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FAOSTAT ANALYTICAL BRIEF 73

Agrifood systems and land-related emissions

Global, regional and country trends 2001–2021

>> FAO Statistics Division

HIGHLIGHTS

→ **In 2021, global agrifood systems emissions were 16 billion tonnes of carbon dioxide equivalent (Gt CO_2eq), an increase of 14 percent since 2001. They represented 30 percent of total anthropogenic emissions (53 Gt CO_2eq).**

→ **The share of agrifood systems in emissions from all sectors decreased from 37 percent in 2001 to 30 percent in 2021, underscoring faster growth in non-agrifood emissions.**

→ **The farm gate represented nearly half of world total agrifood systems emissions, while pre- and post-production processes contributed one-third and land-use change one-fifth.**

→ **Farm-gate emissions were the largest component in Oceania (71 percent), Asia (50 percent) and the Americas (43 percent). Land-use change was the largest contributor in Africa (44 percent), while pre- and post-production processes were the largest contributor in Europe (53 percent).**

→ **Global agrifood systems emissions from land-use change, due to processes such as deforestation, peatland degradation, peat and biomass fires, were 3.9 Gt CO_2eq in 2021. In addition to agrifood systems processes, forest land was a net carbon sink, generating removals of 2.6 Gt CO_2eq.**

→ **Fires in organic soils, mainly tropical peatlands, contributed on average 260 Mt CO_2eq. They remain an important component of land-use change emissions in South-eastern Asia.**

→ **In 2021, the agrifood systems emissions per capita were 2.0 t CO_2/cap, showing little change since 2001.**

AGRIFOOD SYSTEMS GREENHOUSE GAS EMISSIONS

Greenhouse gas (GHG) emissions from agrifood systems are generated within the *farm gate,* by crop and livestock production activities; by *land-use change*, for instance deforestation and peatland drainage to make room for agriculture; and in *pre- and post-production processes*, such as food manufacturing, transport, retail, household consumption and food waste disposal (FAO, 2023a).

This analytical brief provides an update to the year 2021 of all agrifood systems emissions and indicators. At the same time, it offers a more detailed focus on land-use change emissions, considering that emissions within the farm gate and pre- and post-production processes were discussed in detail previously (FAO, 2020; FAO, 2023b).

The FAOSTAT land-use change component of agrifood systems includes processes linked to the conversion of natural ecosystems to new agricultural land for crop and livestock production through peatland drainage, peatland fires and deforestation. These are processes that generate GHG emissions into the atmosphere.

In addition, FAOSTAT also provides emissions from and use, land-use change and forestry (LULUCF), estimated by summing emissions from land-use change to those on forest land. LULUCF is an important component of national GHG inventories (NGHGIs), used by countries to report to the United Nations Framework Convention on Climate Change (UNFCCC). Unlike the land-use change component of agrifood systems, it includes both emissions and removals of carbon dioxide (CO_2). On the one hand, ecosystem degradation through fires, drainage and deforestation activities results in GHG emissions into the atmosphere. On the other, enhanced biomass growth, for instance through afforestation or improved forest management, sequesters CO_2 from the atmosphere, generating a removal. The importance of disseminating statistics on LULUCF cannot be overstated: the world will not be able to reach the net-zero emissions goals of the Paris Agreement without efforts to monitor the amount of carbon sequestration on land.

FAOSTAT data on land emissions and removals are derived from a variety of statistical and non-statistical sources. Forest area and carbon stock change data are taken directly from the national statistics collected by the Food and Agriculture Organisation of the United Nations (FAO) via the Global Forest Resources Assessment (FRA), conducted at five to ten years intervals (FAO, 2020b). Conversely, statistics on burnt area and biomass fires, area of degraded peatlands and related emissions, are computed geospatially and then aggregated at the national scale using maps compiled monthly or annually from remote sensing. As a result, this brief provides data on fire emissions updated to the year 2022, thanks to the near real-time nature of the underlying observations and the ability to perform fast processing. The geospatial data underlying these estimates are available in the FAO Hand-in-Hand geospatial platform as well as in other data gateways such as the Google Earth Engine Catalog and EarthMap. All other components in the FAOSTAT emissions domains were updated to the year 2021, reflecting the use of more traditional statistical processes.

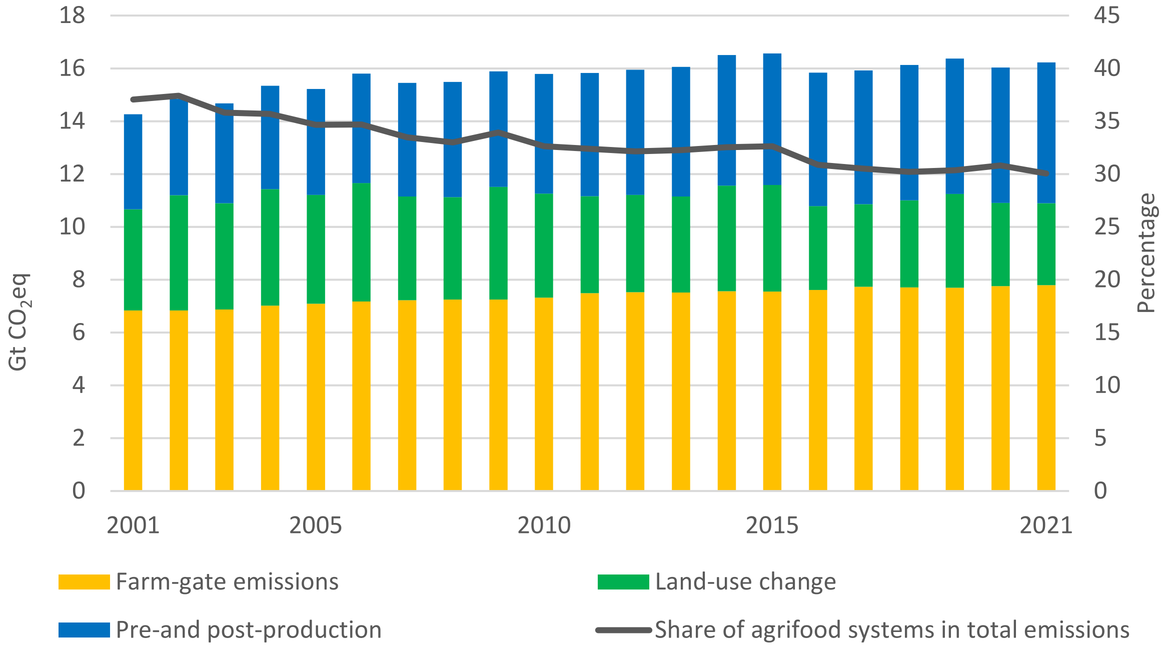
GLOBAL

In 2021, world total anthropogenic GHG emissions reached an all-time high of 53 billion tonnes of CO_2 equivalent (Gt CO_2eq), an increase of 4 percent from 2020 and 40 percent since 2001. This reflected the rebound of the global economy after the COVID-19 pandemic, which had caused a rare dip in total GHG emissions in 2020 compared to 2019 (-4 percent). World total emissions from agrifood systems remained flat from 2019 to 2021 at about 16 Gt CO_2eq but exhibited a 14 percent growth since 2001. These trends together led to a decrease in the share of agrifood systems in world total emissions, from 37 percent in 2001 to 30 percent in 2021 (Figure 1).

The slow growth in agrifood systems emissions during 2001–2021 corresponds to slight decreases in emissions per capita (from 2.3 to 2.0 t CO_2eq/cap) and small changes in emissions on agricultural land per agricultural land area (from 2.2 to 2.3 t CO_2eq/ha). Conversely, strong growth in agricultural production over the same period led to a large decrease in emissions on agricultural land per value of agricultural production, from 4.0 to 2.6 kg CO_2eq/USD (see Explanatory Notes).

Of the three components that characterize agrifood systems, farm-gate emissions represented in 2021 nearly half of the total (7.8 Gt CO_2eq), followed by emissions from pre- and post-production activities (5.3 Gt CO_2eq) and emissions from land-use change (3.1 Gt CO_2eq). Over the period 2001–2021, preand post-production emissions grew the fastest (48 percent); those within the farm gate increased by 14 percent while emissions from land-use change decreased (-19 percent), a result of a significant slowdown in world total deforestation rates (Figure 1).

Figure 1: Global agrifood systems emissions by component



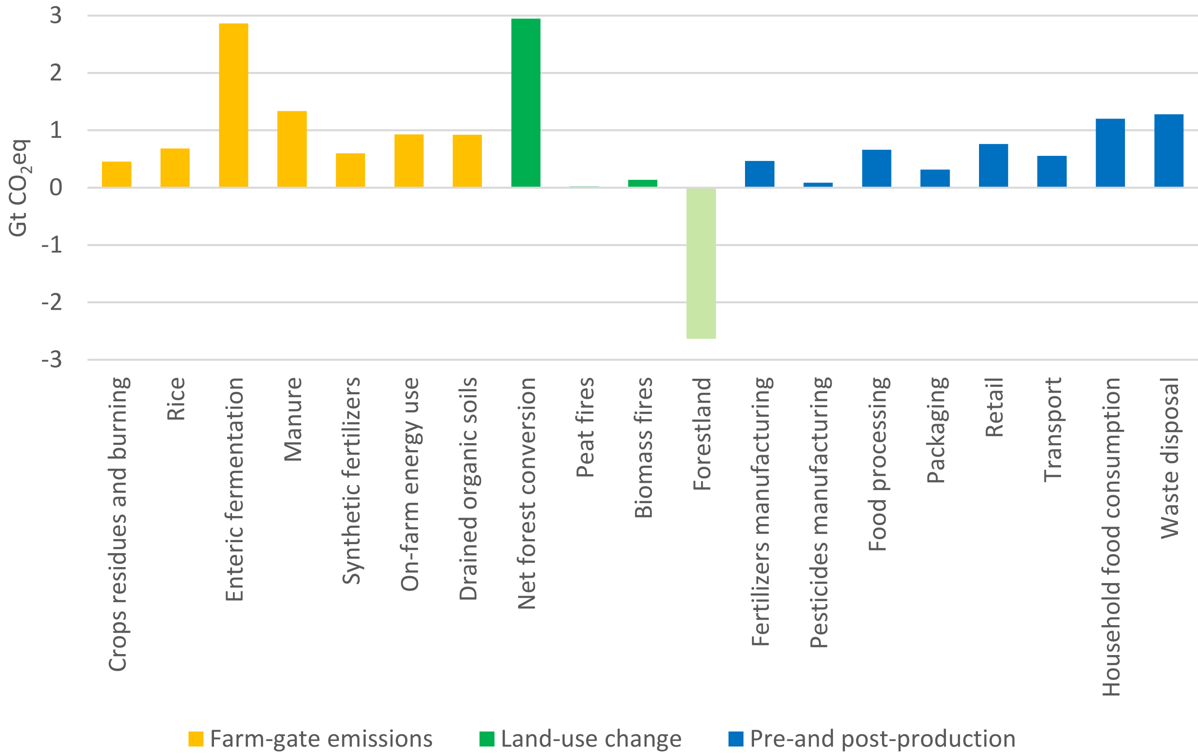
Source: FAO. 2023. Emissions totals. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GT and FAO. 2023. Emissions indicators. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/EM

With respect to specific agrifood systems processes, the most important contributors in 2021 were CO_2 emissions from deforestation and methane (CH_4) emissions from enteric fermentation of ruminant livestock (2.9 Gt CO_2eq each), representing together 40 percent of the agrifood systems total. Other important components were CH_4 emissions from livestock manure (manure management, soil application and manure deposition) and agrifood systems waste disposal, about 1.3 Gt CO_2eq each.

Within the farm gate, total livestock emissions – encompassing enteric fermentation, manure management, manure applied to soils and manure left on pasture – amounted in 2021 to 4.2 Gt CO_2eq, representing 54 percent of farm-gate emissions. Together, emissions from enteric fermentation, and from manure management and its applications to soils were 3.4 Gt CO_2eq, consistently with independent FAO estimates computed at Tier 2 using the GLEAM model (Wisser *et al.*, forthcoming). In 2021, emissions from crops, including those from crop residues decomposition and burning, and rice cultivation, were 0.9 Gt CO_2eq; soil application of synthetic fertilizers generated an additional 0.6 Gt CO_2eq while on-farm energy use added 0.9 Gt CO_2eq to the farm gate total (Figure 2).

The two processes within pre- and post-production activities that generated the largest emissions were household food consumption and agrifood systems waste disposal, each generating about 1.2 Gt CO_2eq.

Figure 2: Agrifood systems emissions by component (2021)



Note: Emissions/removals on forestland (which are not part of agrifood systems emissions) are also shown as included in the FAOSTAT Emissions database.

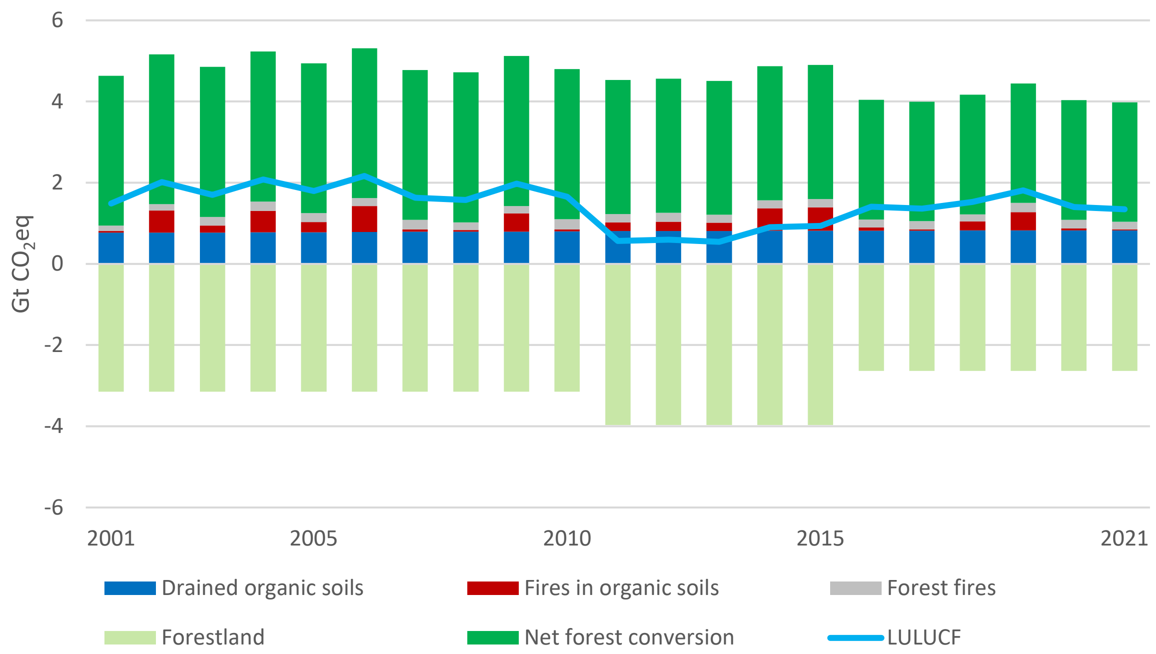
Source: FAO. 2023. Emissions totals. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GT

LAND USE, LAND-USE CHANGE AND FORESTRY

In 2021, world total land-based emissions minus removals from LULUCF – hereafter referred to as net emissions – totalled 1.3 Gt CO_2eq (Figure 3). This corresponded to total emissions of 4.0 Gt CO_2eq and removals of -2.6 Gt CO_2. Emissions consisted of 2.9 Gt CO_2 from net forest conversion (deforestation), 0.8 Gt CO_2eq from drained organic soils and 0.2 Gt CO_2eq from forest fires (mostly in humid tropical forests and driven by deforestation) and tropical peat fires. Conversely, carbon removals corresponded to increases in forest carbon stocks, either through afforestation or management of existing forests.

World total net LULUCF emissions were 1.8 Gt CO_2eq per year on average during 2001–2010. They decreased to 1.1 Gt CO_2eq per year during 2011–2021, reflecting well-documented reductions in deforestation rates (FAO, 2020c). At the same time, the remaining forest land was a significant carbon sink globally, with average sequestration rates of 3.4 Gt CO_2eq over the period 2001–2015 and 2.6 Gt CO_2eq in the more recent 2016-2021 period.

Figure 3: Global land use and land-use change emissions and removals by component



Source: FAO. 2023. Emissions totals. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GT

Fires represent an important contributor to LULUCF emissions, indicating disturbance to ecosystems. In forests, they are closely linked to degradation and deforestation (FAO, 2022). Beyond their climate impact through GHG emissions, fires release particulate matter and toxic gases that can travel great distances, leading to compromised air quality and posing substantial health risks. Therefore, monitoring their trends through dedicated statistics supports the assessment of risk to humans and ecosystems.

Emissions from fires in FAOSTAT were generated through big data processes using as input near real-time remote sensing products. For this reason, they are provided in this update up to 2022, i.e. one more year than possible for the other LULUCF components, which are instead generated by more traditional statistical processes. Several types of fires are covered in the emissions database (see Explanatory Notes). The emissions from fires in humid tropical forest and from management fires of grassland and shrubland vegetation (savanna fires) are part of the land processes generating agrifood systems emissions. Conversely, LULUCF only includes the emissions from forest fires, humid tropical forest and other types of forests whereas the savanna fires are reported to UNFCCC under IPCC Agriculture.

In 2022, satellite data from remote sensing showed 28 million ha of forest and 270 million ha of savanna fires. The area affected by fires in organic soils in South-eastern Asia averaged around 274 million ha annually from 2012 to 2022, roughly 20 percent less than the 2001–2011 period. Similarly, the global area of savanna fires averaged 305 million ha annually between 2012 and 2022, again roughly 20 percent less compared to the previous period. The total area affected by forest fires globally was rather stable during the entire period, including a modest 4 percent reduction in the fires in humid tropical forest and a 7 percent increase in other, mostly temperate and boreal forests.

REGIONAL

In 2021, agrifood systems emissions were largest in Asia (6.8 Gt CO_2eq) and the Americas (4.3 Gt CO_2eq), reflecting the large size of their population and geographical area. More interestingly, the relative role of the components of agrifood systems varied across regions, reflecting structural differences in production and distribution systems around the world (Figure 4). Emissions in Africa and the Americas had significant land-use change components (1.2–1.3 Gt CO_2eq), respectively 43 percent and 31 percent of the total agrifood system, reflecting the prevalence of extensive agriculture production systems in both regions and a tendency to expand into natural ecosystems, mainly via deforestation. Conversely, significant pre- and post- production emissions were observed in Asia (42 percent, or 2.9 Gt CO_2eq) and in Europe (44 percent or 0.9 Gt CO_2eq). Emissions produced within the farm gate remained the dominant component of agrifood systems emissions in Oceania (74 percent), Europe and Asia (52 percent each) and to a lesser extent in the Americas and Africa (43 percent and 42 percent, respectively).

Finally, agrifood systems emissions had significantly different trends across regions between 2001 and 2021. They decreased by 35 percent in Oceania, 12 percent in the Americas and 4 percent in Europe. Conversely, they grew strongly in Africa (40 percent) and in Asia (42 percent).

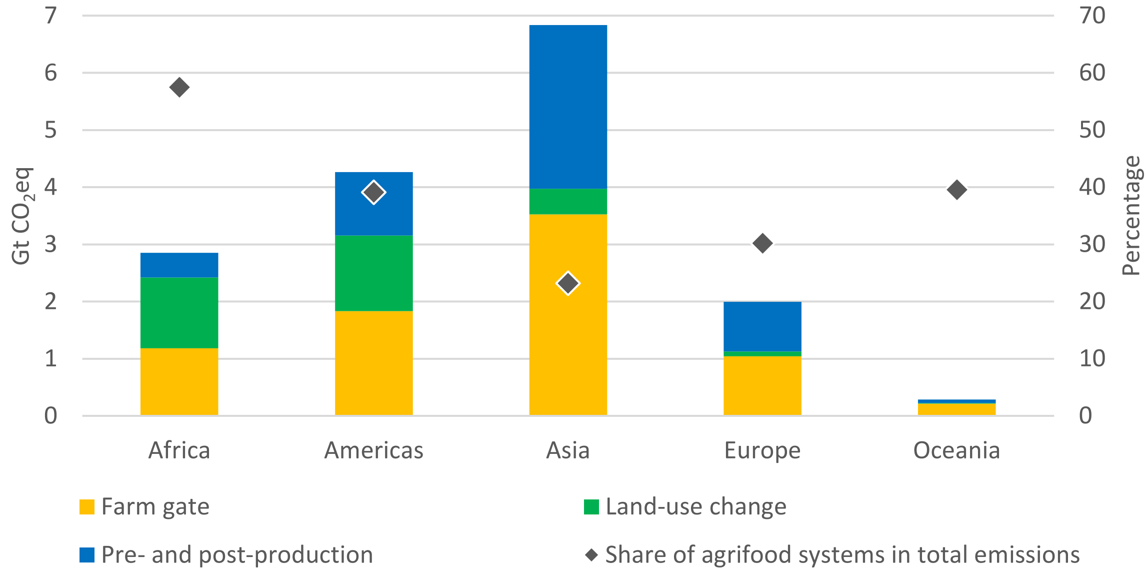
In 2021, Africa had the largest share of agrifood systems emissions in total emissions (58 percent), consistently with the predominance of agriculture in most economies of the region. Shares were much lower in Oceania (40 percent), the Americas (39 percent) and Europe (30 percent) and lowest in Asia (23 percent), reflecting more intensive production systems and strong non-agricultural sectors (Figure 4).

Oceania was the largest per capita emitter (6.4 t CO_2eq/cap) in 2021, followed by the Americas (4.1 t CO_2eq/cap), respectively three and two times the world average. At the same time, these two regions had the most substantial decline in this indicator. Per capita emissions from agrifood systems in Oceania halved since 2001 and decreased by 28 percent in the Americas. Europe (2.7 t CO_2eq/cap) and Africa (2.0 t CO_2eq/cap) had values closer to the world average, while Asia had the lowest per capita emissions at 1.5 t CO_2eq/cap. In Africa and Europe, emissions per capita were 16 and 7 percent lower than in 2001, respectively. They increased by 14 percent in Asia over the period.

In 2021, in terms of the GHG intensity of production, defined as the emissions on agricultural land (including farm gate and land-use change) divided by the value of agricultural production, Africa was the least efficient, at 6.3 kg CO_2eq/USD, nearly three times the global average. Oceania and the Americas had smaller values (3.3–3.4 kg CO_2eq/USD), although still above the global average. Conversely, Europe (2 kg CO_2eq/USD), and Asia (1.9 CO_2eq/USD) had lower emissions intensities, below the world average. Notably, unlike emissions per capita, all regions showed a reduction in this indicator compared to 2001, which was largest in Oceania (-52 percent) and smallest in Europe (-22 percent).

The regional emissions intensity per area of agricultural land varied little across regions, the only exception being Oceania, which at 0.6 t CO_2eq/ha was nearly one-fourth of the global average. This region also exhibited the strongest reduction (-28 percent) in this indicator since 2001, together with the Americas (-18 percent). Finally, this indicator remained stable between 2001 and 2021 in Europe (-4 percent), whereas it went up 21 percent in Asia and 25 percent in Africa since 2001.

Figure 4: Agrifood systems emissions and share in total emissions by region (2021)



Source: FAO. 2023. Emissions totals. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GT and FAO. 2023. Emissions indicators. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/EM

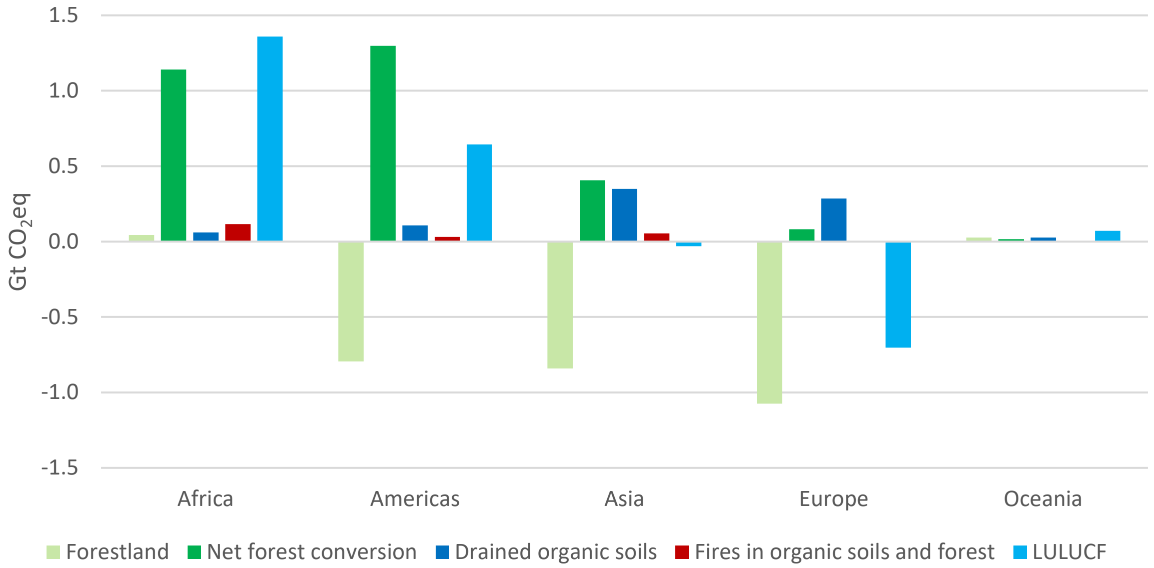
LAND USE, LAND-USE CHANGE AND FORESTRY

Between 2001 and 2021, LULUCF was a consistently net emissions source in all regions except Europe, where it was a net sink (Figures 5 and 6). In 2021, Africa (1.4 Gt CO_2eq) and the Americas (0.6 Gt CO_2eq) were significant net sources of emissions from LULUCF. Europe conversely was a large carbon sink (-0.7 Gt CO_2eq). Asia had a near net zero balance from LULUCF and Oceania a slightly positive LULUCF contribution. Forest emissions and removals represented the dominant LULUCF component in all regions, determining absolute net values as well as their underlying trends.

In Africa, all LULUCF components were net emitters. Deforestation represented the largest flux throughout the period, with 2021 emissions reaching 1.1 Gt CO_2eq (85 percent of the total). Forestland was also a net emitter, due to widespread forest biomass loss (degradation), forest fires and drainage of organic soils, adding together another 0.2 Gt CO_2eq. In Oceania, all LULUCF components were net emitters over most of the period and in 2021, albeit representing small individual fluxes, with emissions from forests and drainage of tropical peatlands each contributing about 0.03 Gt CO_2eq.

Conversely, large emissions and removal components characterized LULUCF in the Americas and in Asia. Specifically, in 2021 in the Americas, large emissions from deforestation (1.3 Gt CO_2eq, the largest among all regions) were partially counterbalanced by strong removals from remaining forest lands (0.8 CO_2eq). In Asia, emissions of 0.8 Gt CO_2eq (contributed to in equal parts by deforestation and the associated degradation of tropical peatlands through drainage and fire) were fully counterbalanced by forest removals (-0.8 Gt CO_2eq), leading to a small net LULUCF sink (-0.03 Gt CO_2eq). Finally in Europe, LULUCF emissions (0.4 Gt CO_2eq), mostly from the drainage of organic soils, were countered by strong removals in forests (-1.1. Gt CO_2).

Figure 5: LULUCF emissions by component and region (2021)

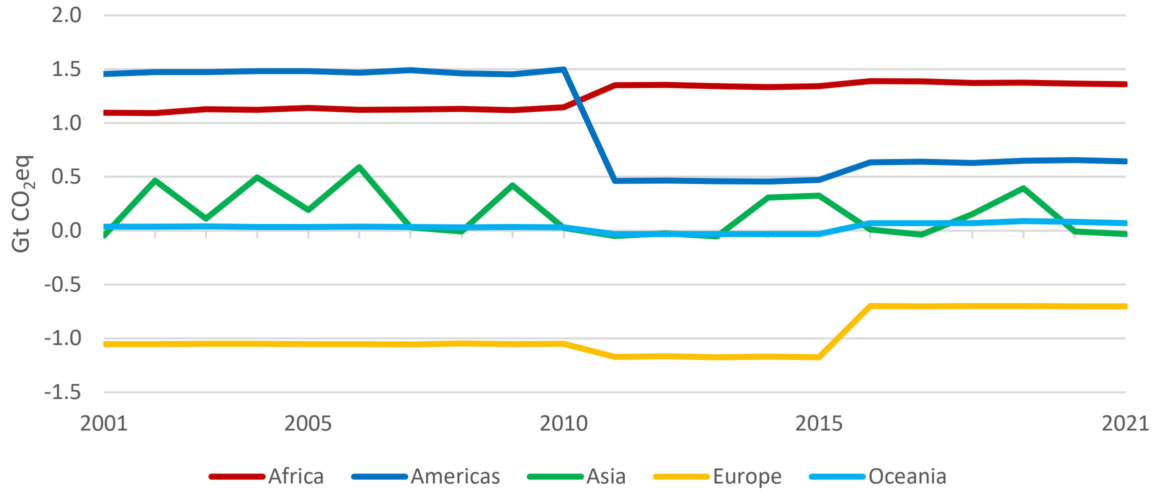


Source: FAO. 2023. Emissions totals. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GT

On average, LULUCF was a net source of emissions between 2001 and 2021 in all regions except Europe (Figure 6). Africa (1.2 Gt CO_2eq on average per year) and the Americas (1.1 Gt CO_2eq on average per year) had the largest LULUCF emissions. However, emissions significantly decreased between 2001–2010 and 2011–2021 in the Americas (-56 percent) due to a marked reduction in deforestation rates, while in Africa they grew by 24 percent due to increases in deforestation and forest degradation processes. In Asia, LULUCF was on average a net source of emissions (0.2 Gt CO_2eq annually) since 2001, with changes over time largely determined by the interannual variability of fires, particularly in tropical peatlands in South-eastern Asia. In Europe, LULUCF was a strong carbon sink throughout the period (-1.0 Gt CO_2), though FAO data suggest smaller removals since 2015. In Oceania, LULUCF was a weak source of emissions between 2001–2021 (just over 30 Mt CO_2eq per year).

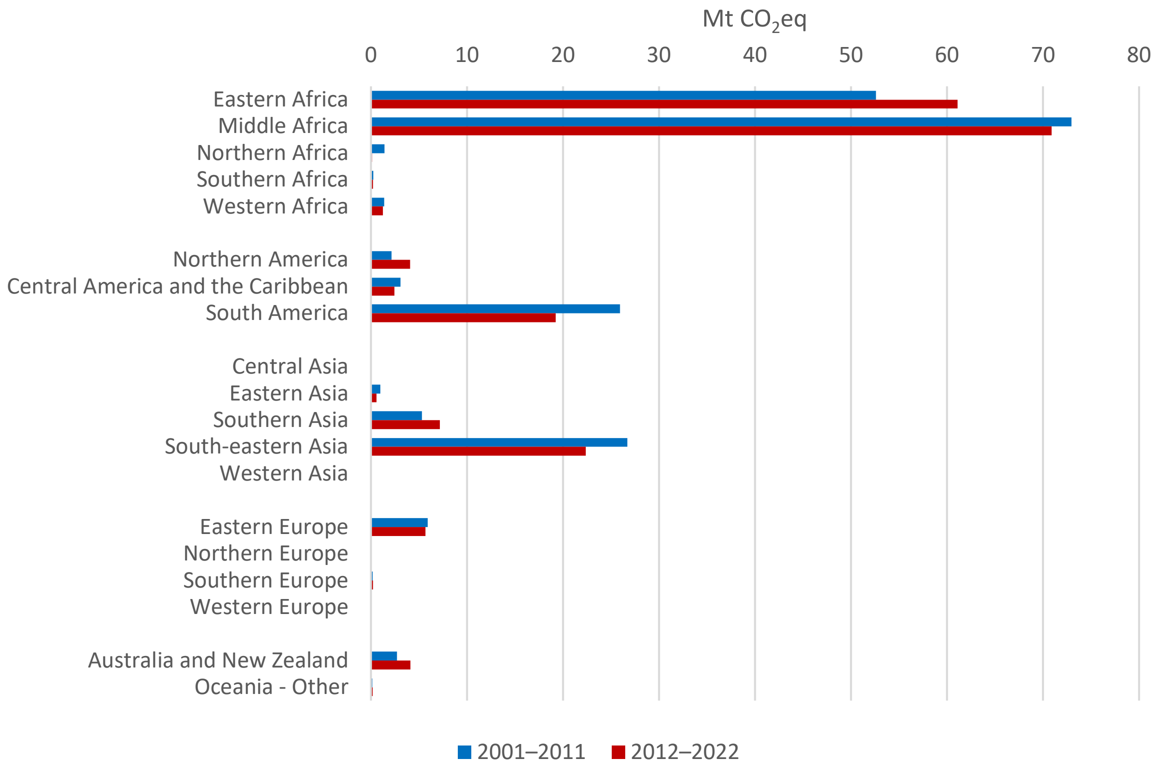
The data show that tropical forests contributed the most to fire emissions between 2001 and 2022. Among subregions, the largest absolute contributors were Middle and Eastern Africa (over 60 Mt CO_2eq each year on average between 2012 and 2022), followed by South-eastern Asia and South America (around 20 Mt CO_2eq each year on average). All these subregions experienced a reduction in emissions from forest fires between 2001–2011 and 2012-–2022, except Eastern Africa where they grew by 16 percent. At the same time, much larger relative increases were computed for Western Asia (133 percent), Northern America (90 percent), Western Europe (58 percent) and Australia and New Zealand (51 percent) (Figure 7).

Figure 6: LULUCF emissions by region



Source: FAO. 2023. Emissions totals. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GT

Figure 7: Emissions from forest fires by subregion



Note: Includes only emissions from CH_4 and N_2O.

Source: Based on FAO. 2023. Emissions from Fires. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GI

COUNTRY

In addition to data on absolute emissions, FAOSTAT provides indicator values for all countries, in terms of GHG emissions per capita, emissions intensity of agricultural production and emissions intensity of land. For each indicator, Table 1 reports summary statistics for the top and bottom ten performers and the median values (using a cut-off value of USD 1 billion of agricultural production).

Table 1: Emissions indicators, summary statistics (2021)

Indicator	Ten lowest values (*range*)	Ten highest values (*range*)	Median
Agrifood systems emissions per capita ($t\ CO_2eq/cap$)	0.5–0.8	8–18	2
Emissions on agricultural land per value of agricultural production ($kg\ CO_2eq/USD$)	0.7–1	13–51	3
Emissions on agricultural land per area of agricultural land ($t\ CO_2eq\ /ha$)	0.1–0.5	11–25	3

Source: Based on FAO. 2023. Emissions indicators. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/EM

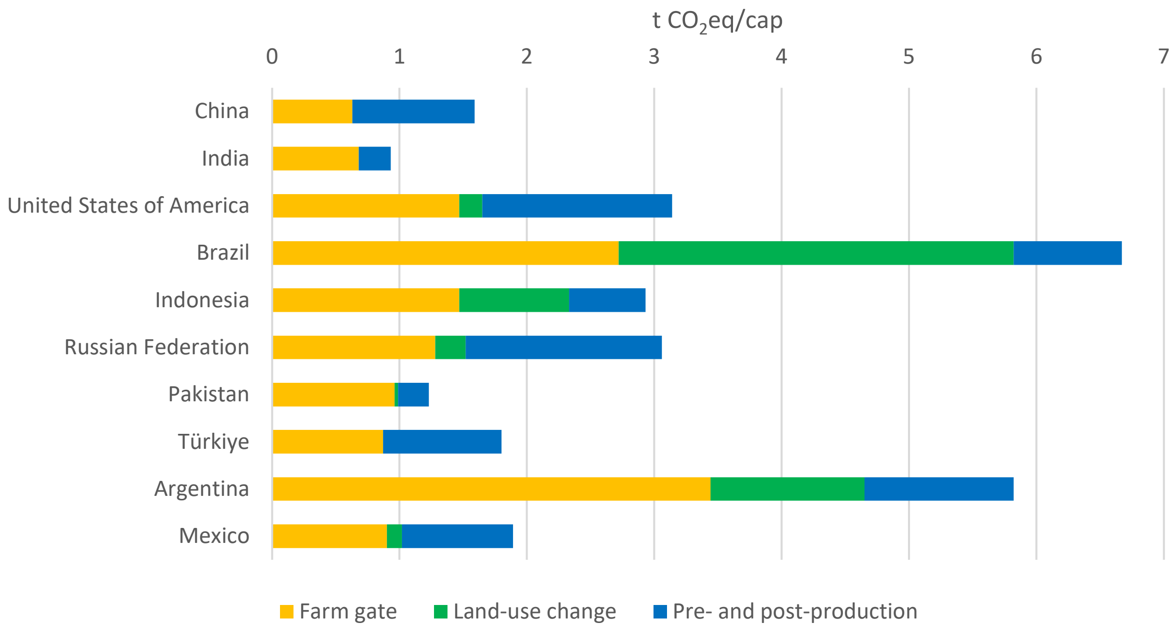
Figures 8 and 9 provide highlights on emissions per capita and per value of agricultural production for the countries with the largest value of agricultural production in 2021. These comprised China (USD 970 billion; 930 Mt CO_2eq of emissions on agricultural land), India (USD 480 billion; 960 Mt CO_2eq), the United States of America (USD 380 billion; 560 Mt CO_2eq), Brazil (USD 250 billion; 1 250 Mt CO_2eq), Indonesia (USD 100 billion; 640 Mt CO_2eq), the Russian Federation (USD 100 billion; 220 Mt CO_2eq), Pakistan (USD 80 billion; 230 Mt CO_2eq), Argentina (USD 75 billion; 210 Mt CO_2eq), Türkiye (USD 80 billion; 70 Mt CO_2eq) and Mexico (USD 65 billion; 130 Mt CO_2eq).

AGRIFOOD SYSTEMS EMISSIONS PER CAPITA

In 2021, Brazil (6.7 t CO_2eq/cap) and Argentina (5.8 t CO_2eq/cap) had per capita emissions from agrifood systems almost three times the global average (2 t CO_2eq/cap). Next were the United States of America, the Russian Federation, and Indonesia (around 3 t CO_2eq/cap each), followed by Mexico, Türkiye and China (1.6–1.9 t CO_2eq/cap). In Pakistan and India, emissions per capita were close to half the world average (Figure 8). In contrast, the highest intensities per capita varied between 8 and 18 t CO_2eq/cap (Table 1). High-intensity countries included Mongolia and Paraguay (13–18 t CO_2eq/cap), followed by New Zealand, the Central African Republic and the Plurinational State of Boliva (10–11 t CO_2eq/cap). Uruguay, Belarus, Ireland, Lithuania and Canada all had comparable values (8–9 t CO_2eq/cap). The Democratic People's Republic of Korea had the lowest intensity per capita (0.5 t CO_2eq/cap).

Brazil and Argentina had the largest share of agrifood systems emissions in total emissions (84 percent and 61 percent, respectively), whereas the share was close to 50 percent in Pakistan and Indonesia. In India and Mexico, the contribution of agrifood systems to total emissions was comparable to the global share (about 30 percent). Agrifood systems contributed one-fourth of the emissions from all sectors in Türkiye and about one-fifth in the Russian Federation, the United States of America and China. The relative contributions of the three components of agrifood systems emissions also differed between these countries. The land-use change component of agrifood systems was largest in Brazil, Argentina and Indonesia, but marginal in the other countries. Pre- and post-production emissions accounted for the largest share in China, Türkiye, the Russian Federation and the United States of America, whereas farm-gate emissions dominated agrifood systems emissions in India and Pakistan.

Figure 8: Agrifood systems emissions per capita, top ten countries by value of agricultural production (2021 ranking)



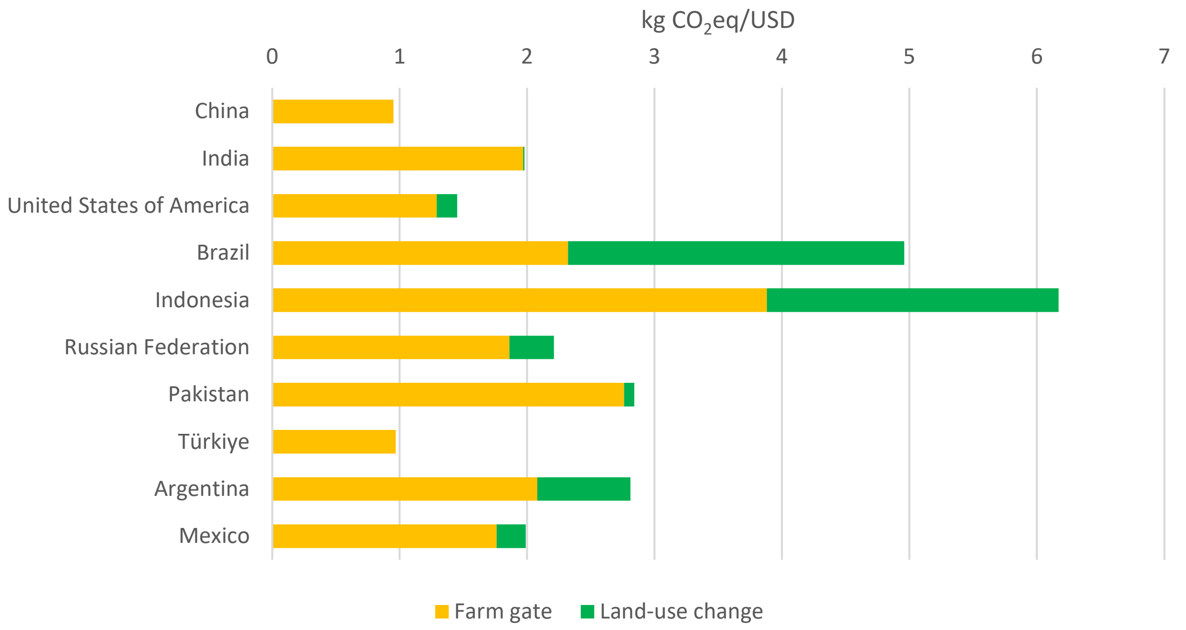
Source: FAO. 2023. Emissions indicators. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/EM

EMISSIONS INTENSITY OF AGRICULTURAL PRODUCTION

In 2021, among the top agricultural producers, Indonesia (6.2 kg CO_2eq/USD) and Brazil (5.0 kg CO_2eq/USD) had the highest emissions intensities of production (Figure 9), more than double the global average. Conversely, China, Türkiye (about 1.0 kg CO_2eq/USD each) were among the world's ten best performers relative to this indicator, with the United States of America relatively close (1.4 kg CO_2eq/USD) (Table 1). The intensities of India, Mexico the Russian Federation (2–2.2 kg CO_2eq/USD) were close to the world average, while those of Pakistan and Argentina were both equal to 2.8 kg CO_2eq/USD. The contribution of farm gate and land-use change processes to the intensity varied across countries: in particular, land-use change contributed to high values in Brazil and Indonesia (where, as noted, deforestation and peatland degradation are strongly linked to agrifood systems).

In absolute terms, the best performers for this indicator included Moldova, Egypt, Lebanon, Ghana, Costa Rica, Greece and Spain, in addition to China and Türkiye. Low-intensity agriculture countries (about 1 kg CO_2eq/USD) also included Italy, Portugal, North Macedonia, Ukraine, Israel, the Syrian Arab Republic and Sri Lanka. Conversely, the highest intensities ranged 13 to over 50 kg CO_2eq/USD in several African countries (the Democratic Republic of the Congo, the Central African Republic, Zambia, Somalia, Chad, South Sudan, Mozambique and Angola), as well as Mongolia in Asia and Bolivia in South America.

Figure 9: Emissions on agricultural land per value of agricultural production, top ten countries by value of agricultural production (2021 ranking)

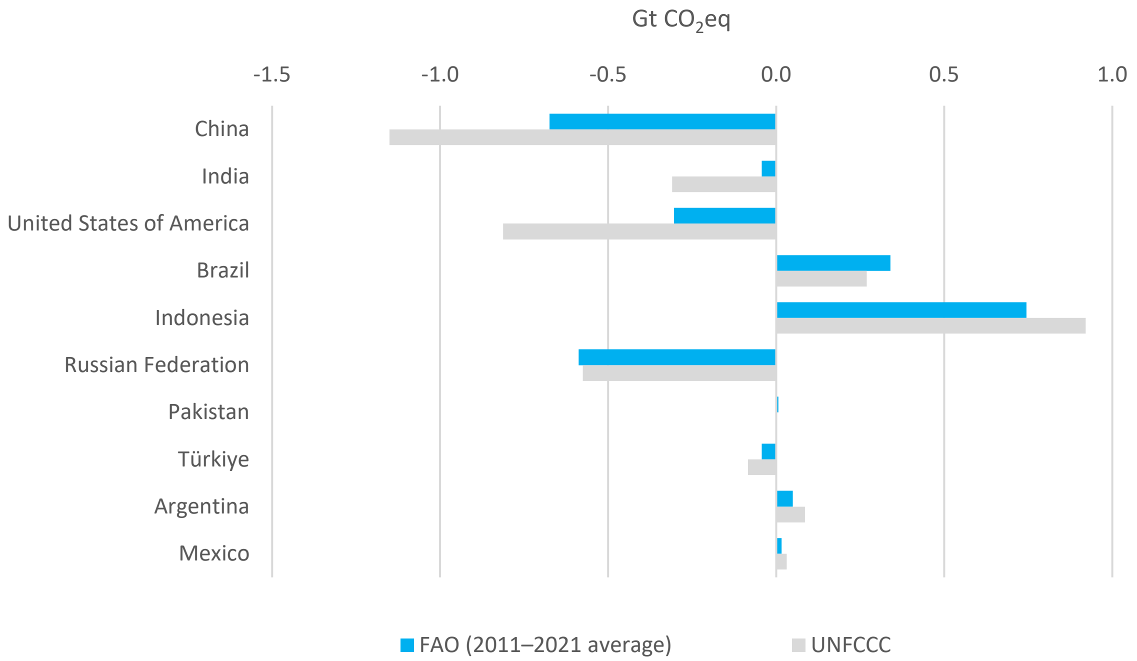


Source: Based on FAO. 2023. Emissions indicators. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/EM

LAND USE, LAND-USE CHANGE AND FORESTRY

The role of LULUCF varied significantly among the countries depicted in Figures 8 and 9. On average over the period 2011–2021, China, the Russian Federation and the United States of America saw LULUCF functioning as a significant net sink as forestland sequestered 0.6, 0.6 and 0.3 Gt CO_2eq, respectively. Additionally, it acted as a modest sink in Türkiye and India. In contrast, it was a net source of emissions in the remaining countries: these were fairly minor in Pakistan, Mexico and Argentina, but significant in Brazil and Indonesia (0.3 and 0.7 Gt CO_2eq). In Brazil, deforestation was the primary driver of these emissions, while in Indonesia, the drainage and burning of organic soils were the major contributors (Figure 10). These FAOSTAT estimates were found to be consistent with the independent data provided by countries to the UNFCCC, which are also available in the same FAO database.

Figure 10: LULUCF net emissions/removals by data source, top countries by value of agricultural production (2021 ranking)

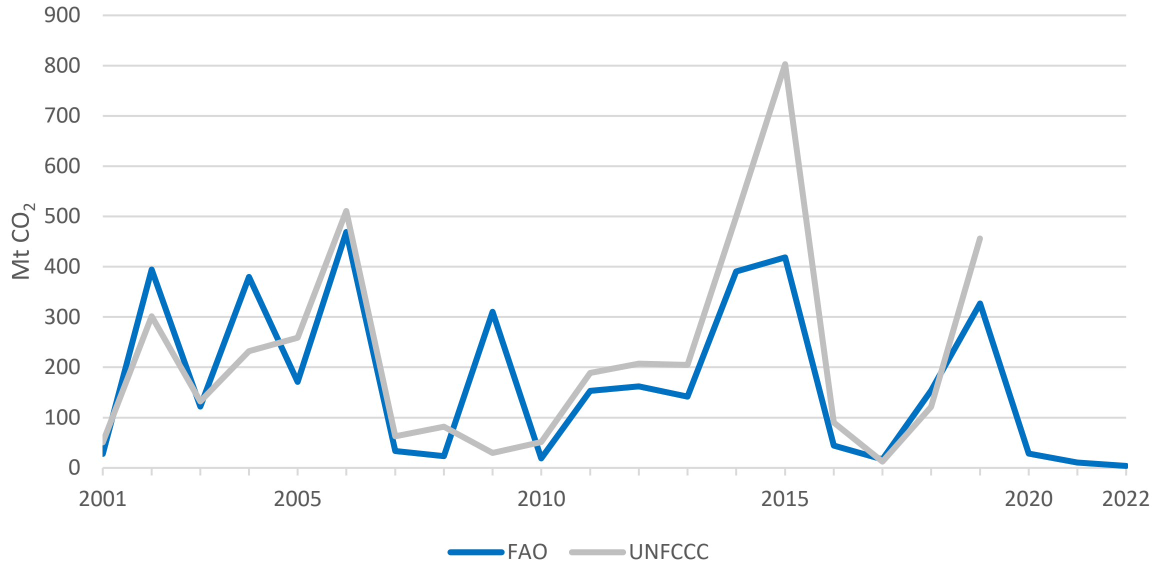


Note: The time coverage of LULUCF data from the UNFCCC is: 2019 (Russian Federation, Türkiye, and the United States of America), 2016 (Brazil and India), 2014 (China), 2013 (Mexico) and 2012 (Argentina). UNFCCC data for Pakistan were not available. UNFCCC data for Indonesia are the sum of 2019 values for deforestation and peat fires.

Source: Based on FAO. 2023. Emissions totals. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GT

In general, values related to burnt area and emissions stemming from major fire events were clearly discernible in the fire estimates at the national level. This is exemplified by the devastating fire events in Portugal in 2017 (Ramos *et al.*, 2023), as well as the major fires in Indonesia in 2019 (Arjasakusuma *et al.*, 2022), for which peaks can be observed in the FAOSTAT data. Peaks in tropical fires emissions closely correspond with El Niño events, which are associated with warmer-than-average sea surface temperatures in the central and eastern equatorial Pacific Ocean and are known to widely affect global weather patterns. For instance, during the very strong 1997–1998 El Niño event, fires in organic soils in South-eastern Asia alone released over 1 Gt CO_2eq in the atmosphere, five times more than their long-term average. Figure 11 illustrates such trends in Indonesia (see the Exploratory notes for information on geospatial processing). The emissions from these fires averaged 0.2 Gt CO2eq per year over the period 2001–2022. FAO estimates closely align with the information reported by the country to the UNFCCC.

Figure 11: CO_2 emissions from fires and drainage of organic soils in Indonesia by data source



Source: FAO. 2023. Emissions from Fires. In: *FAOSTAT*. Rome. [Cited November 2023]. https://www.fao.org/faostat/en/#data/GI

EXPLANATORY NOTES

The FAOSTAT emissions database is composed of several data domains covering the GHG emissions from agrifood systems. The database includes non-CO_2 emissions from agricultural activities (i.e. methane [CH_4] and nitrous oxide [N_2O] emissions); CO_2 emissions from land use and land-use change, and from combustion of fossil fuels for pre- and post-production processes; as well as emissions of F-gases used in the agrifood cold chain. The single domains are all summarized in the Emissions Totals domain, where the single-gas emissions are aggregated in CO_2eq, computed applying the global warming potential from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2014). In the domain, the single categories of emissions are further summarized by FAO aggregates of farm-gate, land-use change and pre- and post-production to break down the emissions from agrifood systems, as well as by the categories of the IPCC for the national GHG inventories (NGHGI) to the UNFCCC, namely IPCC Agriculture and LULUCF. The FAO database jointly disseminates the emissions reported by countries to the UNFCCC. Emission data are sourced directly from the UNFCCC data portal as submitted by countries through their most recent NGHGI or are extracted from biennial update reports (BURs).

FAO estimates of the emissions from agrifood systems are available by country, regional and global aggregates over the period 1961–2021 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 available from 1990 onwards. 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 (1990–2021), savanna, forest fires and fires in organic soils (1990–2022).

Emissions from savanna fires include the emissions from the burning of the following vegetation types: grassland; savanna; woody savanna; open shrubland; and closed shrubland. Following the IPCC guidelines, only the non-CO_2 emissions (N_2O and CH_4) are disseminated for the burning of vegetation in savanna fires with the assumption that the CO_2 emissions would be counterbalanced by CO_2 removals from the subsequent regrowth of the vegetation within one year.

The emissions from the burning of biomass in forest include fires in humid tropical forest and other forest. Total emissions estimates from forest fires exclude the CO_2 emissions, since these are already covered in the carbon stock changes computed in the Forest domain from FRA data. These emissions are however disseminated in the database as a useful independent estimate of carbon losses due to deforestation.

For emissions from fires in organic soils, in line with existing literature, only the emissions from South-eastern Asian countries (e.g. Brunei Darussalam, Indonesia and Malaysia) 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.

Data on emissions from energy use, for all components of pre- and post-production as well as the emissions from other economic sectors are available for the period 1990–2021. Emissions from pre- and post-production processes are calculated by FAO based on activity data (mostly energy use) from the United Nations Statistics Division (UNSD), the International Energy Agency (IEA) and other third parties. For transparency and completeness, emissions totals integrate information on the emissions from other economic sectors from the PRIMAP-hist dataset v2.4.2 (Gütschow and Pflüger, 2023).

The database disseminates in a separate domain the shares of emissions of each category over total emissions and country, regional and global values for three indicators (Table 2): emissions per capita values, emissions per value of agricultural production and the emissions per ha of agricultural land (Emissions indicators).

Table 2: Indicators under emissions indicators and thematic coverage

Indicator	Unit	Scope
Emissions per capita	tonnes CO_2eq per capita	All items
Emissions per value of agricultural production	kg CO_2eq per USD of gross agriculture production value (expressed in constant 2014–2016 thousand I$)	Farm gate; IPCC Agriculture; Emissions on agricultural land
Emissions per area of agricultural land	tonnes CO_2eq per hectare	Farm gate; Emissions on agricultural land; IPCC Agriculture

Source: Authors' own elaboration.

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