production that is generated on peatland. The variables used for calculating the combined palm oil and timber GDP on peat are illustrated in Figure 22.



*Figure 22: Causes tree for palm oil and timber GDP from peatland*

Palm oil and timber production on peat are calculated by multiplying the respective amount of land by a per hectare production rate for oil palms and timber plantations. Oil palm and forest plantations on peat and mineral land are considered in this calculation. Multiplying the production rates of FFB and timber by



a value added per ton multiplier for the respective product yields the value added generated from oil palm and timber plantations on peatland.

#### 1.5.4. Employment from peatland

The employment from peatland module provides information about the employment generated from oil palm and timber production on peatland, and the employment generated from implementing interventions in the peat sector. The different employment variables are presented in Figure 23.

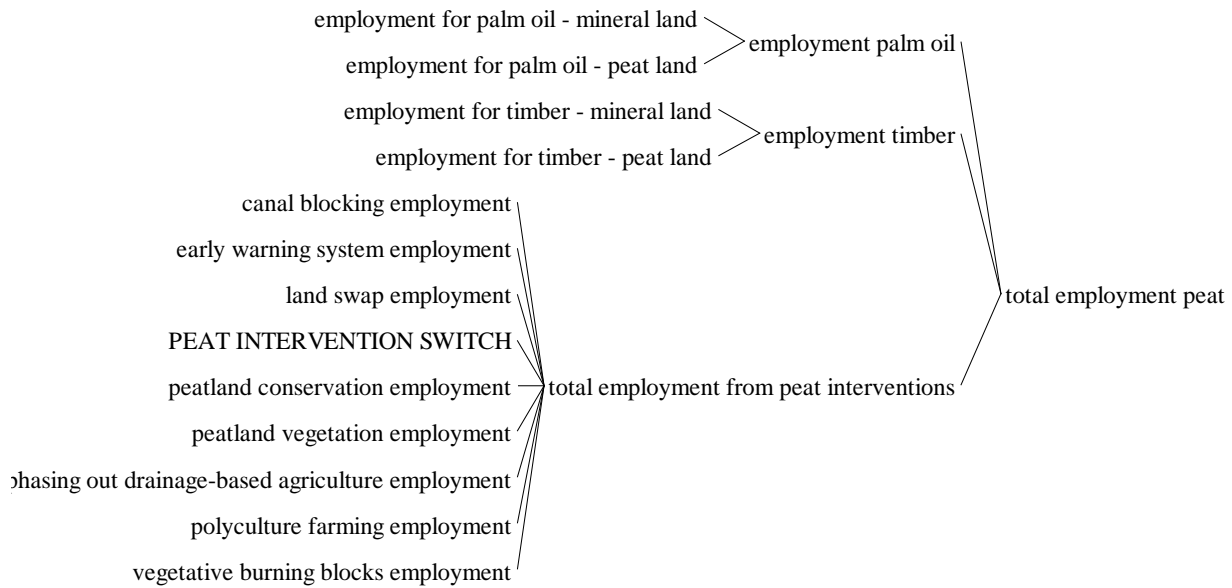


Figure 23: Causes tree for total employment from peatland

The sum of employment from palm oil production on mineral and peatland yields the employment from oil palm, and the sum of employment from timber production on mineral and peatland yields the employment from timber production. The employment from peat interventions is the sum of the variables depicted in Figure 23. The employment from the respective interventions is calculated based on the area on which the interventions are implemented and a per hectare employment multiplier. The equation used to calculate the employment from additional peatland vegetation serves for illustration purposes.

---

$$\text{peatland vegetation employment} = \text{PEATLAND VEGETATION EMPLOYMENT PER HA} * \text{peatland vegetation ha}$$

---

#### 1.5.5. Subsidence

The peat subsidence module provides an overview of peatland subsidence and the emissions from peat fires. Mean subsidence is calculated as the sum of subsidence on agriculture, forest and fallow land. The variables used for calculating the mean subsidence of peatland are illustrated in Figure 24.

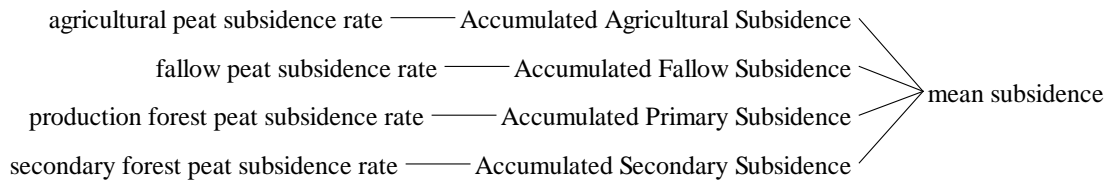


Figure 24: Causes tree of mean peatland subsidence

One of the key indicators for the peat model is land subsidence, which is based on the water table and was estimated to forecast the amount of flooded agricultural land. The model calculates the subsidence rate on different land categories using data from Nusantara et al. (2018)<sup>2</sup> and the equation from Hooijer et al. (2012)<sup>3</sup> which measured a relationship between water table depth and subsidence level, as follows:

---

$$\text{Agricultural peat subsidence rate} = 0.69 - (5.98 * (\text{water table depth agriculture} * - 0.01))$$

---

As a result the model forecasts average peat subsidence of 5 cm per year when no interventions are implemented to conserve or sustainably manage peat land. Based on the subsidence rate, the module then measured the risk of flooding in agricultural peatlands with an equation from Hooijer et al. (2012)<sup>4</sup> that demonstrates the relationship between the accumulated agricultural subsidence and the proportion of flooded agricultural peatlands. The result was then multiplied with the existing agricultural land (in hectare) and the inverted Nino3.4 SST Index (where wet years are positive instead of the other way around) in order to obtain the extent of flooded agricultural land.

Because of the significant influence of the El Nino Southern Oscillation (ENSO) on fire activity in Indonesia (Someshwar et al., 2010)<sup>5</sup>, the model integrates an ENSO indicator, namely Nino3.4 Sea Surface Temperature (SST) Index to forecast fire hotspots.<sup>6</sup> Historical dry season data from the Nino3.4 SST Index

---

<sup>2</sup> Nusantara R.W., R. Hazriani and U.E. Suryadi (2018). Water-table depth and peat subsidence due to land-use change of peatlands. 1st UPI International Geography Seminar 2017. IOP Conf. Series: Earth and Environmental Science 145 (2018) 012090.

<sup>3</sup> Hooijer, A., M. Van der Vat, G. Prinsen, R. Vernimmen, J. J. Brinkman, and F. Zijl, 2008. Hydrology of the EMRP Area –Water Management Implications for Peatlands. Technical Report Number 2, Master Plan for the Rehabilitation and Revitalisation of the Ex-Mega Rice Project Area in Central Kalimantan. Euroconsult Mott MacDonald and Deltares and Delft Hydraulics.

<sup>4</sup> Hooijer et al (2012b), A. Hooijer, B. Triadi, O. Karyanto, S.E. Page, M. van der Vat and G. Erkens, Subsidence in Drained Coastal Peatlands in Southeast Asia: Implications for Sustainability. Paper submission presented to the International Peat Society, June 2012.

<sup>5</sup> Someshwar, Shiv, Rizaldi Boer and Esther Conrad 2010. “World Resources Report Case Study. Managing Peatland Fire Risk in Central Kalimantan, Indonesia.” World Resources Report, Washington DC.

<sup>6</sup> A hotspot is a fire pixel in a satellite imagery that indicates fire in an area. Yet it does not specify the number, size or intensity of fires and burned areas. See further Siegert & Hoffmann 2000.





from 2000 to 2014 and MODIS derived hotspot data from 1998 to 2006 from Reynolds et al. (2002)<sup>7</sup> were used for the calibration of the model. Data from the Nino 3.4 Index was extrapolated to create a trend in the relationship between SST and hotspots until 2040. The historical and extrapolated data were then used to forecast the amount of hotspots per dry season by measuring the relationship between Nino3.4 index data and fire hotspots using an exponential regression analysis as can be seen in Figure 25. Data for Kalimantan were used as a starting point.

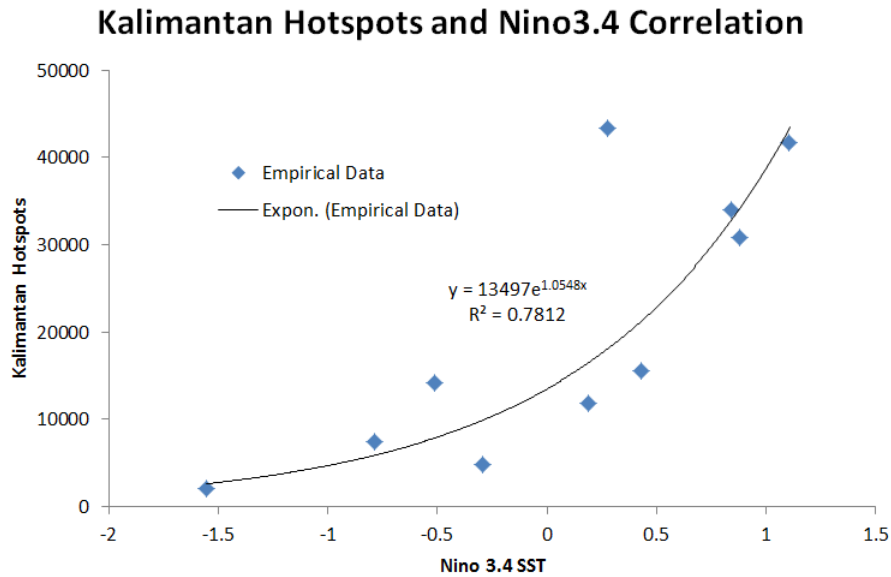


Figure 25: Central Kalimantan Hotspots and Nino3.4 SST Correlation

The formula developed by Tansey et al. (2008)<sup>8</sup> in their study in Central Kalimantan was then used to calculate the total burnt area from the number of hotspots.

---


$$\text{Burnt area} = \text{HA BURNT PER HOTSPOT} * (\text{hotspots per dry season on peatland})$$


---

Finally, to calculate fire emissions, the peatland model adopts a method used by the Indonesia National Forest Reference Emissions Level or FREL (BP REDD+ 2015), but uses a simplified formulation:

$$L_{fire} = A \times MB \times CF \times G_{ef}$$

In which **A** denotes the extent of burnt area (in hectares), **CF** is the combustion factor with a default factor that equals to 1.0 and **MB** denotes the mass of fuel available for combustion. The latter is estimated for

<sup>7</sup> Reynolds, R.W., Rayner, N.A., Smith, T.M., Stokes, D.C., Wang, W. (2002). An Improved In Situ and Satellite SST Analysis for Climate. Journal of Climate, 15, 1609-1625.

<sup>8</sup> Tansey, K. et al., 2008. Relationship between MODIS fire hot spot count and burned area in a degraded tropical peat swamp forest in Central Kalimantan, Indonesia. Journal of Geophysical Research, 113(D23112), pp.1–8.



the BAU scenario by multiplying the mean depth of burned peat with the bulk density (BD) as assumed in the studies by Mulyani et al. (2012)<sup>9</sup> and Ballhorn et al. (2009)<sup>10</sup>. The average depth of burned peat in other scenarios was calculated by estimating the impact of alternative interventions on the water table depth. Furthermore,  $G_{ef}$  denotes the CO<sub>2</sub> emission factor calculated by multiplying the organic carbon content (C<sub>org</sub>, % of weight) of 0.4986 (Mulyani et al. 2012)<sup>11</sup> with the conversion factor from tC to tCO<sub>2e</sub> which is 3.67. This conversion factor was derived through dividing the atomic weight of carbon dioxide (i.e. 44) by the atomic weight of carbon (i.e. 12).

## 1.6. Emission modules

### 1.6.1. Total emissions

The total emissions module provides information about the emissions from different sectors or sources. Figure 26 shows a causes tree illustrating the variables that are used for the calculation of total emission.

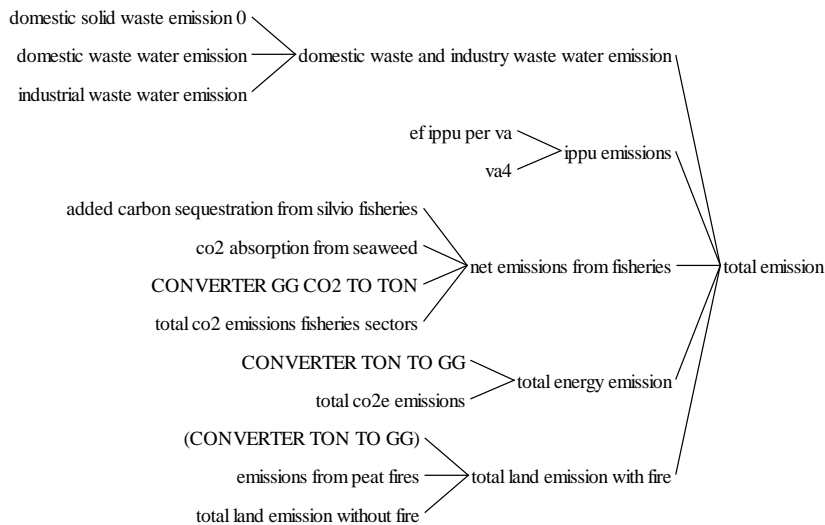


Figure 26: Causes tree for total emissions

Total emissions is the sum if emissions from domestic waste and wastewater, industrial processes and product use (IPPU), fisheries, energy and land use.

Emissions from energy and peat fires have been already described. Domestic waste and industry waste water emissions are calculated by the following equation, and fishery and land use emissions will follow.

<sup>9</sup> Mulyani, H., Sasongko, S.B., dan Soetrisnanto, D. 2012. Pengaruh Preklorinasi terhadap Proses Start Up Pengolahan Limbah Cair Tapioka Sistem Anaerobic Baffled Reactor. Jurnal Momentum, 8(1): 21-27 (Indonesian version).

<sup>10</sup> Ballhorn, U., Siegert, F., Mason, M., & Limin, S. (2009). Derivation of burn scar depths and estimation of carbon emissions with LIDAR in Indonesian peatlands. Proceedings of the National Academy of Sciences of the United States of America, 106, 21213–21218. doi:10.1073/pnas.0906457106

<sup>11</sup> Mulyani, H., Sasongko, S.B., dan Soetrisnanto, D. 2012. Pengaruh Preklorinasi terhadap Proses Start Up Pengolahan Limbah Cair Tapioka Sistem Anaerobic Baffled Reactor. Jurnal Momentum, 8(1): 21-27 (Indonesian version).



---

$$\text{domestic waste and industry waste water emission} = \text{domestic solid waste emission} + \text{domestic waste water emission} + \text{industrial waste water emission}$$

---

Emissions from industrial processes and product use (IPPU) emissions are calculated based on the industrial sector GDP multiplied by an emission intensity per unit of output.

Fishery sector emissions account for sectoral emissions generated through the use of fuel and electricity and the carbon absorption from sustainable aquaculture management systems and the production of seaweed.

---

$$\text{net emissions from fisheries} = (\text{total co2 emissions fisheries sectors} - (\text{co2 absorption from seaweed} + \text{added carbon sequestration from silvio fisheries})) / \text{CONVERTER GG CO2 TO TON}$$

---

Carbon sequestration from aquaculture and seaweed production are deducted from the total CO2 emissions from fuel and electricity use to obtain the net emissions generated by the sector.

CO2 emissions from energy and land use are the sum of emissions from the energy demand module presented and the sum of emissions from the land use described below.

### 1.6.2. Land emissions

The land emissions module provides information about emissions from land use and peatland. The total land emissions from land use without fire are calculated based on the following equation.

---

$$\text{total land emission without fire} = \text{land emission on mineral land in tonco2} + \text{land emission on peat land from land change} + \text{emissions from peat decomposition} + \text{agriculture emission} * \text{CONVERTER TON TO GG}$$

---

The total emissions from land, excluding emissions from fires, are the sum of emissions from mineral land, peatland and agriculture. Agriculture emissions are multiplied by a converter to ensure that all emissions are expressed in GG of CO2. Land use emissions are calculated based on the land conversion flows from the land use module and the carbon stock difference between two different land use types. The equation for emissions from converting agriculture to forest land serves for illustrative purposes.



---

$$\text{emission forest land to agriculture land} = \text{carbon stock difference forest to agriculture land} * \text{forest land to agriculture land rate on mineral land}$$

---

Figure 27 summarizes the different emission streams that are summed up yield the total emissions from land use change on mineral land.

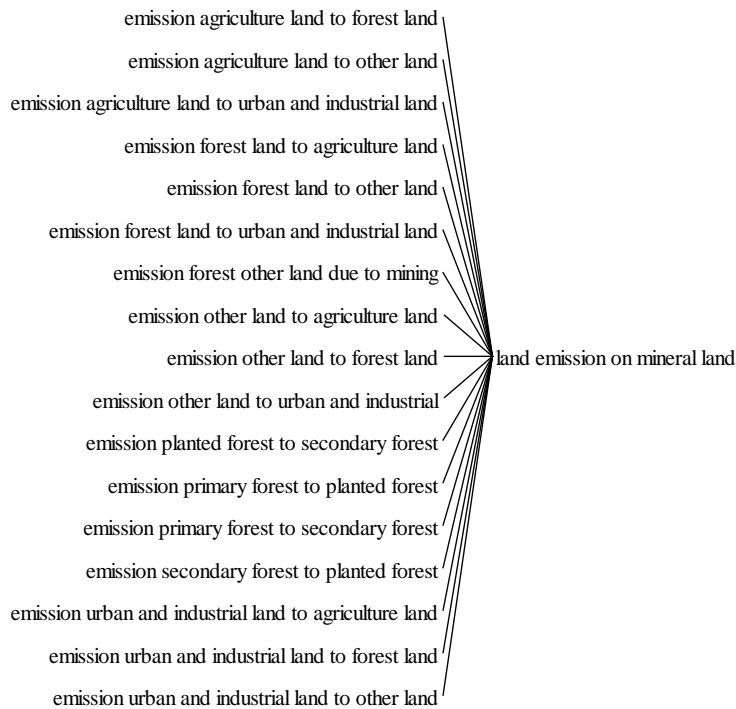


Figure 27: Causes tree of land emissions on mineral land

The total emissions from land including fires are calculated as the sum of total emissions from land and emissions from peat fires.

### 1.6.3. Waste and IPPU emissions

This module provides information about the emissions from the generation of solid waste and wastewater by population and industry. Domestic waste and industry waste water emissions are calculated based on the variables displayed in the causes tree in Figure 28.

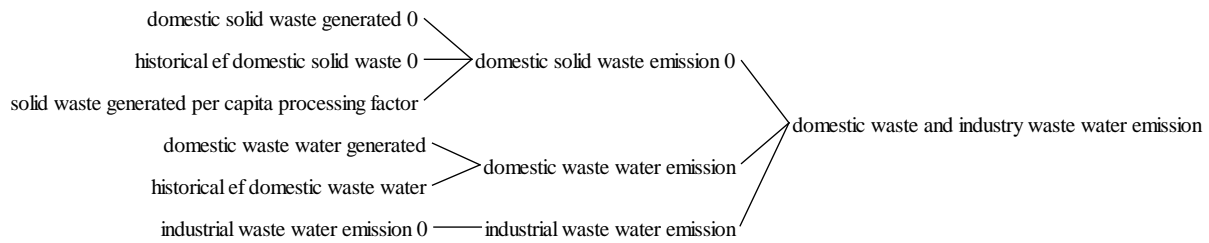


Figure 28: Causes tree domestic waste and industry waste water emissions

Domestic emissions from solid waste are calculated by multiplying domestic solid waste generation by an emission factor per ton of solid waste generated and the fraction of solid waste that is processed. Emissions from wastewater are calculated by multiplying domestic wastewater by an emission factor per unit of wastewater generated. The emissions from industrial wastewater are

## 1.7. Water modules

### 1.7.1. Water demand and supply

The water demand and supply module provides an overview of the available water resources from ground and surface water sources and water availability indicators. Total water supply is the sum of water extracted for domestic and industrial production. The variables used for calculating total water supply are presented in Figure 29.

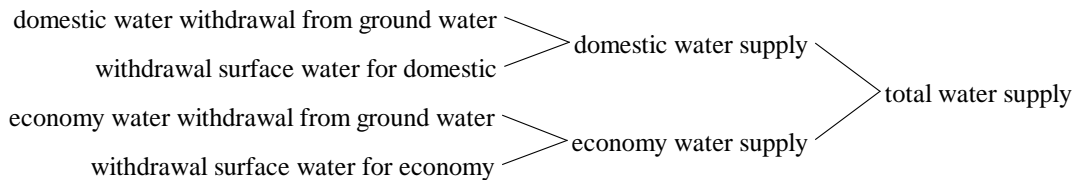


Figure 29: Causes tree total water supply

Water availability from surface and groundwater is based on total water demand and reliable supply from each source. The water demand from surface water, or the desired surface water supply, is the sum of water demand for surface water from agriculture, municipalities and economic production. The reliable surface water supply is calculated by multiplying the fraction of reliable surface water and the water quality impact on surface water availability.

---


$$\begin{aligned}
 & \text{reliable surface water} = \\
 & \text{surface water average debit} * \text{water quality impact to surface water delayed} * \text{FRACTION OF RELIABLE} \\
 & \text{SURFACE WATER}
 \end{aligned}$$


---



The variable surface water available serves as indicator of whether there is sufficient water to fulfil the water demand and is used as input for the estimation of water shortages. The same calculations are made to determine the availability of ground water, with the exception that only domestic and production (e.g. industrial) water demand are assumed to be satisfied by groundwater sources.

Total water demand is the sum of agriculture, economy and domestic water demand from surface and groundwater. Total groundwater demand is the sum of domestic and economy water demand and the desired surface water is the sum of agriculture, economy and domestic water demand. Note in Figure 30 that the model assumes that agriculture water demand is entirely satisfied by surface water.

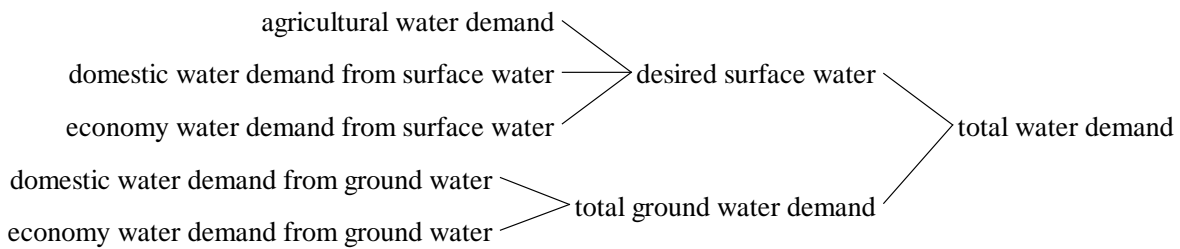


Figure 30: Causes tree total water demand

Economy water demand is calculated by multiplying the total real GDP from industry and services by a water per unit of value added multiplier. Domestic water demand is calculated by multiplying total population by a water demand per capita multiplier. A fraction of groundwater used for economy water demand and domestic water demand is applied to distribute the respective water demand over the two water sources. The equation for equation of economy water demand from surface water serves for illustration purposes.

---


$$\text{economy water demand from surface water} = \text{economy water demand} * (1 - \text{FRACTION OF GROUND WATER FOR ECONOMY WATER DEMAND})$$


---

The groundwater stock increases through the groundwater supply rate and is reduced through water withdrawals for population and economy. The inflow to the stock depends on the available infiltration flows from rainfall and the percolation rate of surface water into groundwater aquifers. The outflows are based on the groundwater demand for economy and domestic uses and a water availability multiplier, as illustrated for groundwater withdrawals for domestic use.

---


$$\text{domestic water withdrawal from ground water} = \text{effect of ground water availability} * \text{domestic water demand from ground water}$$


---



## 1.7.2. Water quality

The water quality module provides an overview of total wastewater and the BOD, COD, and TSS loadings in wastewater. Total wastewater is the sum of wastewater from agriculture, industry and population. The variables used to calculate total wastewater are illustrated in Figure 31.

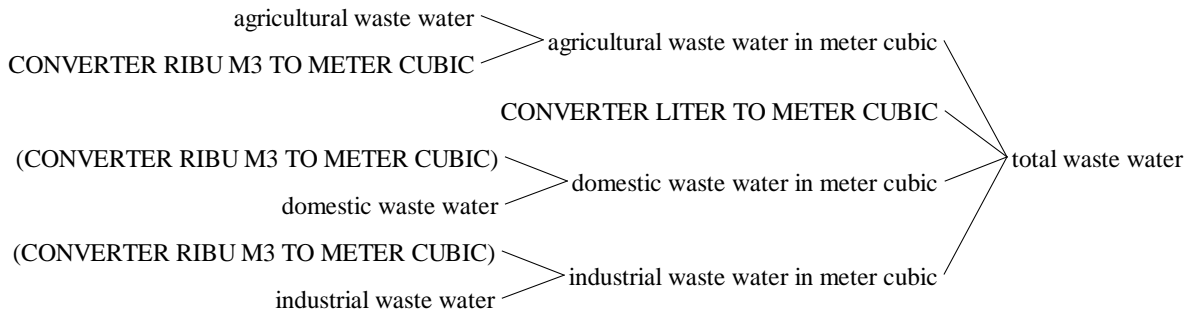


Figure 31: Causes tree total wastewater

The wastewater from each sector is calculated by multiplying the respective withdrawals by a fraction of water that is wastewater and a converter that converts from m3 to liters.

BOD, COD and TSS loadings are calculated using the same equations. This section describes how loadings are calculated using total BOD loadings as example. The total BOD per liter is calculated by dividing the total BOD mass by the surface water demand in liters. Total BOD mass is the sum of BOD loadings from agriculture, industry and population.

---


$$\text{total bod mass} = \text{agriculture bod per year} + \text{domestic bod per year} + \text{industrial bod per year}$$


---

The BOD loadings from agriculture, industry and population are calculated based on an average concentration per liter of wastewater and the wastewater emitted by the respective sector. The equation for calculating BOD from industrial sources serves as an example.

---


$$\text{industrial bod per year} = \text{industrial bod in meter cubic} * \text{industrial waste water} * \text{CONVERTER RIBU M3 TO METER CUBIC}$$


---

All of the loadings are calculated using the respective wastewater stream multiplied by an average concentration per liter of water.



In addition, BOD, COD and TSS loadings from agriculture are affected by the use of sustainable management practices. The model assumes that there are no loadings emitted on land where organic farming practices are implemented.

---


$$\text{agriculture bod per year} = \text{agricultural waste water} * \text{agriculture bod in meter cubic} * \text{CONVERTER RIBU M3 TO METER CUBIC}$$


---

## 1.8. Climate change modules

### 1.8.1. Rainfall variability

The rainfall variability module provides an overview of the annual and seasonal distribution of rainfall and allows for including different rainfall assumptions. Further, it contains the flood and water scarcity indicator, which are used to indicate the flood and drought risk in the model.

Precipitation is defined as the sum of baseline precipitation and the variability in precipitation. Baseline precipitation is modelled as a stock that is changed by a per cent growth rate over time. The growth rate can be used to simulated different precipitation scenarios, such as an increasing or decreasing baseline. The variability in precipitation is defined as the sum of variability below and above normal precipitation, and a growth rate in variability is applied to allow for increasing or decreasing variability in precipitation over time.

---


$$\text{variability in precipitation} = (\text{variability above normal} + \text{variability below normal}) * \text{Growth Rate Variability}$$


---

Precipitation represents the baseline rainfall in the model and is used for the calculation of seasonal precipitation. The variables used for the calculation of seasonal precipitation are presented in form of a causes tree in Figure 32.

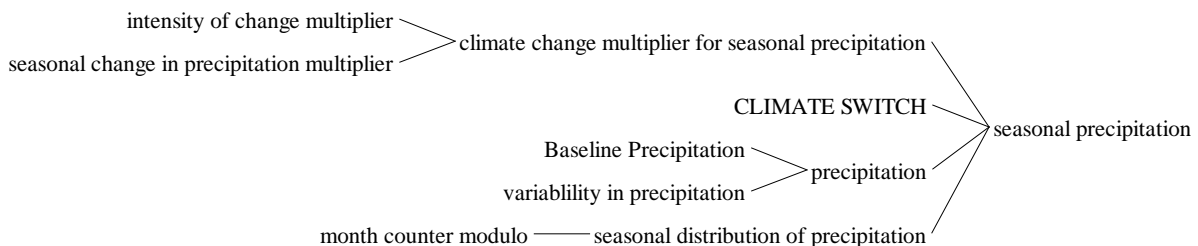


Figure 32: Causes tree seasonal precipitation

Normal seasonal precipitation does not include the additional variability or climate change impacts on seasons and serves as reference seasonal precipitation for the calculation of relative seasonal





precipitation. It is calculated by multiplying the baseline precipitation by the seasonal distribution of precipitation. The seasonal distribution of precipitation is based on the month counter modulo, which splits the annual time step up in 12 sub time steps and allows for distributing rainfall on a monthly basis. A table function is used to distribute the respective shares (per cent values) of annual precipitation over the 12 months.

---

$$\text{normal seasonal precipitation} = (\text{Baseline Precipitation} * \text{seasonal distribution of precipitation})$$

---

Seasonal precipitation, which is used in the model to determine the water supplies and irrigation requirements, is calculated by multiplying precipitation by the seasonal distribution of precipitation.

---

$$\text{seasonal precipitation} = (\text{precipitation} * \text{seasonal distribution of precipitation}) * \text{IF THEN ELSE (CLIMATE SWITCH= 1, climate change multiplier for seasonal precipitation, 1)}$$

---

In addition to the application of the seasonality factor, the model allows for the application of a climate change multiplier that alters the distribution of precipitation throughout the year (i.e. shifting rainy seasons). Whether the multiplier is applied depends on the value of the variable “climate switch”. An IF THEN ELSE function is used to determine whether the policy is active (switch value of “1”) or inactive. If the policy is active, the climate change multiplier for seasonal precipitation is applied to the formulation. If the switch is inactive, the formulation will use the value one as a multiplier, which indicates that seasonal precipitation is not affected by the multiplier.

Relative seasonal precipitation is calculated by dividing the variable seasonal precipitation by the variable normal seasonal precipitation. The variables used for the calculation of relative seasonal precipitation are illustrated in the causes tree in Figure 33

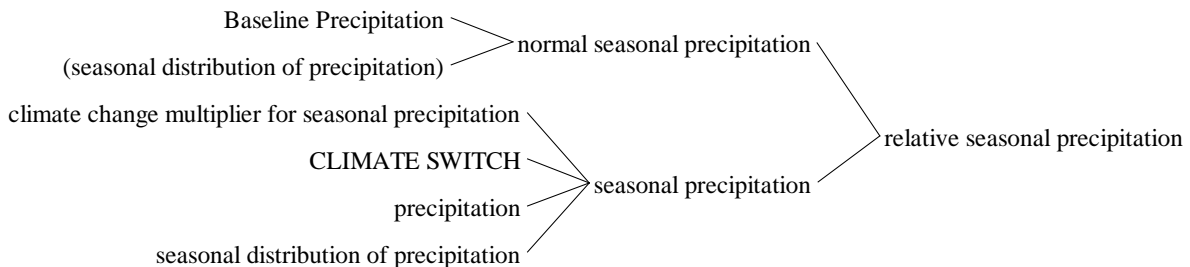


Figure 33: Causes tree relative seasonal precipitation



Relative seasonal precipitation is then used to calculate the flood indicator and the water scarcity indicator. Both indicator values are calculated based on a threshold value, in case of the flood indicator a maximum precipitation value and in case of the water scarcity indicator a minimum precipitation value. The threshold values need to be reviewed and customized in collaboration with local experts or based on a thorough review of historical precipitation data and adverse climate events. To determine a flood or drought, the threshold values are compared to the value of relative seasonal precipitation. The equation for the flood indicator serves for illustration purposes.

---

*flood indicator =*

*IF THEN ELSE ( relative seasonal precipitation > MAXIMUM PRECIPITATION THRESHOLD FOR FLOODS,  
1+(relative seasonal precipitation-MAXIMUM PRECIPITATION THRESHOLD FOR FLOODS), 1)*

---

The IF THEN ELSE value is used to determine whether relative precipitation is (in this case) higher than the maximum precipitation threshold for floods. In case that relative seasonal precipitation is higher, the flood multiplier will take the value of one plus the amount that relative seasonal precipitation exceeds the flood threshold. The model then uses non-linear functions to determine the various impacts of floods (and water scarcity, or droughts) in the different sectors, such as agriculture production or water availability.

### 1.8.2. Global temperature

This module provides information about the assumptions used for global temperature changes and the calculation of the damage multiplier for climate change damages. The changes in global temperature are included as an exogenous time series function that leads temperatures to gradually increase over time. Together with current and corrected global emissions, the change in global temperature is used to calculate the corrected global temperature change.

---

*corrected global temperature change =*

*(smoothed corrected total world emission / total world emission) \* global temperature change*

---

An exogenous time series is used for total world emissions. Corrected total world emissions is the sum of total world emissions and the change in total country emissions compared to the baseline. This formulation corrects world emissions by the amount of emissions emitted or saved from policy interventions in Indonesia. A smooth function is used to gradually capture the impacts of Indonesia's contribution to climate change have on the global temperature change.

The model calculates damages from climate change based on the climate change damage fraction. The climate change damage fraction is calculated based on the corrected global temperature change, the



reference temperature, and two climate change damage multipliers. The variables used to calculate the climate damage fraction are illustrated in

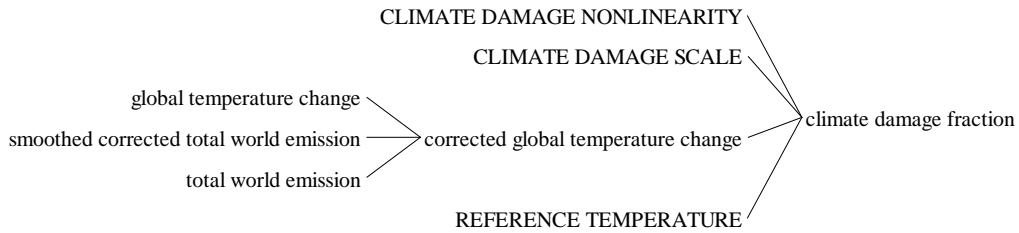


Figure 34: Causes tree for climate damage fraction

The following equation is used for calculating the climate damage fraction.

---

$$\text{climate damage fraction} = \frac{1}{1 + (\text{CLIMATE DAMAGE SCALE} * (\text{corrected global temperature change} / \text{REFERENCE TEMPERATURE})^{\text{CLIMATE DAMAGE NONLINEARITY}})}$$

---



## 2. Description of results

### 2.1. Macroeconomic impacts

Simulation results indicate higher economic growth in the LCDi investment scenarios than in the scenario in which only conventional investments are implemented. With only conventional investments, GDP grows on average at 5.3% per year rate between 2020 and 2045. In the LCDi scenarios with medium and high ambition, GDP growth during this period averages 5.9% and 6.0%. GDP growth in the medium ambition (FAIR) and high ambition (AMBITIOUS) scenarios is on average 0.6% and 0.7% higher than in the baseline. Figure 35 illustrates total real GDP and the GDP growth rate for the baseline, FAIR and AMBITIOUS scenario.

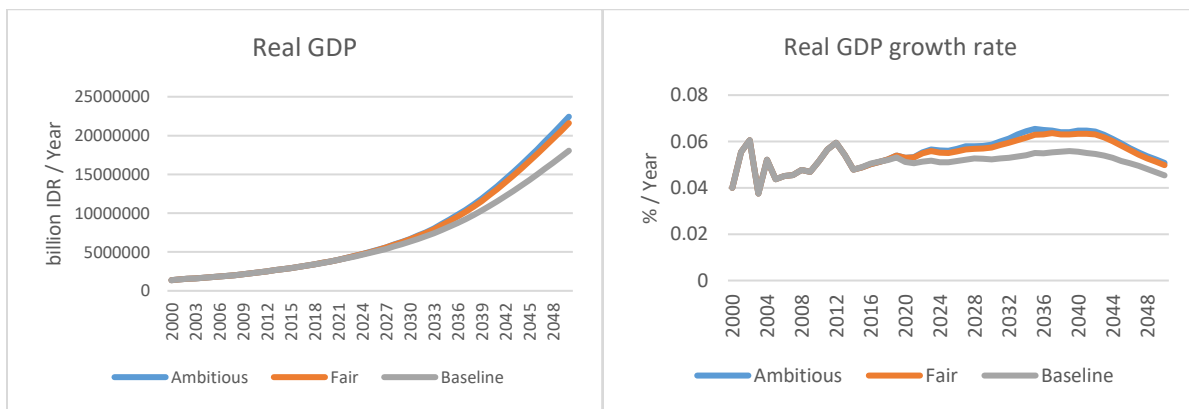


Figure 35: Real GDP and real GDP growth rate

In real USD<sub>2017</sub>, the GDP per capita increases from approximately USD 3,110 per capita in 2018 to USD 10,070 per capita in 2045. For the FAIR and AMBITIOUS scenario, GDP per capita is projected to increase to approximately USD 11,930 and USD 12,340 per capita respectively. In other words, the GDP per capita in the FAIR and AMBITIOUS scenarios is 18.4% and 22.5% higher in 2045. Figure 36 illustrates the development of GDP per capita in the Baseline, FAIR and AMBITIOUS scenario.

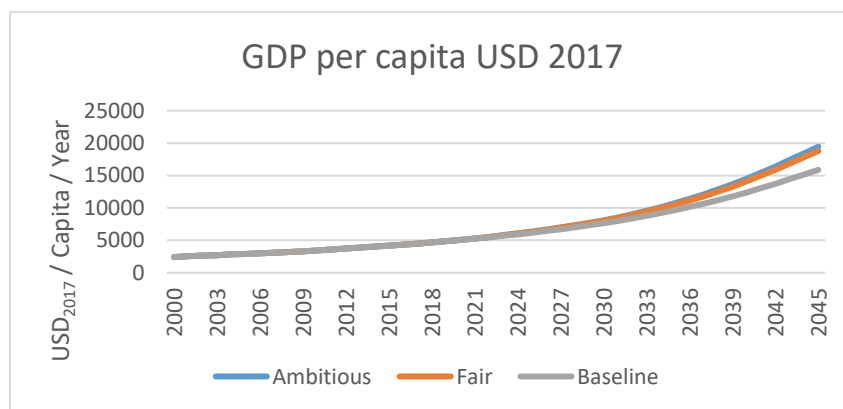


Figure 36: GDP per capita in USD<sub>2017</sub>

The increase in economic growth is primarily driven by energy- and land-use-related synergies created by LCDi interventions. The envisioned interventions are bolstering investment in energy efficiency and



renewable capacity, and the implementation of land-use related policies such as sustainable land-use management techniques, reforestation and conservation efforts. The required investments and emerging benefits for the medium and high ambition scenario are presented in form of an integrated CBA in Table 4.

Job opportunities and higher economic growth resulting from LCDi investments generate additional jobs and contribute to reducing unemployment. As illustrated in Figure 37, unemployment in the baseline increases from 6.6% in 2018 to 14.5% in 2045. The additional employment opportunities from LCDi investments reduces unemployment in 2045 to 12.8% and 11.5% in the FAIR and AMBITIOUS scenarios respectively. Between 2019 and 2045, the average unemployment rate (with an endogenous formulation for labor force) is 1% lower in the FAIR and 1.5% lower in the AMBITIOUS scenario.

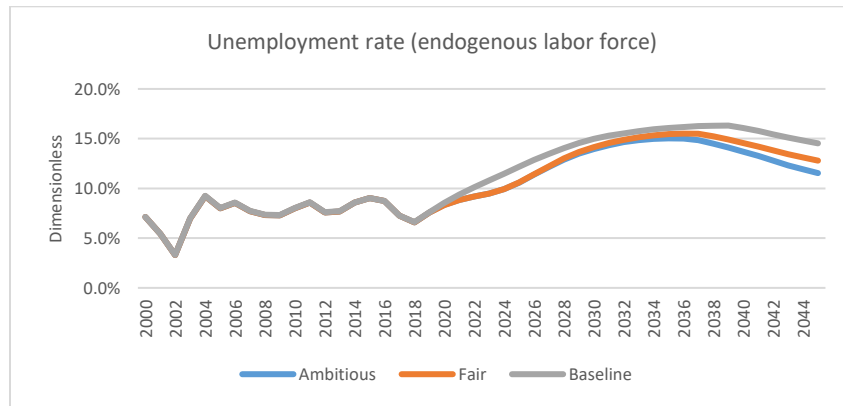


Figure 37: Unemployment rate

## 2.2. Energy demand and supply

### 2.2.1. Energy efficiency

Investments in energy efficiency reduce energy consumption and curb energy demand in the long run. Baseline energy intensity is projected to decline to 1.39 TJ per IDR billion produced. In the LCDi investment scenarios, energy intensity is projected to decline on average by 15.6% (FAIR) and 20.5% (AMBITIOUS) between 2019 and 2045 compared to the baseline. In the FAIR scenario, energy intensity by 2045 is projected at 0.95 TJ per billion IDR generated. Energy intensity in the AMBITIOUS scenarios is projected at 0.84 TJ per billion IDR generated, which is 39.3% lower than in the baseline and 11.3% lower compared to the FAIR scenario.

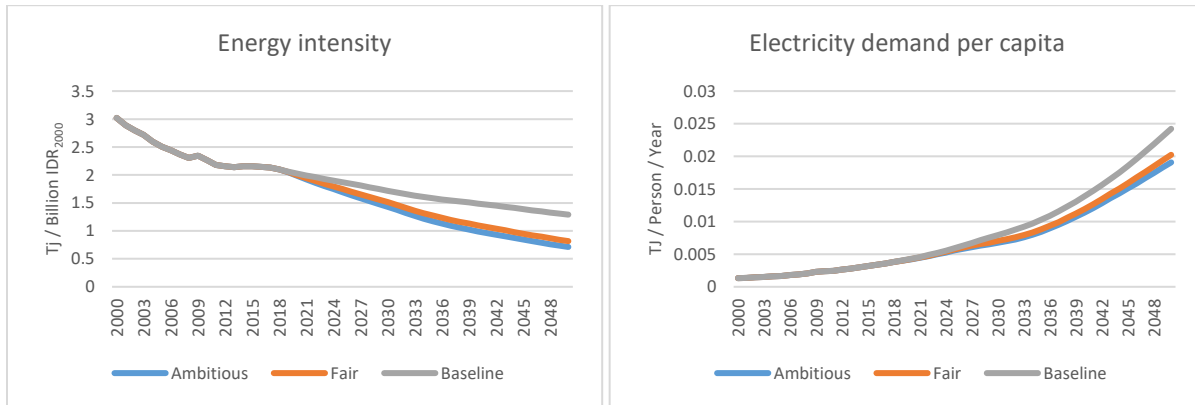


Figure 38: Energy intensity and energy consumption per capita

Baseline electricity demand increases from approximately 0.0038 TJ per capita per year in the year 2000 to 0.0185 TJ per capita per year in 2045. In the FAIR and AMBITIOUS scenario, electricity demand per capita increases to 0.0159 TJ per person and 0.0151 TJ per person respectively, which is 14.2% (FAIR) and 18.6% (AMBITIOUS) lower than in the baseline in 2045.

The higher economic growth of the LCDi scenario leads to the emergence of the rebound effect. In other words, the economic growth that is obtained from reducing energy use and emissions, leads to higher energy consumption and emissions (even if this extra growth is less energy and carbon intensive). This makes so that reaching targets of emission reduction becomes more and more challenging over time, requiring growing efforts/ambition in the medium and longer term.

### 2.2.2. Renewable energy

Figure 39 illustrates the share of renewable electricity generation for the baseline, FAIR and AMBITIOUS scenario respectively. By 2045, LCDi investments contribute to 24.3% (AMBITIOUS scenario) and 14.5% (FAIR scenario) of electricity being generated from renewable sources. Investments in renewable energy (a) create employment, with new technologies being more labor intensive than conventional ones (e.g. for power generation), if infrastructure is built locally; (b) reduce the use of fossil fuels, lowering resource exploitation and import and (c) reduce emissions.

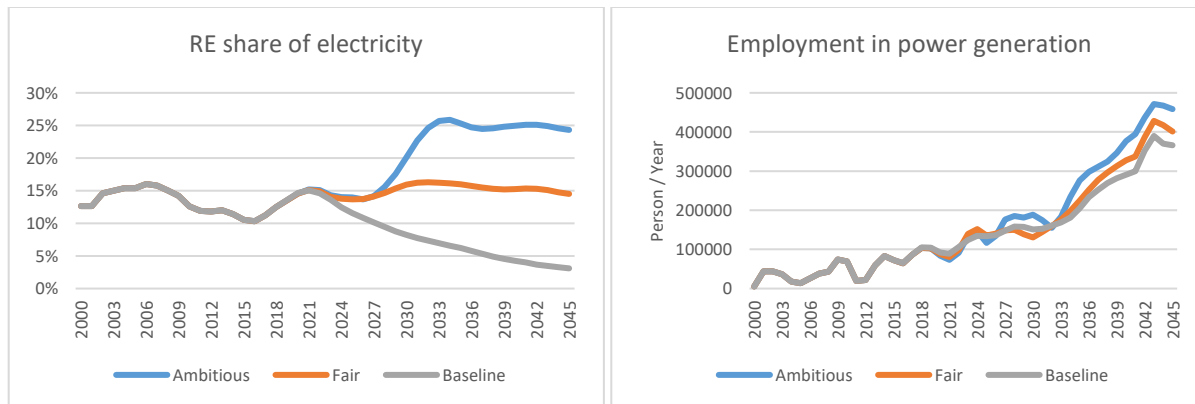


Figure 39: Share of renewable electricity generation



Improving energy efficiency and increasing the renewable share in power generation reduces energy expenditure, resource exploitation and emissions. Reducing energy expenditure increases economic productivity (because the lower energy intensity, and the reduced share of energy cost of GDP) and GDP, especially for the industrial and services sectors.

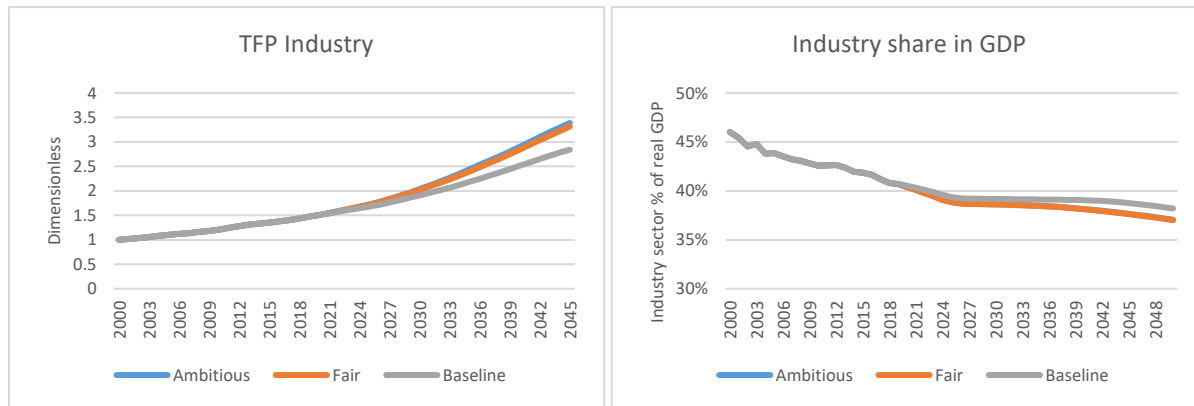


Figure 40: Total Factor Productivity (TFP) Industry and Services

Investing in LCDi interventions increases total factor productivity (TFP) by 23.1% and 26.1% by 2045 in the Fair and Ambitious scenarios respectively.

### 2.3. Resource extraction

Both energy efficiency and renewable energy contribute to lowering the depletion of the stock of fossil fuels. Lower depletion of fossil fuels causes prices to decrease in the medium and longer term, which stimulates economic growth. Coal exploitation and demand for coal are illustrated in Figure 41. The demand for and production of coal decreases in both intervention scenarios. In the baseline scenario, coal demand reaches 9.55 billion tons per year in 2045. In the FAIR and AMBITIOUS scenario, the demand for coal between 2019 and 2045 is on average 18.4% and 27.4% lower compared to the baseline. By 2045, the demand for coal decreases to 6.87 billion tons and 5.61 billion tons per year respectively, which is 28.1% and 41.3% lower compared to the baseline.

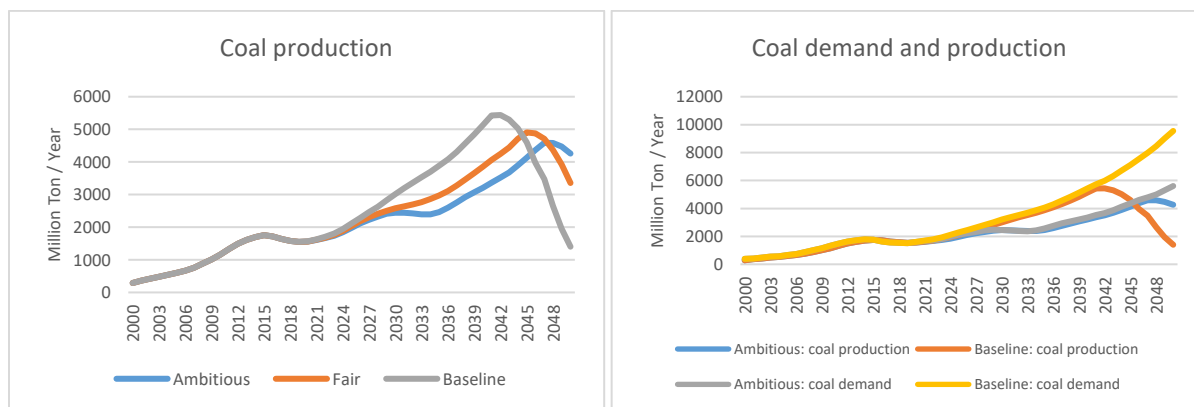


Figure 41: Coal production and demand



On average, coal production in the FAIR and AMBITIOUS scenario is 13.3% and 21.4% lower than in the baseline respectively. Interestingly, the projections indicate that coal production in the baseline starts decreasing the earliest due to higher consumption, around the year 2040. In the FAIR scenario, this decline begins from 2045 and in the AMBITIOUS scenario, the production of coal increases, although at a lower level, until the year 2047, before levelling off and declining.

## 2.4. Energy bill and impacts of pollution

Figure 42 illustrates energy price impacts on productivity (left) and the share of Indonesia's energy bill over GDP (right). The reduction in energy prices, due to LCDi interventions that reduce demand, has a beneficial impact on economic productivity. In the baseline, the share of energy expenditure over GDP is 9% by 2045. In the Fair and Ambitious scenarios, the share of energy expenditure over GDP in 2045 is 7.1% and 5.8% respectively, which is 1.9% and 3.2% lower than in the baseline.

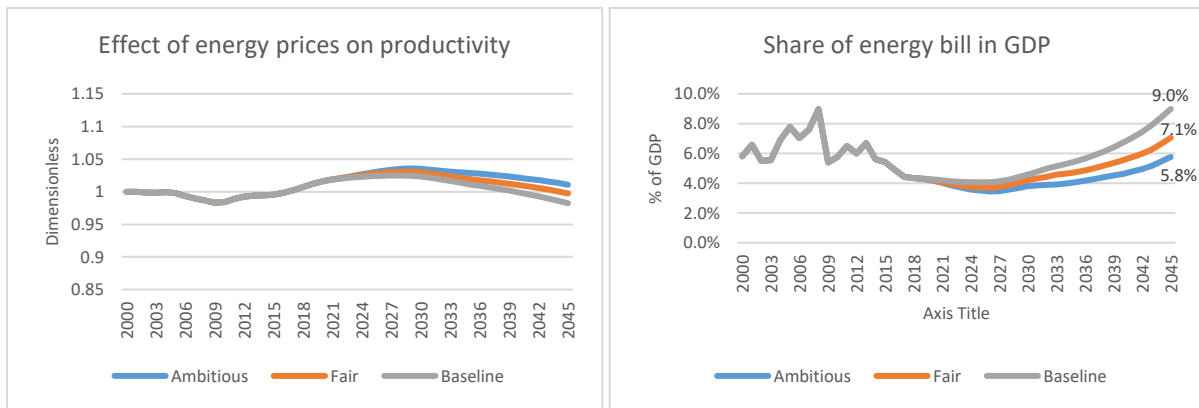


Figure 42: Energy price impacts and share of energy bill over GDP

In addition to directly benefiting the economy through reduced energy prices and lower capacity requirements, energy efficiency and renewable energy indirectly contribute to economic growth by reducing air emissions. Figure 43 presents the relative effect of air pollution on TFP for the three scenarios (left) and the baseline GDP projections with and without externalities (right).

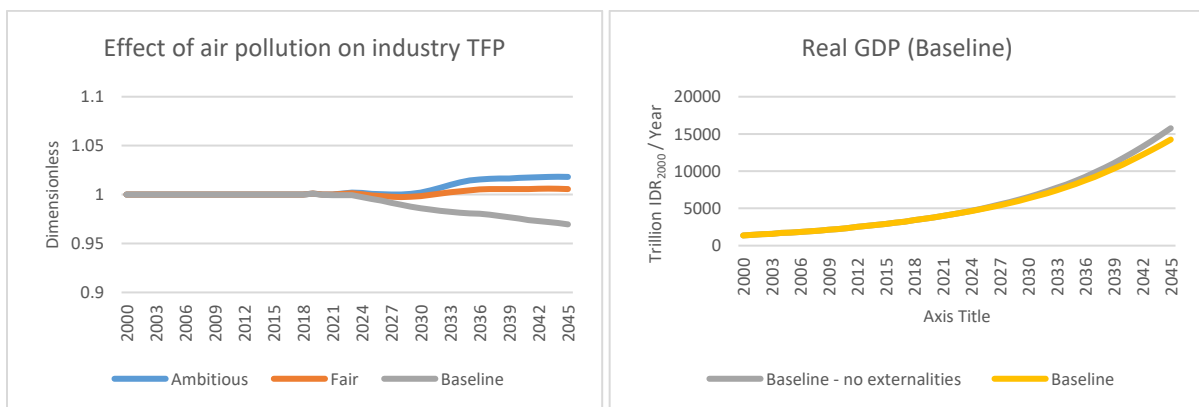


Figure 43: Effect of air pollution on industry TFP and Real GDP (with and without externalities)





The development of GDP including and excluding the impact of pollution is presented in Figure 43 (right). The gray line represents the scenario in which air pollution impacts are not considered. GDP growth in the baseline averages 5.4% per year between 2019 and 2045, while the baseline without the impact of air emissions averages 5.8% during the same period. This indicates that considering the impacts of air pollution on GDP reduces the annual GDP growth rate on average by 0.4%, which indicates that mitigating GHG emissions maintains and improves economic growth.

## 2.5. Land-use and land cover change

Land-use and land cover change (LULC) related investments concern reforestation, avoided deforestation, land management practices (e.g. RIL, certified palm oil, FMAs) and improved land productivity (e.g. for crop production). LULC investments reduce land cover change and emissions, potentially increase the carbon stock, and, in certain instances, allow for premium prices and higher value addition. The reduction of emissions, especially in the case of peat fires, also has a positive impact on economic productivity. The emissions from land cover change are not considered in the estimation of the impact of emissions on economic productivity, due to the fact that such loss of carbon sequestration takes place in areas with low air pollution.

Interventions targeting the agriculture and forestry sector aim at increasing the sustainability of plantations, logging activities and crop production while maintaining or increasing their profitability. Reforestation and conservation practices cause forest-cover to increase from 83.1 million hectares in the baseline to 103.4 million hectare in the FAIR scenario and 112.2 million hectare in the AMBITIOUS scenario. The projections for total forest cover in the Baseline, FAIR and AMBITIOUS scenario are presented in Figure 44.

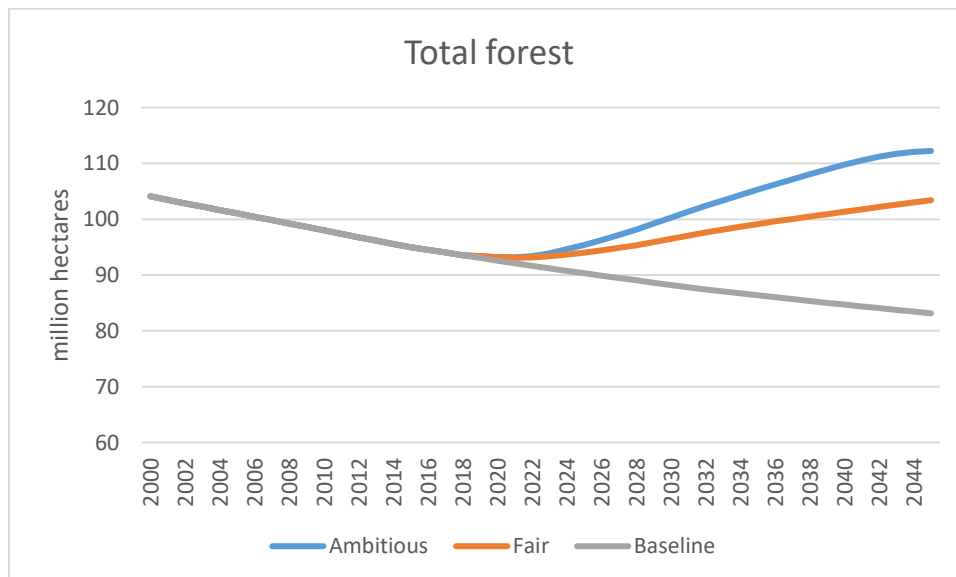


Figure 44: Total forest

The development of primary and secondary forest cover between 2000 and 2045 are illustrated in Figure 45. Deforestation of primary forest in the LCDi scenarios decreases by approximately 50%, and



reforestation efforts increase secondary forest cover. In the AMBITIOUS scenario, secondary forest cover is approximately 2 million hectares higher in 2045 than it was in the year 2000.

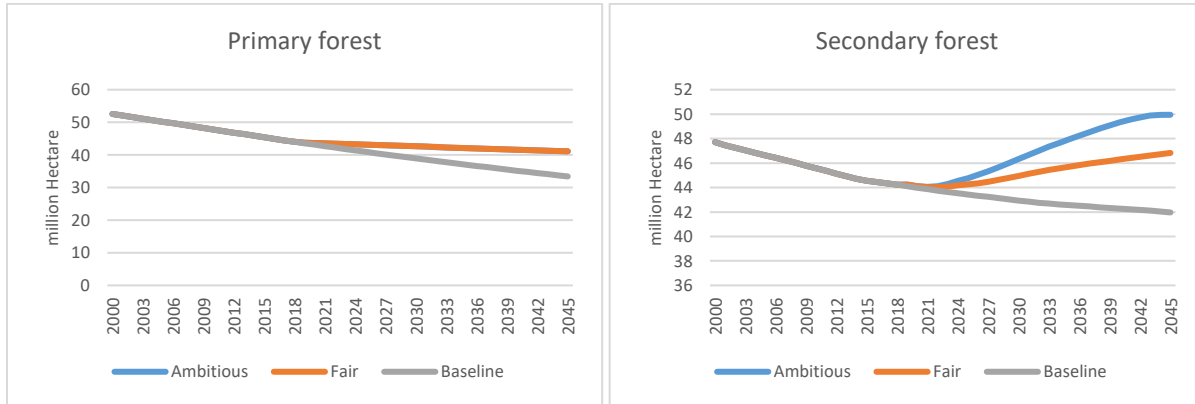


Figure 45: Primary and secondary forest

By the year 2045, conservation and reforestation activities in the LCDi scenarios lead to around 20.3 and 29.1 million hectares in additional forest cover in the FAIR and AMBITIOUS scenario respectively. Interventions related to the conservation of primary forest cover contribute to maintaining an additional 7.7 million hectares of primary forest. In the baseline, total primary forest cover in the year 2045 is projected to be 33.4 million hectares, while total primary forest cover in both LCDi scenario is 41.1 million hectares, or 23.1% higher compared to the baseline.

## 2.6. Palm oil

The area used for oil palm plantations is projected to almost double between 2016 and 2045, from 11.9 million hectares in 2016 to 22.9 hectares in 2045. Between 2018 and 2030, the share of ISPO certified plantations increases from roughly 14% in 2018 to 50% of plantations certified in the year 2045 in the LCDi scenarios. Managing palm oil plantations according to ISPO standards increases plantation productivity and sustainability. As a consequence, ISPO certified plantations are more productive, labor intensive and have slightly higher O&M costs than conventional plantations. By 2045, the fresh fruit bunches (FFB) production rate in the FAIR and AMBITIOUS scenario is approximately 4%, or 14.7 million tons, higher compared to the baseline. Model projections for the area in use for oil palm and the FFB production rate are presented in Figure 46.

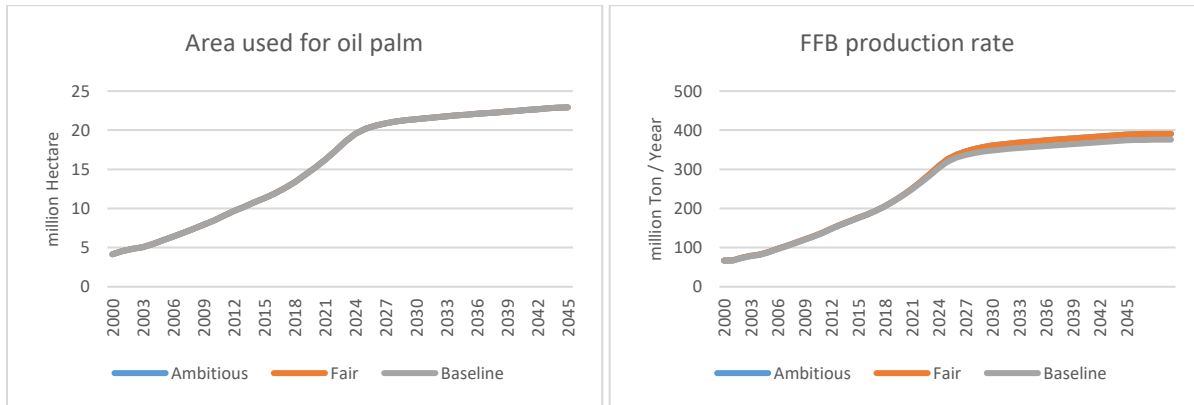


Figure 46: Area in used for oil palm and FFB production rate

The transition towards ISPO certified plantations generates additional employment and leads to higher profit on a per hectare basis. Employment from oil palm in the FAIR and AMBITIOUS scenario is 4.6% higher and sectoral profitability increases by 1.1% compared to the baseline scenario. In addition, ISPO certified plantations are less emission intensive on a per hectare basis than conventional oil palm plantations.

## 2.7. Agriculture production

The total land used for crop production in the baseline scenario decreases from 45.5 million hectares to 41.9 million hectares between 2019 and 2045. In the LCDi scenarios, the amount of cropland is slightly higher with 43.8 million hectares in the FAIR and 43 million hectares in the AMBITIOUS scenario. This is due to higher land availability for conversion, given the conservation efforts implemented to reduce land conversion from other areas. The LCDi scenarios assume an increase in sustainable agriculture land from 0% in 2019 to 50% in the year 2045, which increases sectoral productivity and generates additional jobs. Implementing sustainable agriculture practices generates between 0.6-0.7 million additional jobs, or 8.1% and 6.8% higher in the FAIR and AMBITIOUS scenario respectively.

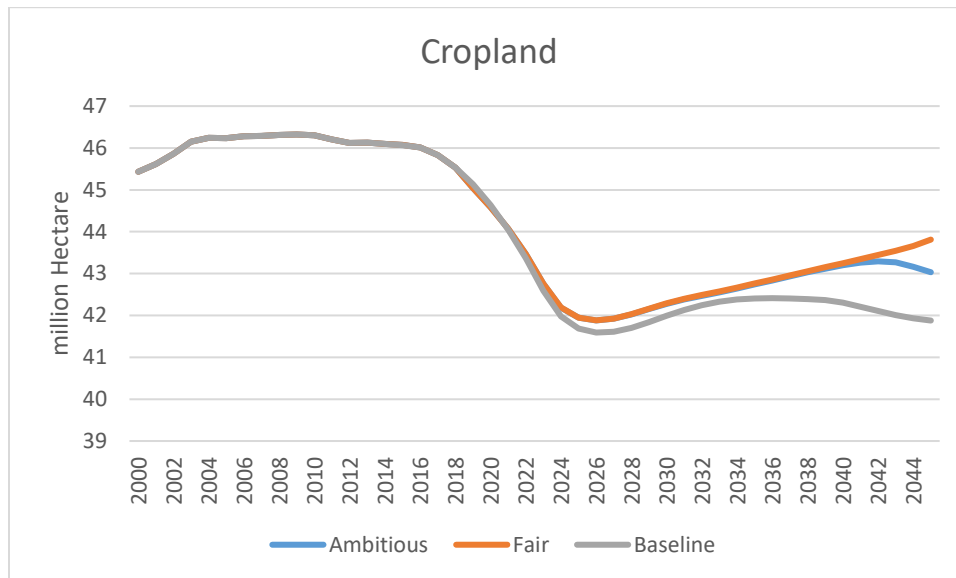
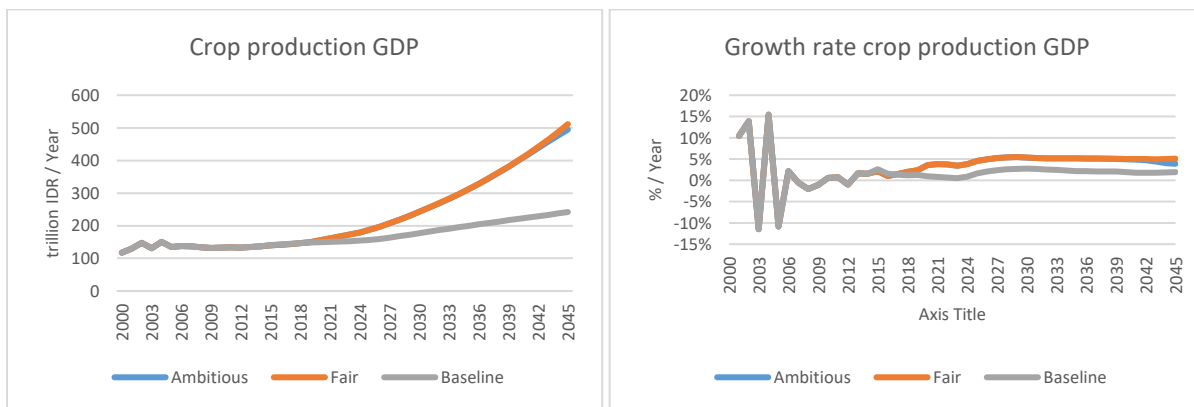


Figure 47: Cropland

Investments in sustainable agriculture lead to higher production and more sectoral value added. In the FAIR scenario total production more than doubles compared to the baseline and is 221.3 million tons higher in the year 2045, compared to a baseline production of 217.8 million tons. In the AMBITIOUS scenario, additional land conservation leads to slightly less agriculture land compared to the FAIR scenario. The increase in production totals 207 million tons by 2045, which is equivalent to an increase of 95% over 26 years.



Higher production increases the value added from crop production. In 2045, GDP from crop production reaches IDR 242 trillion in the baseline. Crop production GDP in the FAIR and AMBITIOUS scenario reaches IDR 511.4 trillion and 494.7 trillion by 2045 respectively. In the baseline, crop production GDP grows on average by 1.88% per year between 2019 and 2045. LCDi investments in sustainable agriculture increase the average GDP growth rate by approximately 2.7%, to 4.7% in the FAIR scenario and 4.6% in the AMBITIOUS scenario.



## 2.8. Fisheries

LCDi investments in the fishery sector focus on (i) capacity building and fishery management, (ii) aquaculture and capture fishery productivity, and (iii) increasing sectoral energy efficiency. Annual fish landings from capture fisheries increase from 7.03 million tons in 2016 to 9.15 million tons in the year 2045. In the FAIR and AMBITIOUS scenarios, LCDi investments in capacity building and sustainable resource management increase total annual fish landings to 15.3 million tons in 2045, which is 6.15 million tons, or 67.2% higher compared to the baseline. The development of annual fish landings for the baseline, FAIR and AMBITIOUS scenario is illustrated in Figure 48.

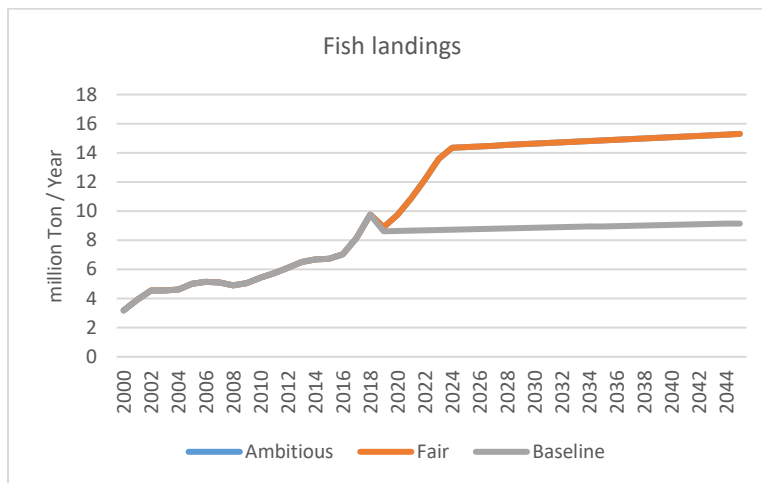


Figure 48: Annual fish landings

The additional fish landings contribute to sectoral employment and economic growth. In the baseline, the fishery sector provides 18.3 million jobs by 2030 and 28.2 million jobs by 2045. LCDi interventions contribute to generating 2.1 million additional jobs in the fishery sector by 2030 and 3.1 million additional jobs by 2045. In the year 2045, fishery sector employment in the FAIR and AMBITIOUS scenario is 10.9% higher than in the baseline. Fishery GDP in the FAIR and AMBITIOUS scenario is 19.5% and 20.8% higher by 2030 and 2045 respectively, which is equivalent to additional value added of IDR 10.5 billion in 2030 and IDR 21.9 billion by 2045.

## 2.9. GHG Emissions and energy intensity

Across all sectors, LCDi interventions contribute to emission reductions between 1.34 - 1.60 million tons per year in 2045, from 4.27 million tons in the baseline to between 2.92 and 2.66 million tons in the FAIR and AMBITIOUS scenario respectively. Total country GHG emissions in the baseline almost double between 2019 and 2045. Emissions increase from approximately 2.19 million tons per year in 2018 to 4.27 million tons in 2045. LCDi interventions contribute to reducing total GHG emissions by between 31.5% (FAIR) and 37.6% (AMBITIOUS). Total GHG emissions for the baseline and the LCDi investment scenarios are presented in Figure 49.

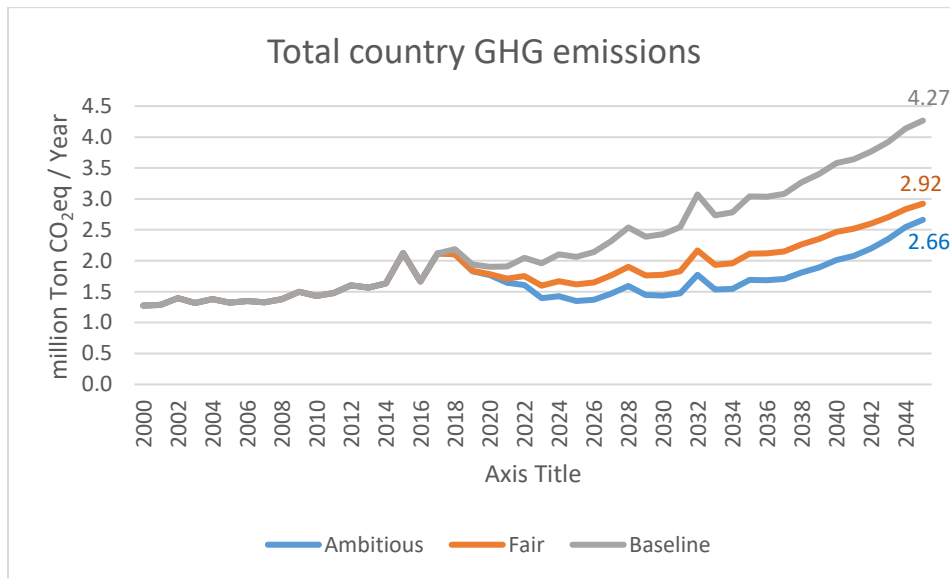


Figure 49: Total country GHG emissions

The reduction in emissions leads to a reduction in emission intensity. Figure 50 presents the development of energy emissions intensity and total emissions intensity over time for the Baseline and both LCDi scenarios.

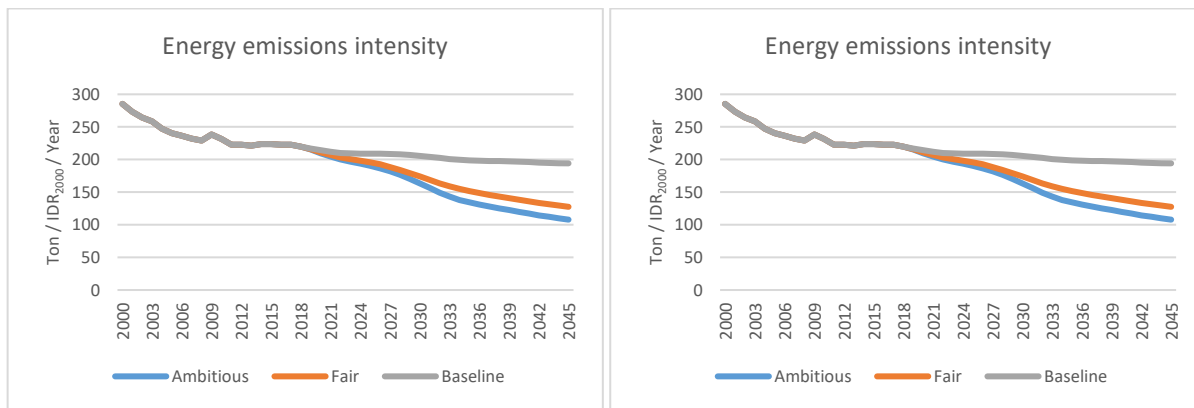


Figure 50: Energy and total emission intensity

Energy emission intensity declines from approximately 219.8 to 194.2 tons of CO<sub>2</sub> per billion IDR produced. In the LCDi scenarios, energy emission intensity decreases by 34.3% in the FAIR and by 44.4% in the AMBITIOUS scenario and decline to 127.5 and 107.9 tons of CO<sub>2</sub>eq per billion IDR produced. Total emissions intensity in the baseline reaches 299.5 tons of CO<sub>2</sub>eq per billion IDR produced in the year 2045, which declines to 175.3 tons of CO<sub>2</sub>eq per IDR billion in the FAIR scenario and 154.6 tons of CO<sub>2</sub>eq per IDR billion in the AMBITIOUS scenario.

## 2.10. Summary

The simulation outcomes presented above are the result of, among many other factors, the inclusion of externalities in the model. The main externalities considered, that have an impact on economic activity,



are air and water pollution. We note that, when calibrating the model to match the FAIR scenario of the Macroeconomic directorate, the impact of externalities is in the range of 1% on average between 2019 and 2050. This value starts at zero in 2018 (to estimate the net difference relative to the forecast of the Macroeconomic directorate) and grows up to 1.5% in the medium and longer term, with the increase of emissions. LCDi interventions more than offset this loss, by improving air and water quality beyond the value of 2018, but not removing their impact entirely (stronger efforts would be required to reach such result).

In addition to water and air quality, two important ecosystem services, the model estimates resource scarcity (e.g. fossil fuel depletion and the impact on energy prices). There are, in addition, other stocks of natural resources in the model that do not directly impact economic activity. LCDi interventions also improve the performance of these indicators, including forest land (which by 2045 is forecasted to be higher than its value in the year 2000), fish stock (forecasted to remain stable also thanks to the growth of aquaculture, with catch at the level of the Maximum Sustainable Yield, rather than declining), reduced degradation of peat land (with reduced water drainage).

Concerning the economic assessment of the intervention options included in the LCDi scenarios (e.g. energy efficiency), an integrated cost benefit analysis indicates positive returns (Table 4). Specifically, GDP is close to 6 times higher than the investment required (taking a societal perspective), government revenues are at the same level as the investment (taking a government perspective) and income creation reaches about 80% of the investment required (taking a household perspective). In addition, it should be considered that the investment estimated totals 1% of GDP in the LCDi Fair scenario and 1.7% of GDP in the LCDi ambitious scenario (or 2.8% and 6.3% of total investment respectively).

Overall, LCDi investment leads to emission reduction of 31.9% and up to 44.8% in 2030 in the Fair and Ambitious scenarios, while simultaneously increasing the annual GDP growth rate by up to 0.8% and 1% per year respectively. This results in GDP being 4.6%-5.6% higher in 2030 and 17%-21% higher in 2045.



<b>Integrated CBA</b> <i>(all values in USD million)</i>	<b>Unit</b>	<b>Ambitious</b>	<b>Fair</b>
<b>Expenditure</b>			
<b>Investments</b>			
Energy	bn USD	62.4	38.9
Fishery	bn USD	7.4	7.4
Land and forestry	bn USD	13.0	8.7
Peat	bn USD	4.3	4.3
<b>O&amp;M</b>			
Energy	bn USD	6.4	1.9
Fishery	bn USD	4.3	4.3
Forestry	bn USD	8.9	8.9
<b>Total investment and O&amp;M</b>	<b>bn USD</b>	<b>106.7</b>	<b>74.4</b>
<b>Avoided costs</b>			
Energy expenditure	bn USD	51.4	19.6
Social cost of carbon	bn USD	367.8	254.3
<b>Total avoided costs</b>	<b>bn USD</b>	<b>419.2</b>	<b>273.8</b>
<b>Added benefits</b>			
Real GDP	bn USD	520.9	422.2
<i>Added GDP over GDP<sub>2018</sub></i>	%	49%	40%
Revenues and grants	bn USD	99.0	80.2
Labor income	bn USD	83.2	63.3
<b>Total added benefits</b>	<b>bn USD</b>	<b>703.5</b>	<b>566.1</b>
<b>Net benefits</b>	<b>bn USD</b>	<b>1,016.0</b>	<b>765.5</b>

Table 4: Integrated CBA IV2045

### 3. Supporting materials (attached)

IV2045 Vensim model file (.mdl) applied to Indonesia.

Simulation results (Excel).