CLIMATE CHANGE
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Mitigating agricultural greenhouse gas emissions in Indonesia

Status, potential and challenges

by:

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NewClimate Institute, Cologne

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Abstract: Indonesia Country Report

This report describes the current state of agriculture in Indonesia with regard to the greenhouse gas (GHG) emissions it produces and the climate and other socio-economic policies that it faces. We identify options that could reduce agricultural emissions and estimate the mitigation potential of those options. Finally, we identify barriers to adopting these mitigation strategies and some possible solutions to overcoming those barriers.

Kurzbeschreibung: Länderbericht Indonesien

Dieser Bericht beschreibt den aktuellen Stand der Landwirtschaft in Indonesien im Hinblick auf die von ihr verursachten Treibhausgasemissionen und die klimapolitischen und anderen sozioökonomischen Maßnahmen, denen sie ausgesetzt ist. Wir identifizieren Optionen, die die landwirtschaftlichen Emissionen reduzieren könnten, und schätzen das Minderungspotenzial dieser Optionen ab. Abschließend werden die Hindernisse für die Einführung dieser Minderungsstrategien und einige mögliche Lösungen zur Überwindung dieser Hindernisse aufgezeigt.

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List of abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
BAU	Business as usual
BIP	Bruttoinlandsprodukt
BUR	Biennial Update Report
CH_4	Methane
CO_2	Carbon dioxide
EUDR	EU Deforestation Regulation
FAO	Food and Agriculture Organisation of the United Nations
GDP	Gross domestic product
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
ISPO	Indonesian Sustainable Palm Oil
LTS	Long-Term Strategy
LULUCF	Land Use, Land-Use Change and Forestry
$MtCO_2e$	Mega tonnes of CO_2 equivalent
NDC	Nationally Determined Contributions (in Paris-Agreement)
N_2O	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
RAN-API	National Action Plan for Adaptation to Climate Change
RAN-GRK	National Action Plan for Reducing Greenhouse Gas Emissions
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SRI	System of Rice Intensification
UNFCCC	United Nations Framework Convention on Climate Change

Summary

The aim of this report is to identify possible emissions mitigation options in the agricultural sector, to identify barriers towards implementing those options and provide some ideas on how to overcome those barriers. The report begins with a description of the current state of agriculture in Indonesia with regard to the GHG emissions it produces, and the climate and socioeconomic policies that shape the sector. We then identify three key options that could reduce agricultural emissions and estimate their mitigation potential. Finally, we identify barriers that act at the farm, national, international and consumer level along with possible steps to overcoming those barriers.

Indonesia is the world's largest archipelago and is the 4th most populous country in the world (FAO, 2017). The agriculture sector contributed 12.7% to Indonesia's gross domestic product (GDP) in 2019, compared to the global average of 3.5% (OECD, 2021; World Bank, 2022). Palm oil production and processing alone contributes between 1.5% and 2.5% of the country's GDP (Gianina, 2020). Indonesia is also a major global producer of coconut, rubber, rice, cacao, coffee and spices (Syuaib, 2016). Despite being an exporter of these products, Indonesia is not self-sufficient and imports some staple items, including grains, horticulture, and livestock products (Quincieu, 2015). Most farmers in Indonesia are smallholders, with less than one hectare of land, but a few large plantations occupy most of the currently farmed land. Agricultural employment is very high in Indonesia, making up 28.5% of the total workforce (World Bank, 2021).

Agricultural emissions, excluding emissions from Land Use, Land-Use Change and Forestry (LULUCF), represent 15% of the Indonesia's total GHG emissions, equating to 148 $MtCO_2e$ (Figure 4). The largest emissions sources are rice cultivation (43%), enteric fermentation (20%), and synthetic fertilisers (11%). Indonesia is both a major producer and consumer of rice and current rice cultivation systems have a high emissions intensity. Although meat consumption rates in Indonesia are low by global standards, consumption is rising and along with it, livestock emissions and embedded land use change emissions.

The LULUCF sector is a significant source of emissions in Indonesia. In 2019, LULUCF emissions were slightly higher than all other sectors put together. Much of these LULUCF emissions are from deforestation and the draining and burning of peatlands. The main drivers are timber and logging operations that are commonly followed by agricultural expansion into the cleared land, particularly for palm oil plantations.

Three mitigation options were identified for detailed analysis based on the contribution of different emission sources, the potential for socio-economic and environmental co-benefits, the country-specific context of the agricultural sector (see Section 1), and the general feasibility for implementation.

For Indonesia, we selected the following three mitigation measures:

- Livestock emissions intensity reduction
- Improved rice cultivation
- Improving palm oil yield gaps to limit future land expansion.

The implementation of the first two mitigation options could contribute to an overall emissions reduction of 29–31 $MtCO_2e$/year compared to 2019 levels (assuming constant levels of production). Additionally, a cumulative 730 $MtCO_2e$ of emissions could be avoided by 2035 through improving palm oil yield gaps by 1.25%/year. To meet Indonesia's Nationally Determined Contributions (in Paris-Agreement) (NDC) emissions reduction target, additional

mitigation action will be needed, both to reduce emissions and to preserve carbon stocks and enhance natural sinks. Options for doing so include more efficient fertiliser application, enhanced natural regeneration, peatland water management, forest fire prevention, and reducing food loss and waste (Hasegawa and Matsuoka, 2013; Jakarta Globe, 2021).

Although some of the identified mitigation options come with additional benefits, considerable barriers remain to their implementation. One huge challenge is the pressure to increase agricultural production, not only to supply the growing demand from the Indonesian population but also to export agricultural products to generate revenue. Increasing agricultural production and ensuring self-sufficiency is the key objective of the Indonesian government, and the mitigation of GHG emissions is often not considered a key success factor of a measure. The current objectives increase the pressure to expand agricultural land, exacerbated by the lack of property rights and regulation on land tenure. Labour scarcity in the agricultural sector is another problem, as it often impedes the uptake of new practices, such as improved irrigation systems for rice fields. Lastly, the nature and small scale of many agricultural activities from a high share of subsistence farming, creates challenges in the dissemination of information and the application of good-practice technologies and approaches. The direct benefits of mitigation actions for smallholder farmers are often too little to create an incentive for a change.

To accelerate the uptake and implementation of the measures described in this report, it is key to 1) more clearly translate national mitigation priorities to the agricultural sector, 2) in turn ensure that all agricultural policies are aligned with mitigation objectives and 3) implement sectoral policies that target the areas where most mitigation is possible. These mitigation policies and incentives should also foster co-benefits between adaptation and mitigation in the agricultural sector. More specifically, Indonesia could enhance mitigation action by improving the monitoring and enforcement of existing legislation (Budiman *et al.*, 2021), considering further financial incentives for smallholder farmers, increasing productivity on existing land and diversifying agricultural production, and promoting awareness of mitigation measures and their co-benefits. As Indonesia is a major exporter of agricultural products, international support and cooperation could help Indonesia's agricultural sector to develop sustainably in synergy with mitigation objectives.

Zusammenfassung

Ziel dieses Berichts ist es, mögliche Optionen zur Emissionsminderung im Agrarsektor aufzuzeigen, Hindernisse bei der Umsetzung dieser Optionen zu identifizieren und einige Ideen zur Überwindung dieser Hindernisse zu liefern. Der Bericht beginnt mit einer Beschreibung des aktuellen Stands der Landwirtschaft in Indonesien im Hinblick auf die von ihr verursachten Treibhausgasemissionen und die klimatischen und sozioökonomischen Maßnahmen, die den Sektor prägen. Anschließend werden drei wichtige Optionen zur Verringerung der landwirtschaftlichen Emissionen aufgezeigt und ihr Minderungspotenzial abgeschätzt. Schließlich zeigen wir Hindernisse auf, die auf betrieblicher, nationaler, internationaler und Verbraucherebene wirken, sowie mögliche Schritte zur Überwindung dieser Hindernisse.

Indonesien ist der größte Archipel der Welt und das viertbevölkerungsreichste Land der Welt (FAO, 2017). Der Agrarsektor trug 2019 zu 12,7 % des indonesischen Bruttoinlandsprodukts (BIP) bei, verglichen mit dem weltweiten Durchschnitt von 3,5 % (OECD, 2021; Weltbank, 2022). Allein die Palmölproduktion und -verarbeitung trägt zwischen 1,5 % und 2,5 % zum BIP des Landes bei (Gianina, 2020). Indonesien ist auch ein weltweit bedeutender Produzent von Kokosnuss, Reis, Kakao, Kaffee und Gewürzen (Syuaib, 2016). Obwohl Indonesien diese Produkte exportiert, ist es nicht autark und importiert einige Grundnahrungsmittel, darunter Getreide, Gemüse und Viehzuchtprodukte (Quincieu, 2015). Die meisten Landwirtinnen und Landwirte in Indonesien sind Kleinbäuerinnen und -bauern, die weniger als einen Hektar Land bewirtschaften, aber einige wenige Großplantagen nehmen den größten Teil der derzeit bewirtschafteten Fläche ein. Die Beschäftigung in der Landwirtschaft ist in Indonesien sehr hoch und macht 28,5 % der Gesamtbeschäftigten aus (Weltbank, 2021).

Die landwirtschaftlichen Emissionen, ohne Emissionen aus Landnutzung, Landnutzungsänderung und Forstwirtschaft (LULUCF), machen 15 % der gesamten Treibhausgasemissionen Indonesiens aus, was 148 $MtCO_2e$ entspricht (Abbildung 4). Die größten Emissionsquellen sind der Reisanbau (43%), die enterische Fermentation (20%) und synthetische Düngemittel (11%). Indonesien ist sowohl ein großer Produzent als auch ein großer Verbraucher von Reis, und der derzeitigen Reisanbau hat eine hohe Emissionsintensität. Obwohl der Fleischkonsum in Indonesien im weltweiten Vergleich niedrig ist, steigt der Verbrauch und damit auch die Emissionen aus der Viehhaltung und den damit verbundenen Landnutzungsänderungen.

Der LULUCF-Sektor ist eine bedeutende Emissionsquelle in Indonesien. Im Jahr 2019 waren die LULUCF-Emissionen etwas höher als die aller anderen Sektoren zusammengenommen. Ein Großteil dieser LULUCF-Emissionen stammt aus der Entwaldung und der Trockenlegung und Verbrennung von Torfgebieten. Die Hauptursachen sind die Holz- und Abholzungstätigkeit, auf die in der Regel die Ausweitung der Landwirtschaft auf die gerodeten Flächen folgt, insbesondere für Palmölplantagen.

Auf der Grundlage des Beitrags der verschiedenen Emissionsquellen, des Potenzials für positive sozioökonomische und ökologische Effekte, des länderspezifischen Kontexts des Agrarsektors und der generellen Durchführbarkeit wurden drei Minderungsoptionen für eine detaillierte Analyse ausgewählt:

- Verringerung der Emissionsintensität in der Viehhaltung
- Verbesserter Reisanbau
- Verbesserung des Palmöl-Ertrags zur Begrenzung der künftigen Flächenausdehnung.

Die Umsetzung der ersten beiden Minderungsoptionen könnte zu einer Gesamtreduzierung der Emissionen um 29–31 MtCO_2e/Jahr im Vergleich zu 2019 beitragen (unter der Annahme eines konstanten Produktionsniveaus). Darüber hinaus könnten bis 2035 kumulativ 730 MtCO_2e an Emissionen vermieden werden, indem der Abstand zwischen den Palmölerträgen um 1,25 %/Jahr verringert wird. Um das NDC-Emissionsreduktionsziel Indonesiens zu erreichen, sind zusätzliche Minderungsmaßnahmen erforderlich, um sowohl die Emissionen zu reduzieren als auch die Kohlenstoffvorräte zu erhalten und natürliche Senken zu stärken. Zu den Optionen hierfür gehören ein effizienterer Düngemitteleinsatz, eine verstärkte natürliche Regeneration, die Bewirtschaftung von Torfmooren, die Vermeidung von Waldbränden und die Verringerung von Nahrungsmittelverlusten und -abfällen (Hasegawa und Matsuoka, 2013; Jakarta Globe, 2021).

Obwohl einige der ermittelten Optionen zur Eindämmung des Klimawandels mit zusätzlichen Vorteilen verbunden sind, bestehen nach wie vor erhebliche Hindernisse für ihre Umsetzung. Eine große Herausforderung ist der Druck, die landwirtschaftliche Produktion zu steigern, nicht nur um die wachsende Nachfrage der indonesischen Bevölkerung zu befriedigen, sondern auch, um landwirtschaftliche Produkte zu exportieren und damit Einnahmen zu erzielen. Die Steigerung der landwirtschaftlichen Produktion und die Sicherstellung der Unabhängigkeit von Importen ist das Hauptziel der indonesischen Regierung, und die Minderung der Treibhausgasemissionen wird oft nicht als wesentlicher Erfolgsfaktor einer Maßnahme angesehen. Die derzeitigen Ziele verstärken den Druck auf die Ausweitung der landwirtschaftlichen Nutzflächen, der durch fehlende Eigentumsrechte und Regelungen für den Landbesitz noch verschärft wird. Ein weiteres Problem ist der Arbeitskräftemangel in der Landwirtschaft, der häufig die Einführung neuer Praktiken, wie z. B. verbesserte Bewässerungssysteme für Reisfelder, behindert. Schließlich stellen die Art und der geringe Umfang vieler landwirtschaftlicher Tätigkeiten mit einem hohen Anteil an Subsistenzlandwirtschaft eine Herausforderung für die Verbreitung von Informationen und die Anwendung von Technologien und Ansätzen mit bewährten Praktiken dar. Der direkte Nutzen von Klimaschutzmaßnahmen für Kleinbäuerinnen und -bauern ist oft zu gering, um einen Anreiz für eine Veränderung zu schaffen.

Um die Übernahme und Umsetzung der in diesem Bericht beschriebenen Maßnahmen zu beschleunigen, ist es entscheidend, 1) die nationalen Klimaschutzprioritäten klarer auf den Agrarsektor zu übertragen, 2) im Gegenzug sicherzustellen, dass alle agrarpolitischen Maßnahmen mit den Klimaschutzzielen in Einklang gebracht werden, und 3) sektorale Maßnahmen zu ergreifen, welche auf die Bereiche, in denen der größte Klimaschutz möglich ist, abzielen. Diese Minderungsmaßnahmen und Anreize sollten auch den gemeinsamen Nutzen von Anpassung und Minderung im Agrarsektor fördern. Konkret könnte Indonesien seine Klimaschutzmaßnahmen verbessern, indem es die Überwachung und Durchsetzung bestehender Gesetze verbessert (Budiman et al., 2021), weitere finanzielle Anreize für Kleinbäuerinnen und -bauern in Erwägung zieht, die Produktivität auf bestehenden Flächen steigert, die landwirtschaftliche Produktion diversifiziert und das Bewusstsein für Klimaschutzmaßnahmen und deren Zusatznutzen fördert. Da Indonesien ein wichtiger Exporteur von landwirtschaftlichen Erzeugnissen ist, könnte internationale Unterstützung und Zusammenarbeit dem indonesischen Agrarsektor helfen, sich in Synergie mit den Zielen des Klimaschutzes nachhaltig zu entwickeln.

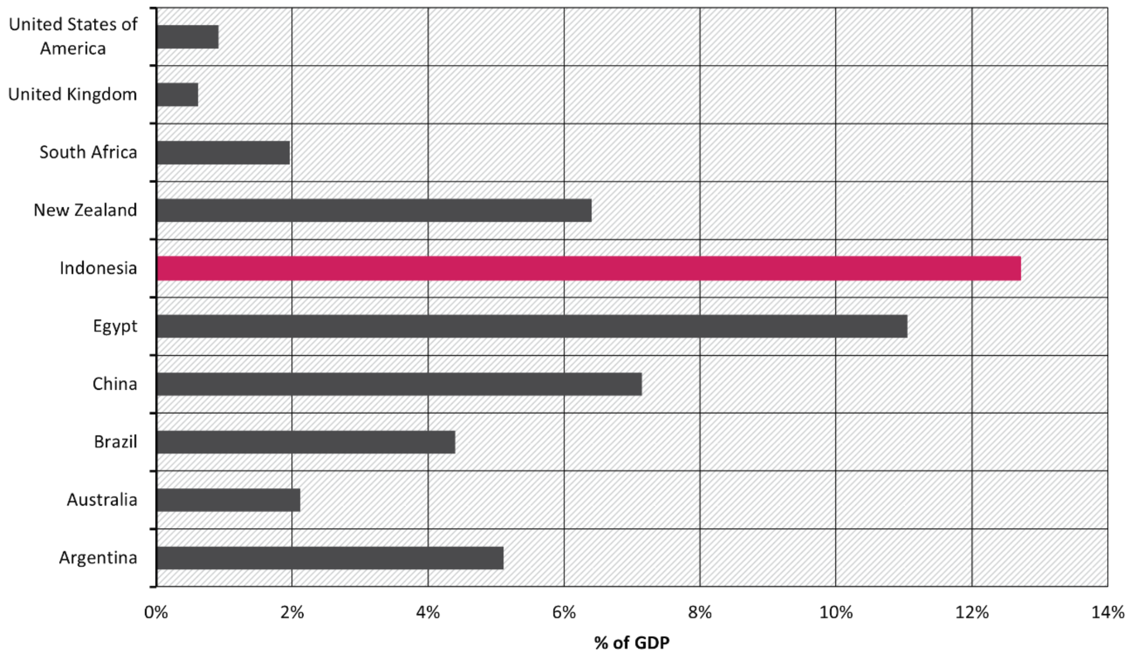
1 General characteristics of the agricultural sector and policy landscape

1.1 Characteristics of the agriculture sector in Indonesia

Indonesia is the world's largest archipelago and is the 4th most populous country in the world (FAO, 2017). The country is the largest economy in Southeast Asia, in which the agriculture sector plays an important role (ibid).

The agriculture sector contributed 12.7% to Indonesia's GDP in 2019, compared to the global average of 3.5% (OECD, 2021; World Bank, 2022). Palm oil production and processing alone contributes between 1.5% and 2.5% of the country's GDP (Gianina, 2020).

Figure 1: Agriculture, fisheries, and forestry's contribution to GDP (2019)



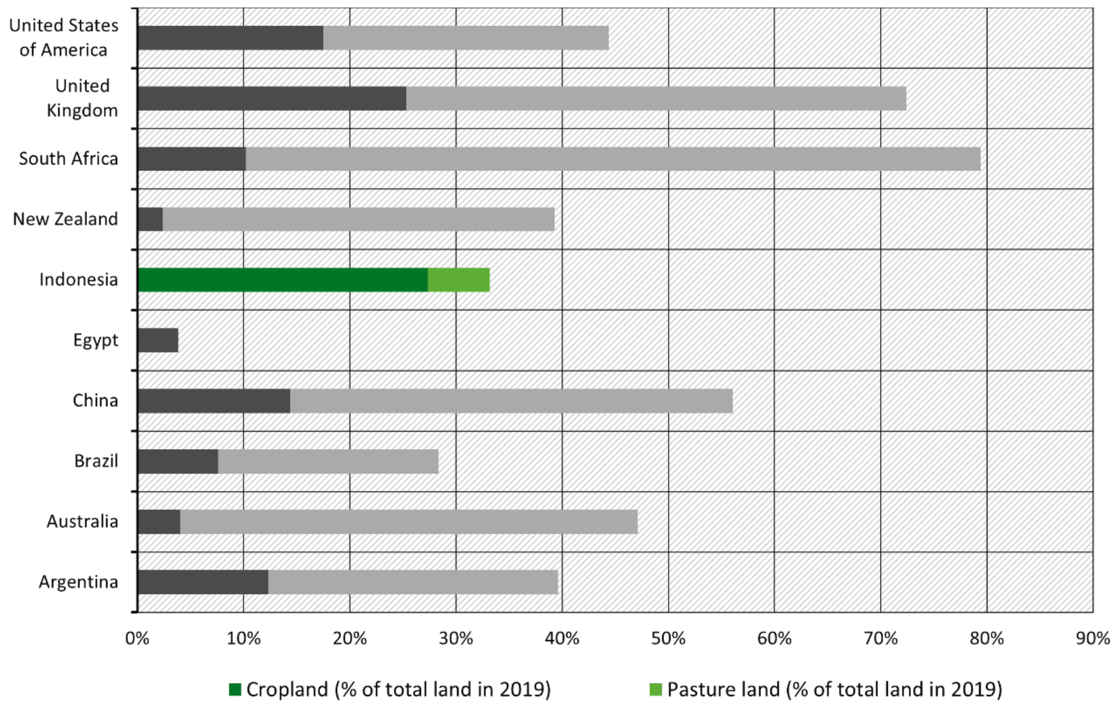
Source: **World Bank (2022)** data for all countries except New Zealand due to lack of data. Value for New Zealand was taken from **OECD (2021)**.

Indonesia is the world's top producer of palm oil, coconut, and rubber, and is in the top three global producers of rice, cacao, coffee, and spices (Syuaib, 2016). However, Indonesia is not self-sufficient in terms of production due to the growing demand for key crops such as rice, maize, soybean, and sugar. The country is a net importer of wheat, soya, maize, rice, sugar and cattle (Savelli *et al.*, 2021).

Due to the large extent of its estate crop production, Indonesia is a net agricultural exporter. The agricultural sector represents 18.4% of Indonesia's total exports (OECD, 2021). The main export commodities include palm oil, rubber, and coffee (Savelli *et al.*, 2021). Palm oil is one of Indonesia's top exports, and generated 10% of national export earnings in 2020 (Simoes and Hidalgo, 2022).

Agricultural land makes up around 33% of Indonesia's total land area (Figure 2). Indonesia's agricultural landscape is dominated by smallholders, where 68% of farmers operate on less than one hectare of land. Contrarily, large plantations primarily grow export crops on 15% of Indonesia's total agricultural area (FAO, 2017).

Figure 2: Agricultural land as a share of total country area (2019)

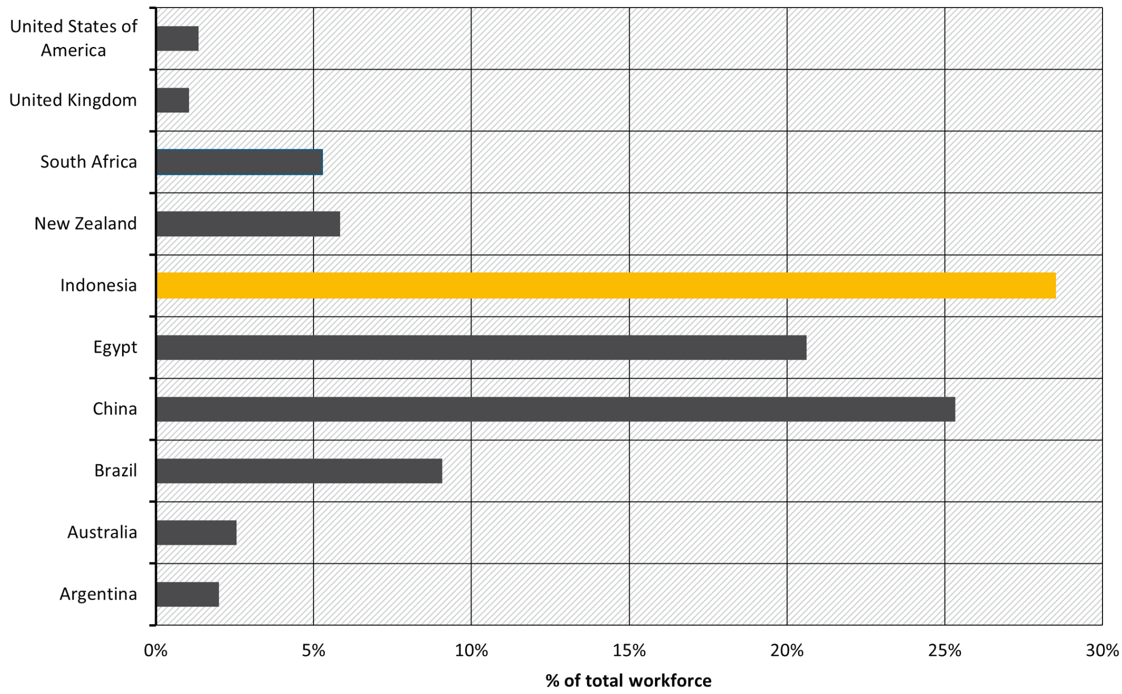


Source: **FAO (2022a)** data for all countries. Data includes "Cropland" and "Land under permanent meadows and pastures".

1.2 Socio-economic dimensions

Agricultural employment makes up 28.5% of the total workforce (Figure 3). Indonesia's low labour productivity and low rates of mechanisation are a result of small farm sizes, the declining rural labour force, and topographical challenges (Arifin *et al.*, 2019).

Figure 3: Agricultural employment as a share of total workforce (2019)



Source: **World Bank (2021)** data for all countries except Argentina due to data discrepancy. Value for Argentina was taken from **OIT (2021)**.

Agriculture continues to be a significant source of livelihood and sustenance for Indonesia's population. 93% of agricultural producers in Indonesia are smallholders, who hold an average 4.9 hectares of land (Savelli *et al.*, 2021). However, decreasing revenues, tight profit margins, shifting diets, a lack of investments, and climate hazards are driving youth to seek employment elsewhere, depleting crucial labour inputs from Indonesia's agricultural system (Rozaki, 2020).

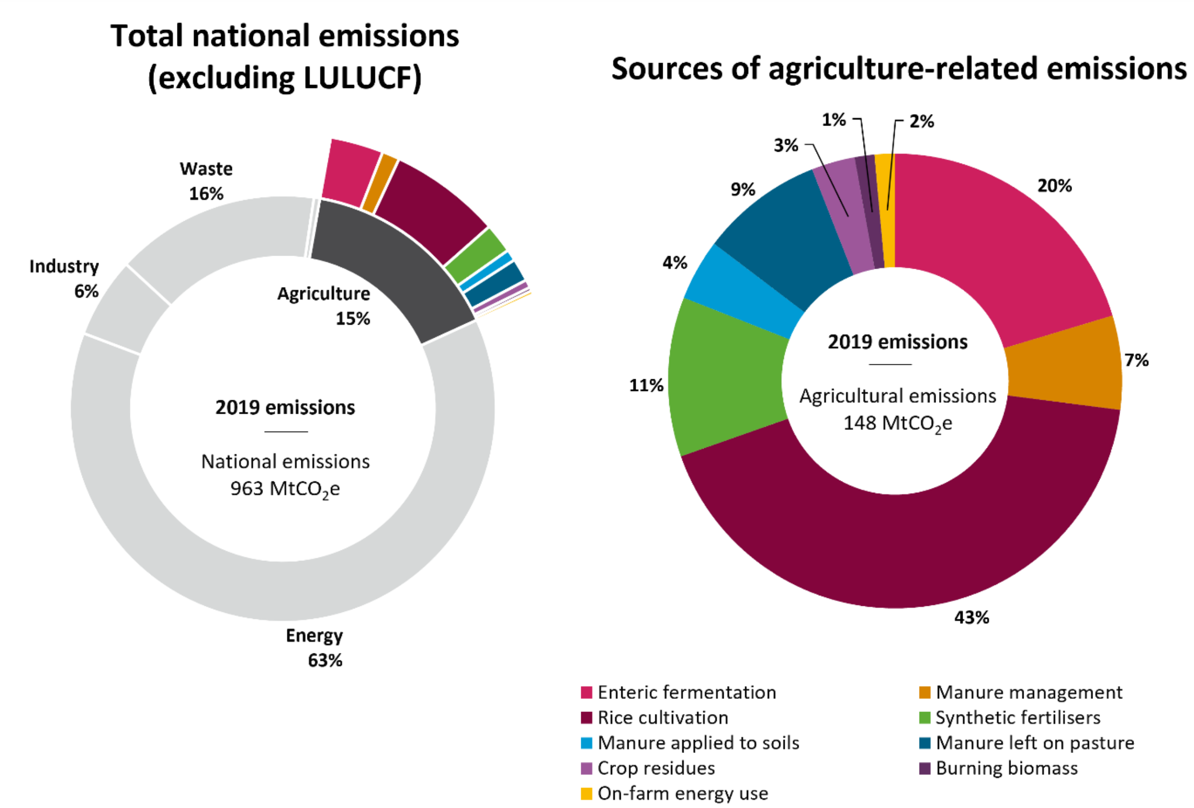
Land tenure has important implications for agricultural productivity and deforestation in Indonesia. Much of the land that farmers use in Indonesia is not formally titled, since the costs are relatively high, and the divide between private and government-owned land is especially ambiguous at forest margins (Kubitza *et al.*, 2018). The provision of formal land titles can incentivise farmers, in particular smallholders, to intensify agricultural activities on their land rather than expanding onto forest land (ibid).

Land use change, illegal logging activities, industrialisation, and urbanisation have led to watershed degradation and surface and groundwater contamination, putting pressure on Indonesia's water resources (Fulazzaky, 2014). As a result of water pollution, more than 60% of the country's rural population lacks access to potable drinking water and farmers face challenges with severe crop damage. The same drivers and government-related delays in irrigation pipeline repairs, have caused considerable water stress in Indonesia's agricultural sector (Savelli *et al.*, 2021). Water access problems are exacerbated by the country's large extent of deforestation, which diminishes forests' capabilities for natural water filtration and protection against flooding (ibid).

1.3 Greenhouse gas emissions from agriculture, forestry, and other land use (AFOLU) and the main drivers

Agricultural emissions in 2019, excluding emissions from land use, land use change and forestry (LULUCF), represented 15% of the Indonesia's total GHG emissions, equating to 148 $MtCO_2e$ (Figure 4). The largest emissions sources, as reported by Food and Agriculture Organisation of the United Nations (FAO), are rice cultivation (43%), enteric fermentation (20%), and synthetic fertilisers (11%). For this report, the analysis and calculations are based on internationally reported data from FAO, while highlighting the differences with national reports where relevant.

Figure 4: Indonesia's GHG emissions profile (2019)



Source: **Gütschow et al. (2021)** for energy (excl. on-farm energy use), industry, waste, and other sectors. **FAO (2022b)** for agriculture and agriculture-related emissions.[1,2]

FAO estimates for agricultural emissions in 2019 differ quite considerably from the GHG emission inventory provided by Indonesia in the 3rd Biennial Update Report (BUR3), where total agricultural emissions amounted to 105 $MtCO_2e$ in 2019, or 73% of the FAO estimate (Republic of Indonesia, 2021). In particular, there were differences in the largest source categories, including enteric fermentation, rice cultivation and synthetic and manure fertiliser inputs to

[1] The PRIMAP-hist dataset used for all non-agriculture-related emissions combines multiple datasets but prioritises country-reported data (Gütschow *et al.*, 2016, 2021). FAO data may differ from nationally reported agricultural emissions under the UNFCCC, and thus agricultural emissions reported under PRIMAP-hist, as a result of data uncertainties and differing methodological approaches to reporting emissions in this sector. We use FAO for these graphs for non-Annex I countries since it includes a complete time series from 1990 to 2019, has a higher level of detail for non-Annex 1 countries (e.g. enteric fermentation emissions per category of animal), and to maintain consistency across the assessed countries.

[2] While on-farm energy use is generally reported under the energy sector emissions for both PRIMAP-hist (Gütschow *et al.*, 2021) and national data, we include it as an agriculture-related emissions source in this study because it is part of agricultural production (fuel use in harvesters, stable heating, grain drying etc.) and its relevance in several countries in terms of magnitude and mitigation potential. We refer to 2019 instead of 2020 data which was the latest data available at the time of writing, due to COVID-related economic dynamics that affected national emissions in 2020.

soils. FAO uses simple Tier 1 methods for all categories, whereas Indonesia uses higher tier methods and country-specific emission factors, which is likely to be the reason for the differences. The discrepancies also show that emission uncertainties are generally high in the agriculture sector.

Table 1: Comparison of agricultural GHG emissions data between FAO and Indonesia's 3rd Biennial Update Report

Agricultural category	2019 FAO emissions ($MtCO_2e$) (AR5)	2019 BUR ($MtCO_2e$) (AR5)
Enteric fermentation	28.9	23.9
Rice cultivation	62.1	33.6
Manure management	10.1	12.3
Synthetic and organic inputs to soils	39.0	33.6
Biomass burning	1.4	1.9
Total (excl. on-farm energy use)	141.6	105.3

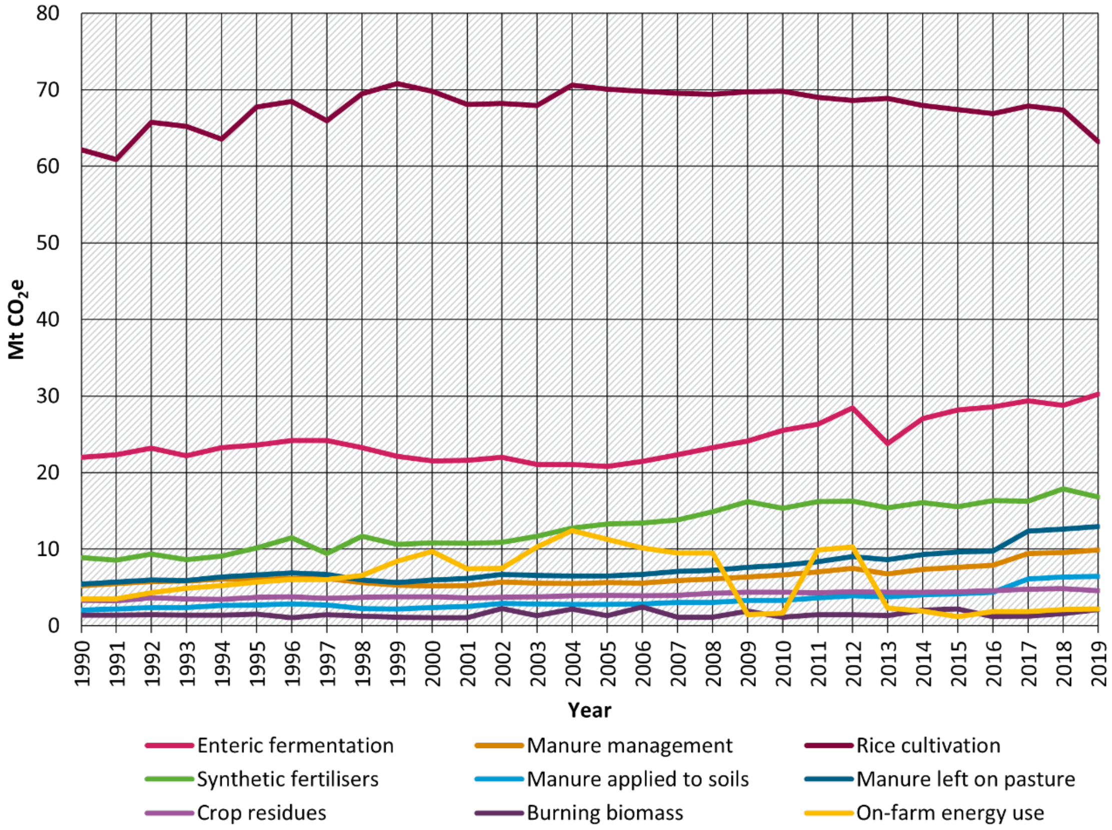
Indonesia is the third-largest rice producer in the world, and one of the biggest global consumers of the staple crop. Since the Indonesian government is aiming to achieve self-sufficiency, rice cultivation is predicted to intensify and new paddy fields to open on unproductive land, which will substantially increase GHG emissions (Setyanto *et al.*, 2018). Lowland rice production in Indonesia is still dominated by continuous flooding practices, which produces significant amounts of methane under anaerobic conditions compared to drainage systems (ibid).

Although meat consumption rates in Indonesia are low by global standards, consumption is rising and along with it, livestock emissions and embedded land use change emissions. From 2000 to 2015, the total livestock population in Indonesia increased by 40% (Nugrahaeningtyas *et al.*, 2018). This is also evident from the steady increase in enteric fermentation and manure-related emissions in that period (Figure 5). Poultry production and consumption in particular grew substantially in the country between 2010 and 2020. Aiming for self-sufficiency in poultry production via import bans could result in future agricultural expansion to grow corn feed (Vermeulen *et al.*, 2019).

The use of synthetic fertilisers in Indonesia is 70% above the world average; their overuse is heavily subsidised due to Indonesia's focus on achieving food self-sufficiency (Vermeulen et al. 2021). Despite the subsidy programme making up half of the government's agricultural budget and a 60% increase in fertiliser subsidies, annual rice yields have only marginally risen (FAO 2017). This is likely due to an overuse of urea driven by subsidies, which can have a negative impact on yields (Gomez Osorio *et al.*, 2011).

In general, agriculture-related greenhouse gas emissions have increased since the 1990s (Figure 5). Livestock emissions have increased by over 50% between 2000 and 2019, which, as mentioned before, is primarily attributed to the growth in cattle herd size from rising meat demand (Republic of Indonesia, 2021).

Figure 5: Agriculture-related emissions in Indonesia (1990–2019)



Source: **FAO (2022a)**[3]

The LULUCF sector is a significant source of emissions in Indonesia. In 2019, LULUCF emissions were slightly higher than emissions from all other sectors put together (Figure 6). In addition to high emissions from forest converted to other land uses, the draining and burning of peatlands for agricultural expansion releases substantial amounts of GHG emissions (ibid).

FAO estimates for LULUCF are relatively in line with estimates from Indonesian GHG inventory data. Indonesia's BUR estimates 2019 GHG emissions from peat decomposition to be 398 MtCO_2e and emissions from peat fires to be 456 MtCO_2e, together amounting to around 855 MtCO_2e or 1.3 times the total GHG emissions from the energy sector in Indonesia in the same year (Republic of Indonesia, 2021).

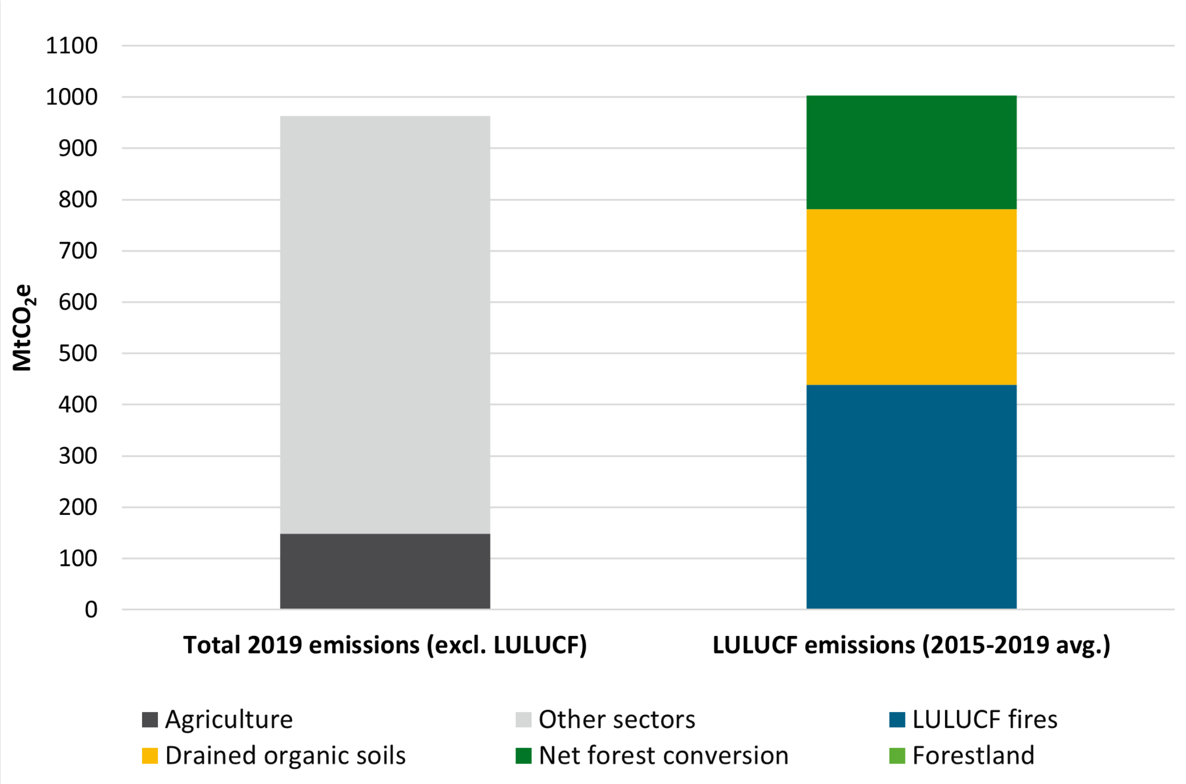
Between 2000 and 2010, deforestation and peat degradation in Indonesia contributed between 1% and 4% of total global anthropogenic GHG emissions (Busch *et al.*, 2015). Deforestation in Indonesia is primarily driven by the expansion of highly profitable palm oil plantations and timber and logging operations (ibid). Land use dynamics indicate that the immediate cause of deforestation is usually clearing for timber and pulp, but palm oil plantations have been established on most of the cleared land (PROFOR, 2019).

Palm oil satisfies 30% of global vegetable oil demand, of which 61% comes from Indonesia (Lam *et al.*, 2019). Thus, Indonesian palm oil contributes 18% of global vegetable oil demand. Since 1975, palm production has accounted for half of all agricultural land expansion in the country. While palm oil is the most efficient vegetable oil in terms of yield per hectare, land clearing for

[3] For consistency we include the same emissions category across all country papers in the series. We note that the time series for "On-farm energy use" in Indonesia is highly fluctuating, which is surprising for an energy end-use sector that is rather expected to undergo gradual change. The fluctuations suggest high uncertainty in this sub-category and data should be interpreted with care.

production is associated with high GHG emissions and irreparable losses to biodiversity (Vermeulen *et al.*, 2019). Most palm oil is exported, and only 15% of palm oil production is used domestically. The emissions from Indonesia's domestic consumption of palm oil are double the emissions from burning fossil fuels if land use change emissions are included (ibid). Converting forest to palm oil plantations in Indonesia is particularly emission-intensive because it happens frequently on peat soils, which are drained after deforestation releasing large amounts of emissions. The drained peatlands are subsequently vulnerable to intense peatland fires.

Figure 6: Indonesia's land use, land use change and forestry (LULUCF) emissions (average over the period 2015–2019) relative to total national emissions in 2019 (excl. LULUCF)



Source: **Gütschow et al. (2021)** for total emissions (excl. LULUCF). **FAO (2022a)** for agriculture-related and LULUCF emissions. LULUCF fires includes the FAO categories "Forest fires," "Fires in humid tropical forests," and "Savanna fires"[4]. Emissions from LULUCF have high interannual variability so average emissions over 5 years (2015 to 2019) is presented to avoid outliers.

Historically, Indonesia's LULUCF sector has been a major emissions source since the 1990s (Figure 7). It has exhibited extreme fluctuations based on the extent of peat fire activities associated with agricultural expansion (Republic of Indonesia, 2021).

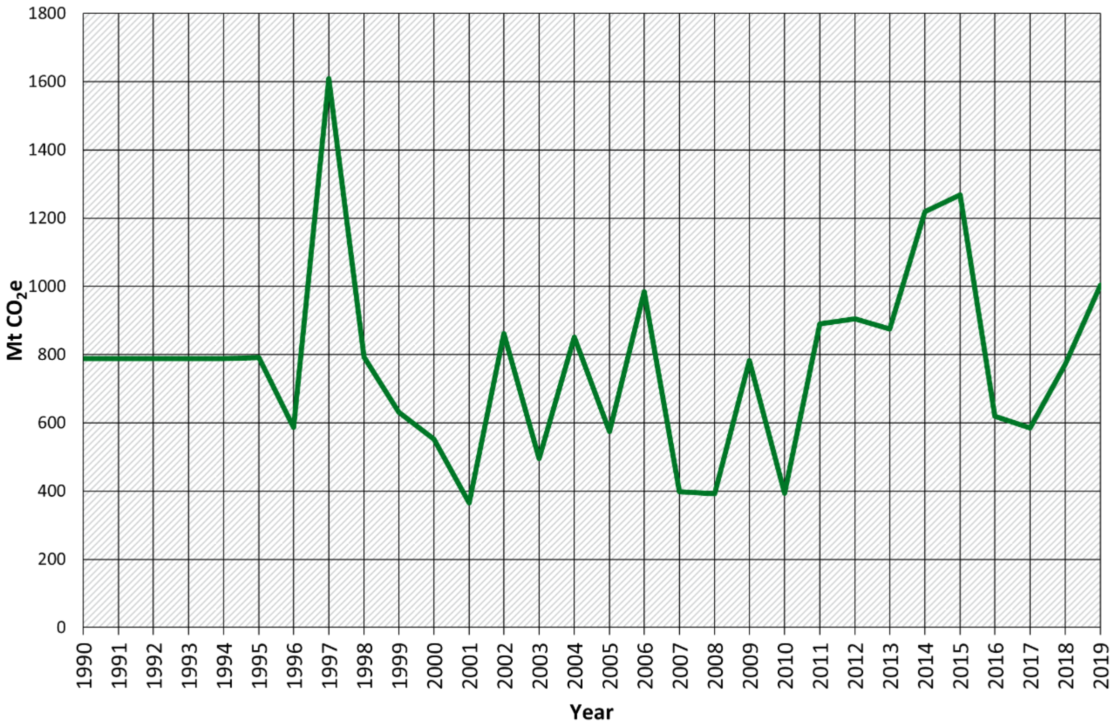
Peatlands are important for carbon storage, but have been subject to drainage and burning for agricultural expansion (in particular palm oil), making them a significant emissions source. Peatland fires are not only a large source of greenhouse gas emissions, but have adverse impacts

[4] In some countries, "Savanna fires" (which includes the prescribed burning of grassland) is accounted for in agricultural emissions under the burning biomass category instead of in the LULUCF sector. In this case, we followed national accounting standards based on UNFCCC reports to allocate the "Savanna fires" category under agriculture or LULUCF emissions. Savanna fires are reported under LULUCF for Australia, Brazil, New Zealand, and the United States, while they are reported under burning biomass for China and Indonesia. South Africa and Argentina report CO_2 emissions from savanna fires under LULUCF, but CH_4 and N_2O emissions under burning biomass. Since all emissions from savanna fires in both countries are non-CO_2 gases, they are accounted for under burning biomass.

on human health, such as the 2015 wildfire and haze crisis in Indonesia that caused 19 direct deaths, 100,000 premature deaths and cost the country $16.1 billion (Rodríguez Vásquez *et al.*, 2020).

Mangrove deforestation is another significant source of LUC emissions in Indonesia. While existing mangroves only make up 2.6% of land area, mangrove deforestation accounts for 8% of the country's forestry emissions (Arifanti *et al.*, 2021; Republic of Indonesia, 2021). While the main driver of mangrove deforestation is aquaculture, agricultural expansion and the establishment of oil palm plantations has also resulted in considerable mangrove conversion (Arifanti *et al.*, 2021).

Figure 7: LULUCF emissions in Indonesia (1990–2019)



Source: **FAO (2022a)**. Includes FAO categories "Forestland," "Net forest conversion," "Forest fires," "Fires in humid tropical forests," "Forest fires," "Fires in organic soils," "Savanna fires,"[4] and "Drained organic soils". Note that FAO data differs from national data and uses forest activity data in 5-year intervals, meaning data is averaged over the 5-year periods and can highly fluctuate between those intervals. This report uses FAO data for consistency with the other non-Annex I countries in this report series.

1.4 Government structures and agricultural policy framework

In their NDC, Indonesia pledged to reduce emissions by 32% (unconditional) and up to 43% (conditional upon international support) of their Business-As-Usual (BAU) scenario by 2030 (Republic of Indonesia, 2022b). While Indonesia's current policies indicate that they will overachieve their NDC target, the target itself is highly incompatible with the Paris Agreement's 1.5°C temperature limit (Climate Action Tracker, 2022).

There is an unconditional emissions reduction target in the agriculture sector to slightly reduce emissions to a level of 110 $MtCO_2e$ in 2030 compared to a BAU projection of 120 $MtCO_2e$ in 2030. The mitigation pathway for the sector outlined by the government includes measures such as the use of low-emission crops, water efficiency implementation, manure management for biogas (applied to 0.06% of total cattle population), and feed supplementation for cattle (applied to 2.5% of total cattle). This scenario assumes that the best available technology will increase cattle productivity and reduce the extent of land use change for agricultural use (Republic of Indonesia, 2022b).

The unconditional mitigation target in the LULUCF sector aims to go from 714 $MtCO_2e$ in 2030 under BAU to 214 $MtCO_2e$ in 2030, which would be achieved by drastically reducing the deforestation rate (not exceeding a deforestation rate of 359,000 ha/year in the 2021-2030 period), avoiding forest degradation, rehabilitating land, and restoring peatlands (ibid).

Indonesia established their National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK), which addresses mitigation actions on a per-sector basis, in 2011. For agriculture, the plan included six core mitigation actions that had the potential to reduce cumulative emissions by 131 $MtCO_2e$ by 2020. Under their NDC, Indonesia aims to reduce 2030 agriculture emissions by 10 $MtCO_2e$, relative to a BAU scenario of 120 $MtCO_2e$ (Republic of Indonesia, 2022a). The outlined mitigation actions included the repair and maintenance of irrigation networks, land optimisation, the application of plant cultivation technology, the use of organic fertilisers and bio-pesticides, the development of plantation area (for palm oil, rubber, cocoa) on non-forested or degraded land, and the utilisation of livestock manure and agricultural waste for biogas (Republic of Indonesia, 2018). These actions are mainly implemented by the country's Ministry of Agriculture. It is unclear when and if the action plan will be updated considering its short-term targets are now outdated.

Many of Indonesia's agricultural policies are aimed at food security and becoming self-sufficient, particularly with rice, but also maize, soy, sugar, and beef. For instance, the government has provided significant market price support and fertiliser subsidies to farmers, and has also introduced an insurance scheme for rice production (FAO, 2017). However, these policy interventions have dramatically increased the domestic rice prices relative to international prices, which has had a negative effect on food access while also discouraging crop diversification (ibid). While the 2020 Omnibus Law loosened restrictions on food imports, Indonesia's complex regulatory system based on self-sufficiency goals still poses barriers for foreign exporters wanting to enter the Indonesian market (Burns *et al.*, 2021).

The RAN-GRK also included 13 core mitigation activities for the land use and forestry sector, primarily aimed at avoiding deforestation and forest degradation and enhancing carbon sinks via reforestation (Republic of Indonesia, 2018). This includes improved peatland management for sustainable agriculture and developing agricultural land management in abandoned and degraded peatlands. In total, the outlined land use mitigation efforts were estimated to be able to reduce emissions by a cumulative 811 $MtCO_2e$ by 2020 (ibid).

Indonesia explores scenarios that would lead to net zero emissions by or before 2060 in their Long-Term Strategy (LTS). The country's ambitious, Paris-compatible pathway envisions the forestry sector becoming a net sink by 2030. However, this target is only possible if existing land use measures are expanded and enforced, deforestation is limited to a cumulative 6.8 Mha in the coming years, and peatland drainage is reversed while peat fires are stopped (Government of Indonesia, 2021; Climate Action Tracker, 2022).

Indonesia is a key country involved in the United Nations Framework Convention on Climate Change (UNFCCC) Reducing Emissions from Deforestation and Forest Degradation (REDD+) framework. In 2010, Indonesia signed a Letter of Intent with Norway in which the latter pledged a direct financial contribution (1 billion USD) in exchange for reduced forestry emissions (Savelli *et al.*, 2021). Despite the coordination agency disbanding in 2015, Indonesia received 56 million USD from Norway in 2020 for a 60% reduction in the deforestation rate, avoiding 17 MtCO2e emissions in 2016–2017. These funds will be used for restoring peatlands and other critically degraded land (ibid). Though it is a promising policy tool, REDD+ should be combined with strengthened domestic policy frameworks and new international funding streams, whereas funds should be distributed to local stakeholders in areas where future deforestation is likely to occur (ibid).

The Government of Indonesia first instituted a ban on new permits to clear primary forest and peatlands in 2011, which was made permanent in 2019, along with a moratorium on licenses for new palm oil plantations and stricter peatland regulation (Drost *et al.*, 2021). However, the moratorium has been criticized due to its lack of sanctions, the deliberate re-zoning of moratorium areas, the exploitation of loopholes, for not protecting secondary forests, and for not addressing deforestation on existing land concessions (ibid; Busch et al., 2015).

Recent developments have put the moratorium even more at risk. In response to the COVID-19 pandemic, the Indonesian government enacted the Omnibus Law on Job Creation, which amended over 70 laws to promote economic growth at the expense of environmental regulations (Climate Action Tracker, 2021). This included the removal of the "strict liability" clause, making it more difficult to prove and prosecute businesses who illegally clear land, and the removal of minimum forest cover requirements for river basins and islands (Climate Action Tracker, 2022). The Indonesian Constitutional Court declared the law as "conditionally unconstitutional" on procedural grounds in November 2021, meaning amended legislation would revert to its original enaction unless lawmakers redo the legislative process by November 2023. Until then, the law will continue to be enforced (Sidharta *et al.*, 2021).

The Government of Indonesia established the Indonesian Sustainable Palm Oil (ISPO) certification system in 2011 to support efforts to avoid deforestation and environmental damages from the expansion of palm oil plantations and unsustainable production practices. ISPO certification is mandatory for companies and voluntary for smallholders (Republic of Indonesia, 2021). The efficacy of the ISPO is questionable, since certified plantations have been involved in recent deforestation activities and social conflicts (Climate Action Tracker, 2022). ISPO has also been criticised for its ambiguity and leniency. As of 2019, less than 30% of palm oil plantation area has been ISPO certified (Choiruzzad *et al.*, 2021).

1.5 Current developments and trends

Given Indonesia's focus on rice as a staple crop and achieving self-sufficiency, there are many opportunities for production to adhere to climate-smart practices. The Government of Indonesia has made significant investments in promoting the system of rice intensification (SRI) (Prabhakar *et al.*, 2013). SRI involves early seed transplants, shallow and sparse planting, and intermittent irrigation practices that are shown to significantly reducing watering (up to 42%) and improve yields (up to 78%) without additional chemical or technological inputs (Savelli et al. 2021). The application of alternate wetting and drying techniques in SRI can reduce rice emissions by up to 46% (ibid). It is unclear to what extent SRI has been adopted in Indonesia, but its uptake faces challenges due to increased labour requirements.

In order to meet projected future demand, palm oil production would require a 46% increase relative to 2018 levels by 2035. Current palm oil yields represent only 62% and 53% of attainable yields in large and smallholder systems, respectively (Monzon *et al.*, 2021). Improving the yield gap can prevent future land expansion for palm oil production, which occurs at the expense of significant GHG emissions and biodiversity loss. These measures should be complemented by moratorium policies and certification programmes to ensure proper land-use planning for peatlands and forests (ibid).

The Indonesian government aims to integrate conservation agriculture practices into national policy. Conservation agriculture has been adopted by nearly 13,000 farmers with help from FAO. This includes practices such as low- or no-till, using crop residues as mulch, using high-quality seed varieties, and crop rotation or intercropping. Farms applying conservation agriculture practices were much more resilient to the long drought brought on by El Niño, and harvested 70% more product than those using traditional methods (Win, 2017).

Agroforestry can significantly benefit peatland restoration efforts in Indonesia. Implementing agroforestry in conjunction with cash crops (e.g. peppers or pineapples), coffee, or honey on non-peat soils or shallow peat areas in buffer zones can secure community support for the protection and re-wetting of peatlands while providing economic benefits (Applegate *et al.*, 2022). This approach applies traditional indigenous knowledge for ecosystem protection. Secure land rights and market accessibility are crucial for smallholders to be able to access initial capital to invest in tree planting (Samsudin *et al.*, 2020).

1.5.1 Diets and food waste

In addition to supply-side measures, Indonesia's agricultural landscape has been shaped by demand-side and external factors. Food waste, dietary habits, the COVID-19 pandemic, and global crises all influence agricultural processes and related emissions.

While Indonesia is a middle-income country, its dietary patterns resemble that of a low-income country, with extreme dependence on a single staple food (rice) and low meat consumption (Vermeulen *et al.*, 2019). However, urbanisation and income growth are changing consumption patterns, with rice demand levelling off as the consumption of animal products, fruits and vegetables, and processed foods grows (Arifin *et al.*, 2019). While beef consumption is quite low at only 2.2 kilograms per capita per year, this is expected to double or triple over the next 20 years, driving increased livestock production (Vermeulen *et al.*, 2019).

Indonesia has a relatively high per capita rate of food loss and waste, reaching an estimated 115–184 kilograms per capita per year, where the consumption stage contributed 58% of waste (Jakarta Globe, 2021). The total food wasted in Indonesia can meet the nutritional requirements of an additional 61–125 million people per year (ibid). Causes of food waste related to pre-consumer stages include poor infrastructure and complex value chains (FOLU, 2019).

1.5.2 Recent developments in national context

The COVID-19 pandemic has had a considerable impact on Indonesia's agriculture sector. The availability and accessibility of inputs such as fertiliser and pesticides (in terms of price) became uncertain, which halted production activities in some cases and affected food supply (Rozaki, 2020). Production capacities were additionally affected by employee shortages (ibid).

COVID-19 has also had implications for Indonesia's food security, considering there were struggles to balance food supply and demand even before the pandemic. Greater unemployment, drastically fluctuating food prices, and the reliance on imports impacted the population's access to food, which was exacerbated by changes in domestic agricultural productivity (ibid).

The Indonesian government's strategies to overcome COVID-19 impacts in the agricultural sector included promoting self-sufficiency, accelerating strategic commodity exports to support the domestic economy, educating farmers to prevent the spread of COVID-19, providing direct access to cash funds, and optimising local food and logistics infrastructure (ibid).

In the midst of Russia's invasion of Ukraine, street protests over rising domestic vegetable oil prices prompted the Indonesian government to ban palm oil exports. Although short-lived, this move exacerbated the existing international oil shortage and heightened concerns on global food inflation (Listiyorini *et al.*, 2022; Root, 2022).

The EU adopted the EU Deforestation Regulation (EUDR) in June 2023, which aims to stop the sale of agricultural products originating from land deforested after 2020 on the EU market. The regulation covers seven commodities: palm oil, soy, coffee, cocoa, rubber, timber, and beef. The Indonesian and Malaysian governments have voiced numerous concerns over the regulation, citing that it discriminates against their palm oil industries and serves to protect Europe's domestic oilseeds market rather than combat deforestation. Palm oil originating from high-risk countries must undergo a rigorous due diligence process to access the EU market, including traceability and geolocation data requirements. European Commission, Indonesia and Malaysia have thus established a Joint Task Force to address such concerns (Goh, 2023).

1.6 Vulnerability and adaptation

Climate change poses risks to Indonesian food production via changes in precipitation, temperature, water availability, soil organic matter, pest and disease profiles, and invasive species. The extent of available arable land is predicted to decrease due to increased coastal flooding and desertification (World Bank Group, 2021).

Climate change will impact most of the country's key agricultural commodities. Rice production, a major staple food in Indonesia, is highly vulnerable to changes in temperature and to changes in the onset and length of wet seasons. A 1°C increase in surface temperature could reduce national rice production levels by 10–25% (ibid). The climactic suitability of regions could decrease or shift for palm oil and coffee, respectively. A shift in climate could increase deforestation pressure in regions where climate suitability improves (ibid). Climate change and natural resource degradation will likely halve GDP growth from 7% to 3.5% by 2050 (FOLU, 2019).

The adverse effects of climate change on food production will potentially impact food prices. On average, low-income groups in Indonesia spend two-thirds of their income on food, particularly rice, meaning they are highly vulnerable to rising food prices (Quincieu, 2015). A theoretical 100% increase in food prices would increase the number of Indonesians in extreme poverty by 25% (World Bank Group, 2021).

Indonesia has developed a National Action Plan for Adaptation to Climate Change (RAN-API). The plan includes national adaptation measures such as crop and livestock diversification, infrastructure upgrades, incorporating climate-adaptive technologies, and disseminating climate-smart information systems (Savelli *et al.*, 2021). The plan also outlines regional adaptation measures including improving extension services, establishing farmer cooperatives, providing access to high-quality seeds, enhancing water efficiency, and promoting reforestation (ibid).

2 Key areas with high mitigation potential

2.1 Introduction

In this section, we quantify the potential of three mitigation options and explore the co-benefits and barriers to their implementation in a country-specific context. In selecting which three mitigation options to quantify, the contribution of different emission sources was considered, along with the potential for socio-economic and environmental co-benefits, the country-specific context of the agricultural sector (see Section 1) and the general feasibility for implementation.

2.1.1 Selection of priority mitigation options

The livestock sector is responsible for about 40% of Indonesia's agricultural GHG emissions (see enteric fermentation and all manure-related emissions in Figure 4) and is primarily attributed to the country's beef sector. The emissions intensity of cattle is relatively high in Indonesia compared to other upper-middle income countries. There is sizable scope for potential emission reductions by implementing good practices in livestock rearing, which can also result in improved productivity. This is especially relevant since beef consumption is expected to double or triple in line with increasing incomes and urbanisation (Vermeulen *et al.*, 2019). However, Indonesia should simultaneously avoid shifting towards highly intensified livestock production, which is associated with significant environmental degradation, increased manure management emissions, and high indirect emissions resulting from feed production and associated land use change.

Indonesia is one of the world's top rice producing countries. Rice is critical to Indonesia's food security, considering the country exports less than 1% of its domestic production (Savelli *et al.*, 2021). Rice cultivation is the largest source of Indonesia's agricultural GHG emissions (43%) according to FAO data (see Figure 4), but only 24% of agricultural emissions according to the national GHG inventory. In addition to its high mitigation potential, improving rice cultivation practices has important co-benefits relevant to Indonesia's development goals, including higher yields and increased incomes.

The land use sector accounts for more than half of Indonesia's total GHG emissions, most of which is attributed to deforestation, peatland draining, and peatland fires driven by palm oil expansion (Figure 6). Multiple strategies will be required to protect forests and peatlands, including overarching policies that preserve land rights and prevent deforestation. For the scope of this paper, we focus on mitigation measures in the agricultural sector and how on-farm palm oil cultivation practices can relieve pressures on forests by improving production on existing farmland. Indonesian palm oil production supplies over 18% of global vegetable oil demand, and palm oil alone generated 10% of national export earnings. Current palm oil yields represent only 62% and 53% of attainable yields from large producers and smallholder production systems, respectively (Monzon *et al.*, 2021). Thus, there is significant potential to improve palm oil yields and meet future demand while limiting further land expansion.

Against this background, we selected the following measures for Indonesia:

- Livestock emissions intensity reduction
- Improved rice cultivation
- Improving palm oil yield gaps to limit future land expansion.

There is currently a scientific and knowledge gap related to the sustainable management and restoration of peatlands in Indonesia including on paludiculture (farming with high water table) options, optimised water management, and appropriate water levels for peat conservation and restoration (Sabiham *et al.*, 2018). Many management options to mitigate emissions from peat drainage and peat fires are related to land use and land use change and water management and therefore are not strictly part of agriculture mitigation options. Therefore, this report does not address mitigation measures related to emissions from peatland beyond its role in agriculture, despite the fact that these emissions dominate the LULUCF sector.

2.1.2 Overall mitigation potential

According to our calculations[5] and other literature estimates, implementing the prioritised mitigation options could contribute to overall agricultural emissions reductions of 30–38 $MtCO_2e$/year compared to 2019 levels (assuming constant levels of beef and milk production). Based on a literature review, improved palm oil yields could also result in avoided cumulative emissions of 732 $MtCO_2e$ in the LULUCF sector by 2035 (see section 2.2.3). These estimates do not account for any changes in livestock production systems.

In order for Indonesia to meet its NDC, 58% of total emissions reductions should come from the AFOLU sector (Hasegawa *et al.*, 2016). According to other studies, Indonesia can reduce their 2030 agricultural emissions by 21 $MtCO_2e$/year relative to a business as usual scenario by implementing the midseason drainage of rice paddies, incorporating rice straw during offseason, and efficient fertiliser application, while LULUCF emissions can be reduced by 640 $MtCO_2e$/year mainly by enhanced natural regeneration, peatland water management, and forest fire prevention (Hasegawa and Matsuoka, 2013). The mitigation measures outlined in the following sections thus form a part of a broader set of measures that would be necessary to bring Indonesia's AFOLU sector on track to reaching long-term climate targets. While demand-side mitigation options are outside the scope of this study, Indonesia has a relatively high per capita rate of food loss and waste, and measures to reduce food waste can reduce GHG emissions from the production of eventually wasted food while feeding an additional 61–125 million people per year (Jakarta Globe, 2021).

2.2 Emissions reduction potential from priority mitigation options

2.2.1 Livestock emissions intensity reduction

Measure	The emissions intensity per tonne of meat or milk from cattle can be improved by employing good practices in livestock rearing, including improved health monitoring and disease prevention, breeding optimisation, diet and nutrition optimisation, herd management, and improvements in manure management and handling. These measures can help to lower the emissions intensity per unit of meat or milk either by reducing absolute enteric fermentation emissions or by improving animal productivity. We assumed that these measures would be applied to existing production systems and do not involve a shift towards more intensive livestock farming.
Status	While Indonesian beef production increased by 173% between 1990 and 2019, the enteric fermentation emissions intensity per tonne of beef decreased by 15% in the same period. However, Indonesia's emissions intensity per tonne of beef is

[5] See section 2.2.1. Further methodological details can be found in the final report for this project, available at https://www.umweltbundesamt.de/publikationen/ambitious-ghg-mitigation-opportunities-challenges.

very high (43 tCO_2e/t product) compared to most high-producing countries (FAO, 2022b, 2022a).

Potential

Based on our own calculations[6] and FAO emissions data, if Indonesian livestock systems applied good practices across feedlot, mixed, and grassland beef and dairy systems, it could result in potential emissions reductions of around 8 $MtCO_2e$/year in 2030 compared to 2019 levels (23% reduction in enteric fermentation emissions, 10% in manure management emissions), assuming meat and dairy production remain constant at 2019 levels.

If beef and milk production were to continue to increase following the 10-year historical trend, it would result in a lower magnitude of emission reductions (~6 $MtCO_2e$/year) in 2030 compared to 2019 levels (18% reduction in enteric fermentation emissions, 7% reduction in manure management emissions).

The estimates outlined above represent a maximum emission reduction potential based on decreasing the emissions intensity per tonne of beef or milk produced. While our calculations aim to not consider changes to existing livestock production systems, there is a risk that further grain supplementation to achieve higher yields and lower emissions intensities would result in increased indirect emissions from feed production and associated land use change. Intensive livestock production also contributes to significant environmental pollution and rising manure management emissions.

Co-benefits

Livestock health monitoring tends to improve animal welfare conditions, which results in enhanced food safety and biodiversity conservation (Llonch *et al.*, 2017). Higher livestock productivity can help meet rising demand for ruminant meat products and benefits food security, while improving farmer's incomes and livelihoods (Dickie *et al.*, 2014).

Improved livestock management will generally increase adaptive capacity and resilience to climate change impacts (Rojas-Downing *et al.*, 2017).

Barriers

Economic barriers: While there is an economic case for improved livestock management practices, small-scale subsistence farmers only will see minor, if any, economic returns (Gerber *et al.*, 2013). In general, farmers may lack the financial means to access the technology and labour needed to improve their livestock management practices.

Technical barriers: Applying good practices to extensive, pasture-based livestock systems can pose practical barriers since cattle are able to move around freely (Kipling *et al.*, 2019). Additionally, more than 90% of Indonesian beef production comes from smallholder systems, in which households often have only 2 to 3 cattle (Nugrahaeningtyas *et al.*, 2018). This makes it difficult to scale up improved livestock management practices.

Biophysical/environmental barriers: High temperatures and subsequent pest and disease outbreaks impact feed provisions, water access, and forage quality, resulting in poor health or death in livestock. Climate change is expected to exacerbate these conditions, and Indonesian farmers currently lack the

[6] Further methodological details can be found in the final report for this project, available at https://www.umweltbundesamt.de/publikationen/ambitious-ghg-mitigation-opportunities-challenges.

information services and aid needed to be prepared for such hazards (Savelli *et al.*, 2021).

Socio-cultural barriers: Subsistence livestock farming is common in Indonesia as in many developing countries. Animals with low productive potential are often used for draft power or to manage household risk, resulting in high emissions intensities due to their long lives and poor nutrition (Nugrahaeningtyas *et al.*, 2018). Reducing their emissions would require major changes in the socio-economic structure of the agricultural sector (Dickie *et al.*, 2014), but should not compromise rural livelihoods and traditions.

2.2.2 Improved rice cultivation

Measure

Good practices in rice cultivation include intermittent irrigation practices in place of continuous flooding, applying compost or organic nutrient inputs instead of synthetic fertilisers, and improving straw residue management (Hussain *et al.*, 2015). In line with these principles, the Indonesian government has promoted the System of Rice Intensification (SRI) as an alternative rice farming system that promotes climate change adaptation and mitigates GHG emissions without compromising yields and without the need for additional chemical or technological inputs (Savelli *et al.*, 2021).

Status

Despite its many benefits, the adoption of SRI has been relatively low among Indonesian rice farmers. In the 2010–2015 period, SRI was applied to less than 5% of Indonesian rice area (Arif *et al.*, 2019).

Potential

Applying SRI across all Indonesian rice area has a cumulative mitigation potential of 25 $MtCO_2e$/year in 2030, corresponding to 39% of rice cultivation emissions in 2019 (Prabhakar *et al.*, 2010; FAO, 2022b). This is in line with Roe et al. (2021), who estimate the technical mitigation potential of improved rice cultivation practices to be between 22–30 $MtCO_2e$/year in Indonesia.

Co-benefits

Implementing intermittent irrigation practices can reduce water use by up to 15–20% compared to continuous flooding systems without compromising yields. Reducing the amount of irrigation required can additionally reduce costs associated with water pumping and fuel use, leading to increased incomes for farmers (MacSween and Feliciano, 2018). Continuously flooded paddy fields can be breeding grounds for vector-borne illnesses, so intermittent irrigation systems can have positive implications for human health (ibid).

Optimising nutrient application in rice cultivation will reduce the need for nitrogen fertiliser, resulting in cost savings for farmers (MacSween and Feliciano, 2018). Rice produced using SRI principles is also considered to be of higher quality and have health benefits, fetching higher prices on the market (Arsil *et al.*, 2022).

Barriers

Economic barriers: Adopting improved rice cultivation practices requires increased labour spent on planting, weeding, fertilisation, and irrigation activities (Arsil *et al.*, 2022). The Indonesian agricultural sector is already facing issues with crucial labour inputs shifting to other industries, which can impede the implementation of improved management practices. Indonesian farmers can also lack the capital needed to cover the high investment costs associated with irrigation systems (Malahayati and Masui, 2018).

Institutional barriers: Public policy priorities in Indonesia are linked to food self-sufficiency and economic development rather than emissions mitigation (Vermeulen *et al.*, 2019).

Technical barriers: Around 46% of Indonesian irrigation systems are in unserviceable condition, contributing to poor water management practices. There is little incentive to fix the system, considering farmers can still apply continuous flooding practices and repair and operational costs are high (Malahayati and Masui, 2018).

2.2.3 Improving palm oil yield gaps to prevent future land expansion

Measure

The conversion of Indonesian rainforests and peatlands for palm oil cultivation has significantly contributed to global GHG emissions. Effectively preventing peat fires and deforestation on such a large scale requires a multi-faceted approach that includes policy levers, stringent enforcement, and intragovernmental cooperation, but there is also scope for improvements in the agricultural sector to influence LULUCF dynamics.

For example, there is considerable potential to increase the average annual yield on existing oil palm plantations to meet future demand without significant further land expansion through improved management practices. Measures to improve yield gaps include more advanced harvest methods, field maintenance, and improved nutrient management, the adoption of which can be facilitated by increased access to technological and knowledge inputs and productivity incentives (Monzon *et al.*, 2021).

Adopting advanced harvesting methods (and thus more machinery) could result in increased on-farm energy GHG emissions. However, the magnitude of increase is highly negligible compared to the potential avoided emissions. Nutrient deficiencies are a common yield-limiting factor for smallholder farmers. Efforts to improve yield gaps by increased fertilisation could result in higher managed soil emissions if fertiliser inputs are improperly applied. Other palm oil plantations overuse fertiliser and have an excess of nutrients. Addressing both nutrient deficiencies and surpluses to achieve a nutrient balance would still result in lower GHG emissions from fertiliser compared to BAU (ibid).

Status

Current palm oil yields comprise only 62% and 53% of potential yields in large and smallholder plantations, respectively (ibid).

Potential

Improving yield gaps in palm oil production by 1.25% per year (to reach 70% of the yield potential) while ensuring land expansion is limited to low-carbon land where carbon stocks are lower than in palm oil plantations (i.e grasslands, avoiding further conversion of forests, peatlands) would save 2.6 million hectares in forests and peatlands while avoiding a cumulative 732 $MtCO_2e$ in LULUCF emissions by 2035 (Monzon *et al.*, 2021). This estimate does not include the mitigation potential from the reduction in peat fires as a result of minimised palm oil plantation expansion.

Co-benefits

Reducing the extent of peat fires driven by land expansion will have positive impacts on human health while providing economic savings from reduced health spending (Rodríguez Vásquez *et al.*, 2020). Protecting primary forests from further conversion and degradation will enhance biodiversity (Lucey *et al.*,

	2015). Improving smallholder palm oil yields can support rural livelihoods and alleviate poverty (Mohd Hanafiah *et al.*, 2022).
Barriers	**Technical barriers:** There is a lack of access to technological and knowledge inputs to reduce yield-limiting factors and financial risks, especially for smallholder palm oil production systems (Monzon *et al.*, 2021). **Policy/legal barriers:** Current policies to avoid emissions from palm oil production, such as moratoriums or certification programmes, do not explicitly outline the need for intensification (Monzon *et al.*, 2021). Palm oil producers receive support under Indonesia's biofuel mandate, which can provide perverse incentives for further expanding production (Vermeulen *et al.*, 2019). **Economic barriers:** Smallholder farmers in particular lack the financial resources and capital to purchase improved machinery and sufficient fertiliser inputs (Monzon *et al.*, 2021).

3 Barriers to implementing mitigation potential

In this section, we examine the main barriers to the mitigation of agricultural emissions identified for Indonesia, building on the findings of a report on general barriers prepared under this research project[7] and the country-specific circumstances described in Section 1 of this report. The analysis of barriers below follows the clustering proposed in the previous report, according to the relevant governance level for taking action, while taking into account the classification from the Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land (IPCC, 2019) within each of the governance levels.

3.1 Farm level

The high share of smallholder farms in Indonesia presents challenges for disseminating information and encouraging the uptake of good practices, which would be beneficial to increasing the knowledge base on possible climate-smart improvements to production. The small scale of many agricultural activities and the nature of subsistence farming also make some improvements culturally challenging. Smallholder farmers lack the financial resources needed to invest in new technologies or build knowledge, while many measures that would reduce GHG emissions do not provide sufficient direct returns to the farmers.

3.2 National level

30% of the workforce in Indonesia is employed in the agricultural sector, but this share is declining as the workforce is shifting to other economic areas. Labour scarcity, which was exacerbated by the COVID-19 pandemic, is a key barrier to implementing new practices.

Increasing food production and national self-sufficiency in food supply are predominant policy objectives of the Indonesian government. The government supports some measures in the agricultural sector that also decrease emissions, such as the System of Rice Intensification, but the primary purpose of the measures is to increase food production. Other measures with the same aim provide perverse incentives while contradicting mitigation objectives, such as fertiliser subsidies leading to overuse and only minor yield improvements. On the other hand, policies to avoid emissions from palm oil production, such as moratoriums or certification programs, do not explicitly outline the need for intensification and productivity improvements (Monzon *et al.*, 2021).

Research also suggests that the current strategy for self-sufficiency, including import restrictions, leads to limitation in nutritional profiles, and argues that "investment in increased productivity rather than in agricultural expansion" along with measures to diversify available nutrition sources would be beneficial for consumers and the environment (Vermeulen *et al.*, 2019).

The weak enforcement of existing laws allows illegal logging and further expansion of agricultural lands into pristine forest areas and peatlands, releasing considerable GHG emissions. This is worsened by a lack of property rights and regulation on land tenure, factors that also cause a barrier to the implementation of management changes and necessary reductions in LULUCF emissions.

[7] See https://www.umweltbundesamt.de/publikationen/barriers-to-mitigating-emissions-from-agriculture.

3.3 International level

Indonesia is a major contributor to palm oil supply globally, and international demand is one key driver for the expansion of palm oil production in the country. Long supply chains for agricultural products make regulation and monitoring challenging, even if some countries or regions have limited the imports of palm oil, considering their environmental impact (Murphy *et al.*, 2021).

The EU's Deforestation Regulation adopted in May 2023 is intended to put the onus on companies to ensure that their products are not produced on land that has been subject to deforestation or forest degradation since 31 December 2020 (Council of the European Union, 2023). Policies such as these have the potential to provide a push toward a reduction in deforestation but may need to be accompanied by support to countries like Indonesia to improve yield gaps on existing agricultural land.

3.4 Consumer level

While meat demand in Indonesia is rising, it is still far below the world average on a per capita basis. Food waste, however, is high (see section 1.5.1) and causes unnecessary GHG emissions through the agricultural production of unused food products and through methane emissions from waste management.

4 Recommendations

In a world compatible with the Paris Agreement, the agricultural sector will need to meet the growing food demand of people and animals, while contributing to other equally relevant climate and development objectives and adapt to a changing climate. Mitigation action in Indonesia, one of the large emitters globally, is essential for limiting the rise in global temperature. This includes action in the agricultural sector. The mitigation of climate change is also essential to Indonesian agriculture. Indonesia aims at self-sufficiency for food production, but rice production in particular is threatened by water scarcity and heat waves are catalytic to peat fires.

This study described and quantified three mitigation actions in Indonesia's agricultural sector that would improve productivity and provide environmental and economic co-benefits: Emissions intensity reduction of livestock, improving rice cultivation and improving palm oil yields to prevent future land expansion.

To maximise emission reductions in the agriculture sector, Indonesia would need to take a broader, multi-faceted approach. A particularly large mitigation potential arises from preventing the expansion of palm oil fields on forests and peatlands by improving yield gaps. An estimated 732 $MtCO_2e$ in emissions from forest clearing and peat soils could be avoided by 2035 this way (Monzon *et al.*, 2021). This potential is similar in size to current net emissions from the Land Use, Land-Use Change and Forestry sector. Expanding improved management of rice fields could contribute emissions reductions of about 22–30 $MtCO_2e$, corresponding to almost 40% of current GHG emissions from rice cultivation. Moving to good-practice emissions intensity levels in livestock emissions could reduce emissions another 8 $MtCO_2e$ compared to 2019 when assuming current production levels remain constant. Under a likely scenario where cattle meat production increases, the reduction compared to 2019 would be slightly lower.

The identified potential in the agricultural sector exceeds the 10 $MtCO_2e$ reduction relative to the 2030 BAU scenario targeted in Indonesia's NDC (Republic of Indonesia, 2022a). However, further action may be needed in the LULUCF sector; the cumulative mitigation potential of 732 $MtCO_2e$ by 2035, by preventing forest clearing via palm oil yield improvements, is not sufficient to meet the NDC emissions reductions target of about 500 $MtCO_2e$/year relative to the 2030 BAU scenario. Additional actions could include the restoration of abandoned or degraded peatlands and sustainable water management. It is important to note that Indonesia's NDC is currently deemed to be critically insufficient and is far from a 1.5°C compatible target in line with the Paris Agreement (Climate Action Tracker, 2022).

Although some of the identified mitigation options come with additional benefits, considerable barriers remain. One huge challenge is the pressure to increase agricultural production, not only to supply the growing demand from the Indonesian population but also to export agricultural products to generate revenue for the economy. Increasing agricultural production and ensuring self-sufficiency is the key objective of the Indonesian government, and the mitigation of GHG emissions is often not considered a key success factor of a measure. The objectives increase the pressure for more agricultural land, exacerbated by the lack of property rights and regulation on land tenure. Labour scarcity in the agricultural sector is another problem, as it often impedes the uptake of new practices, such as improved irrigation systems for rice fields. Lastly, the nature and small scale of many agricultural activities in Indonesia, with a very high share of subsistence farming, creates challenges in the dissemination of information and the application of good-practice technologies and approaches. The direct benefits of mitigation actions for smallholder farmers are often too little to create an incentive for a change.

To accelerate the uptake and implementation of the measures described in this report, it is key to enhance the national mitigation framework in the agricultural sector and synergising agricultural goals and mitigation options, while strengthening the international competitiveness of the sector. Some concrete options are outlined in the following paragraphs:

1. *Enhancing the national climate mitigation framework in agriculture*

Indonesia already has important legislation in place to limit peatland drainage and avoid logging of primary forest and peatland conversions, which has led to decreasing deforestation rates in Indonesia (Weisse and Goldman, 2022). These laws could be more impactful through stricter monitoring and enforcement. The government has also established an institution – the Peatland Restoration Agency – to restore mangroves and peatlands (Budiman *et al.*, 2021) which, with continued resources and agency, can drive emissions reductions and increase biodiversity (Mursyid *et al.*, 2021).

For a more effective implementation of production improvements, in addition to information dissemination, financial incentives to farmers can make a change in practices attractive. Here it is important to also consider the specific circumstances of smallholder farms.

2. *Align overall agricultural framework with climate mitigation objectives*

While Indonesia's National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK) had specified some mitigation actions for the agricultural sector, its short-term targets are now outdated and were not achieved. Currently, there is no mitigation strategy that covers the agricultural sector beyond the NDC. The NDC targets, overall, are set in a way that they will likely be overachieved, and the current target is far from a 1.5°C compatible target (Climate Action Tracker, 2022). Analysis on the achievement of the targets in the agricultural sector is not available, but it seems likely that a 10 $MtCO_2e$ reduction below a BAU is more than feasible with implemented measures. Indonesia could thus re-examine its agricultural policy framework and potentially increase its mitigation targets. A clearer direction for mitigation in the sector could reconcile some of the conflicts with other objectives.

The current agricultural strategies aim at increasing production, particularly of a few key crops. However, diversifying agricultural production can enhance environmental protection and improve diets and nutrition (Vermeulen *et al.*, 2019). Current strategies could further emphasise the need for productivity improvements and its mitigation co-benefits. To avoid further expansion of the agricultural sector into new land while increasing production, it is important to increase the productivity on existing land, particularly for smallholders. For example, our study shows that palm oil yields can be increased significantly.

Some regions in the world are starting to limit imports of products that have caused deforestation (Taylor, 2022). Research estimates that the EU's limitations on palm oil imports from Indonesia will have a minor impact on the Indonesian economy (Rifin *et al.*, 2020; Rum *et al.*, 2022), but Indonesia strongly opposes such developments (Embassy of the Republic of Indonesia in Brussels, 2019). If governments are serious with the 1.5°C limit, such regulations will increase in number. Indonesia could work towards turning this threat to its export revenues into incentives for increasing the sustainability of its agricultural products and collaborate with other international actors on the establishment of sustainable global supply chains.

3. Selected ideas on how mitigation could be strengthened in particular areas

Building on existing policy structures and initiatives, the Indonesian government can foster mitigation in the agricultural sector while providing significant environmental and socioeconomic co-benefits, including climate resilience and adaptation. Possible activities span promoting and incentivising improved agricultural practices and strengthening the governance framework around existing laws. Some more concrete, non-exhaustive ideas are:

- **Promote the awareness of mitigation measures and provide financial support**, particularly in rice management and among smallholder farmers. For rice production, a considerable source of GHG emissions in the agricultural sector, expanding the SRI can serve as the starting point since it provides numerous co-benefits including improved yields and less water use.
- **Improve subnational coordination of peatland restoration initiatives** to clarify responsibilities, decrease bureaucracy and ensure standards for the implementation of measures (Budiman *et al.*, 2021).
- **Reduce food loss and waste** through improved infrastructure and simplified value chains. Some solutions are already emerging, including providing farmers more direct access to consumers through mobile applications to decrease losses across long supply chains (Food and Land Use Coalition, 2019). In particular, household-level food waste increasingly contributes to GHG emissions and could be mitigated through incentivising changes in consumer behaviour (Bappenas, 2021).

While this report focuses on improvements on the production of agricultural products, it is essential to highlight that without changes to dietary patterns, mainly in developed countries, a sustainable and just 1.5°C pathway is not feasible. Discussing alternative narratives next to current plans for agricultural expansion plans could help understand the implications of a shift to largely plant-based diets and potentially avoid disruptions in the sector in the medium to long term. International research reports that demand-side measures, such as shifting to less meat intensive diets and reducing food waste, have a high mitigation potential while contributing to other co-benefits at relatively lower costs (Roe et al., 2021).

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