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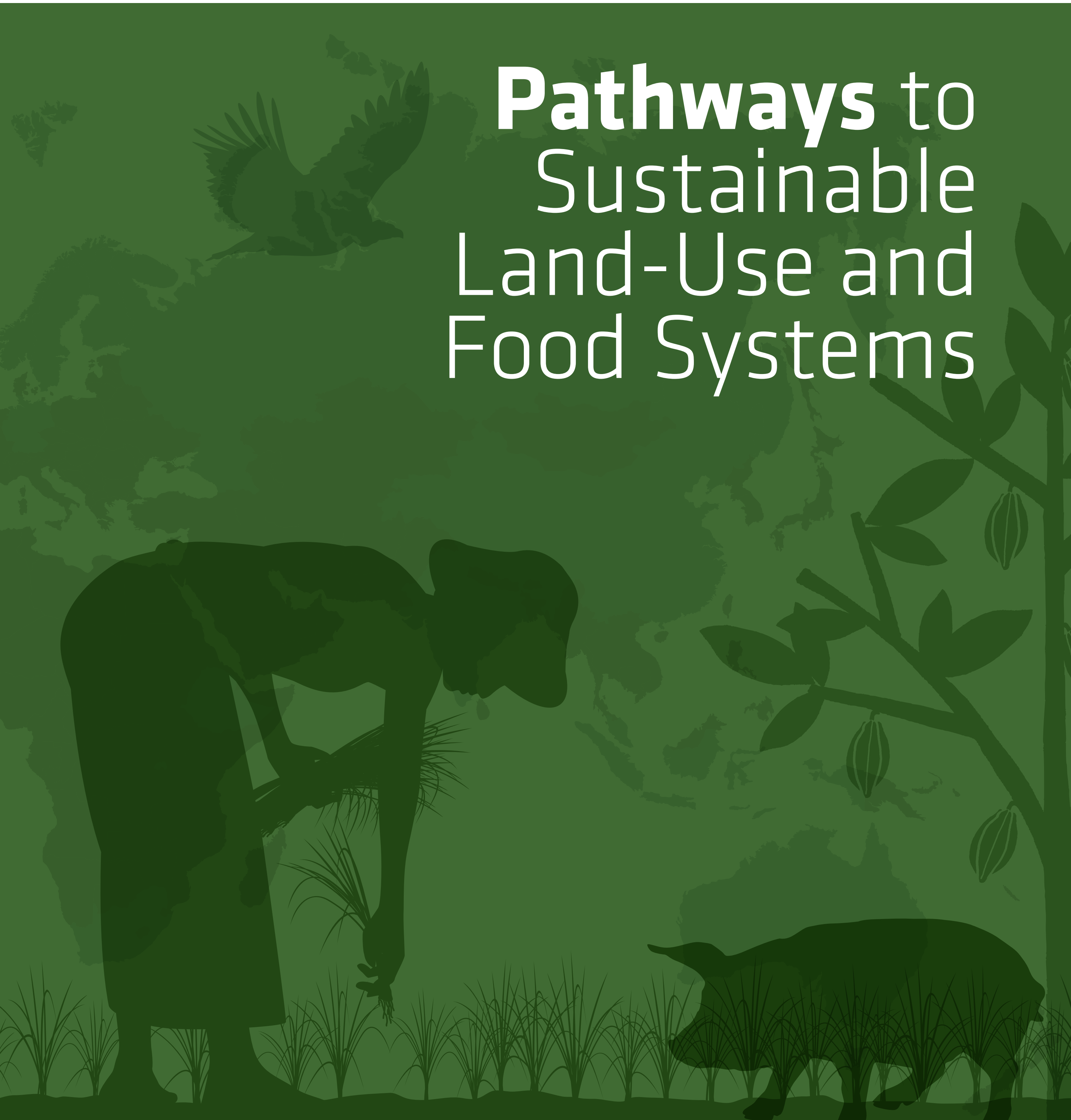
The Food and Land Use Coalition

2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems



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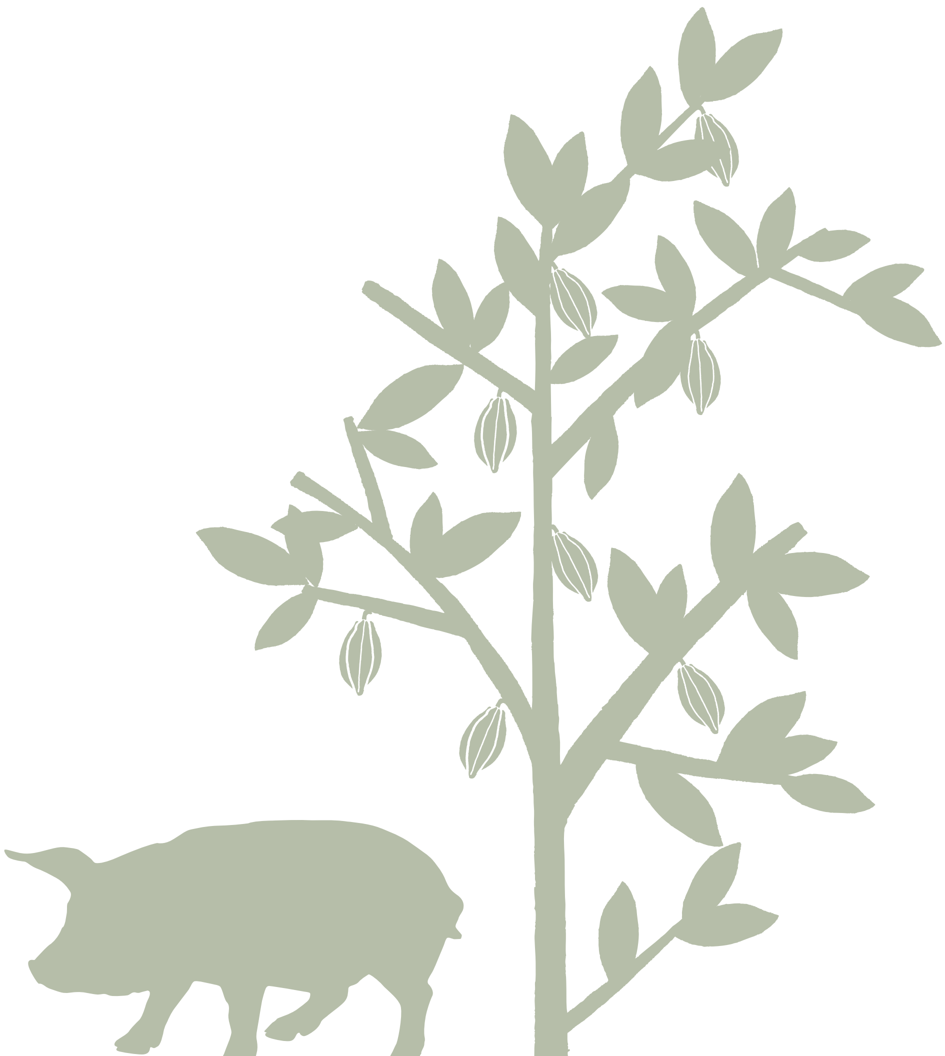
2020 Report of the FABLE Consortium

Pathways to Sustainable Land-Use and Food Systems in Indonesia by 2050



Indonesia

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This chapter of the 2020 Report of the FABLE Consortium *Pathways to Sustainable Land-Use and Food Systems* outlines how sustainable food and land-use systems can contribute to raising climate ambition, aligning climate mitigation and biodiversity protection policies, and achieving other sustainable development priorities in Indonesia. It presents two pathways for food and land-use systems for the period 2020-2050: Current Trends and Sustainable. These pathways examine the trade-offs between achieving the FABLE Targets under limited land availability and constraints to balance supply and demand at national and global levels. The Indonesian FABLE team developed and modeled them with the FABLE Calculator (Mosnier, Penescu, Thomson, and Perez-Guzman, 2019). See Annex 1 for more details on the adaptation of the model to the national context.

Climate and Biodiversity Strategies and Current Commitments

Countries are expected to renew and revise their climate and biodiversity commitments ahead of the 26th session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 15th COP to the United Nations Convention on Biological Diversity (CBD). Agriculture, land-use, and other dimensions of the FABLE analysis are key drivers of both greenhouse gas (GHG) emissions and biodiversity loss and offer critical adaptation opportunities. Similarly, nature-based solutions, such as reforestation and carbon sequestration, can meet up to a third of the emission reduction needs for the Paris Agreement (Roe et al., 2019). Countries' biodiversity and climate strategies under the two Conventions should, therefore, develop integrated and coherent policies that cut across these domains, in particular through land-use planning which accounts for spatial heterogeneity.

Table 1 summarizes how Indonesia's NDC and Forest Reference Emission Level (FREL) treat the FABLE domains. According to the NDC, Indonesia has committed to reducing its GHG emissions by 29% by 2020 compared to 2010. This does include emission reduction efforts from agriculture, forestry, and other land use (AFOLU). Envisaged mitigation measures from agriculture and land-use change include enhanced actions to study and map regional vulnerabilities as the basis of an adaptation information system, strengthen institutional capacity and the promulgation of climate-change-sensitive policies and regulations by 2020, and implement a strategic approach predicated on 4 principles: 1) employing a landscape approach, 2) highlighting existing best practices, 3) mainstreaming the climate agenda into development planning, and 4) promoting climate resilience in food, water, and energy. Under its current commitments to the UNFCCC, Indonesia mentions biodiversity conservation.

Table 1 | Summary of the mitigation target, sectoral coverage, and references to biodiversity and spatially-explicit planning in current NDC and FREL

	Total GHG Mitigation					Mitigation Measures Related to AFOLU (Y/N)	Mention of Biodiversity (Y/N)	Inclusion of Actionable Maps for Land-Use Planning[1] (Y/N)	Links to Other FABLE Targets
	Baseline		Mitigation target		Sectors included				
	Year	GHG emissions (Mt CO_2e/yr)	Year	Target					
NDC (2016)	2010	1.8 (2005)	2020	29% unconditional, 41% conditional	IPPU, Energy, Waste, Agriculture, Forestry and Land-use Change.	Y	Y	N	water, food, forests
FREL 2016	1990-2012	0.351 0.217	n/a	n/a	Deforestation and degradation Peat Decomposition	Y	N	N	n/a

Note. The NDC "Total GHG Mitigation" and "Mitigation Measures Related to AFOLU" columns are adapted from IGES NDC Database (Hattori, 2019)

1 We follow the United Nations Development Programme definition, "maps that provide information that allowed planners to take action" (Cadena et al., 2019).

Table 2 provides an overview of the targets included in the National Biodiversity Strategies and Action Plan (NBSAP) from 2017, as listed on the CBD website (CBD, 2020), which are related to at least one of the FABLE Targets. The Indonesia Biodiversity Strategy and Action Plan strives to increase the awareness and participation of all national stakeholders to acknowledge the importance of biodiversity at the national and global levels over the long term (Bappenas, 2016). Links were made to map the national targets to the Aichi Targets,thus creating a connection to the Global FABLE Targets.

Table 2 | Overview of the NBSAP targets in relation to FABLE targets

NBSAP Target	FABLE Target
(5) **Development of ex-situ conservation areas to protect local ecosystems**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(11) **Realization of sustainable maintenance and improvement of conservation areas**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate
(15) **Realization of conservation and restoration of degraded ecosystems in the region**	**BIODIVERSITY:** No net loss by 2030 and an increase of at least 20% by 2050 in the area of land where natural processes predominate

Brief Description of National Pathways

Among possible futures, we present two alternative pathways for reaching sustainable objectives, in line with the FABLE Targets, for food and land-use systems in Indonesia.

Our Current Trends Pathway corresponds to the lower boundary of feasible action. It is characterized by medium population growth (from 270 million in 2020 to 324 million in 2050), no constraints on agricultural expansion, a 2 Mha afforestation target, no change in the extent of protected areas, high productivity increases in the agricultural sector, and no change in diets (see Annex 2). Moreover, as with all FABLE country teams, we embed this Current Trends Pathway in a global GHG concentration trajectory that would lead to a radiative forcing level of 6 W/m2 (RCP 6.0), or a global mean warming increase *likely* between 2°C and 3°C above pre-industrial temperatures, by 2100. Our model includes the corresponding climate change impacts on crop yields by 2050 for corn, rice, and soybean (see Annex 2).

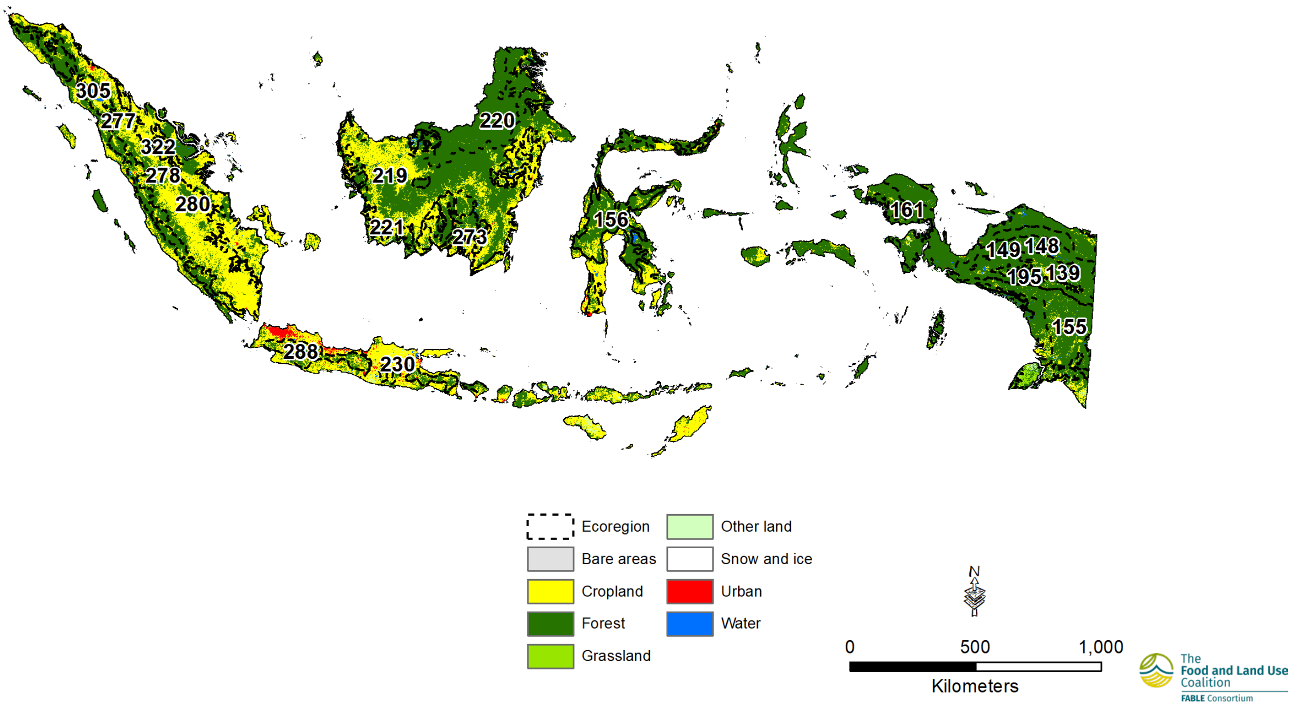
Our Sustainable Pathway represents a future in which significant efforts are made to adopt sustainable policies and practices and corresponds to a high boundary of feasible action. Compared to the Current Trends Pathway, we assume that this future would lead to greater expansion of protected areas by 2050, more constraints on agricultural expansion, and an increase in the afforestation target, set at 5 Mha (see Annex 2). This corresponds to a future based on the strong ambition of the Government of Indonesia to restrict land expansion by the moratorium on new permits/concessions on primary forest and peatland (Government of Indonesia, 2015) and to make considerable progress in sustainable forest management and biodiversity conservation measures (Bappenas, 2016). With the other FABLE country teams, we embed this Sustainable Pathway in a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m^2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

Land and Biodiversity

Current State

In 2015, Indonesia was covered by 42% cropland, 4% grassland, 53% forest, 1% urban and 0.3% other natural land. Forest and other natural lands can be mostly found on Papua Island where 148-Northern New Guinea lowland rain and freshwater swamp forests dominates but can also be found in 140-Maluku Halmahera Rain Forest, 157-Sulawesi Montane Rain Forest, 219-Kalimantan Borneo Lowland Rain Forest, and 273-Freshwater Swamp Forests (Map 1). Whereas cropland can be found in 288-Java Western Java Montane Rain Forest, 280-Sumatera Sumatran Peat Swamp Forest, 278-Sumatran Lowland Rain Forest, and part of 156-Sulawesi lowland rain forest. Settlements and urban land are more centralized on Java Island where the most populated provinces are located (49 million people live in West Java). Indonesia currently faces challenges in managing data and information on biodiversity richness and its utilization, therefore data collection activities, including exploration and expeditions, are critically needed to uncover the existence of new species and the current state of others. For example, collected samples of mammal locations only cover about 26% of all Indonesian provinces, thus showing the urgency to increase coverage (Bappenas, 2016).

Map 1 | Land cover by aggregated land cover types in 2010 and ecoregions

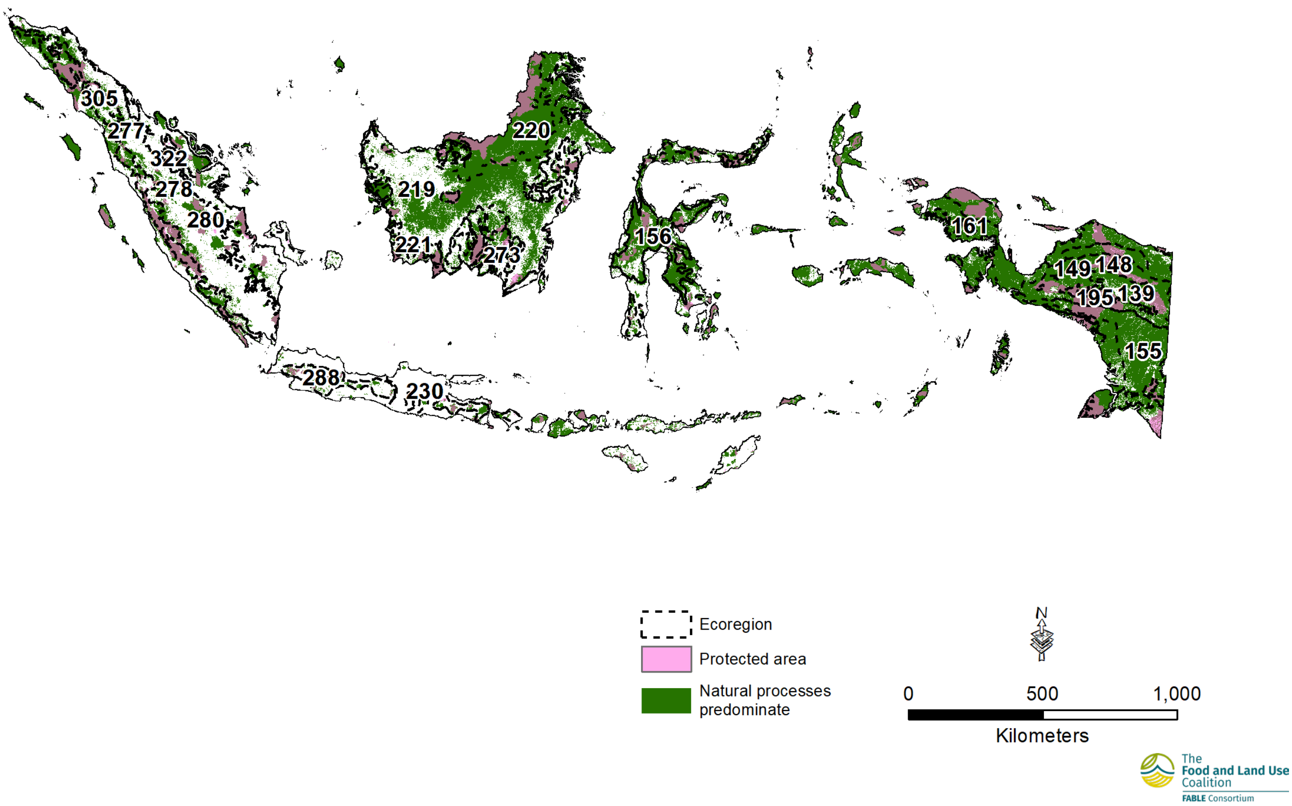


Notes: The correspondence between national land cover map classes and aggregated land cover classes displayed on the map and an overview of biodiversity indicators for the current state at the ecoregion level can be and can be found in Annexes 3 and 4, respectively .
Sources: countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); land cover – National Land Cover Map (KLHK, 2019)

We estimate that land where natural processes predominate[2] accounted for 55% of Indonesia's terrestrial land area in 2010 (Map 2). The 219-Borneo Lowland Rain Forest holds the greatest share of land where natural processes predominate, followed by 278-Sumatran Lowland Rain Forest and 156-Sulawesi Lowland Rain Forest (see Annex 4). Across the country, while 22 Mha of land is under formal protection (12% of total land), falling short of the 30% zero-draft CBD post-2020 target, only 21% of the land where natural processes predominate is formally protected. This indicates the urgency of preserving and better managing the above-mentioned ecoregions as pressure on the land system is increasing rapidly, specifically the impact of cropland expansion is imminent. For example, designated areas for a major rice production site include 156-Sulawesi Lowland Rain Forest of South Sulawesi.

Approximately 52% of Indonesia's cropland was in landscapes with at least 10% natural vegetation in 2010. These relatively biodiversity-friendly croplands are most widespread in 219-Borneo lowland rain forest, followed by 278-Sumatran Lowland Rain Forest and 156-Sulawesi Lowland Rain Forest (see Annex 4). The regional differences in the extent of biodiversity-friendly cropland can be explained by regional production intensity of, for example, paddy fields and rice in 156-Sulawesi Lowland Rain Forest, palm oil and coconut in 278-Sumatran lowland rain forest, and rubber and palm oil in 219-Borneo lowland rain forest.

Map 2 | Land where natural processes predominated in 2010, protected areas and ecoregions



Note: Protected areas are set at 50% transparency, so on this map dark purple indicates where areas under protection and where natural processes predominate overlap.
Sources: countries - GADM v3.6; ecoregions – Dinerstein et al. (2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International (2019), intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

2 We follow Jacobson, Riggio, Tait, and Baillie (2019) definition: "Landscapes that currently have low human density and impacts and are not primarily managed for human needs. These are areas where natural processes predominate, but are not necessarily places with intact natural vegetation, ecosystem processes or faunal assemblages".

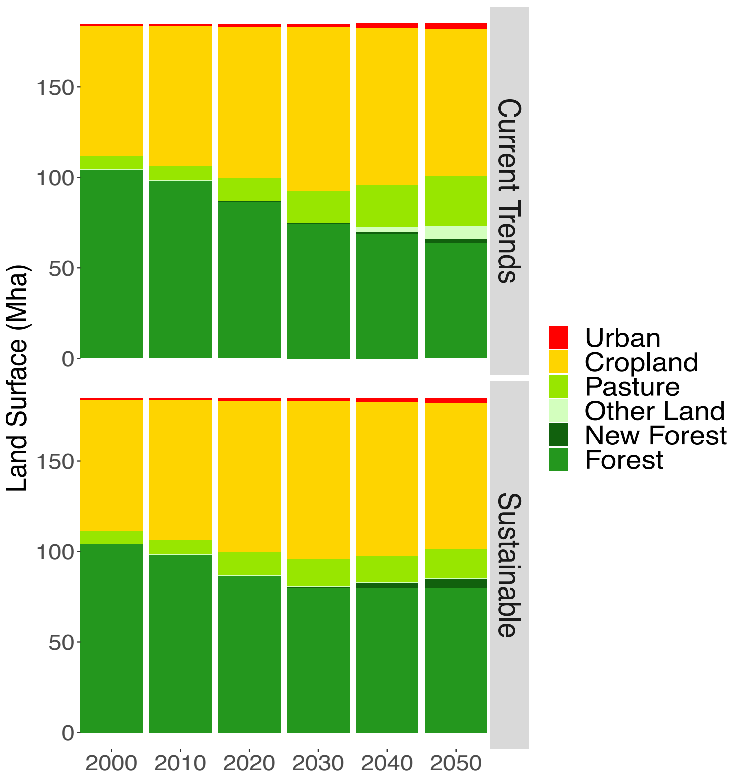
Pathways and Results

Projected land use in the Current Trends Pathway is based on several assumptions, including no constraints on land conversion beyond protected areas, 2 Mha of reforestation/afforestation by 2050 following the Bonn Challenge commitment, and protected areas remaining at 22 Mha, representing 12% of total land cover in 2050 (see Annex 2).

Historical deforestation in Indonesia decreased from 1 Mha in 2014-2015, to 0.43 Mha in 2015-2016, and 0.31 Mha in 2016-2017 (Kementerian Lingkungan Hidup dan Kehutanan, 2018). Our results show a higher average annual deforestation: 1.3 Mha between 2015-2020. By 2030, we estimate that the main changes in land cover in the Current Trends Pathway will result from an increase of cropland area, an increase in pasture area, and a decrease in forest area. Between 2015 and 2030, Forest area is estimated to decrease by 21%, totaling 74 Mha in 2030, resulting in an average annual deforestation of 1.3 Mha. For comparison, national scenarios in Indonesia's NDC used 0.8 Mha deforestation rate for the BAU Scenario over 2012-2030, and other national scenarios (CM1 unconditional / CM2 conditional) assume an annual rate of 0.3 Mha of deforestation (Minister of Environment and Forestry, 2017). Our results are explained by expansions in cropland (0.7 Mha per year) and pasture (0.5 Mha per year) in pasture expansion over the period 2015-2030. However, historically, pasture area has decreased in Indonesia, so this computed expansion of pasture area largely explains the overestimation of deforestation in our results.

Over the period 2030-2050, computed cropland area decreases and grassland area further increases (Figure 1). The expansion of the planted area for oil palm fruit, rubber, and nuts explains 81% of total cropland expansion between 2010 and 2030: 37% from oil palm fruit, 29% from rubber, and 15% from nuts. For oil palm fruit, 81% of expansion is explained by an increase in palm oil exports and 19% by an increase of nonfood domestic consumption. For rubber, 96% of the expansion is due to an increase in exports. Finally, for nuts, most of the expansion results from an increase in internal demand for food. Pasture expansion is mainly driven by the increase in the domestic consumption of milk and red meat despite an increase in the cattle productivity per head over the period 2020-2030.

Figure 1 | Evolution of area by land cover type and protected areas under each pathway



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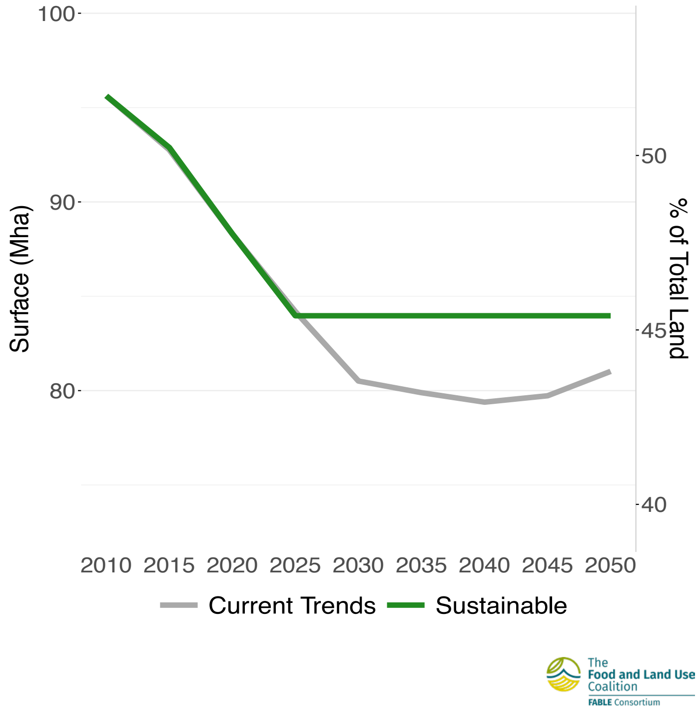
Note. Other land includes bare soil, ice, and all land areas that do not fall into any of the other five categories
Source. Authors' computation based on National land cover map of Indonesia for the area by land cover type for 2000, (KLHK, 2019)

Between 2030-2050, the increase in pasture area is explained by a continued increase in the domestic consumption of milk and red meat coupled with the relative stabilization of cattle productivity. Over the same period, cropland reduction is explained by a decrease in the level of palm oil production combined with an increase in productivity of oil palm trees. Despite our initial assumptions of strong growth in exports, palm oil exports are cut by 8% in 2050 compared to 2030 after trade adjustment. This is due to global imports for palm oil only growing by 5% even though Malaysia also projected large increases in their palm oil exports, which led to a large over-estimation of palm oil exports globally. Moreover, the reduction in corn area is explained by the fact that we assume a very large increase in productivity that leads to land savings combined with continuously higher production. The same is true for rice though the assumed growth in productivity is lower. This results in a reduction of land where natural processes predominate by 16 % by 2030 and by 15% by 2050 compared to 2010, respectively (Figure 2).

Figure 2 | Evolution of the area where natural processes predominate



In the Sustainable Pathways, assumptions on agricultural land expansion and reforestation have been changed to reflect the strong ambition of the Government of Indonesia to reduce deforestation under presidential instruction. The main assumptions include the prevention of deforestation by 2030 and 5.5 Mha reforestation/afforestation by 2050 (see Annex 2).

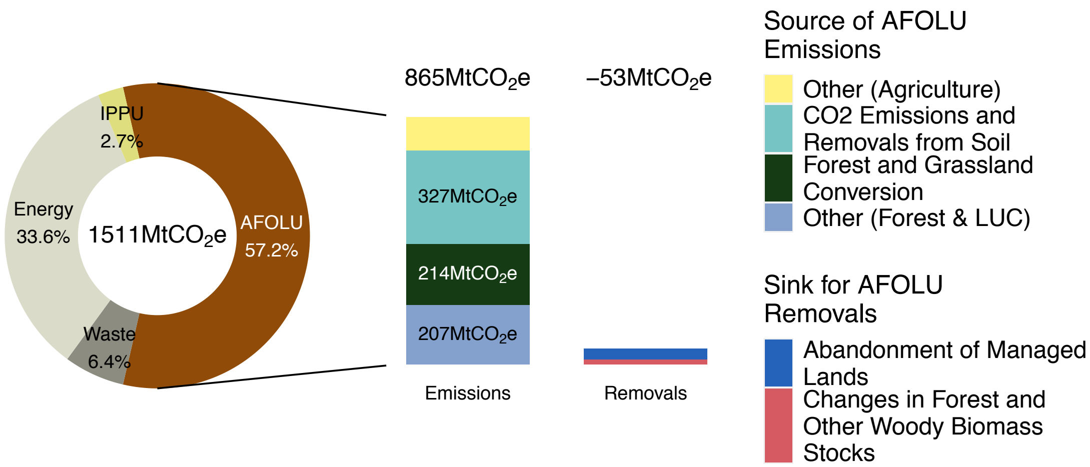
Compared to the Current Trends Pathway, we observe the following changes regarding the evolution of land cover in Indonesia in the Sustainable Pathway: (i) 10 Mha of avoided deforestation between 2030 and 2050, (ii) a 1% increase in the total land where natural land processes predominate, reaching 45% in 2050, (iii) limiting pasture area expansion to 1.3 Mha between 2030 and 2050, and (iv) increasing reforested/afforested land. The prevention of deforestation is equivalent to preventing any agricultural expansion as the area classified as other natural land is already at the minimum (i.e. within protected areas in the model). Palm oil exports are further reduced compared to the Current Trends pathway due to lower international demand for palm oil in the Sustainable pathway. Additionally, increases in the productivity of rice also contributes to the differences between the *Current Trends* and *Sustainable* pathways. These changes lead to the stabilization in the area where natural processes predominate after 2025 (Figure 2).

GHG emissions from AFOLU

Current State

Direct GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) accounted for 57.2% of total emissions in 2012 (Figure 3). Forest and grassland conversion is the principle source of AFOLU emissions, followed by CO_2 emissions and removals from soil (peatland). This can be explained by oil palm estate expansion, rice cultivation, and rubber plantation expansion into forests, including on peatland between 1990 and 2000, the expansion of pulp and paper and sawn timber plantations after 2000, and transmigration policies and illegal logging (Margono et al., 2012).

Figure 3 | Historical share of GHG emissions from Agriculture, Forestry, and Other Land Use (AFOLU) to total AFOLU emissions and removals by source in 2012



Note. IPPU = Industrial Processes and Product Use
Source. Adapted from Indonesia's First Biennial Update Report (Republic of Indonesia, 2015)

Pathways and Results

Under the Current Trends Pathway, annual GHG emissions from AFOLU increase from 863 Mt in 2015 to 1,291 Mt in 2030 before decreasing to 989 Mt in 2050 (Figure 4). In 2050, land-use conversion is the largest source of emissions (602 Mt CO_2e/yr from deforestation and 527 Mt CO_2e/yr from peat in 2030) while land also acts as a small sink (-10 Mt CO_2e/yr in 2030). Over the period 2020-2050, the strongest relative increase in GHG emissions is computed for emissions from livestock and peat while emissions from deforestation decrease over time (-66%).

In comparison, the Sustainable Pathway leads to a reduction of AFOLU GHG emissions by 45% by 2050 compared to the Current Trends Pathway (Figure 4). The potential emissions reductions under the Sustainable Pathway are dominated by a reduction in GHG emissions from deforestation, peat, and livestock (Figure 5). Efforts on stopping deforestation by 2030 and changing diets are the most important drivers of this reduction. Indonesia's commitments under UNFCCC (Table 1) are to reduce total GHG emissions by 29% by 2030 and up to 41% compared to a BAU equivalent, or 522 Mt CO_2e/yr and 738 Mt CO_2e/yr, respectively. Our results show that AFOLU emissions could be reduced by 689 Mt CO_2e/yr by 2030 compared to BAU in 2030. This suggests that the reduction of GHG emissions AFOLU sector could allow for some increase of emissions in other sectors.

Figure 4 | Projected AFOLU emissions and removals between 2010 and 2050 by main sources and sinks for the Current Trends pathway

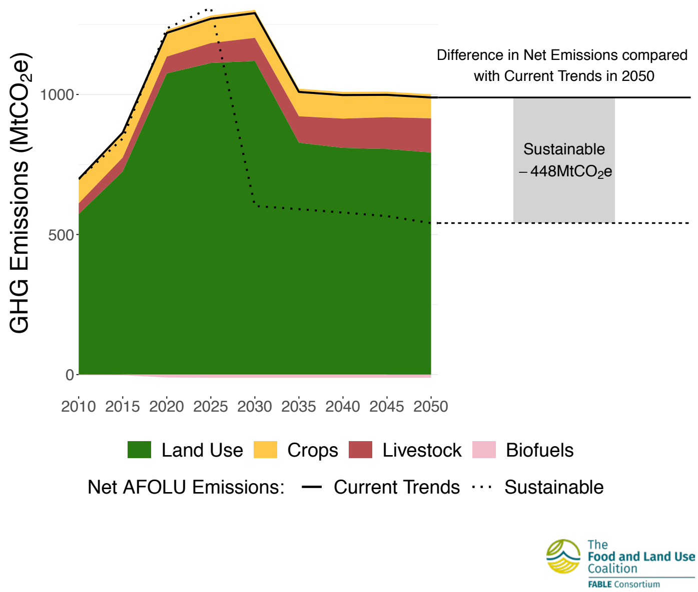
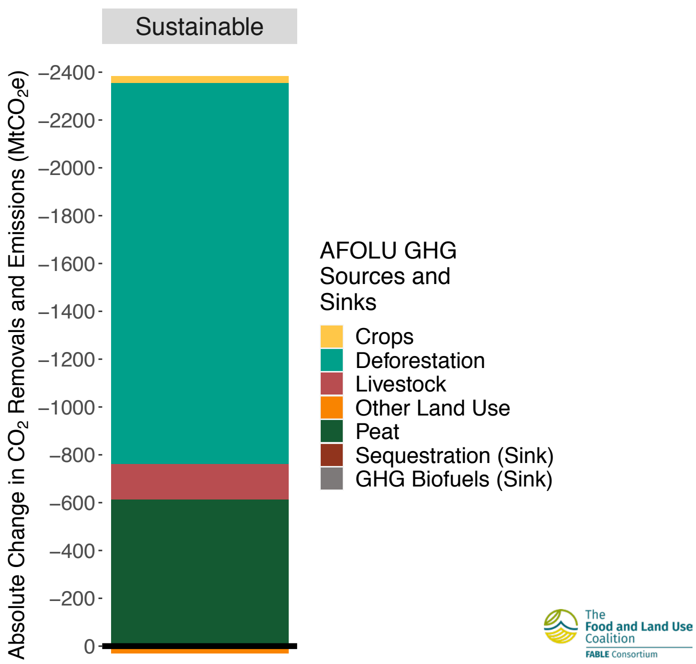


Figure 5 | Cumulated GHG emissions reduction computed over 2020-2050 by AFOLU GHG emissions and sequestration source compared to the Current Trends Pathway



Food Security

Current State

Undernutrition

7.6% of the population undernourished in 2014 - 2016. This share has decreased since 2011 (FAO, 2017b).

36.4% of children under 5 stunted and 12.1% wasted in 2015 (UNICEF, 2017).

Micronutrient Deficiency

33% of women and 23% of children suffer from anemia in 2010, which can lead to maternal death (Institute for Health Metrics and Evaluation [IHME], 2020).

16.7% of the population are deficient in vitamin A (IHME, 2020), which can notably lead to blindness and child mortality, and 0.5% are deficient in iodine, which can lead to developmental abnormalities (IHME, 2020).

Overweight/ Obesity

28% of the population, and 11% of adolescent girls and 11% of adolescent boys were overweight in 2018 (Maehara et al., 2019). These shares have increased since 2015 (Harbuwono, Pramono, Yunir, & Subekti, 2018).

33% of adults and 9.4% of children, were overweight in 2014. These shares have increased since 1994 (Oddo, Maehara, & Rah, 2019).

Disease Burden due to Dietary Risks

14.1% of the population suffers from diabetes and 4.6% from cardiovascular diseases, which can be attributable to dietary risks (IHME, 2020).

Table 3 | Daily average fats, proteins and kilocalories intake under the Current Trends and Sustainable Pathways in 2030 and 2050

	2010	2030		2050	
	Historical Diet (FAO)	Current Trends	Sustainable	Current Trends	Sustainable
Kilocalories (MDER)	2,570 (2,058)	2,482 (2,080)	2,313 (2,080)	2,437 (2,084)	2,412 (2,084)
Fats (g) (recommended range)	50 (57-85)	57 (55-83)	52 (51-77)	66 (54-81)	64 (53-80)
Proteins (g) (recommended range)	57 (64-224)	62 (62-217)	59 (57-202)	68 (61-213)	67 (60-211)

Notes. Minimum Dietary Energy Requirement (MDER) is computed as a weighted average of energy requirement per sex, age class, and activity level (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015) and the population projections by sex and age class (UN DESA, 2017) following the FAO methodology (Wanner et al., 2014). For fats, the dietary reference intake is 20% to 30% of kilocalories consumption. For proteins, the dietary reference intake is 10% to 35% of kilocalories consumption. The recommended range in grams has been computed using 9 kcal/g of fats and 4kcal/g of proteins.

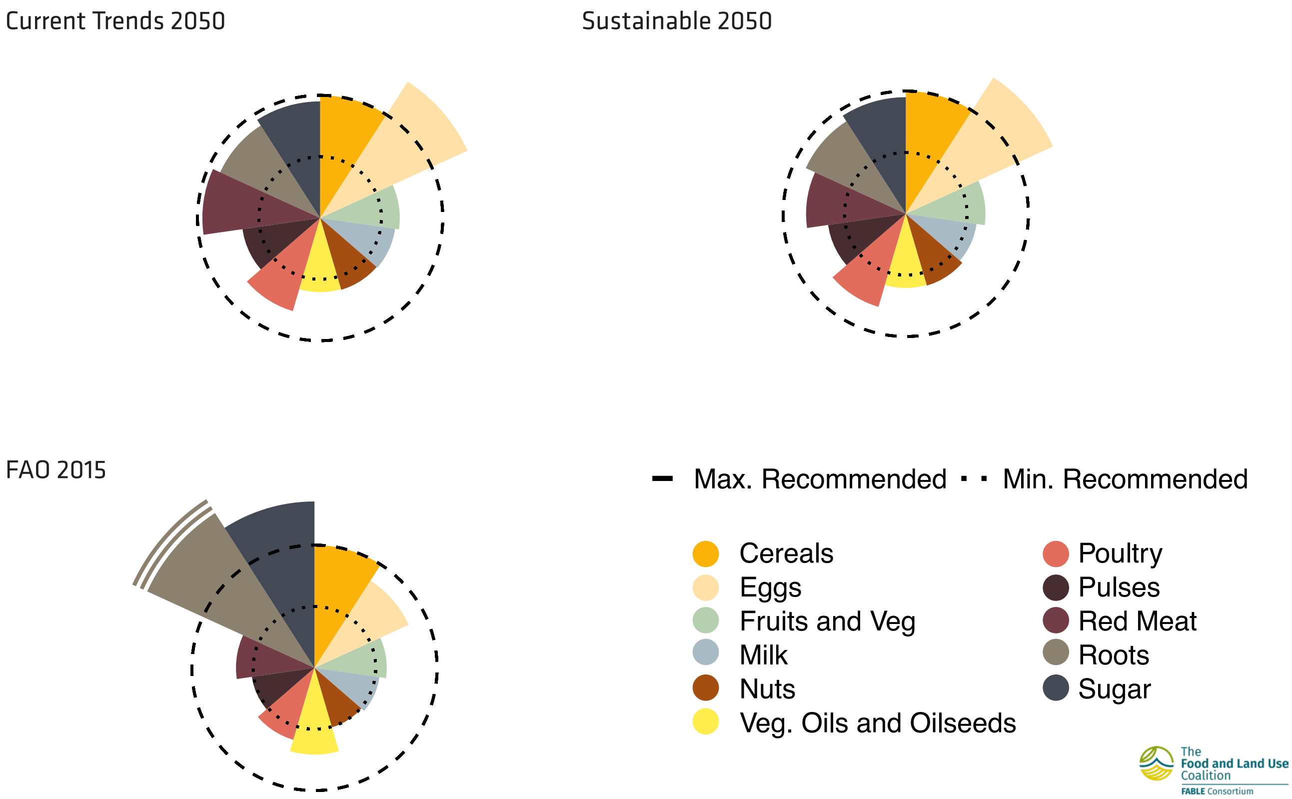
Pathways and Results

In both pathways, we base our diet scenarios on the historical energy consumption intake in 2017 as reported by the National Food Security Agency, which made these calculations following Indonesia's Targeted Food Pattern (PPH) (Satriani & Martianto, 2019). The PPH is composed of 9 food groups that we included in the FABLE Calculator in effort to provide more detailed dietary scenarios that reflect these groups. When the PPH value was not available for certain commodity groups, we took historical consumption data.

Under the Current Trends Pathway, compared to the average Minimum Dietary Energy Requirement (MDER) at the national level, our computed average calorie intake is 19% higher in 2030 and 17% higher in 2050 (Table 4). The current average intake is mostly satisfied by cereals, oil and fat, and fruit and vegetables. Animal products represent only 10% of the total calorie intake. We assume that the per capita kilocalorie consumption of animal products including fish, will increase by 68% between 2020 and 2050. The consumption of oil and fat, and nuts will also increase while cereals, sugar, and roots consumption will decrease. Compared to the EAT-Lancet recommendations (Willett et al., 2019), in 2015 roots consumption is above and cereals and sugar are close to the maximum recommended. By 2050, only eggs are over the maximum recommended, while cereals just reach the maximum limit (Figure 6). Moreover, there is an increasing demand for milk consumption but it remains within the recommended range.

Under the Sustainable Pathway, we assume similar diets compared to the Current Trends Pathway. However, compared to the Current Trends, the ratio of the computed average intake over the MDER decreases to 11% in 2030 and 15% in 2050. This is explained by the fact that in the Sustainable pathway we applied a zero deforestation policy after 2030. Since other natural land is already at the minimum level (i.e. only found within protected areas), agricultural land cannot expand after 2030. This penalizes livestock production in particular, and, in the absence of further productivity gains or increases in the imports of livestock products, the internal consumption for livestock products has to be reduced. Compared to the EAT-*Lancet* recommendations, the consumption of red meat is still within the recommended range and is now closer to the average recommended daily intake in 2050 (Figure 6). Moreover, the fat and protein intake per capita are in line with the dietary reference intake (DRI) in 2030, showing a slight decrease compared to the Current Trends Pathway but remaining within recommended boundaries (Figure 6).

Figure 6 | Comparison of the computed daily average kilocalories intake per capita per food category across pathways in 2050 with the EAT-Lancet recommendations



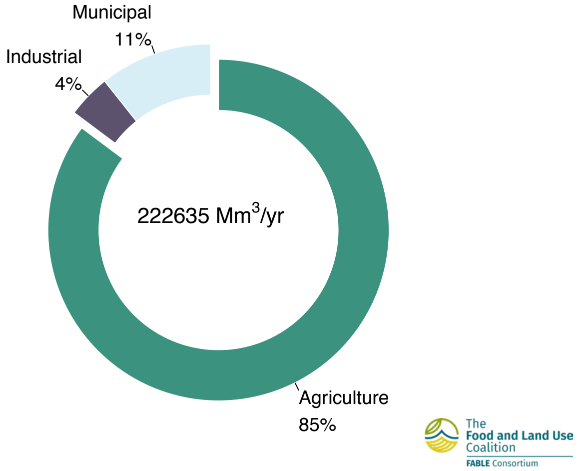
Notes. These figures are computed using the relative distances to the minimum and maximum recommended levels (i.e. the rings), therefore different kilocalorie consumption levels correspond to each circle depending on the food group. The EAT-Lancet Commission does not provide minimum and maximum recommended values for cereals: when the kcal intake is smaller than the average recommendation it is displayed on the minimum ring and if it is higher it is displayed on the maximum ring. The discontinuous lines that appear at the outer edge of roots indicate that the average kilocalorie consumption of this food category is significantly higher than the maximum recommended.

Water

Current State

Indonesia is characterized by a tropical climate, with 2,702 mm average annual precipitation that mostly occurs between December to March. The agricultural sector represented 85.2% of total water withdrawals in 2016 (Figure 7). Moreover in 2013, 17% to 20% of agricultural land was equipped for irrigation. Irrigation water demand is estimated at 5,441 m^3/s (Asian Development Bank, 2016). Rice occupies 80% of total harvested irrigated area, with corn, groundnuts, soybean, and vegetables mostly accounting for the rest (AQUASTAT 2005).

Figure 7 | Water withdrawals by sector in 2016

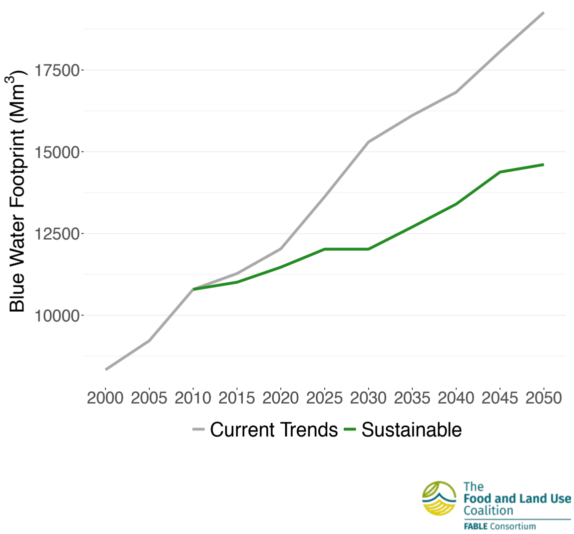


Source. Adapted from AQUASTAT Database (FAO, 2017b)

Pathways and Results

Under the Current Trends Pathway, blue water use increases between from 11,273 Mm^3/yr in 2015, to 15,297 Mm^3/yr and 19,261 Mm^3/yr in 2030 and 2050, respectively (Figure 8), with rice, corn, and sugarcane accounting for 79%, 9%, and 6% of computed blue water use for agriculture by 2050[3]. In contrast, under the Sustainable Pathway, the blue water footprint in agriculture reaches 12,019 Mm^3/yr in 2030 and 14,607 Mm^3/yr in 2050, respectively. We did not assume a change in the water efficiency, and the production level of the main irrigated commodities does not significantly change between the Current Trends and the Sustainable pathways. Therefore, this change is solely driven by the estimated impact of climate change on water demand: under the Current Trends pathway, we assume a higher concentration pathway than in the Sustainable pathway at the global level (RCP 6.0 vs RCP 2.6) (see Annex 2). According to the national average estimates from the GEPIC crop model using climate inputs from the climate model hadgem2, the per tonne irrigation water use would increase by more than 30% in 2050 compared to 2010 for corn and rice under the Current Trends pathway while it would stay constant for corn and only increase by 11% for rice.

Figure 8 | Evolution of blue water footprint in the Current Trends and Sustainable Pathways



3 We compute the blue water footprint as the average blue fraction per tonne of product times the total production of this product. The blue water fraction per tonne comes from Mekonnen and Koekstra (2010a, 2010b, 2011). In this study, it can only change over time because of climate change. Constraints on water availability are not taken into account.

Resilience of the Food and Land-Use System

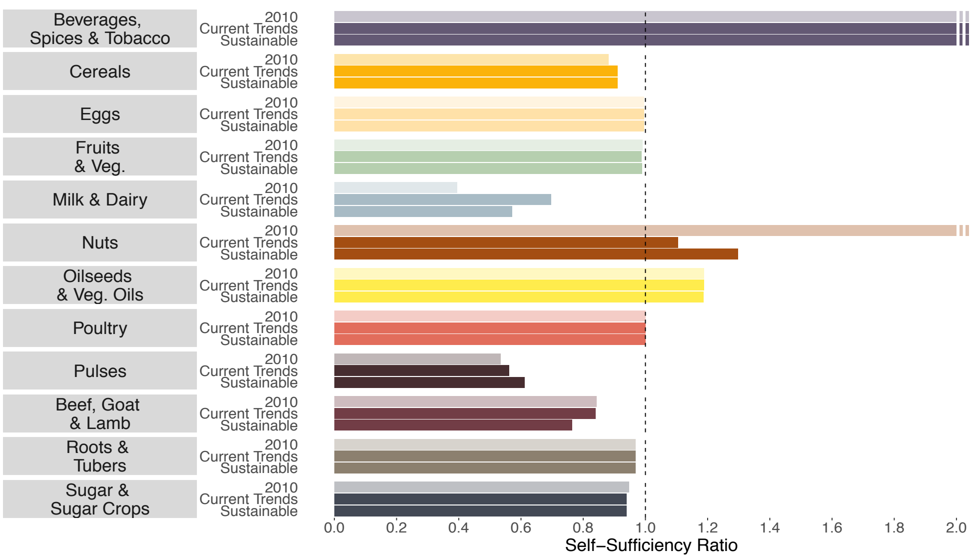
The COVID-19 crisis exposes the fragility of food and land-use systems by bringing to the fore vulnerabilities in international supply chains and national production systems. Here we examine two indicators to gauge Indonesia's resilience to agricultural-trade and supply disruptions across pathways: the rate of self-sufficiency and diversity of production and trade. Together they highlight the gaps between national production and demand and the degree to which we rely on a narrow range of goods for our crop production system and trade.

Self-Sufficiency

The 2012 Indonesian law on food regulates the pursuit of food security and self-sufficiency of certain key commodities, rice, maize, sugar, soybean, and beef.

Under the Current Trends Pathway, we project that Indonesia would be self-sufficient in eggs, fruits and vegetables, nuts, oilseed and vegetable oils, and poultry meat in 2050, with self-sufficiency by product group remaining stable for the majority of products from 2010 to 2050 (Figure 9). The product groups where Indonesia would depend the most on imports to satisfy internal consumption are cereals, milk and dairy, pulses, and red meat. By 2050, Indonesia would be 80% self-sufficient in cereals and red meat and less than 50% self-sufficient in pulses and milk and dairy. These trends are similar in the Sustainable Pathway, with the exception of milk and red meat, for which self-sufficiency would decrease, and pulses, for which it would increase, by 2050. Among the specific commodities for which Indonesia aims to achieve self-sufficiency (rice, maize, sugar, soybean, and beef), only soybean and sugar would not achieve this target by 2050. Finally, the self-sufficiency ratio for beef is reduced in 2050 by 12% in the Sustainable pathway. This is explained by the reduction in cattle production, which is due to stronger restrictions on the expansion of agricultural land.

Figure 9 | Self-sufficiency per product group in 2010 and 2050



Note. In this figure, self-sufficiency is expressed as the ratio of total internal production over total internal demand. A country is self-sufficient in a product when the ratio is equal to 1, a net exporter when higher than 1, and a net importer when lower than 1. The discontinuous lines on the right side of this figure, as appear for beverages, spices and tobacco and nuts, indicate a high level of self-sufficiency in these categories.

Diversity

The Herfindahl-Hirschman Index (HHI) measures the degree of market competition using the number of firms and the market shares of each firm in a given market. We apply this index to measure the diversity/concentration of:

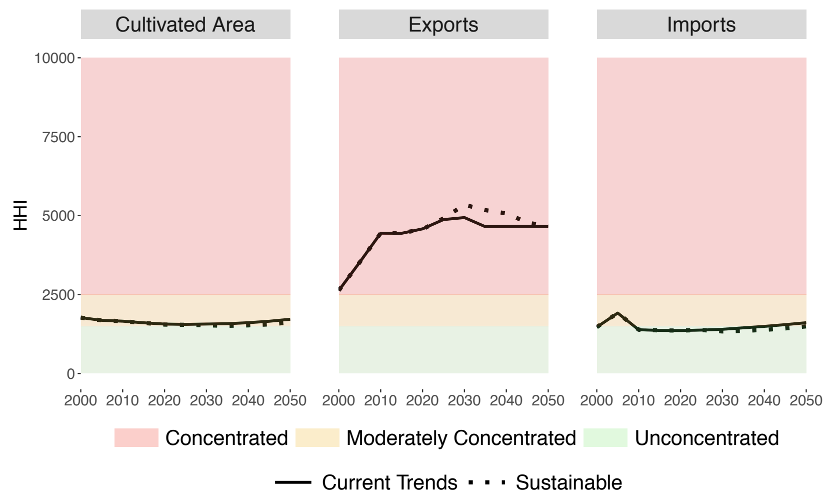
- **Cultivated area:** where concentration refers to cultivated area that is dominated by a few crops covering large shares of the total cultivated area, and diversity refers to cultivated area that is characterized by many crops with equivalent shares of the total cultivated area.
- **Exports and imports:** where concentration refers to a situation in which a few commodities represent a large share of total exported and imported quantities, and diversity refers to a situation in which many commodities account for significant shares of total exported and imported quantities.

We use the same thresholds as defined by the U.S. Department of Justice and Federal Trade Commission (2010, section 5.3): diverse under 1,500, moderate concentration between 1,500 and 2,500, and high concentration above 2,500.

In 2010, 5 crops represented 79% of the cultivated area with shares of total cropland area varying between 2% and 15% for, by order of importance, rice, rubber, oil palm, corn, and coconut. For imports, four commodities (wheat, milk, soyabean, and soycake) represented 62% of the total volume of imported commodities. Finally, Indonesia exported low quantities of palm oil and rubber, two major commodities, which already represent 74% of the total volume of exported crops.

Under the Current Trends Pathway, we project high concentration of crop exports, a medium to low concentration of imports, and a medium to low concentration of planted crops in 2050, trends which slightly increase between 2010 and 2050. This indicates moderate to high levels of diversity across the national production system and for imports, but low diversity for exports. Under the Sustainable Pathway, our results remain similar to the Current Trends pathway, except for the projection of higher concentration of crop exports compared with the Current Trends pathway, in which they peaked between 2025 and 2045 (Figure 10).

Figure 10 | Evolution of the diversification of the cropland area, crop imports and crop exports of the country using the Herfindahl-Hirschman Index (HHI)



Discussion and Recommendations

The Current Trends and Sustainable Pathways presented in this chapter show two alternative futures for land use and food systems in Indonesia. Under the Current Trends Pathway, we projected medium population growth (from 270 million in 2020 to 324 million in 2050), with no constraints on agricultural expansion, a 2 million hectare afforestation target, no change in the extent of protected areas, high productivity increases in the agricultural sector, and no change in diets. In contrast, under the Sustainable Pathway, there are significant efforts to adopt sustainable policies reflecting the strong ambition of the Government of Indonesia.

In terms of land and biodiversity, we find that under the Current Trends Pathway, deforestation will continue to increase in the future due to increases in cropland and pasture areas, while reforestation will be limited to 2 million hectares. In contrast, under the Sustainable Pathway, we assumed the implementation of zero-deforestation policies by 2030 and increased the reforestation target to 5.5 million hectares, which leads to a net gain in forested land after 2030 and an increase in total land where natural processes predominate.

Currently, Indonesia's agricultural sector is highly fragmented, it comprises large plantations, both state-owned and private enterprises, and small-scale farmers. Plantation areas are dominated by export commodities such as oil palm and rubber, while staple crops are dominated by rice, maize, and cassava. Low productivity issues for staple goods have been a major concern for Indonesia's food security and increasing crop productivity and cropping intensity are the main targets for the agricultural sector to reduce demand for land. Indonesia's agricultural policy aims to increase agricultural productivity (non-oil palm commodities) by 4% per year (LCDI, 2019). The low productivity of agricultural staple crops in Indonesia is due the large number of "petani gurem" or smallholder farmers with less than 0.5 hectares of land. One problem faced by smallholder farmers is agricultural land conversion to non-agricultural land. In addition, many smallholder farmers have to transition from a situation where they operate their own land to a one where they either rent or share ownership. Another problem that leads to low agricultural productivity is that many farmers still practice slash and burn (shifting cultivation) in forest areas, which contributes to forest loss and it is the main cause of land degradation.

Two government programs could be especially helpful to smallholder farmers in the future, the Tanah Objek Reforma Agraria (TORA) program and Social Forestry (SF). Under the TORA program, a community is provided legal certainty over land ownership. Farmers with legal ownership of land will have access to government subsidies, credit, and extension services for supporting their farming activities. Under the SF program, local communities can manage forest themselves, including for agroforestry or timber plantations. The government targeted approximately 4.1 million hectares of land distributed through the TORA program me and 12 million hectares of forest area for SF. These programs will contribute to increasing crop production.

In the Sustainable Pathway, there is a 45% reduction in GHG emission by 2050 that comes from reduced deforestation, well-managed peat, and improved livestock productivity. Restrictions on deforestation are the important drivers of this reduction in our model. The Mitigation Action and Emission Reduction Target in National Action Plan – Green House Gas (RAN-GRK) from the Indonesian government lists the following actions to reduce emissions in the agriculture and forestry sectors: (i) sustainable forestry, (ii) avoiding deforestation and degradation, (iii) reforestation, and (iv) land optimization (NDC, 2017). The realization of these actions will play a key role in reducing GHG emissions in Indonesia. Indonesia has taken a significant step towards a moratorium on new licences to protect primary forests and peatlands conversion. This moratorium provides legal rights of villagers, smallholders, and forest protection and provides the opportunity to undertake critical forest governance and agricultural and land-use reforms.

Our findings suggest that the implementation of no-deforestation policies might reduce food availability if not accompanied by other measures. The adoption of dietary changes that follow the national dietary guidelines of Indonesia might be part of the solution. The country's new Food Development Strategy for 2020-2024 also includes a national reduction strategy for food loss and waste. We will include these two components into our future analyses.

Water is also crucial to support food security. The climate change impact estimates that we used suggest that Indonesia might suffer from a reduction in precipitation under RCP 6.0 (Current Trends Pathway) leading to a large increase in water use for irrigation. While we have only used one crop model and one climate model in this analysis, we recognize that uncertainties related to future climate change may be large. We will complement our analysis with additional estimates from other crop and climate models to evaluate the level of confidence about future climate change impacts on agriculture in Indonesia.

The new regulation on water resources in Indonesia states its priorities to increase access for daily needs and estate crops agriculture (GoI, 2019). In the future, Indonesia may see increasing blue water usage to tackle its low crop productivity. Restoring critical watersheds and sources with regulation that controls water usage can lead to improved water efficiency in Indonesia.

Limitations were also recognized in our models. We are aware of the challenges on data collection and availability to build the scenarios and assumptions to complete the analysis of the FABLE Calculator. The implementation of One-Map policy of the Government of Indonesia may be of interest to feed into our future efforts in modeling the pathways for a sustainable land-use system that can support decision making on land reforms and agricultural developments in Indonesia.

Further improvements to our Sustainable Pathway will require exchange and knowledge sharing with others in the modeling community. In this light, the FABLE Indonesian team is building a community of practice on land-use modeling. This community of practice acts as a hub to create future opportunities for information exchanges, network building, and discussion around the FABLE domains. It brings together all modeling activities undertaken in Indonesia to support long-term strategies such as the LCDI and other sustainability objectives. Through these efforts, we will continue to further improve our analysis and ignite discussions on the modeling of food and land use systems to provide support to The Government of Indonesia. Due to the large heterogeneity of Indonesian landscapes and strong decentralization, in the future we would also like to adapt the FABLE Calculator to the sub-national level, including island-wide analyses. Through this, we can engage provincial level governments in developing a food and land component to various sustainable pathways.

Annex 1. List of changes made to the model to adapt it to the national context

- Making use of National Population Projection up to 2035, including comparing it with population projections.
- Using national land cover map of Indonesia, which has been aggregated to the FAO class land (KLHK, 2019)
- Taking GDP projections from the National Medium Term Development Plan (RPJMN) from Bappenas for Current Trends pathway
- Adapting the dietary scenario to the national context by drawing on data from the Indonesia Self-Sufficiency Institute
- Adding peat classification and ensuring that peat decomposition is taken into account.

Annex 2. Underlying assumptions and justification for each pathway

POPULATION Population projection (million inhabitants)

Current Trends Pathway	Sustainable Pathway
Estimated increase from 302.86 million people in 2035 to 323.57 million people in 2050. According to the national demographic projection, it is estimated that, in 2035, Indonesia will have 305.6 Million people. Scenario selected showed realistic percentage growth according to national statistics (Badan Pusat Statistik, 2018). (UN_InstantReplacement scenario selected)	Same as Current Trends. We consider no change because the current projections already meet the numbers of national projection until 2035 and are thus in line with national statistics.

LAND Constraints on agricultural expansion

Current Trends Pathway	Sustainable Pathway
No further regulation on land conversion in forestry area. Currently, there seems to be a low coordination between all stakeholders which creates a situation non-conducive to reform and enforcement of the regulation on palm oil moratorium (Anderson, Kusters, McCarthy, & Obidzinski, 2016). These scenarios describe the future of uncontrolled expansion.	High level of enforcement in forestry sector to target zero deforestation in 2030. Indonesia is increasing enforcement and building coordination between levels of governance and stakeholders creating less conflict on the regulation of moratorium of new permits or licenses in some types of forest area and peatland.

LAND Afforestation or reforestation target (1000 ha)

Current Trends Pathway	Sustainable Pathway
Afforestation/Reforestation target inline according to Bonn Challenge with 2 Mha forest replanted.	Indonesia's implementation on Land Restoration and Rehabilitation Target is enforced. Adding 5.5 Mha of rehabilitated land to natural habitat, including forest. According to RPJMN 2020 -2024 (Bappenas, 2019). This scenario assumes that forest and land rehabilitated target for 2020 is 5.5 Mha and 1.9 Mha would be achieved.

BIODIVERSITY Protected areas (1000 ha or % of total land)

Current Trends Pathway	Sustainable Pathway
Total protected areas remain constant to 2050 at 22.5 Mha (Bappenas 2019).	The by-default assumption in the FABLE Calculator were used, which is that in the ecoregions where current level of protection is between 5% and 17%, the natural land area under protection increases up to 17% of the ecoregion total natural land area by 2050.

PRODUCTION Crop productivity for the key crops in the country (in t/ha)

Current Trends Pathway	Sustainable Pathway
Estimated productivity for key crops between 2015 and 2050: 1. Palm oil fruit: 17t/ha to 24 t/ha 2. Rice: 3,4t/ha to 4,8t/ha 3. Corn: 4.6t/ha to 16.7 t/ha 4. Soybean: 1.4t/ha to 2.2t/ha 5. Sugarcane: 61.7t/ha to 87.8t/ha Indonesia's national statistics reported productivity for selected commodities in 2015: 1. Rice: 5,152 t/ha 2. Corn: 4.84 t/ha 3. Soybean: 1,416 t/ha Differences with national data on production still remain, but estimated productivity captured national values of Indonesian data for selected commodities	Same as Current Trends The Current Trends pathways values of productivity for major crops in Indonesia, such as corn and soyabean, are in the range of national historical values, thus we opted to make no change on the productivity scenario.

PRODUCTION Livestock productivity for the key livestock products in the country (in t/head of animal unit)

Between 2015 and 2050, the productivity per head range: 1. Beef: 0.043 t/TLU to 0.044 t/TLU 2. Chicken: 0.282 t/TLU to 0.506 t/TLU 3. Milk: 2,175 t/TLU to 2,257 t/TLU	Same as Current Trends There are no official records of productivity projection in Indonesia between 2015 and 2050, but Indonesia's target on self-sufficiency mentions beef products. Increasing production and productivity of beef is included in The Ministry of Agriculture strategy to empower food sovereignty (Sulaiman, Subagyono, Soetopo, Sulihanti, & Wulandari, 2018)

PRODUCTION Pasture stocking rate (in number of animal heads or animal units/ha pasture)

The average livestock stocking density remains constant at 1.89 TLU/ha of pasture between 2015 and 2050. We assume no change for the pasture stocking rate scenario	Same as Current Trends We have not found national data for comparison. Therefore, we make assumptions that are in line with 6 Strategic Targets from The Ministry of Agriculture (The Ministry of Agriculture Republic of Indonesia, 2015) .

PRODUCTION Post-harvest losses

We assume a 50% decrease in the share of post-harvest losses between 2010 and 2050 Based on the Ministry of Agriculture, which has set the following national targets on post-harvest loss of major crops: Rice: from 10.48% (baseline) to a 0.4 % decrease in 2019 Corn: from 4.81% (baseline) to a 0.9% decrease in 2019 Soyabean: from 14.7% (baseline) to a 1.3% decrease in 2019 Cassava: from 11.58% (baseline) to a 0.3% decrease in 2019 Decreasing the share of post-harvest loss through good handling practices was included in the Strategic Targets of Agriculture Development (Direktorat Pascapanen Tanaman Pangan, 2015)	Same as Current Trends The national targets on post-harvest losses are only available until 2019. Therefore, we assume a 50% decrease between 2010 and 2050, which is in line with national goals.

TRADE Share of consumption which is imported for key imported products (%)

Current Trends Pathway	Sustainable Pathway
The share of total consumption which is imported between 2015 and 2050: 1. For rice: a decrease from 1.58% to 0.85% 2. For corn: a decrease from 8.8% to 4.7% 3. For soyabean: an increase from 58.6% to 68.8% National Ambition in self-sufficiency of selected crops.	Same as Current Trends Values in Current Trends pathways captures the national ambition of reaching self-sufficiency in selected strategic crops.

TRADE Evolution of exports for key exported products (1000 tons)

Current Trends Pathway	Sustainable Pathway
The exported quantity increases between 2015 and 2050: 1. Palm Oil: from 24 Mt to 45 Mt 2. Rubber: from 2.8 Mt to 4 Mt Based on national data from the Ministry of Agriculture, in 2015 Indonesia exported 26.5 Mt of palm oil and 2.6 Mt of rubber. Increasing exports on major commodity such as palm oil and rubber is mentioned in national agendas (The Ministry of Agriculture Republic of Indonesia, 2015)	Same as Current Trends Different results showed in the calculation can be explained by the implementation of land scenarios.

FOOD Average dietary composition (daily kcal per commodity group or % of intake per commodity group)

Current Trends Pathway	Sustainable Pathway
Indonesia's kcal consumption requirement (AKE) in 2018 is (in kcal/cap/day): Grains/rice: 1,315 Tubers: 53 Meat: 233 Oil and fat: 240 Oily fruit/seeds: 22 Nuts: 60 Sugar: 78 Vegetables and fruits: 113 Others: 52	Same as in Current Trends

FOOD Share of food consumption which is wasted at household level (%)

Current Trends Pathway	Sustainable Pathway
Between 2015 and 2050, the share of final household consumption which is wasted decreases from 10% to 5%. There is no official record or research on food waste targets in Indonesia. We; nevertheless, assume increasing commitments from the government by 2050.	Same as Current Trends

Indonesia

BIOFUELS Targets on biofuel and/or other bioenergy use

Current Trends Pathway	Sustainable Pathway
Based on by-default OECD projections. Palm oil is still the major crop for producing biodiesel in Indonesia. According to the National Development Plan, biofuel by 2020, 2025 and 2050 are targeted to reach 7.7 MKL, 10.8 MKL, and 54.6 MKL (Metric Kilo Litre) respectively (Bappenas, 2019). Meanwhile. there is a strong regulation on blending (B30) that requires 30% blending of biodiesel with Diesel Oil to stimulate the renewable energy sector in Indonesia.	Same as Current Trends Currently, the given scenario reflects the ambition of Indonesia to increase the usage of biofuel nationally.

CLIMATE CHANGE Crop model and climate change scenario

Current Trends Pathway	Sustainable Pathway
We assumed a global GHG concentration trajectory that would lead to a radiative forcing level of 6 W/m2 by 2100 (RCP 6.0). The model includes the corresponding climate change impacts on crop yields by 2050 as estimated with GEPIC crop model for corn, rice, and soybean.	We assumed a global GHG concentration trajectory that would lead to a lower radiative forcing level of 2.6 W/m2 by 2100 (RCP 2.6), in line with limiting warming to 2°C.

Annex 3. Correspondence between original ESA CCI land cover classes and aggregated land cover classes displayed on Map 1

FABLE classes	ESA classes (codes)	National Land Cover Map
Cropland	Cropland (10,11,12,20), Mosaic cropland>50% - natural vegetation <50% (30), Mosaic cropland><50% - natural vegetation >50% (40)	Shrubs, Estate Crops,Swampy Shrubs, Dryland Agriculture, Mixed Dryland Agriculture, Paddy Field
Forest	Broadleaved tree cover (50,60,61,62), Needleleaved tree cover (70,71,72,80,82,82), Mosaic trees and shrub >50% - herbaceous <50% (100), Tree cover flooded water (160,170)	Primary Dryland Forest, Secondary Dryland Forest, Primary Mangrove Forest, Secondary Mangrove Forest, Primary Swamp Forest, Secondary Swamp Forest, Plantation Forest
Grassland	Mosaic herbaceous >50% - trees and shrubs <50% (110), Grassland (130)	Settlements, Savanna/Grass, Transmigration
Other land	Shrubland (120,121,122), Lichens and mosses (140), Sparse vegetation (150,151,152,153), Shrub or herbaceous flooded (180)	Bare Land,Airport, Mining
Bare areas	Bare areas (200,201,202)	
Snow and ice	Snow and ice (220)	
Urban	Urban (190)	
Water	Water (210)	

Annex 4. Overview of biodiversity indicators for the current state at the ecoregion level[4]

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with at > 10% natural vegetation within 1km²(%)
136	Banda Sea Islands moist deciduous forests	690,6	15,1	74,8	18,3	81,7	134,9	60,7
137	Biak-Numfoor rain forests	257,1	18,6	72,6	23,8	76,2	18,8	73,4
138	Buru rain forests	849,0	0,8	68,5	1,1	98,9	186,9	61,9
139	Central Range Papuan montane rain forests	7.500,1	28,2	90,8	29,7	70,3	160,9	90,5
140	Halmahera rain forests	2.549,1	8,1	80,7	10,0	90,0	79,2	78,0
148	Northern New Guinea lowland rain and freshwater swamp forests	5.966,4	23,3	92,6	22,8	77,2	94,1	76,7
149	Northern New Guinea montane rain forests	1.666,7	20,4	94,0	20,2	79,8	24,2	57,1
151	Seram rain forests	1.879,0	10,6	79,8	13,3	86,7	128,7	74,0
154	Southern New Guinea freshwater swamp forests	5.037,1	17,0	87,2	19,1	80,9	267,2	77,4
155	Southern New Guinea lowland rain forests	7.582,8	7,1	90,6	7,8	92,2	301,1	78,9
156	Sulawesi lowland rain forests	11.323,5	7,3	45,9	14,8	85,2	3.559,2	42,4
157	Sulawesi montane rain forests	7.597,8	14,8	79,5	18,4	81,6	929,4	60,3
160	Vogelkop montane rain forests	2.166,4	57,0	95,8	58,6	41,4	13,7	89,0
161	Vogelkop-Aru lowland rain forests	7.433,3	8,9	88,9	9,2	90,8	163,9	76,7
162	Yapen rain forests	234,4	48,4	87,3	55,3	44,7	0,5	99,2
163	Lesser Sundas deciduous forests	3.838,1	7,6	42,1	17,0	83,0	1.495,6	52,9
165	Sumba deciduous forests	1.071,2	9,0	21,3	41,2	58,8	618,9	56,2

4 The share of land within protected areas and the share of land where natural processes predominate are percentages of the total ecoregion area (counting only the parts of the ecoregion that fall within national boundaries). The shares of land where natural processes predominate that is protected or unprotected are percentages of the total land where natural processes predominate within the ecoregion. The share of cropland with at least 10% natural vegetation is a percentage of total cropland area within the ecoregion.

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with at > 10% natural vegetation within 1km²(%)
166	Timor and Wetar deciduous forests	1.819,5	5,2	28,4	15,6	84,4	977,7	55,7
188	Trans Fly savanna and grasslands	821,1	49,7	55,2	49,9	50,1	196,0	75,9
195	Papuan Central Range sub-alpine grasslands	978,5	62,0	98,1	62,8	37,2	6,5	97,1
217	New Guinea mangroves	1.992,8	28,4	81,0	29,9	70,1	16,4	72,6
219	Borneo lowland rain forests	29.176,0	2,9	54,3	4,7	95,3	4.823,9	63,2
220	Borneo montane rain forests	8.128,6	28,0	98,6	28,4	71,6	15,3	94,3
221	Borneo peat swamp forests	4.602,0	10,4	47,5	20,6	79,4	1.247,3	61,9
229	Eastern Java-Bali montane rain forests	1.591,2	7,4	26,2	22,5	77,5	487,5	69,9
230	Eastern Java-Bali rain forests	5.347,9	2,6	4,9	48,8	51,2	3.797,2	27,8
245	Mentawai Islands rain forests	598,3	30,9	90,7	33,7	66,3	4,8	92,7
265	Peninsular Malaysian rain forests	532,4	2,6	53,0	0,6	99,4	176,8	47,8
273	Southwest Borneo freshwater swamp forests	3.676,5	14,3	42,1	31,1	68,9	1.251,1	57,1
277	Sumatran freshwater swamp forests	1.802,9	3,9	11,7	28,0	72,0	1.117,8	44,0
278	Sumatran lowland rain forests	25.842,7	7,1	28,2	23,6	76,4	8.851,2	53,8
279	Sumatran montane rain forests	7.310,4	31,9	70,2	43,5	56,5	1.092,0	58,6
280	Sumatran peat swamp forests	8.760,2	7,7	23,4	30,5	69,5	4.179,5	46,6
281	Sundaland heath forests	7.593,8	9,8	35,9	25,1	74,9	2.603,2	53,9
288	Western Java montane rain forests	2.634,2	7,8	19,7	34,3	65,7	940,0	69,2
289	Western Java rain forests	4.150,5	2,0	4,7	38,3	61,7	2.057,5	35,6
305	Sumatran tropical pine forests	276,6	39,5	77,4	46,0	54,0	33,5	58,3

Indonesia

	Ecoregion	Area (1,000 ha)	Protected Area (%)	Share of Land where Natural Processes Predominate (%)	Share of Land where Natural Processes Predominate that is Protected (%)	Share of Land where Natural Processes Predominate that is Unprotected (%)	Cropland (1,000 ha)	Share of Cropland with at > 10% natural vegetation within 1km²(%)
322	Sunda Shelf mangroves	2.678,8	12,0	39,1	24,8	75,2	738,2	58,5
136	Banda Sea Islands moist deciduous forests	690,6	15,1	74,8	18,3	81,7	134,9	60,7

Sources: ccountries - GADM v3.6; ecoregions – Dinerstein et al. (2017); cropland, natural and semi-natural vegetation – ESA CCI land cover 2015 (ESA, 2017); protected areas – UNEP-WCMC and IUCN (2020); natural processes predominate comprises key biodiversity areas – BirdLife International 2019, intact forest landscapes in 2016 – Potapov et al. (2016), and low impact areas – Jacobson et al. (2019)

Units

°C – degree Celsius

% – percentage

/yr – per year

cap – per capita

CO_2 – carbon dioxide

CO_2e – greenhouse gas expressed in carbon dioxide equivalent in terms of their global warming potentials

g – gram

GHG – greenhouse gas

Gt – gigatons

ha – hectare

kcal – kilocalories

kg – kilogram

km^2 – square kilometer

km^3 – cubic kilometers

kt – thousand tonnes

m – meter

Mha – million hectares

mm – millimeters

Mm^3 – million cubic meters

Mt – million tonnes

t – ton

TLU –Tropical Livestock Unit is a standard unit of measurement equivalent to 250 kg, the weight of a standard cow

t/ha – tonne per hectare, measured as the production divided by the planted area by crop by year

t/TLU, kg/TLU, t/head, kg/head- tonne per TLU, kilogram per TLU, tonne per head, kilogram per head, measured as the production per year divided by the total herd number per animal type per year, including both productive and non-productive animals

USD – United States Dollar

W/m^2 – watt per square meter

yr – year

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