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FAOSTAT ANALYTICAL BRIEF 25

Emissions from agriculture and forest land

Global, regional and country trends

1990–2019

>> FAO Statistics Division

HIGHLIGHTS

- → **In 2019, global emissions from agriculture (farm gate and land use change processes) were nearly 11 billion tonnes of CO_2 equivalent (CO_2eq), having remained largely constant for the last 30 years, due to a balance of increasing emissions within the farm gate and decreases from land use change.**
- → **Regional emissions in 2019 were the largest in Asia on an absolute basis (4 billion tonnes), and in Oceania and Latin America on a per capita basis (4–6 tonnes/cap). The largest increase since 1990 was in Africa (30 percent), while the largest decrease was in Latin America (20 percent).**
- → **Brazil, Indonesia and China represented more than 50 percent of global emissions from agriculture. Emissions from deforestation and from peat fires dominated the national emissions from agriculture in Brazil and Indonesia, respectively, whereas farm-gate emissions were the larger contributor in China.**
- → **Non-CO_2 (methane and nitrous oxide) and CO_2 emissions within the farm gate contributed in 2019 more than 7 billion tonnes CO_2eq, a 9 percent increase since 1990. Two-thirds of the non-CO_2 emissions were related to livestock.**
- → **Land use change added 3.5 billion tonnes CO_2eq, mostly as CO_2 from carbon losses via deforestation and peatland fires. The former decreased by roughly 30 percent since 1990, while the latter increased by nearly 60 percent.**
- → **Fossil fuel energy use within the farm gate emitted 0.5 billion tonnes CO_2 in 2019, with a significant decrease since 1990 of over 30 percent, largely due to a shift to electricity generated off-farm.**
- → **Estimates of activity data and GHG emissions were disseminated for the first time together with data officially reported by countries to the UN Framework Convention on Climate Change (UNFCCC), to facilitate analysis and validation in line with the guidelines of the Intergovernmental Panel on Climate Change (IPCC).**

FAOSTAT EMISSIONS FROM AGRICULTURE AND FOREST LAND

BACKGROUND

Agriculture is a significant contributor to climate change, in addition to being one of the economic sectors most at risk from it. Greenhouse gas (GHG) emissions due to agriculture are generated both within the farm gate by crop and livestock production activities, and through land use change processes at the conversion boundary between natural ecosystems and agricultural land. Together they contribute about 20 percent of total emissions from all human activities (IPCC, 2019a; Tubiello *et al*., 2021).

The FAOSTAT Emissions database provides estimates at the country, regional and global levels, including methane (CH_4) and nitrous oxide (N_2O) emissions from crop and livestock production, as well as carbon dioxide (CO_2) emissions and removals from land use, land use change and fossil fuel energy use. This analytical brief extends previous FAO analyses to the period 1990–2019, mapping relevant

emissions within and across the farm-gate/land use production boundaries. The new mapping provided is useful to compare the Food and Agriculture Organization of the United Nations (FAO) estimates to the country data officially reported to the United Nations Framework Convention on Climate Change (UNFCCC) under the ''agriculture'' and ''land use, land use change and forestry (LULUCF)'' sectors of national GHG inventories. To this end, the 2021 FAOSTAT update allows for the first time to visualize jointly FAO and UNFCCC data, the latter sourced from the most recently available greenhouse gas national inventories (NGHGI), national communications and biennial update reports (BURs). The IPCC (2019b) guidelines, which regulate country reporting to the UNFCCC, already promote the use of FAOSTAT emissions data for quality assurance/quality control (QA/QC) and validation processes in support of NGHGI development. Furthermore, a recent meeting of UNFCCC Annex I Lead Reviewers highlighted the "usefulness of the [FAO] data sources for supporting GHG inventory reviews, and requested the secretariat to explore ways of incorporating the FAO data resources as an authoritative supporting data source for reviews in the 2021 cycle and beyond."

In the following analyses, emissions from agriculture are divided into emissions generated within the farm gate and those generated at the land use change boundary between farms and natural ecosystems. The same are mapped to categories used for UNFCCC reporting of NGHGI and IPCC categories, with a mapping provided in the explanatory notes section of this report (see Figure 13).

RESULTS: GLOBAL TRENDS, 1990-2019

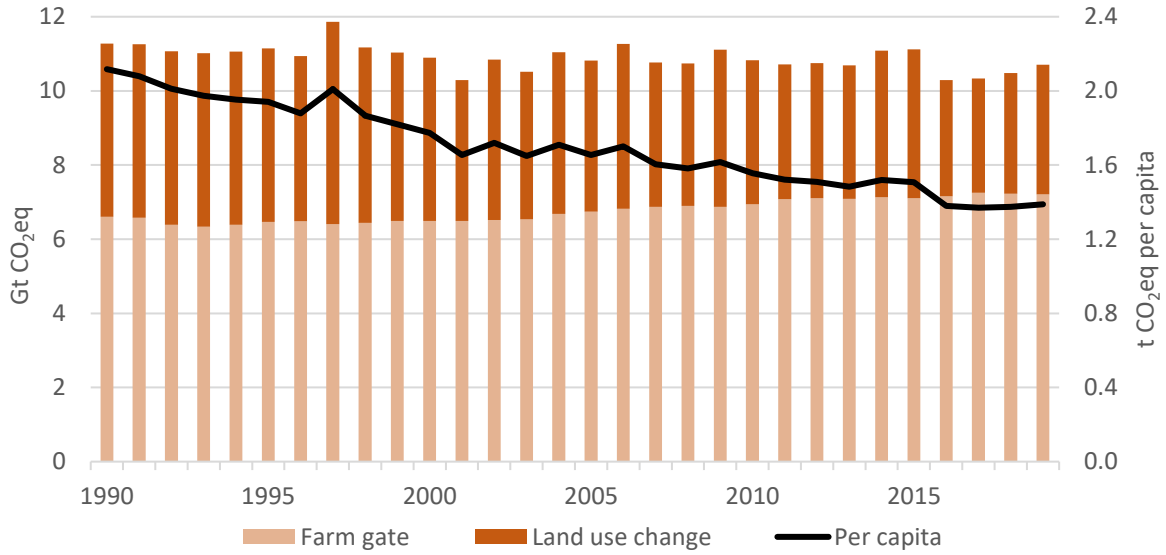
In 2019, total emissions from agriculture, i.e. generated within the farm gate and at the farm boundary with natural ecosystems, were 10.7 billion tonnes of carbon dioxide equivalent (Gt CO_2eq). These emissions remained fairly constant over the entire 1990–2019 period, with no statistically significant trend (Figure 1), considering that the underlying data uncertainty is around 30 percent[1] (Tubiello *et al*., 2013).

Emissions generated within the farm gate and those associated to land use change were nonetheless characterized by opposite trends, which tended to cancel each other out. Specifically, the former increased by about 10 percent over the period 1990–2019, from 6.6 to 7.2 Gt CO_2eq, while the latter decreased by 25 percent, from 4.7 to 3.5 Gt CO_2eq.

Whereas total emissions from agriculture remained virtually unchanged over the last 30 years, they decreased on a per capita basis, by nearly 35 percent, from 2.1 to 1.4 t CO_2eq per capita, as a result of improvements in the efficiency of agricultural production processes and of reductions in land conversions, especially deforestation (Figure 2).

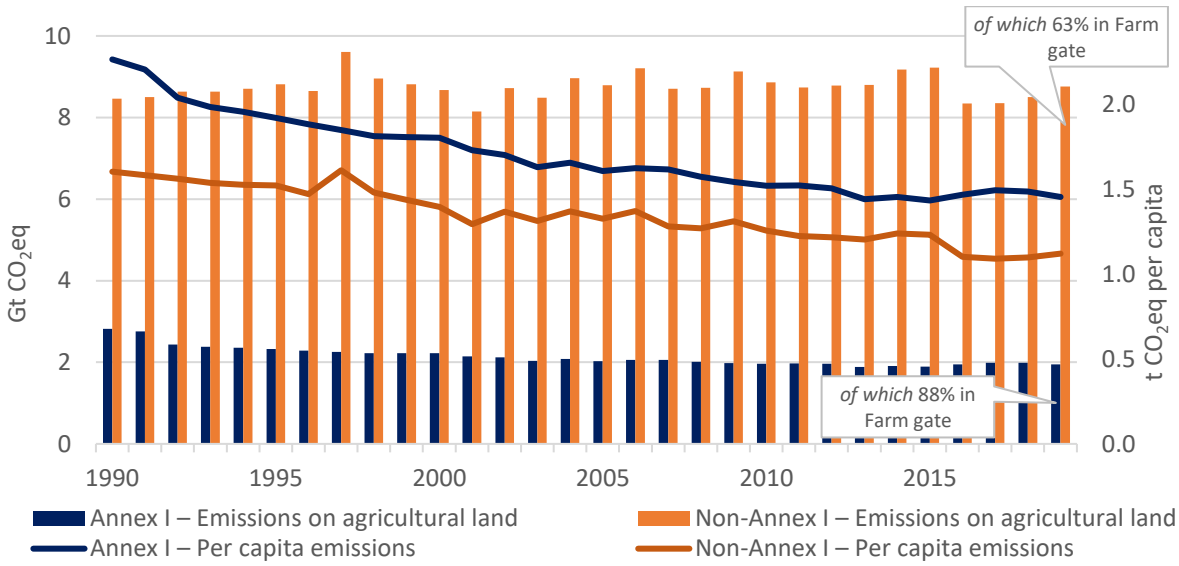
[1] Overall uncertainty stems from uncertainties in both the activity data and in the emissions factors coefficients applied for the emissions estimates.

Figure 1. Global absolute and per capita emissions from agriculture, detailing farm-gate and land use change components, 1990–2019



Source: FAOSTAT, 2021.

Figure 2. Emissions in absolute and per capita levels from agriculture, by Annex I (developed countries, according to the UN Climate Convention) and Non-Annex I countries (developing)[2] 1990–2019



Source: FAOSTAT, 2021.

[2] The list of the type of parties reporting to the UN Climate Convention is available at https://unfccc.int/process/parties-non-party-stakeholders/parties-convention-and-observer-states.
For corresponding FAOSTAT area codes, please see the tab 'Country Group' in the FAOSTAT Definitions and Standards http://www.fao.org/faostat/en/#definitions.

Of the 7.2 Gt CO_2eq generated within the farm gate in 2019, methane (CH_4) emissions from enteric fermentation in digestive systems of ruminant livestock were the largest contributor (2.8 Gt CO_2eq), followed by emissions from the use of fertilizers on agricultural soils. The latter were in the form of nitrous oxide (N_2O) emissions, totalling 1.5 Gt CO_2eq arising from applications of livestock manure (0.9 Gt CO_2eq) – either left on pasture by grazing animals or used as organic fertilizer – and of synthetic fertilizers (0.6 Gt CO_2eq). The third most important process was the drainage of organic soils and peatlands (Conchedda and Tubiello, 2020), generating 0.8 Gt CO_2eq in 2019, largely as CO_2 gas, followed by methane emissions from rice (0.6 Gt CO_2eq) and CO_2 emissions from fossil fuel energy use (0.5 Gt CO_2eq) for farm operations (Figure 3).

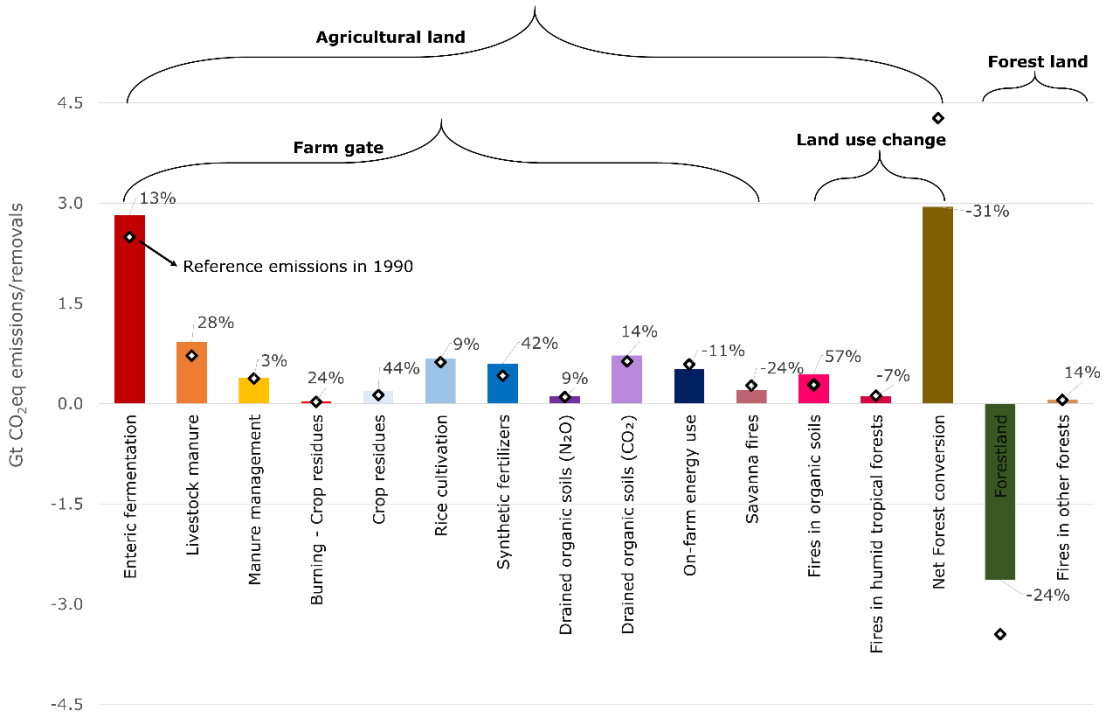
Forest conversion (a proxy for deforestation) generated 2.9 of the 3.5 Gt CO_2eq emissions from land use change (Figure 3). Fires in tropical peatlands in South-eastern Asia, part of a cycle of drainage and deforestation processes, were the second largest source of land use change emissions (0.4 Gt CO_2eq) in 2019.

Overall, the new estimates show that enteric fermentation and net forest conversion alone, each emitting about 3 Gt CO_2eq in 2019, represented more than 50 percent of all emissions on agricultural land. Together with emissions from fertilizers and drained organic soils, these four components emitted over three-quarters of the total emissions on agricultural land.

While agriculture generated net emissions into the atmosphere, forest land instead generated net removals in 2019 and in general over the entire 1990–2019 study period (see also: Tubiello *et al.,* 2021). Specifically, removals on forest land were about 2.9 Gt CO_2eq in 2019, nearly counterbalancing emissions from net forest conversion. At the same time, fires in other forests added a relatively small amount of non-CO_2 emissions, in the order of 0.2 Gt CO_2eq in 2019.

Of the emissions components discussed above, nitrogen-related emissions from synthetic fertilizers and crop residues showed the largest growth since 1990 (+44 and +42 percent respectively), reflecting growth in crop production over the same period. At the same time, emissions from deforestation saw significant decline (-31 percent), in connection with more stringent regulation in key countries. In terms of land use change, emissions from fires in organic soils increased strongly (+31 percent), reflecting the ongoing conversion of these natural ecosystems to agriculture, especially in South-eastern Asia. Results also indicate that removals of CO_2 by forests, i.e. their sink strength in partially counterbalancing emissions, decreased significantly in the past 30 years, by 24 percent, albeit forests remain an overall carbon sink today (Figure 3).

Figure 3. Emissions from agriculture and forest land for the year 2019, by component. Percent values represent changes with respect to reference emissions levels in 1990 (except for energy use, set to 1992)



Source: FAOSTAT, 2021.

REGIONAL

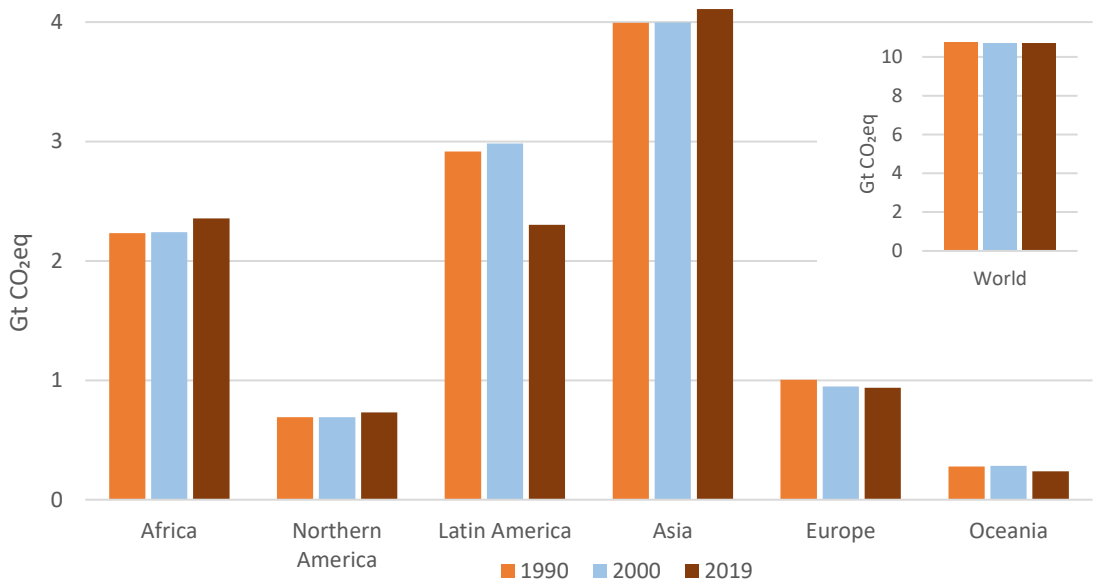
The global trends discussed above mask significant differences among regions (Figure 4).

First, results show that in the last decade 2010–2019, global emissions from agriculture were dominated by Asia (4 Gt CO_2eq), followed by Latin America (comprising of Central and South America) and Africa (2.3 Gt CO_2eq each), Europe (0.9), Northern America (0.7) and Oceania (0.3).

By comparing the most recent decade to the early 1990s, in **Asia** and **North America** total emissions from agriculture have remained rather stable over the last 30 years. Conversely, and while showing similar values in the most recent decade, emissions in **Africa** increased by a significant 30 percent since the 1990s, while they decreased in **Latin America** by more than 20 percent – the latter largely in relation to well-documented decreases in deforestation particularly in South America (FAO, 2020).

The most significant decreases in emissions over the study period were computed for **Europe** (-25 percent), linked to reductions of farm-gate emissions, and **Oceania** (-15 percent).

Figure 4. Trends in regional emissions from agriculture (1990, 2000, 2019)

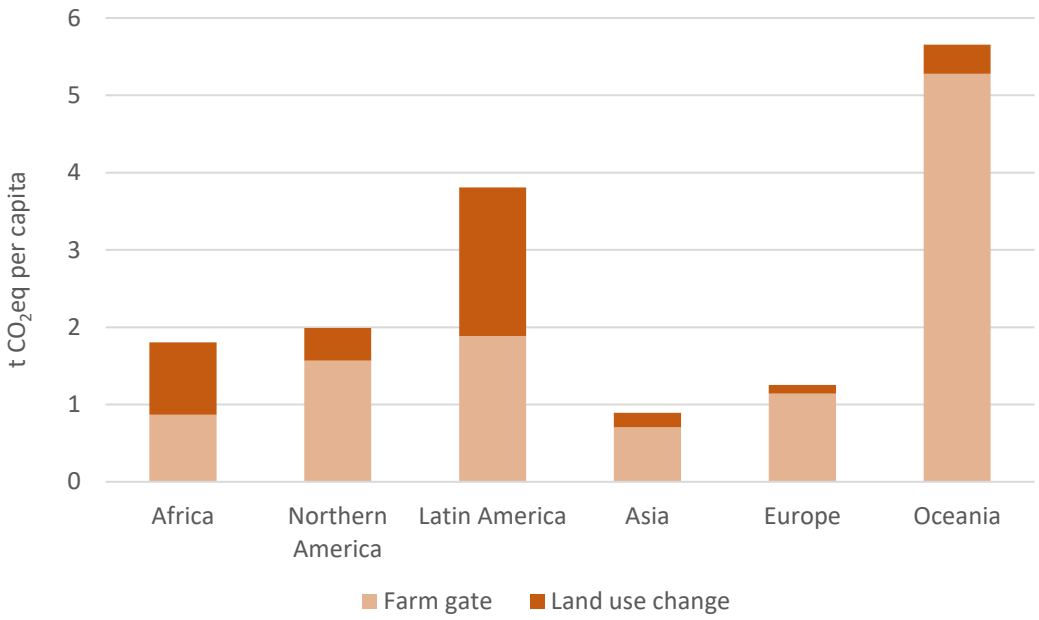


Source: FAOSTAT, 2021.

Furthermore, farm-gate production and land use change processes contributed differently to total emissions in the regions analysed (Figure 5). In 2019, emissions within the farm gate contributed more than two-thirds of the agriculture total in **Oceania** (78 percent), **Europe** (74 percent), **North America** (67 percent) and **Asia** (67 percent). Emissions from land use change processes were conversely the largest contributor of emissions from agriculture in **Africa** (55 percent) whereas farm-gate and land use change emissions contributed equally in **Latin America**.

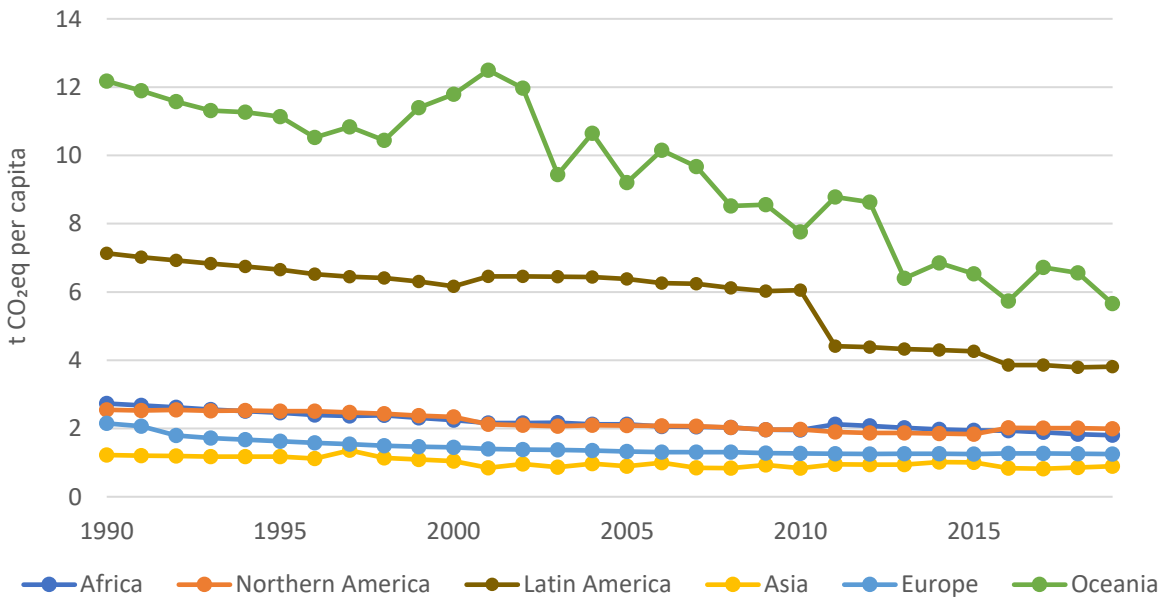
In 2019, global per capita emissions due to agriculture averaged 1.4 t CO_2eq per person, down nearly 35 percent from 2.1 t CO_2eq per capita in 1990. Per capita emissions varied significantly across regions, although they declined consistently over time (Figures 5 and 6). Per capita emissions in Latin America and Oceania, at 3.8 and 5.6 t CO_2eq per capita respectively in 2019, were two and three times the world average, despite having both more than halved from 1990 values. Per capita values for North America and Africa (1.6–1.7 t CO_2eq per capita) were slightly higher than the global average and remarkably similar, with no significant trend over the period 1990–2019. The same similarity and lack of trends characterized per capita emissions in Europe and Asia, albeit with values about half of the global average (0.7–0.9 t CO_2eq per capita).

Figure 5. Regional per capita emissions from agriculture, detailing farm-gate and land use change components, 2019



Source: FAOSTAT, 2021.

Figure 6. Trends in regional per capita emissions from agriculture, 1990–2019

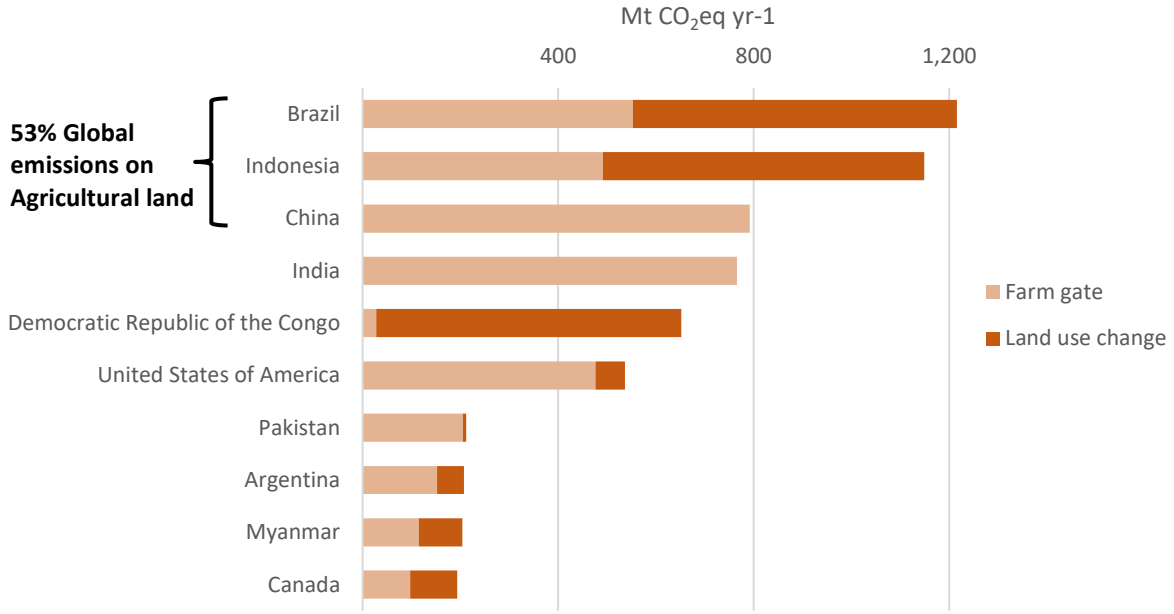


Source: FAOSTAT, 2021.

COUNTRY

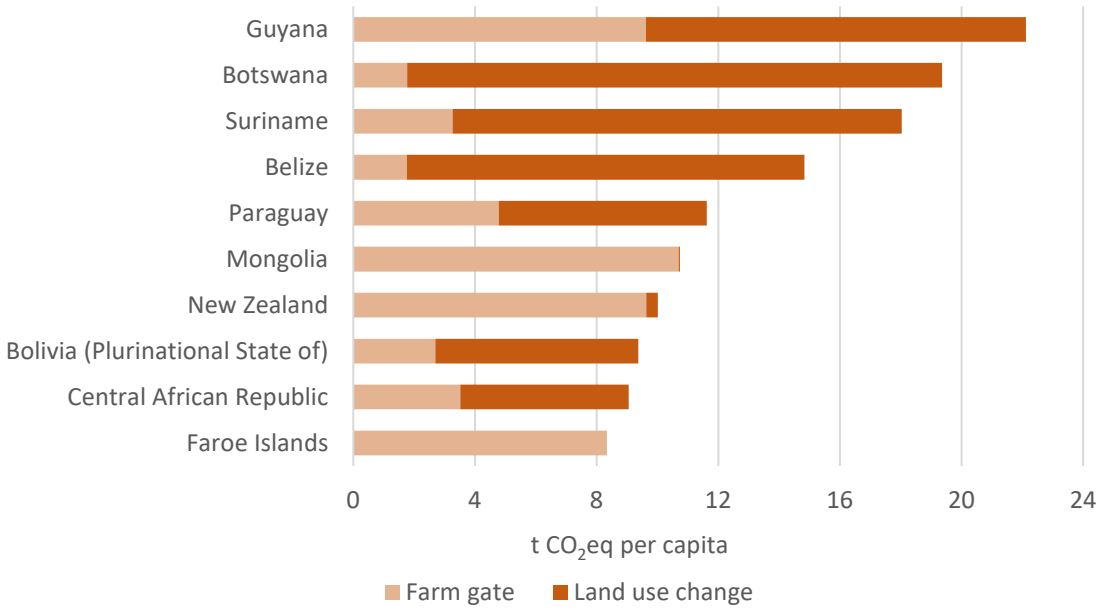
The list of the top ten emitters from agriculture naturally correlates with countries characterized by a large area and population (Figure 7). In 2019, **Brazil, Indonesia** and **China** represented more than 50 percent of world emissions from agriculture. The first two countries emitted each nearly 1 billion tonnes of CO_2eq. **China and India** had the largest emissions from within the farm gate (nearly 800 million tonnes of CO_2eq each) while **Brazil, Indonesia** and the **Democratic Republic of the Congo** had the largest contributions from land use change. A different set of countries, however, dominated per capita emissions (Figure 8), with values ranging between 8–20 tonnes CO_2eq/capita, i.e. 6 to 15 times the world average in 2019. Among these, the highest per capita emissions were generated in countries with small populations and high levels of land use change emissions. Conversely, high per capita emissions values computed in New Zealand and Mongolia (around 10 tonnes CO_2eq/capita) were largely related to livestock activities.

Figure 7. Top ten countries by emissions from agriculture, including farm gate and land use change components, 2019



Source: FAOSTAT, 2021.

Figure 8. Top ten countries by per capita emissions from agriculture, with farm gate and land use change components, 2019



Source: FAOSTAT, 2021.

COMPARISON TO UNFCCC DATA

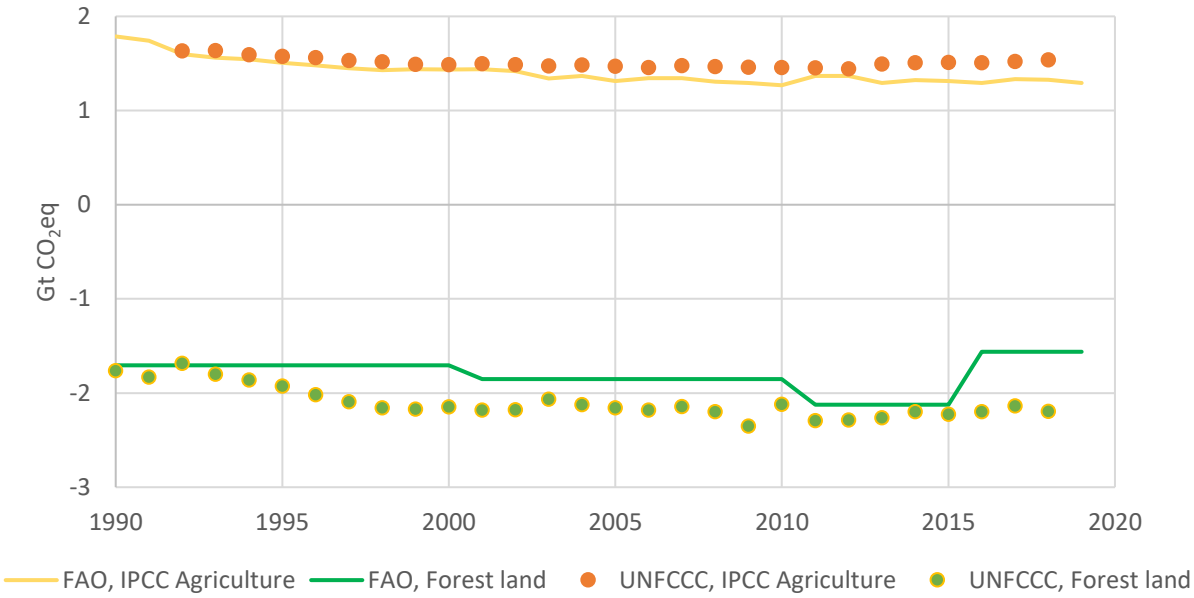
The FAOSTAT emissions estimates were compared for the first time to data officially reported by countries to the UNFCCC, using the most recently available NGHGI, national communications or BURs. At the time of writing, data reported to UNFCCC were available up to 2018.

FAO emissions estimates and underlying activity data can be compared to official country data submitted to the UNFCCC for main categories ''IPCC Agriculture'' and ''Forestland'', as well as for their sub-domains (see mapping table in Explanatory Notes, Figure 13). In particular, ''IPCC Agriculture'', which is available as an aggregate in the FAOSTAT Emissions Totals domain, includes the non-CO_2 emissions generated from crop and livestock production activities covered by the IPCC (2006) guidelines. "Farm gate" emissions, also available as an aggregate in the FAOSTAT Emissions Totals, include in addition CO_2 emissions from drained organic soils, as well as CO_2 and non-CO_2 emissions from on-farm energy use. In the same vein, the category ''Forestland'' corresponds to carbon emissions/removals on forest land (FAO, 2020 and Tubiello *et al*., 2021). While the database offers the possibility to compare activity data and emissions by country, we provide here for simplicity comparisons across the relevant aggregate of Annex I parties to UNFCCC, composed largely of Organisation for Economic Co-operation and Development (OECD) developed economies. Such comparisons are facilitated by the fact that UNFCCC data for this group are complete, considering that Annex I countries are required to report their emissions annually through national GHG inventories. For this group of countries there is close alignment between the FAO estimates and UNFCCC data, for both IPCC Agriculture and forestland emissions categories, over the entire available time series (Figure 9).

Conversely, for the non-Annex I country group, which is composed largely of developing countries, significant data gaps exist due to incomplete and less regularly submitted country reports. The

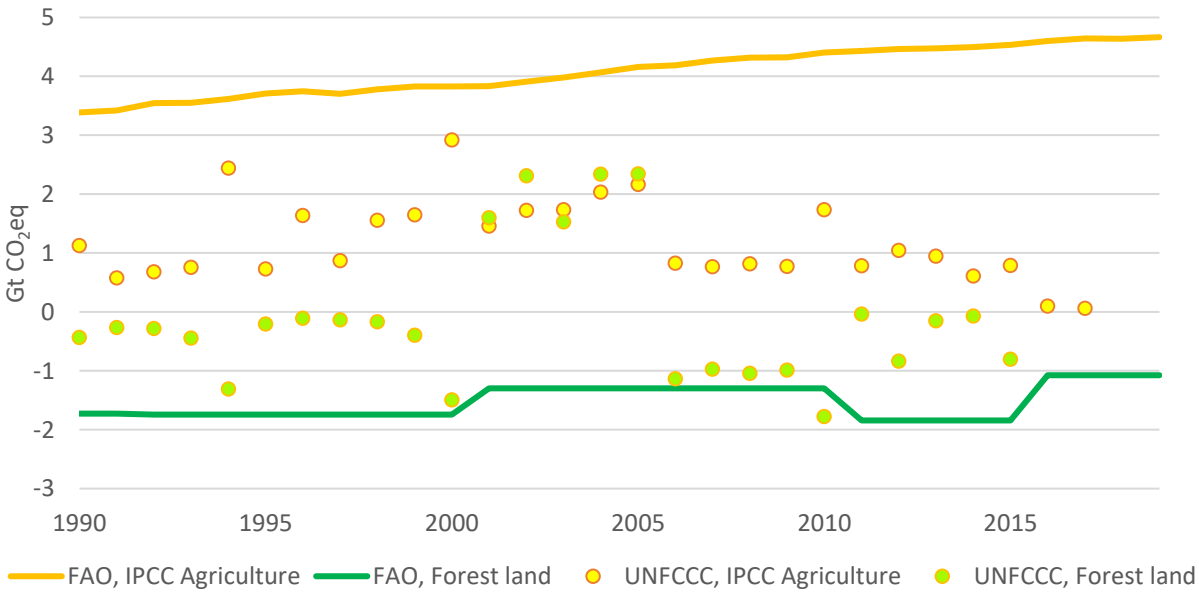
comparison of the complete set of FAO estimates to available UNFCCC country data underscores such a situation, thus highlighting the complementary importance of the FAO information to better characterize regional and country trends (Figure 10). Detailed comparisons for Brazil (Figure 11) and China (Figure 12) help to further document the usefulness of FAO information with respect to existing country data, i.e. for use in a range of QA/QC processes, as suggested by the relevant section of the most recent IPCC (2019b) Guidelines and UNFCCC Lead Reviewers' recommendations with regards to FAOSTAT.

Figure 9. Comparison of FAOSTAT estimates to UNFCCC data, aggregated by Annex I parties, over the period 1990–2019



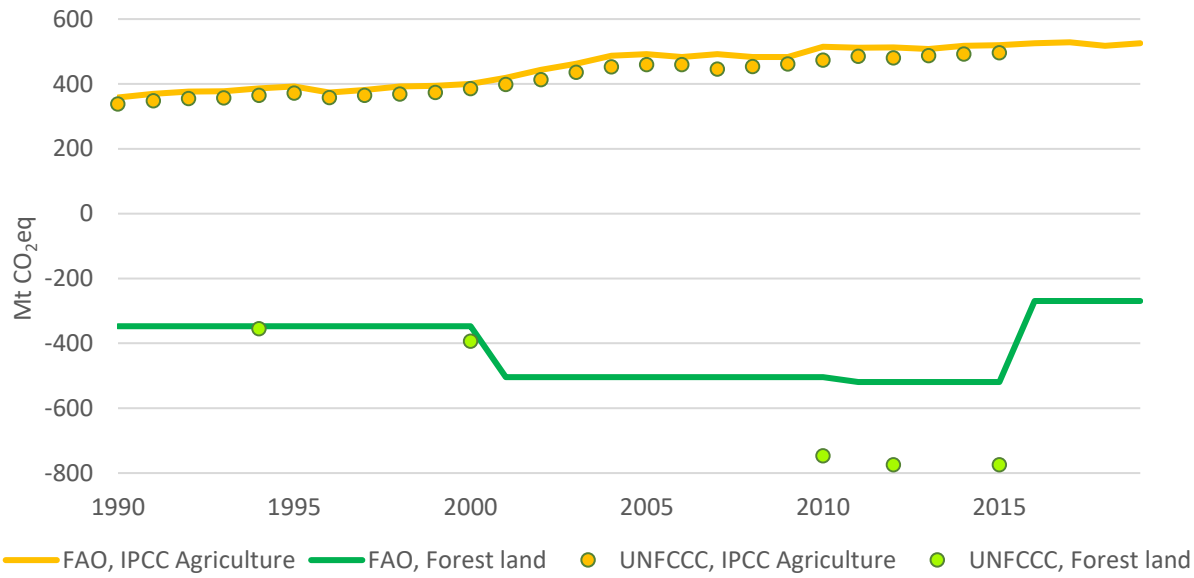
Source: FAOSTAT, 2021.

Figure 10. Comparison of FAOSTAT estimates to UNFCCC data, aggregated by Non-Annex I parties, over the period 1990–2019



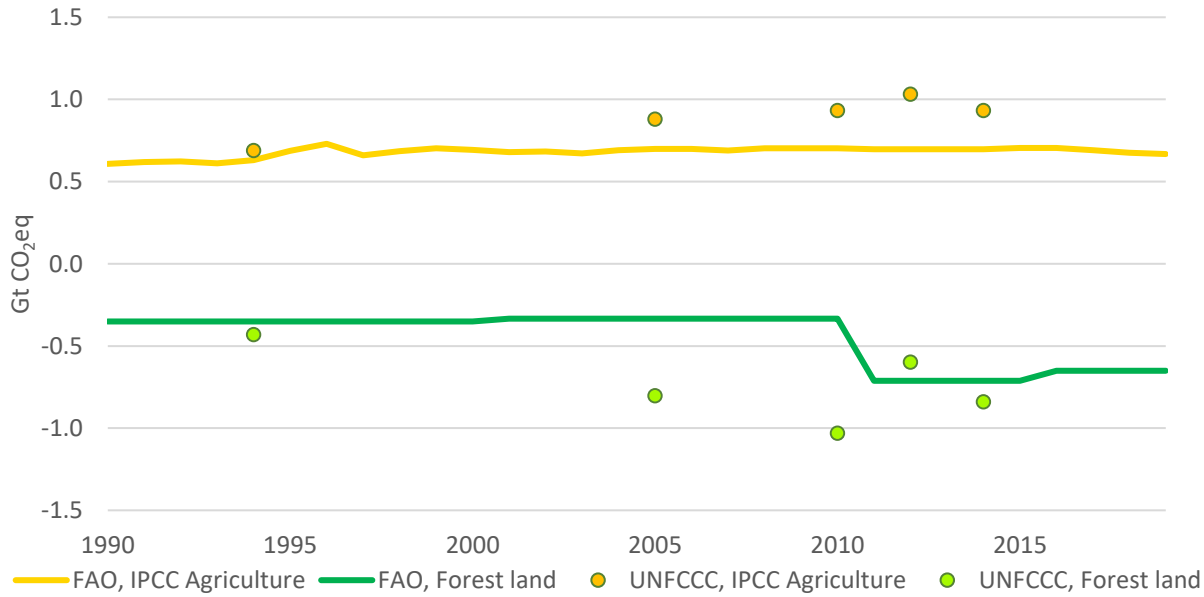
Source: FAOSTAT, 2021.

Figure 11. Country example (Brazil): Country reported data and correspondence with FAO estimates



Source: FAOSTAT, 2021.

Figure 12. Country example (China): Country reported data and correspondence with FAO estimates



Source: FAOSTAT, 2021.

EXPLANATORY NOTES

The FAOSTAT emissions database is composed of several data domains covering the categories of the IPCC Agriculture, Forestry and Other Land Use (AFOLU) sector of the NGHGI to the UNFCCC. Energy use in agriculture is additionally included as relevant to emissions from agriculture and as an economic production sector under the International Standard Industrial Classification of All Economic Activities (ISIC A) statistical classification. We recognize however that, in terms of IPCC, these emissions are instead part of the energy sector of the national GHG inventory. Specifically, as depicted schematically in Figure 13, UNFCCC reporting categories of the NGHGI, corresponding to IPCC (2006) categories of AFOLU and a set of detailed reporting categories, can be mapped to FAO land use classes of agricultural land (comprised of cropland and permanent meadows and pastures), forest land and other land. In turn, activities on cropland and permanent meadows and pastures can be largely comprised within the farm gate, while activities representing conversion of (largely) forest land to agriculture can be mapped onto land use change activities (on agricultural land), such as deforestation and peat fires (see also Tubiello *et al*., 2021).

Non-CO_2 emissions from agricultural activities – i.e. methane (CH_4) and nitrous oxide (N_2O) emissions – as well as CO_2 emissions from the single domains are all summarized in Emissions Totals. This newly constructed domain disseminates emissions aggregates in CO_2eq, computed applying the Global Warming Potential from the Fifth Assessment Report of the IPCC (IPCC, 2014).

FAO emissions estimates are available over the period 1961–2019 for agriculture production processes, i.e. crop and livestock activities. The activity data underlying these emissions are based on country data officially reported to FAO (for instance, livestock numbers, harvested area, fertilizers use in agriculture). Projections to 2030 and 2050 are also available. They are computed with respect to the 2005–2007 baseline, following Alexandratos and Bruinsma (2012).

Land use and land use change emissions and removals are instead generally available only for the period 1990–2019. The activity data for forests are collected from FAO Forest Resources Assessments (FRA) in five-year cycles. Geospatial data complement existing national statistics and provide the source of activity data for emissions on drained organic soils, savanna, forest fires and fires in organic soils. These emissions estimates are currently available for the period 1990–2019. Finally, data on energy use are available for the period 1990–2019.

For emissions from fires in organic soils, in line with existing literature, only the emissions from South-eastern Asian countries (e.g. Indonesia, Malaysia and Brunei Darussalam) were considered anthropogenic. Conversely, emissions estimates for the other countries and territories provided in FAOSTAT were not considered anthropogenic, to reflect the lack of evidence to this end in existing literature. As a result, although the emissions from fires in organic soils are disseminated for all the countries and territories where these fires occur, the values from countries in the FAOSTAT regional aggregate ‘South-eastern Asia’ only contribute to relevant thematic, regional and world total aggregates.

Figure 13. Correspondence between NGHGI, IPCC, FAO Land Use and FAOSTAT emissions categories

NGHGI	IPCC	FAO		
LULUCF	AFOLU	Wetlands, settlements and other land		OTHER LAND
		Forest land	Forestland	FOREST LAND
		Burning biomass	Fires, other forest	
			Fires, humid tropical forest	LAND USE CHANGE / AGRICULTURAL LAND
			Fires, organic soils	
		Forest land converted to cropland and grassland	Net forest conversion	
		Drained organic soils	Drained organic soils	FARM GATE / AGRICULTURAL LAND
AGRICULTURE		Cultivation of histosols		
		Inorganic N fertilizers	Synthetic fertilizers	
		Crop residues	Crop residues	
		Manure deposited on pasture, range and paddock	Manure left on pasture	
		Manure applied to soils	Manure applied to soils	
		Manure management	Manure management	
		Enteric fermentation	Enteric fermentation	
		Prescribed burning of savanna	Savanna fires	
		Burning-crop residues	Burning-crop residues	
		Rice cultivation	Rice cultivation	
		Liming; urea application		
ENERGY			On-farm energy use	

Source: FAOSTAT, 2021.

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