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A country profile

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Photo by Terry Sunderland/CIFOR
Rice fields in Vietnam.

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Summary

According to the latest IPCC assessment, the global food system is responsible for 23% to 42% of total net anthropogenic emissions. This share is expected to increase in the future, driven by the increasing needs of a growing population and by intentions, expressed in many global and national policy contexts, for progressive decarbonization of other sectors and thus, the whole global economy system. Therefore, without rapid and radical transformations in food systems, the Paris Agreement targets will remain out of reach.

Vietnam's food system provides food security for the people of Vietnam, and contributes to food security globally. This document is a first brief description of food system related greenhouse gas (GHG) emissions in Vietnam. It examines land use, production from agriculture, agroforestry, fisheries and aquaculture, national food supply, diets and food systems emissions. It describes emissions in Vietnam's food systems based on data available at FAO, and identifies possible pathways to reduce emissions and achieve low-emissions development for Vietnam, by taking a food systems view.

Following IPCC guidelines, data on GHG emissions are generally collected and analysed by distinguishing four economic sectors, namely: (i) energy; (ii) industrial processes and product use (IPPU); (iii) agriculture, forestry and other land use (AFOLU); and (iv) waste. Food system emissions span across all these sectors but we still lack sufficiently comprehensive data to fully describe them.

Food systems comprise "all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes" (HLPE 2014). This means a food system goes beyond land use to include the pre- and post-production elements of food production and consumption.

This report looks at food system emissions in Vietnam, but excludes forestry and agroforestry, areas to be covered in future work. The report briefly discusses emissions from fisheries and aquaculture, but the data basis so far is scant. Hence this document focuses mainly on crop and livestock products.

Based on the data available at FAO[1], Vietnam's food system emissions increased in absolute levels over the past decade (from 96.4 to 104.5 $MtCO_2eq$/year between 2010 and 2020), while their share in national emissions decreased (from 34% to 26.5%). The largest emission sources in the food system are, by decreasing order of importance, rice cultivation (34% of total food system emissions), enteric fermentation (12%), manure (11%), synthetic fertilizers (10%), food system waste disposal (8%), and household food consumption (8%). Altogether, these six activities emitted 86.1 $MtCO_2eq$ in 2020 and accounted for 83% of all food system emissions.

Based on this analysis the following priorities for action emerge in perspective to reduce food system emissions in Vietnam: (i) reducing emissions from rice production; (ii) addressing emissions from enteric fermentation and manure management; (iii) reducing emissions from synthetic fertilizer production and use; and

1 See https://www.fao.org/faostat/en/#home

(iv) improving the data situation to understand and pinpoint the focus areas and address emissions from household food consumption and food loss and waste (FLW).

This analysis is so far based mainly on FAO data[2], and must be further improved using national datasets. In its latest Nationally Determined Contribution (NDC), Vietnam prioritises the forestry and other land use sector, and emphasises the important role of forestry in reducing emissions as it is the only sector with negative net emissions, i.e. carbon sinks (Socialist Republic of Viet Nam 2022). Yet not all emissions from forestry and other land use (FOLU) are linked to the food system.

In addition, to be able to identify and pursue so far overlooked options for climate actions, more comprehensive data are needed on fisheries and aquaculture, an important sector for food production in Vietnam, as well as on FLW, and household consumption.

2 We explain in Section 1 the use of FAO data. This paper is part of a series of papers on various countries and using the same source for the country statistics was central to a comparative approach.

1 Introduction: Food systems and their global emissions

The global food system provides critical food security and income to millions on the planet. The term 'food system' refers to the complex network of activities, processes and actors involved in producing, processing, distributing and consuming food.[3] It encompasses all aspects of food production and consumption; from the supply of farming inputs like fertilizers, seeds and machinery; to the growing and harvesting of crops and livestock; the packaging, transportation and sale of food products; as well as the preparation and consumption of food by individuals and communities. The food system also includes all the social, economic and environmental factors that influence food production and consumption, such as land use, labour practices, food policies and cultural preferences.

Annually, the global food system moves USD 7–8 trillion (EcoNexus and Berne Declaration 2013). Yet, it also generates externalities amounting to USD 12 trillion annually (Nature 2019). Some of these externalities are worrying: some 33% of soils globally are degraded (FAO and ITPS 2015), with 52% of agricultural land affected by soil degradation; some 20% of the world's aquifers are at risk of running dry (Jasechko and Perrone 2021); 34% of the world's fishery stocks are over-depleted (FAO 2020); and agriculture is an identified threat to 86% of species at risk of extinction (Benton et al. 2021).

Importantly, the global food system also generates substantial greenhouse gas (GHG) emissions. In 2018, according to the latest assessment by the Intergovernmental Panel on Climate Change (IPCC) (Babiker et al. 2022), the global food system was responsible for emissions of 17 $GtCO_2eq$ – that is 31% (accounting for a range of 23% to 42%) of the total global net anthropogenic emissions of 54 $GtCO_2eq$. Agriculture, consisting of crop and livestock production, accounts for the largest part of these emissions at 6.3 $GtCO_2eq$/year, or 37% of food system emissions, and 12% of global emissions[4]. This is followed by land use, land-use change and forestry (LULUCF, 24% of food system emissions), energy use (23%), waste management (10%) and industrial processes in the food industry (5%) (Babiker et al. 2022; see also Table 1).

LULUCF emissions are as high as the emissions from energy use across the food supply chain, including electricity, heat and refrigeration. They are followed in size by waste management (food waste, wastewater and packaging waste) and the relatively low emissions of industrial processes in food systems. The latter, as well as transport emissions, comprises a large share of emissions related to refrigeration (Babiker et al. 2022).

However, it is worth noting that, when the last three GHG sources (energy use, waste management and industrial use) of the food system are taken together – arguably a good representation of pre- and post-farm activities –, their joint emissions amount to 6.5 $GtCO_2eq$/year. This accounts for 12% of global emissions, on a par with agriculture, and over one third of food system emissions.

3 By the definition of the High-Level Panel of Experts on Food Security and Nutrition (HLPE 2014), a food system combines "all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food, and the outputs of these activities, including socio-economic and environmental outcomes".

4 By another estimate, livestock (meat and dairy) directly and indirectly contributes 60% of global food system emissions (Pörtner et al. 2021). This value includes emissions from related land-use changes, feed production, enteric fermentation (digestion) in cattle, sheep, and goats, manure management, processing and transportation of animal products, as well as waste management. Unlike the emissions from livestock within agriculture in Babiker et al. (2022), it includes on- and off-farm activities along the whole value chain. In its own way this supports the role of the pre- and post-farm activities.

Table 1. Global greenhouse gas emissions and food system emissions overview

Sector	Subsector	Emissions ($GtCO_2e$/ year)	Percent of total emissions	Percent of food system emissions	Range of global GHG emissions ($GtCO_2eq$/ year)		(%)	
					Low	High	Low	High
Total global emissions		54	100					
Food system		17	31.5	100	13	23	23	42
	Agriculture (livestock and crop production)	6.3	11.7	37.1	2.6	11.9	5	22
	Land use, land use change and forestry (LULUCF)	4	7.4	23.5	2.1	5.9	4	11
	Energy use	3.9	7.2	22.9	3.6	4.4	7	8
	Waste management	1.7	3.1	10	0.9	2.6	2	5
	Industrial processes and product use (IPPU)	0.9	1.7	5.3	0.6	1.1	1	2
	Combined total of energy, waste and IPPU	6.5	12	38.2	5.1	8.1	9	15

Source: Babiker et al. (2022)

Within this, food loss and waste (FLW) account for around 8% to 10% of global emissions, a significant amount, mainly from the production and disposal of wasted food (FAO 2013, 2015; Mbow et al. 2019). When food waste ends up in landfills, it also produces methane (CH_4), a potent GHG[5].

Reducing these emissions is critical to mitigating climate change. Collectively, global food system emissions – which account for 31% of overall global emissions – are on a par with the total GHG emissions of China (31% of global emissions in 2020), and well above total emissions from the United States (13.5%) (data from GCP 2021;[6] FAOSTAT). "Making the food system healthy for people and the planet" has been identified in a recent report for the Club of Rome (Dixson-Declève et al. 2022) as one of only five major "turnarounds"[7] urgently needed to put the planet on a trajectory towards prosperity for all, while keeping resource use within the planetary boundaries.

Nationally Determined Contributions (NDCs) are usually structured around the four economic sectors identified in IPCC guidelines;[8] however, we are yet to see a comprehensive approach

5 The global warming power of methane is 27 times higher than that of carbon dioxide over a 100-year horizon, according to IPCC AR6 (Nabuurs et al. 2022)

6 https://www.globalcarbonproject.org/carbonbudget/archive/2021/GCP_CarbonBudget_2021.pdf

7 The other turnarounds being poverty, equality, gender empowerment and energy.

8 These four sectors are energy; industrial processes and product use (IPPU); agriculture, forestry and other land use (AFOLU); and waste.

to addressing emissions from the food system that spans these four IPCC economic sectors. Therefore, analysis of food system emissions in diverse countries is complicated by lack of data on activities, missing specific emission factors, data overlap, a lack of overview across food system emissions as a whole, and a lack of systematic data collection across the system.

In negotiations at the United Nations Framework Convention on Climate Change (UNFCCC), some parties and other actors expressed concerns that addressing food system emissions could threaten food security and nutrition, particularly for the most vulnerable, poor and hunger-stricken parts of populations. Given the large share of emissions from food systems, as well as the fact that climate change has started to affect all aspects of human life, including food production, this position should be carefully reconsidered based on data. Striving for more holistic, low-emission, resilient, fair and sustainable food systems that provide food and nutrition to all, and livelihoods to many, is key to ensuring a more sustainable future for the planet and for the people and biota living on it. Such an approach will also help reconcile mitigation of and adaptation to climate change – two objectives often treated separately in climate talks, yet inherently interlinked.

While food systems form the basis of food security and nutrition as well as provide meaningful livelihoods and socioeconomic benefits, they remain key contributors to climate change, soil degradation, freshwater depletion, and biodiversity loss. We have enough scientific evidence, technical, and human resources to advance low-emission and sustainable food systems, and finance streams need to be redirected towards this goal. However, important knowledge gaps remain: reliable national primary data are missing in most countries on critical food system components like FLW; reliable indicators and MRV[9] systems are missing; and our understanding of complex systemic interactions and feedback loops is still insufficient. All this must be filled by further research at the global and national level. Effectively prioritizing action should focus on viable, cost-efficient actions that provide multiple benefits.

9 Here, MRV stands for: Monitoring, Reporting and Verification.

Box 1. Mitigate+: a Low-Emission Food System Initiative

'Mitigate+', an initiative launched under the Consultative Group for International Agricultural Research (CGIAR), aims to offer a comprehensive and holistic view of food system emissions, considering the whole food supply chain in selected partner countries where the initiative explores so-far neglected yet promising pathways that reduce GHG emissions while enhancing food security and nutrition. M+ works closely with key national actors in the partner countries, including civil society, multilateral institutions, national government, academic and private sector actors, to ensure they are equipped with the knowledge, information and tools they need to make robust evidence-based decisions and address challenges in policy discourse, development and implementation to reduce GHG food system emissions.

To foster low-emission development in line with the Paris Agreement without compromising food security and nutrition and livelihoods, it is vital that the knowledge and information that reflect national contexts, and that the tools required for evidence-based decision making become available to civil society, governmental, academic and private sector actors. This is the main purpose of the Low-Emissions Food Systems Initiative (also called 'Mitigate+'; see Box 1).

To advance on this goal, here we offer novel views onto so-far neglected, yet promising pathways to emission reductions, by taking a view across the sectors normally separated in NDCs, but which together belong to the food system. CIFOR-ICRAF, as part of the Mitigate + initiative, is developing a series of analytical papers, so-called country profiles, identifying the issues that emerge when taking a food-systems view on emission reductions. Besides for Vietnam, similar country profiles have also been developed for other countries: China (Song et al. 2023), Colombia (Martius et al. 2023b) and Kenya (Martius et al. 2023a). By using publicly available global datasets (mainly FAOSTAT) we facilitate comparisons between these countries.

This document is a first brief description of food system related GHG emissions in Vietnam. It examines land use, production from agriculture, agroforestry, fisheries and aquaculture, national food supply, diets and food systems emissions. It describes emissions in Vietnam's food systems based on data available at FAO, and identifies possible pathways to reduce emissions and achieve low-emissions development for Vietnam, by taking a food systems view.

2 Vietnam: The national context

Vietnam is one of the ten richest biodiversity centres in the world. Because of its long coastline (3,260 km) situated in the "typhoon belt" of Southeast Asia, and because of and its large and densely populated river deltas, Viet Nam, and particularly its aquaculture sector, is highly vulnerable to climate change impacts such as floods, storms, cyclones, sea level rise, disease outbreaks or algal blooms (Barange et al. 2018; WBG/ADB 2021; Chu et al. 2022; Tran et al. 2022; Tu et al. 2022).

The country spans 313,430 km^2 of land area and, in 2020, had a population of 96.6 million people, a 10.6% increase compared to 2010 (87.4 million people)[10]. The urban population rose by 35.8% between 2010 and 2020, increasing much faster than the total population. However, Vietnam's population was still predominantly rural in 2020, with 62.7% of its population living in rural areas. The most populated city in Vietnam is Ho Chi Minh City, with a current population of 8.44 million inhabitants[11] (8.34% of the total national population). The population of the greater Ho Chi Minh City area including its suburbs was estimated at 12.2 million inhabitants in 2023[12]. The second and third largest urban areas are, respectively, Ha Noi, the capital (7.94 million inhabitants), and Hai Phong (1.88 million). These three urban areas are driving urban population growth in Vietnam, but their development also triggers territorial disparity within the country (OECD 2020). These dynamics create a demographic imbalance between rural and urban areas. Women migrants are more than 52% of all migrants going to urban areas. 80% of workers in the garments and electronics industries – two key sectors of Vietnam's industrialization and exports – are women. As people migrate for employment, elderly mostly live in rural areas, widening social disparities in Vietnam. However, remittances from urban to rural areas contribute to the improvement of living standards of family members left behind (Vo 2021).

With a GDP of USD 363 billion in 2020 (current USD), Vietnam is the third largest economy in Southeast Asia after Indonesia (USD 3,302 billion), and Thailand (USD 1,270 billion). Vietnam ranks 84th in the world in terms of GDP. The country's current GDP per capita[13], which stands at USD 3,526 in 2020, more than doubled (+111%) between 2010 and 2020. In the meantime, the GDP per capita – expressed in constant 2015 USD[14] – rose by 64.5% (standing at USD 3,316 in 2020).[15] Growth has been driven by manufacturing exports, strong domestic consumption and improved foreign direct investments (FDI).[16] The contribution of agriculture, forestry and fishery to national GDP increased from 38.1% in 1986 to 46.3% in 1988, but then gradually reduced to 11.9% in 2022 (World Bank 2022)[17]. Despite the decline in their contribution to GDP, agriculture, forestry and

10 https://www.fao.org/faostat/en/#data/OA

11 According to 2017 estimates from the General Statistics Office. See https://worldpopulationreview.com/world-cities/ho-chi-minh-city-population

12 According to UN World Urbanization Prospects. See https://population.un.org/wup/. The last census was performed in 2009; the population of Ho Chi Minh City then stood at 7,521,130 people.

13 Per capita values for gross domestic product (GDP) are expressed in current international dollars, converted by purchasing power parity (PPP). https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD

14 Data are in constant 2015 prices, expressed in USD. Dollar figures for GDP are converted from domestic currencies using 2015 official exchange rates. See https://databank.worldbank.org/metadataglossary/world-development-indicators/series/NY.GDP.MKTP.KD

15 All data accessed 13 December 2022 from World Bank: https://databank.worldbank.org/source/world-development-indicators#%20

16 https://fulcrum.sg/vietnams-high-gdp-growth-rate-masks-its-economic-difficulties/

17 Agriculture, forestry and fishing, value added (% of GDP) – Vietnam. Accessed 23 October 2023. https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=VN

fishery provide the largest share of employment in Vietnam (29.04%)[18]. Women represent 60% of the total labour force in the agriculture sector in Vietnam (World Bank 2021).

With a Human Development Index (HDI) value[19] of 0.704, Vietnam ranked 118th out of 189 countries in 2019 (UNDP 2020). This represents a slight improvement from the previous year's HDI value of 0.7 and a change of one position in the country ranking. The mean number of years of schooling for adults aged 25 years and older was 8.3 years in 2019, while the expected number of years of schooling for children was 12.7 years and life expectancy at birth is 75.4 years.

The country's economic development and improvement in living standards has mostly benefited the ethnic majority (the Kinh and Hoa people). A higher proportion of ethnic minorities live in poverty: while ethnic minorities account for just 14% of the total population, they represent up to 50% of the total poor population (Phung et al. 2016). Women from ethnic minorities are further disadvantaged as they face greater social and economic inequalities, with lower education rates, child marriage and early childbirth contributing to high poverty amongst ethnic minority groups (World Bank 2022). Despite recent improvements, Vietnam continues to face significant problems with food security and chronic malnutrition among children, particularly in the uplands (Rocha et al. 2022).

18 Vietnam – Employment in Agriculture (% of Total Employment). Accessed 23 October 2023. https://tradingeconomics.com/vietnam/employment-in-agriculture-percent-of-total-employment-wb-data.html

19 HDI is a composite measure of three basic dimensions of human development: health (measured by life expectancy at birth), education (measured by years of schooling), and standard of living (measured by Gross National Income per capita). HDI ranges from 0 and 1. Maximum HDI value in 2019 was 0.957 for Norway; minimum HDI value in 2019 was 0.394 for Niger.

3 Land use, agriculture and diets

3.1 Land use

Forest is the main land use[20] in Vietnam (Table 2), covering 47% of Vietnam's total land area. Naturally regenerating forests account for 70% of forestland and cover a third of the country's total land area. Forest area increased by 9.4% between 2010 and 2020, driven by an expansion of planted forest area.

Agricultural land, the second largest land use in Vietnam, represents 39% of total land area. It is almost exclusively dedicated to cropland, which accounts for 95% of all agricultural land, while rangeland accounts for the remaining 5%. Agricultural land area increased by nearly 15% between 2010 and 2020, mostly due to the increase in the area of permanent crops.

Table 2. Land use in Vietnam (expressed in units of 1000 ha).

Land use in Vietnam	2010	2020
	'000 hectares	
Land area	**31,329**	**31,343**
Agricultural land	**10,760**	**12,360**
Cropland	10,118	11,718
Arable land	6,437	6,787
Permanent crops	3,681	4,931
Permanent meadows and pastures	642	642
Forest land	**13,388**	**14,643**
Naturally regenerating forest	10,305	10,294
Planted forest	3,083	4,349
Other land	**7,181**	**4,340**

a A precise date is indicated for each extraction of FAOSTAT data in this document because FAOSTAT database is continuously updated as and when countries report new data or methodologies improve. The date of the last update is indicated on the webpage of each table included in the FAOSTAT database.

Source: FAOSTAT. Accessed 28 November 2022.[a] https://www.fao.org/faostat/en/#data/RL

3.2 Agriculture

3.2.1 Agricultural inputs

Vietnam uses significant amounts of agricultural fertilizers nitrogen, phosphate and potash – twice the world average per area of cropland in 2020 (Table 3). Vietnam's use of fertilizer was already high in 2010 before use of nitrogen and potash further increased, by 31% and 29%, respectively, between 2010 and 2020. Only phosphate use per area of cropland decreased by 13.7%. This high use of fertilizers however is translated into relatively high yields for the five main crops compared to the world average, except for maize. The rice yield in Vietnam was 5.34 t/ha in 2010 and increased by 10% to 5.92 t/ha in 2020, increasing less than the levels of fertilizers by hectare. Rice yields in Vietnam were 20.3% higher than the world average. In 2010, Vietnam ranked 20th globally for rice yield, and dropped to 26th globally in 2020.

This high use of fertilizers is caused by various factors including – in many cases – excessive use of fertilizer beyond recommended levels, in spite of a shift to high-yield varieties; lack of education on proper fertilizer use leading to incorrect timing of application; and poor-quality fertilizer products, contributing to significant waste of phosphate

20 Land use refers to the destination of the land, while land cover refers to the (bio)physical cover observed on the Earth's surface. For instance, after a clear cut, a forest remains a forest if its intended use does not change, even if the land cover has changed temporarily. Land-use changes include changes in land cover and changes in land management practices (FAO and ITPS 2015).

Table 3. Agricultural use of fertilizers in Vietnam

Fertilizer use in agriculture	Vietnam				World average
	2010		2020		2020
	Metric tons	kg/ha of cropland	Metric tons	kg/ha of cropland	kg/ha of cropland
Nitrogen N	1,196,159	118.2	1,814,300	154.8	72.5
Phosphate P_2O_5	741,023	73.2	740,375	63.2	30.8
Potash K_2O	414,101	40.9	619,303	52.8	25.1

Source: FAOSTAT. Accessed 19 January 2023. https://www.fao.org/faostat/en/#data/RFN

and potash in rice farming, and overarching soil and water pollution (Nguyen 2017). Meanwhile, cropping intensity in Vietnam (i.e., the number of times a crop is planted per year across a given agricultural area) is among the highest in the world (Zhang et al. 2021), which at least in part explains these high fertilizer rates.

3.2.2 Harvested area for major crops

In 2020, Vietnam's croplands covered 37% of total surface land area and 95% of total agricultural area. Rice is, by far, the most cultivated crop in Vietnam: in 2020, it occupied 62% of total cropland area (and 23% of total land area) (Table 4). However, rice area decreased between 2010 and 2020, both in absolute terms (from 7.5 to 7.2 million ha) and in its relative share of total cropland area (from 74% to 62%). This shows a trend towards agricultural and nutritional diversification (with annual consumption of rice dropping from 116 kg to 91 kg per capita).[21] The decrease in harvested rice area in recent years can also be attributed to government policy, which has been promoting other crops and advising against triple rice cultivation (rice crops cultivated three times per year) as this aggravates climate change impacts. Indeed, the triple rice cultivation requires irrigation during the dry season, including pumping groundwater. Combined with reduced river water flow, land subsidence and sea level rise, this aggravates salinity intrusion and droughts (Yuen et al. 2021)and much of the rice grown is concentrated in the Red River Delta (RRD.

The significant increase in area planted with vegetable crops (+80%) is consistent with this trend (Table 4). In 2020, the area of vegetable production came close to the area dedicated to maize, a significant increase as maize area was twice as large as the area harvested in vegetables in 2010. The area dedicated to vegetables doubled in ten years while maize harvested area decreased by 16% between 2010 and 2020. Table 4 also highlights an increase in the areas of perennial crops like coffee (+25% in harvested area), natural rubber (+66%) and cassava (+5%)[22]. Yet, the total share of the 5 major crops in Table 4 (excluding vegetables), in terms of total cropland area, decreased between 2010 and 2020 (from 99% to 86%), confirming the diversification trend.

Table 4. Harvested area by major crop in Vietnam

Area harvested (ha)	2010	2020
Rice	7,489,400	7,222,618
Maize (corn)	1,126,391	939,563
Vegetables	425,927	853,824
Natural rubber in primary forms	438,563	728,764
Coffee, green	511,900	637,563
Cassava, fresh	498,000	524,483
Total cropland	**10,118,100**	**11,718,000**

Source: FAOSTAT. Accessed 15 November 2023. https://www.fao.org/faostat/en/#data/QCL

3.2.3 Livestock

By weight, pig meat is by far the most significant animal product in Vietnam, with production reaching 2.5 million metric tons in 2020. Then come poultry meat, milk and eggs (Table 5). Looking at trends, milk production experienced the steepest increase, more than tripling between 2010 and 2020. In the meantime, poultry meat, eggs and pig meat production experienced lower,

21 See https://www.statista.com/statistics/1240210/vietnam-monthly-average-rice-consumption-per-capita/

22 See FAOSTAT: https://www.fao.org/faostat/en/#data/QCL

Table 5. Animal products in Vietnam

Production (metric tons)	2010	2020
Pig meat on the bone, fresh or chilled	2,217,000	2,467,000
Poultry (chicken and duck) meat	531,397	1,319,238
Milk, total	338,328	1,076,338
Eggs, primary	321,100	473,660
Beef and buffalo meat, primary	199,400	302,232
Sheep and goat meat	8,190	21,318

Source: FAOSTAT. Accessed 19 April 2023. https://www.fao.org/faostat/en/#data/QCL

yet significant, increases (respectively, +148%, +48% and + 11%). Beef, sheep and goat meat are less important in the Vietnamese diet and, hence, in its livestock production sector.

3.2.4 Fisheries and aquaculture

According to the FAO FishStatJ database[23], Asia is, by far, the biggest producer of aquaculture in the world, producing 88% of total aquaculture in 2020. With around 35,000 fishing vessels over 90 hp[24] and 1.1 million ha of aquaculture area in 2020 (GSO 2021; Chu et al. 2022), Vietnam is a major actor in global fisheries and aquaculture. The country is the fourth biggest producer of fish and other aquatic plants and animals, just after China, Indonesia and India, with total production nearing 8.3 million metric tons in 2021 (the latest available year), including 4.7 million metric tons from aquaculture, and 3.5 million metric tons from capture-related production. Since 2014, Vietnam has also been the third largest exporter of aquatic products, just after China and Norway, with the total value of exports coming in at about USD 9 billion in 2021 (5% of the world total) (FishStatJ). Vietnam exports seafood products to 164 countries, with major client markets including the United States, the European Union, Russia, Japan, China and South Korea. [25]

The sector of fisheries and aquaculture is essential for the national economy in Vietnam, representing about 5% of national GDP in 2020 (World Bank 2021) and almost 25% of the agricultural GDP in 2020 (Tu et al. 2022). The sector supports about 4.7 million direct and indirect jobs across the country. This is about 5% of the total national workforce, ten times more than the average 0.5% observed in OECD countries (World Bank 2021). Fisheries and aquaculture are an essential alternative source of livelihoods for small farmers, especially rice farmers, as well as rural communities. The sector represents the main source of income for about 4% of Vietnam's rural households; and for other households it offers additional opportunities to transition towards more efficient, resilient and sustainable agri-food systems (Chu et al. 2022). The sector ranks fifth in terms of export value, after telephone, textiles, electronics, and footwear (World Bank 2021) and accounts for almost 10% of national export value (GDC 2022; Chu et al. 2022).

Fisheries and aquaculture have experienced rapid development in Vietnam over the past two decades. Between 2000 and 2021, total captures more than doubled from 1.6 to 3.5 Mt, while aquaculture production increased almost tenfold, from 0.5 to 4.7 million metric tons. Since 2007, aquaculture production (in Mt) has exceeded total captures (FishStatJ). After centuries dominated by low-intensity traditional aquaculture practices, Vietnam has developed, since the 1960s, a more intensive and modern aquaculture sector. However, the real shift occurred after 2000, when farmers were encouraged by a Vietnamese government resolution[26] to convert low productivity saline rice fields, as well as uncultivated coastal areas and salt pans, into brackish-water ponds for aquaculture. This resolution encouraged public investments in infrastructure, as well as private investments in both production and processing facilities.

In terms of tonnage and export value, the two main aquatic species farmed in Vietnam are the striped catfish (*Pangasianodon hypophthalmus*) and brackish water shrimp (white-leg shrimp: *Penaeus vannamei,* and tiger shrimp: *Penaeus Monodon*).

23 See FishStatJ: https://www.fao.org/fishery/en/statistics/software/fishstatj (version updated in July 2023)

24 hp stands for horse power

25 See https://www.globenewswire.com/en/news-release/2022/09/07/2511396/28124/en/Vietnam-Fisheries-Industry-Report-2022-Development-Environment-Supply-and-Demand-Imports-and-Exports-Market-Competition-Major-Enterprises-Outlook-to-2031.html

26 Government of Vietnam, Resolution No.09/2000/NQ-CP of 15 June 2000. See https://english.luatvietnam.vn/resolution-no-09-2000-nq-cp-of-june-15-2000-on-a-number-of-undertakings-and-policies-on-economic-restructuring-and-consumption-of-farm-produce-15-5356-doc1.html

Five percent of catfish production and 80% of brackish water shrimp production are concentrated in the Mekong River Delta (GSO 2021; Chu et al. 2022; Le et al. 2022).

With almost 1.5 million metric tons in 2021, Vietnam is, by far, the main global producer of striped catfish. India comes next with less than 0.7 million metric tons. Since 2000, striped catfish production in Vietnam increased nearly 15 times (FishStatJ). However, national catfish production covers a relatively small area of 5,800 ha, reflecting highly intensive production methods (D-Fish 2022; Quyen et al. 2022). The catfish sector is estimated to generate more than 60,000 jobs in farming and 190,000 in processing (Tu et al. 2022), as well as an export value of about USD 1.5 billion (FishStatJ).

With its white-leg shrimp production reaching almost 0.7 million metric tons in 2021, Vietnam lands in fifth position globally, after China, India, Ecuador and Indonesia. Since 2002, when it was first recorded, white-leg shrimp production in Vietnam has increased by almost 70 times. Giant tiger shrimp (*Penaeus monodon*) is the second most cultivated shrimp and prawn species in Vietnam, with a production of around 270,000 metric tons in 2021 (FishStatJ). Shrimp farming in Vietnam covers over almost 750,000 ha, i.e., around two-thirds of the total area devoted to aquaculture (D-Fish 2021; Quyen et al. 2022).

Shrimp farming systems in Vietnam are very diverse, from super-intensive, intensive and semi-intensive, to improved extensive, shrimp-rice or shrimp-mangrove integrated systems (Chu et al. 2022; Quyen et al. 2022). Shrimps and prawns are the first export commodity with a total value of USD 3.8 billion in 2021[27] (FishStatJ). Vietnam's government plans to rapidly expand this sector and reach USD 10 billion of shrimp and prawn exports by 2025.[28]

Table 6. Agricultural production value of different commodities in Vietnam

Gross production value (current thousand USD)	2010	2020
Rice	11,582,826	12,496,296
Chicken meat, fresh or chilled	1,705,705	5,272,112
Pig meat, on the bone, fresh or chilled	3,471,604	5,260,553
Cassava, fresh	1,020,135	2,462,168
Coffee, green	1,386,691	2,409,063
Other	6,876,238	12,651,206
Total	**27,264,144**	**41,818,438**

Source: FAOSTAT. Accessed 20 January 2023. https://www.fao.org/faostat/en/#data/QV

3.2.5 Value of agricultural production

The gross production value of agriculture in Vietnam increased by 53% between 2010 and 2020 (Table 6). Rice was by far the main agricultural product in Vietnam in 2020, not only by area (Section 3.2.2) but also by value, generating 12.5 billion current USD. Yet, despite an 8% increase in rice gross production value between 2010 and 2020, its relative share in Vietnam's agricultural gross production value decreased from 42.5% to 30% over the same period. The increase in value added was mostly driven by a 7% increase in rice production between 2010 and 2020.

Rice is both an important food source and export commodity for Vietnam. Food security and rice export rank high on the government's agenda. Although the amount of rice exported decreased by about 2% compared to 2019, mainly to ensure food security, the export value increased by 11%. This is due to a higher price per ton of rice, largely contributing to benefits for rice farmers[29,30]. Rice cultivation needs to be considered in the context of climate change mitigation and adaptation to ensure that food security and export value is maintained, while the sector is transitioning towards low-emission rice cultivation systems.

27 That is over 40% of the national total export value of aquatic food in Vietnam.

28 Government of Vietnam, Decision No. 79/QD-TTg of 18 January 2018. See https://english.luatvietnam.vn/decision-no-79-qd-ttg-dated-january-18-2018-of-the-prime-minister-on-introducing-the-national-action-plan-on-development-of-vietnams-shrimp-indust-158292-doc1.html

29 Vietnam Ministry of Industry and Trade https://vioit.org.vn/en/strategy-policy/vietnam-s-rice-exports--opportunities-and-challenges-4404.4144.html#:~:text=Rice%20is%20both%20an%20important,%2D6.5%20million%20tons%2Fyear.

30 FFTC Agricultural Policy Platform: https://ap.fftc.org.tw/article/1176

According to FAOSTAT figures, the gross production value of chicken meat more than tripled in ten years, making it the second most important agricultural product in 2020. The value of pig meat increased by 51.5% between 2010 and 2020. Together, chicken and pig meat represent a gross production value of USD 10.5 billion.

3.3 Diets

3.3.1 National food supply

Vietnam's total food supply, expressed in kcal/capita/day, is very close to the world average (Table 7). Yet, Vietnam's food supply is 31.1% higher than Vietnam's average dietary energy requirements (2,293 kcal/capita/day in 2021), and 68.6% higher than Vietnam's minimum dietary energy requirement (1,782 kcal/capita/day) (FAOSTAT)[31].

Calorie intake comes mainly from vegetal products (79%), in the same proportion as the world average. However, the share of cereals is much higher in Vietnam, with 53% of average daily energy intake coming from cereals, compared to the global average of 44%. Rice represents 83% of cereal intake, and 44% of the daily calorie intake in Vietnam (1,309 kcal/capita/day).

FAO data shows Vietnam's total protein supply[32] at 88.1 g/capita/day, which is close to the world average (Table 7). It is worth noting that Vietnam's protein supply is considerably higher than the recommended intake by the FAO, which refers to the proteins actually consumed, and which should be between 30 and 56 g/day for women and 37.5 and 60 g/day for men[33]. Studies conducted at national level found similar results for the protein intake (a mean of 82 g/day, see Nguyen et al. 2013). However, calorie intake from meat is almost twice the world average. In 2020, Vietnamese people consumed on average 458 kcal/capita/day of meat – mainly pig meat (79.9%) and poultry (13.3%) – that is 96% higher than the world average. Consequently, meat represents a larger part of Vietnam's food supply, amounting to 15.2% of daily calorie intake compared to 7.8% for the world average.

Total fat supply amounts to 80.8 g/capita/day, 9% lower than the world average. Animal and meat products also account for an important part of total fat supply in Vietnam, respectively 63.6% and 51.5%, whereas these food groups account for just 43.4% and 21.4% of fat supply as a world average (Table 7).

3.3.2 Food from fisheries and aquaculture

"Aquatic foods are increasingly being recognized as having an important role to play in an environmentally sustainable and nutritionally sufficient food system" (Henriksson et al. 2021). According to FAOSTAT Food Balance Sheets (FBS),[34] fish, seafood and other aquatic products in 2020 represented 12.6% of the total daily protein intake in Vietnam, against 6.9% for the world average. Aquatic foods provide essential amino acids, vitamins, phosphorus and minerals (including iodine and magnesium), and are a primary source of heart-healthy omega-3 fatty acids (FAO 2022). They thus enhance food security and nutrition, dietary quality and diversity.

3.3.3 Food security and nutrition

With the exception of undernourishment, food security indicators (Table 8) are lower in Vietnam than the world average. Vietnam's prevalence of obesity in the adult population is particularly low, standing at 1.5% of the adult population, almost 8 times lower than the world average (11.5%). The prevalence of anaemia in women is also relatively low, 40% lower than the world average.

31 The minimum dietary energy requirement is derived from the results of a FAO/WHO/UN university expert consultation held in 2001 (FAO/WHO/UN 2004). This established energy standards for different gender and age groups with sedentary lifestyles and a minimum acceptable body weight for their height. The average energy requirement is the food energy necessary to maintain body weight, composition and suitable physical activity levels for long-term good health. Recommended dietary energy intake for a population group corresponds to the average energy requirement of healthy, well-nourished individuals within that group. Source: https://www.who.int/data/nutrition/nlis/info/population-below-minimum-level-of-dietary-energy-requirement-(undernourishment)#:~:text=The%20average%20energy%20requirement%20is,with%20long%2Dterm%20good%20health

32 Protein supply refers to the total amount of protein available for human consumption resulting from the multiplication of the quantity of food available by its protein content. Hence it includes not only the protein actually consumed but also the protein finally lost or wasted during the consumption phase. Source: FAO Statistics Division

33 https://www.fao.org/3/AA040E/AA040E09.htm#:~:text=For%20adults%20the%20protein%20requirement,digestibility%20of%20milk%20or%20egg

34 Accessed 13 July 2023. See https://www.fao.org/faostat/en/#data/FBS

Table 7. National supply of food, fat and protein for the main food groups in Vietnam (2020 values)

	Vietnam		World	
	Value	% of total	Value	% of total
Total food supply (kcal/capita/day)	**3005**	**100%**	**2982**	**100%**
Animal products, including meat	638	21.2%	533	17.9%
Meat only	458	15.2%	233	7.8%
Vegetal products, including cereals (excluding beer)	2367	78.8%	2449	82.1%
Cereals only (excluding beer)	1585	52.7%	1317	44.2%
Total fat supply (g/capita/day)	**80.8**	**100%**	**88.7**	**100%**
Animal products, including meat	51.4	63.6%	38.5	43.4%
Meat only	41.7	51.5%	19.0	21.4%
Vegetal products, including cereals (excl. beer)	29.4	36.4%	50.2	56.6%
Cereals only (excluding beer)	6.1	7.5%	6.1	6.9%
Total protein supply (g/capita/day)	**88.1**	**100%**	**84.6**	**100%**
Animal products, including meat	36.7	41.7%	33.7	39.9%
Meat only	19.1	21.7%	14.5	17.2%
Vegetal products, including cereals (excl. beer)	51.4	58.3%	50.8	60.1%
Cereals only (excluding beer)	33.9	38.5%	32.5	38.5%

Source: FAOSTAT. Accessed 13 December 2022. https://www.fao.org/faostat/en/#data/FBS

Table 8. Food security indicators compared between Vietnam and the world average

Indicator (in %)	Vietnam	World
Prevalence of undernourishment in total population	9.8	8.4
Prevalence of stunting in children under 5	26.8	26.9
Prevalence of overweight in children under 5	4.0	5.6
Prevalence of obesity in adult population (over 18)	1.5	11.5
Prevalence of anaemia in women aged 15–49	17.0	28.5

Source: FAOSTAT. Accessed 13 December 2022. https://www.fao.org/faostat/en/#data/FS

However, Harris et al. (2020) show that Vietnam is at the start of its nutrition transition, with undernutrition falling, obesity rising and nutrition-related chronic diseases accounting for a more significant share of diseases and death. Cardiovascular diseases, cancers, chronic obstructive pulmonary disease and diabetes mellitus were major contributors to non-communicable diseases, which, in 2010, accounted for 318,000 deaths, that is 72% of total deaths in Vietnam (Nguyen and Hoang 2018).

Vietnamese diets saw a switch from animal to vegetable oils due to the latter's perceived health benefits and lower costs, with volume and value of edible oils raising by 30% between 2013 and 2019 (Harris et al. 2020). However, even though wet markets for daily fresh food purchases continue to dominate food purchasing behaviour (85% of grocery sales in 2016), the transition in nutrition includes a drop in vegetable consumption and an increase in meat and milk consumption. The supply of sweets and sweetened beverages has risen in recent years – sugar and sweeteners intake per capita has increased by 77% and sugar supply almost doubled (+96%) (Harris et al. 2020). The expenditure share of food eaten away from home, often associated with less healthy food, has also increased in both rural and urban areas. According to Harris et al. (2020), expenditure shares are larger in urban areas (30.4% in 2014, higher than 22.4% in 2002) than in rural areas (18.8% in 2014 compared to 8.7% in 2002). This category includes both processed fast foods, traditional restaurants and street foods.

4 Food system emissions

4.1 Economy-wide emissions

Vietnam's share of global emissions (across all sectors, including LULUCF) increased from 0.6% to 0.8% between 2010 and 2020. The country's share of global emissions (across all sectors except LULUCF) increased in the same proportion. Vietnam's total emissions increased sharply between 2010 and 2020. Emissions with LULUCF increased by 39%, reaching 395 $MtCO_2eq$ in 2020; whereas emissions without LULUCF increased more rapidly (+53%), suggesting that the LULUCF sector contributed to slowing down the increase in overall emissions over this period (Table 9). These increases are also significantly higher than those seen globally over the same period, respectively: + 6.7% (with LULUCF) and +7.5% (without LULUCF).

In its updated NDC (Socialist Republic of Viet Nam 2022), Vietnam reported total national GHG emissions of 284 MtCO2eq in 2014. Vietnam's NDC further disaggregates GHG emissions sources and sinks by sectors (Table 10). The agriculture sector is second only to the energy sector. In 2014, the LULUCF sector was a net sink, contributing to removing 37.5$MtCO_2eq$ from the atmosphere.

Table 9. Vietnam's economy-wide annual GHG emissions compared to global emissions totals

Total GHG emissions (MtCO2eq/year)	2010		2020	
	Vietnam	World	Vietnam	World
All sectors with LULUCF	284	48,738	395	52,010
All sectors without LULUCF	266	47,099	407	50,617

Source: FAOSTAT. Accessed 17 March 2023. https://www.fao.org/faostat/en/#data/GT

Table 10. Vietnam's annual GHG emissions by sector

GHG emissions by sector (MtCO2eq/year)	National communication (2014)	FAOSTAT	
		2010	2020
Energy	171.6	148.7	249.1
Agriculture	89.8	71.7	73.5
LULUCF	-37.5	18.3	-12.4
Waste	21.5	24.5	57.0
IPPU	38.6	20.1	26.1
All sectors with LULUCF	284.0	284.5	395.1

Sources: Vietnam Third National Communication (MNRE 2019) and FAOSTAT https://www.fao.org/faostat/en/#data/GT. Accessed 30 March 2023.

Table 11. Vietnam's total GHG emissions per capita

All GHG emissions (tCO_2eq per capita)	2010		2020	
	Vietnam	World	Vietnam	World
All sectors with LULUCF	3.25	6.98	4.09	6.63
All sectors without LULUCF	3.05	6.74	4.22	6.46

Source: FAOSTAT. Accessed 17 March 2023. https://www.fao.org/faostat/en/#data/GT

Table 12. Food system emissions in Vietnam and globally

	2010		2020	
	Vietnam	World	Vietnam	World
Food system GHG emissions ($MtCO_2eq$/year)	96.4	15,921.3	104.5	16,138.6
Percent of total emissions	33.9%	32.7%	26.5%	31.0%

Source: FAOSTAT. Accessed 27 January 2023. https://www.fao.org/faostat/en/#data/GT

Table 13. Food system emissions per capita in Vietnam

	2010		2020	
	Vietnam	World	Vietnam	World
Food system emissions per capita (tCO2eq per capita)	1.10	2.28	1.08	2.06

Source: FAOSTAT. Accessed 17 March 2023. https://www.fao.org/faostat/en/#data/GT and https://www.fao.org/faostat/en/#data/OA

Per capita, Vietnam's GHG emissions in 2020 (Table 11) were significantly lower than the world average, by 38.4% and 54.8%, respectively, with and without LULUCF. Yet Vietnam's emissions per capita have increased considerably between 2010 and 2020, both with and without LULUCF, by 26% and 38%, respectively. While, globally, per capita emissions without LULUCF are slightly smaller than with LULUCF, in Vietnam this relationship is inverted, with per capita emissions without LULUCF being slightly larger, as LULUCF was a net sink for Vietnam in 2020.

4.2 Food system emissions

Even though Vietnam's food system emissions increased by 8% between 2010 and 2020, from 96.4 to 104.5 $MtCO_2eq$, their share in total national emissions (with LULUCF) decreased during the same period, from 34% in 2010 to 26.5% in 2020 (Table 12). Despite being now lower than the world average (31%), food system emissions in Vietnam still represent a significant share of national emissions.

Per capita, food system emissions were considerably lower (by about 53%) in Vietnam than the world average (Table 13); these have remained quite stable over the last decade.

4.2.1 Emissions from fisheries and aquaculture

Seafood has a much lower feed conversion ratio (FCR)[35] than terrestrial animals, meaning that they represent a much more resource-efficient source of food. FCRs have been estimated in the range of 6.0–10.0 for beef, 2.7–5.0 for pigs, and 1.7–2.0 for chicken, versus only 1.0–2.4 for farmed fish and shrimp (Le et al. 2022).[36] Based

35 i.e., the quantity of feed (kg) required to produce 1 kg of animal product. FCR has no unit.

36 For the same animal species, FCR estimations can vary a lot depending on the country, production system and calculation method. Online estimations include: https://www.statista.com/statistics/254421/feed-conversion-ratios-worldwide-2010/; https://www.omnicalculator.com/biology/fcr and https://www.navfarm.com/blog/fcr-guide/. In 2002, FAO undertook a literature review to estimate FCR for various farmed fish species: https://www.fao.org/3/y3781e/y3781e0a.htm

on feed consumption therefore, farmed fish species are estimated to have a lower carbon footprint than terrestrial animals: respectively 87% and 49% smaller than beef and poultry (Poore and Nemecek 2018). MacLeod et al. (2020)[37] for instance, found that, for most finfish, emission intensity falls in the range of 4–6 $kgCO_2eq/kg$ of carcass weight, i.e., per kg of edible flesh, against the average of 36 $kgCO_2eq/kg$ of beef meat given by Poore and Nemecek (2018). Feed is often the main source of emissions in aquaculture, while energy and fuel used in motorized fishing vessels is the predominant source of emissions in fisheries (Quyen et al. 2022).

On the other hand, the conversion of peatlands, mangroves and forested estuaries to shrimp aquaculture is known to produce enormous emissions in Southeast Asia (Kauffman et al. 2017). These are related to land conversion and the GHG emissions associated with the loss of enormous amounts of soil carbon, previously stored for centuries in organic soils acting as a carbon sink (Dung et al. 2016). Mangrove removal, and the strategy of interspersing shrimp ponds with partial mangrove conservation, seem to be questionable practices in terms of GHG emissions (Järviö et al. 2017). Kauffman et al. (2017) found that GHG emissions from shrimp produced on land that was formerly mangrove amounted to 1,603 $kgCO_2eq$ per kg of shrimp, presumably due to the large CO_2 emissions from the mangrove soils. The carbon footprint of aquaculture thus needs more attention in the context of the overall life-cycle emissions of fisheries and aquaculture, and precise data need to be collected for Vietnam's aquaculture, particularly in the Mekong Delta. Moreover, peatlands mangroves and forested estuaries are also central to address the very high vulnerability of Vietnam's low-lying coastal and river delta regions to sea-level rise. The World Bank Group and the Asian Development Bank (WBG/ADB 2021) estimated that, depending on the emission scenarios and with no effective adaptation strategy, between 6 and 12 million people could potentially be affected by coastal flooding by the end of this century (2070–2100).

Even though, they represent 17.4% of all animal proteins in the average human diet globally (FAOSTAT FBS),[38] fisheries and aquaculture have been estimated to generate together about only 0.58 $GtCO_2eq/year$ globally (Barange et al. 2018), i.e., less than 10% of global agricultural GHG emissions and just 1% of total GHG anthropogenic emissions. Because of this small share in global emissions, fisheries and aquaculture have so far not often been considered a priority sector for mitigation strategies. GHG emissions from this sector are rarely studied in the scientific literature, and thus data and methods are lacking. Moreover, the sector has not been covered in the IPCC (2006, 2019) Guidelines. Consequently, it is often overlooked in national GHG inventories and mitigation strategies (Mbow et al. 2019), including in Vietnam (Quyen et al. 2022; Tu et al. 2022). The Mitigate+ initiative aims to contribute to data collection on GHG emissions from fisheries and aquaculture in partner countries and to complete the current information gap.

As there are almost no primary data on GHG emissions from fisheries and aquaculture, we tried to approximate their order of magnitude through different approaches. Our first rough estimation used the production data presented in Section 3.2.4 together with figures given in Our World in Data[39], based on Gephart et al. (2021), to determine median (and range: minimum – maximum) GHG emissions per kilogram of seafood. For capture fisheries, the result is 25.5 (13.3 – 37.5) $MtCO_2eq/year$; and for aquaculture, 47.9 (44.2 – 54.1) $MtCO_2eq/year$. Taken together, the emissions per kilogram of seafood from fisheries and aquaculture together would reach 73.5 (57.5 and 91.5) $MtCO_2eq/year$. This rough estimation can seem very high when compared to total food system emissions in Vietnam, as assessed by FAOSTAT (104.5 $MtCO_2eq$ in 2020). However, the large emissions from wetland conversion need to be considered.

Using FAOSTAT FBS can provide two alternative ways to calculate rough estimates of fish and seafood emissions, using a simple rule of three. First, in 2020, fish and seafood represent around 2% of total Vietnam food supply, expressed in

37 Poore and Nemecek (2018) address the GHG footprint cover the whole food chain. MacLeod et al (2020) "quantifies the main GHG emissions arising 'cradle to farm-gate', from the following activities: the production of feed raw materials; processing and transport of feed materials; production of compound feed in feed mills and transport to the fish farm; rearing of fish in water".

38 Accessed 13 July 2023. See https://www.fao.org/faostat/en/#data/FBS

39 See https://ourworldindata.org/grapher/ghg-emissions-seafood

kcal. Considering that fish and seafood have a lower carbon impact than other animal products, related GHG emissions should be lower than 2% of total food system emissions, that is about 2 $MtCO_2eq$. Second, fish and seafood supply in Viet Nam represent about 2% of worldwide fish and seafood supply, expressed in kcal. Global emissions from fisheries and aquaculture have been estimated by FAO at 580 MtCO2eq (Barange et al. 2018). Hence, as a first approximation, fish and seafood emissions in Vietnam should represent be about 2% of global emissions from the sector, i.e. nearly 12 MtCO2eq.

These two alternative approaches provide a lower, and maybe more realistic, range (2 – 12 MtCO2eq) from Vietnam emissions from fisheries and aquaculture that could be used as a basis for discussion with national experts of the sector. However, they do not consider the extreme diversity of emission factors across countries, species and production systems. This is why more accurate primary data need to be collected to better understand emissions from this sector and to which extent they are included in FAOSTAT data presented in Table 14.

4.2.2 Disaggregation of food system emissions

Vietnam's Third National Communication (MNRE 2019), the latest one available, does not disaggregate food system emissions. However, its methodology includes emissions from "manufacturing industries and construction: fertilizers" and the food manufacturing industry, which are respectively estimated at: 5.01MtCO2eq (1.36% of national emissions) and 3.58 MtCO2eq (0.97%). In the Third National Communication and the latest NDC, ensuring food security appears as one of the main objectives when it comes to implementing the NDC targets and achieving climate change adaptation.

This section on disaggregated food system emissions is based on FAOSTAT data from 2010 and 2020 (Table 14).

FAOSTAT splits food system emissions into three main categories: land-use change, farmgate, and pre-and post-production emissions. In 2020, farmgate activities were the largest source of GHG emissions from the food system in Vietnam (78.8 MtCO2eq; 75% of total food system emissions), followed by pre- and post-production activities (25.0 MtCO2eq; 24%) and land-use change (0.7 MtCO2eq; 1%)[40].

Rice cultivation was responsible for 35.7 MtCO2eq (45% of farmgate emissions) and 34% of total food system emissions in 2020, despite a slight decrease (-3.6%) compared to 2010 levels. The three sources of emissions from manure distinguished in Table 14[41] should be considered altogether. Hence, the three other main sources of emissions at farmgate in 2020 were enteric fermentation (13 MtCO2eq; 16.5% of farmgate emissions), manure (11.4 Mt; 14.4% of farmgate emissions); and synthetic fertilizers (10MtCO2eq; 12.7% of farmgate emissions). According to FAOSTAT, emissions from enteric fermentation and manure management remained quite stable over the period, thus Vietnam did better than, e.g., major global producers of meat and dairy whose emissions increased (FAIRR 2023).

Emissions beyond farmgate, linked to pre- and post-production activities, amounted to 25 MtCO2eq in 2020, about 37% higher than in 2010, with very large increases in food packaging (+331%), food processing (+249%) and on-farm electricity use (+517%). However, the two most important sources of emissions beyond farmgate remain food system waste disposal and household food consumption. Emissions from food system waste disposal remained stable between 2010 and 2020, but emissions related to household food consumption increased by 52%. These two emission sources represent, respectively, a sizeable 34.3% and 32.6% of pre- and post-production activities.

Overall, the largest emissions from the food system are, by decreasing order of importance: rice cultivation (34% of total food system emissions); enteric fermentation (12%); emissions from

40 This small figure may rather reflect a problem of reporting in FAOSTAT database for this specific emission category than the reality on the ground. This figure can be compared for instance to the carbon sink of -37.5 reported for the year 2014 for land use, land use change and forestry (LULUCF) in Vietnam's Third National Communication (MNRE 2019).

41 I.e. manure applied to soils, manure left on pasture and manure management.

Table 14. GHG emissions from the food system in Vietnam

Sources of GHG emissions	GHG emissions ($MtCO_2eq$/year)		Percentage of total emissions (2020)	Percentage change 2010–2020
	2010	2020		
Food systems (= 1 + 2 + 3)	**96.4**	**104.5**	**100**	**8**
1. Land-use change	**0.7**	**0.7**	**1**	**4**
Fires in humid tropical forests	0.4	0.2	0	-43
Fires in organic soils	0.3	0.5	0	57
Net forest conversion	0	0	0	
2. Farmgate	**77.5**	**78.8**	**75**	**2**
Burning – crop residues	0.5	0.5	0	-7
Crop residues	2.5	2.6	2	2
Drained organic soils	4.1	4.0	4	-4
Drained organic soils (CO_2)	4.0	3.8	4	-4
Drained organic soils (N_2O)	0.2	0.2	0	-4
Enteric fermentation	13.1	13.0	12	-1
Manure applied to soils	1.6	1.8	2	12
Manure left on pasture	2.6	3.1	3	17
Manure management	7.1	6.5	6	-9
On-farm energy use	1.8	1.5	1	-18
Rice cultivation	37.0	35.7	34	-4
Savanna fires	0.3	0.1	0	-54
Synthetic fertilizers	6.6	10.0	10	52
3. Pre- and post- production	**18.2**	**25.0**	**24**	**37**
Fertilizer manufacturing	n.a.	n.a.		
Household food consumption	5.3	8.1	8	52
Food packaging	0.1	0.2	0	332
Food processing	0.1	0.3	0	249
Food retail	0.9	1.1	1	23
Food system waste disposal	8.1	8.6	8	6
Food transport	3.3	3.9	4	17
On-farm electricity use	0.4	2.7	3	517

Source: FAOSTAT. Accessed 20 March 2023. https://www.fao.org/faostat/en/#data/GT. Food system corresponds to FAOSTAT's term 'agrifood system'. Note the units (MtCO2eq/year). n.a. = not available. The exact definitions for each source of food system emissions are given in Annex 1.

manure (11%); synthetic fertilizers (10%)[42]; food system waste disposal (8%); and household food consumption (8%). Together, these six activities emitted 86.1 $MtCO_2eq$ in 2020 and accounted for 83% of all food system emissions.

Finally, pre- and post-production activities, making up 24% of total food system emissions in 2020, have gone up by 37% and now represent an important source of emissions, in particular from household consumption and food system

42 This figure includes only emissions associated with synthetic fertilizer application. As shown in Table 14, no data is reported for emissions related to synthetic fertilizer manufacturing in Vietnam

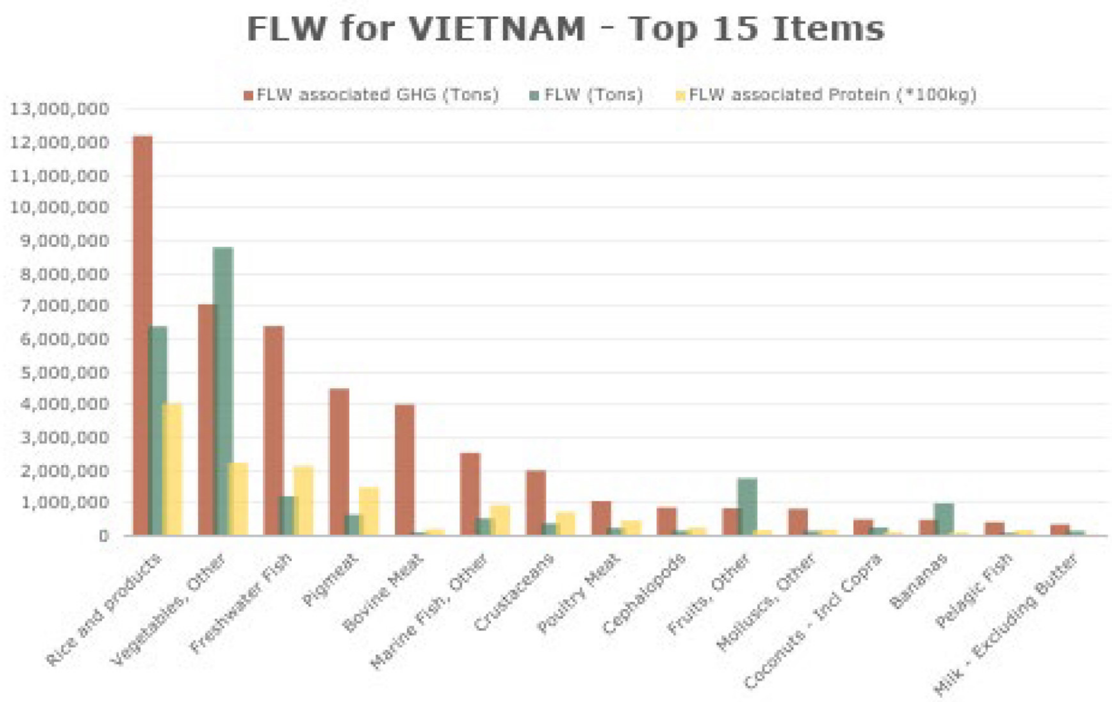

Figure 1. Top 15 hotspot categories of FLW in Vietnam, ranked on FLW-associated GHG emissions (in tCO_2eq/year), loss and waste volumes, and loss of protein.

Note: Protein losses are depicted by 100 kg to make the values visible and comparable; FLW total values are in metric tons. Figure taken from Axmann et al. (2022). Initial release of an evolving dataset, subject to ongoing elaboration and updates.

waste disposal. Some of these subsectors have doubled, tripled or even quintupled their emissions (food packaging, food processing and on-farm energy-use) which may be due to an increase in production and activities that so far lack low-emission approaches, as well as to inefficiencies in infrastructure and logistics.

4.3 Food loss and waste (FLW)

When FAO considers emissions from food system waste disposal (Table 14), it does not include emissions associated with FLW at different stages of food value chains. In the FAOSTAT methodology the item "food system waste disposal" covers the four following categories: (1) solid food waste disposed in landfills; (2) domestic wastewater; (3) industrial wastewater; and (4) incineration of materials used in food systems (Karl and Tubiello 2021). FLW is a more inclusive category, referring both to the decrease in quantities at production, processing and distribution stages (food loss) and the decrease in quantities at retail and consumption stages (food waste) (Axmann et al. 2022).

Globally, 31% of food is lost or wasted.[43] Consensus is growing around the fact that the world now produces enough food for everybody. Hence, eliminating hunger and malnutrition is more a distribution than a food production issue. Halving FLW, as suggested under Sustainable Development Goals (SDG) 12.3, would make a critical contribution to food security and nutrition while reducing the food system emissions overall.

Using a bottom-up mass flow model developed by Guo et al. (2020), the University of Wageningen considered the main FLW hotspots across food value chains at country level in terms of GHG emissions and nutrient loss associated to FLW. In Vietnam, the five main FLW hotspots, ranked according to associated GHG emissions, are rice (12.2 $MtCO_2eq$), vegetables (7 $MtCO_2eq$), freshwater fish (6.4 $MtCO_2eq$), pig meat (4.5 $MtCO_2eq$) and bovine meat (4 $MtCO_2eq$) (Figure 11). Vegetables become the main hotspot when considering FLW as a percentage of total production (54%).

43 Around 14% of food produced is lost between harvest and retail, and 17% is wasted (11% in households, 5% in the food service and 2% in retail). Accessed 19 March 2023. See: https://www.un.org/en/observances/end-food-waste-day

There are claims that actual FLW in developing countries could potentially be lower than this, due to opportunities for capturing and re-utilizing lost and wasted food in the informal economy. However, there is a lack of data to confirm this. It becomes evident that a lack of accurate primary data at micro, meso, and macro levels across food value chains, is significantly impeding a comprehensive understanding of emissions from FLW (HLPE 2014). Without knowing which products and which parts of their production chain must be predominantly addressed, interventions cannot be targeted and efficient. The collection of primary FLW data in key value chains – including seafood production – is essential to direct the formation of FLW interventions tailored to these chains.

Were such data to become available, it could help identify potential interventions to reduce FLW that would directly reduce food system emissions. These interventions may include hardware solutions like improved packaging and cooling systems, organizational solutions like better arrangements in supply chains (so-called orgware in industry jargon[44]), and software solutions like improved knowledge and information sharing. Additionally, comparison of supply chains for similar product categories can help identify best practices that can be adopted to improve efficiency (Axmann et al. 2022).

44 The "systems set of organizational, economical, legislative and managerial arrangements" (Dobrov 1979).

5 Vietnam's Nationally Determined Contribution (NDC)

Following submission of its Intended Nationally Determined Contribution in 2015, Vietnam submitted its NDC in December 2020 and updated it recently, in October 2022 (Socialist Republic of Viet Nam 2022). This updated NDC is briefly analysed in the following sub-sections.

5.1 Business-as-usual scenario

Table 15 shows emissions for the energy, agriculture, LULUCF, waste and IPPU sectors, disaggregated according to the IPCC guidelines

Table 15. Vietnam's annual GHG emissions by sector under the business-as-usual (BAU) scenario (in $MtCO_2eq$/year)

Sectors	2014	2020	2025	2030
Energy	171.6	347.5	500.7	678.4
Agriculture	89.8	104.5	109.2	112.1
LULUCF	-37.5	-35.4	-37.9	-49.2
Waste	21.5	31.3	38.1	46.3
Total	**284.0**	**528.4**	**726.2**	**927.9**

Source: Vietnam's updated NDC (Socialist Republic of Viet Nam 2022)

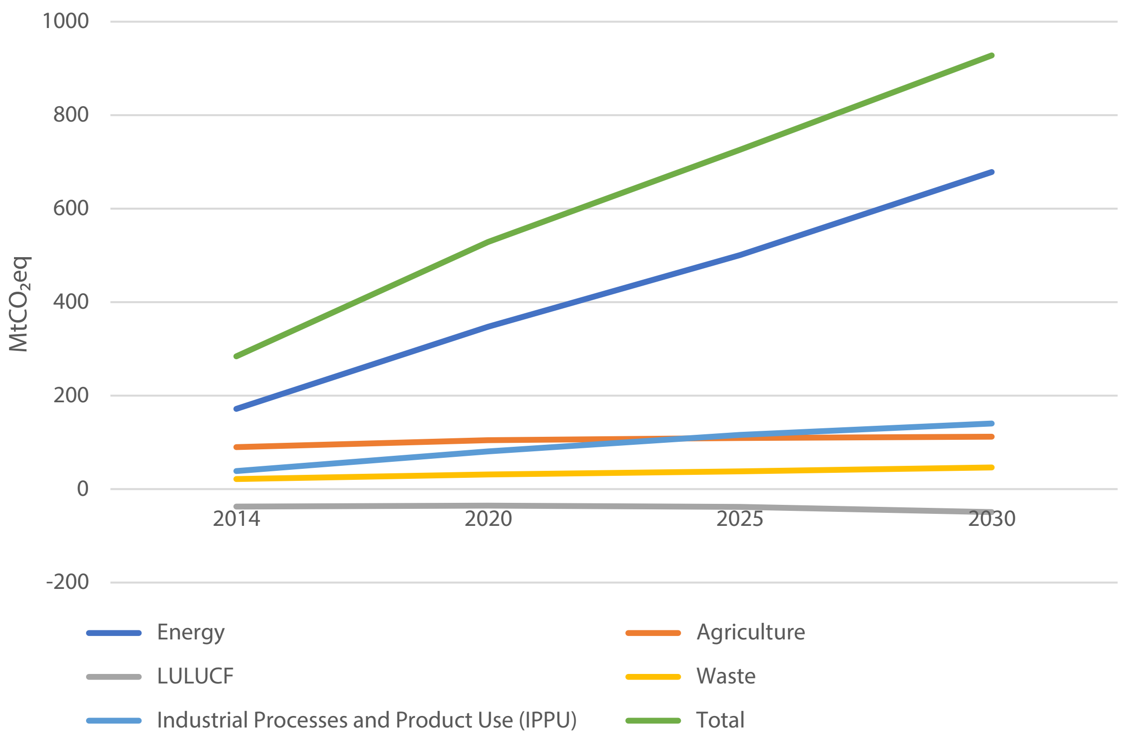

Figure 2. Annual GHG emissions under the BAU scenario ($MtCO_2eq$/year)

Source: Vietnam updated NDC (Socialist Republic of Viet Nam 2022)

Table 16. Sectoral emission reduction targets in Vietnam

Sector	Unconditional reduction targets		Conditional reduction targets	
	Contribution to total emissions reduction		Contribution to total emissions reduction	
	%	$MtCO_2eq$	%	$MtCO_2eq$
Energy	7.0	64.8	24.4	227.0
Agriculture	1.3	12.4	5.5	50.9
LULUCF	3.5	32.5	5.0	46.6
Waste	1.0	8.7	3.2	29.4
IPPU	3.0	27.0	4.4	49.8
Total	**15.8**	**146.3**	**43.5**	**403.7**

Source: Vietnam's Updated NDC (Socialist Republic of Viet Nam 2022)

for implementing the national GHG inventory. Under the business-as-usual (BAU) scenario, economy-wide GHG emissions are expected to increase by +227%, from 528.4 $MtCO_2eq$ in 2020, to 726.2 $MtCO_2eq$ in 2025, and 927.9 $MtCO_2eq$ in 2030.

5.2 Emissions reduction targets

Vietnam's updated NDC includes the following commitments:

- by 2030, reduce GHG emissions by 43.5% relative to the business-as-usual (BAU) scenario of 927.9 $MtCO_2eq$. The economy-wide emission reduction target has been set at 403.7 $MtCO_2eq$ and the financial need to support this has been estimated at USD 86.8 million.
- by 2030, reduce methane emissions by 30% compared to the 2020 level.

Vietnam's NDC presents specific emissions reduction targets for each sector, both unconditional (based on national resources) and conditional (depending on international support) (Table 16).

Vietnam's 'net zero' pledge is described in The National Climate Change Strategy to 2050, issued in September 2022, which sets emissions reduction targets for all sectors by 2030 and 2050. It features specific measures to mitigate climate change, such as maintaining a 43% forest coverage. These sectoral targets, set as a percentage of the BAU scenario in each sector, are also included in the NDC:

- 43% reduction in agriculture sector emissions, with total emissions not to exceed 64 $MtCO_2eq$/year
- 70% increase in LULUCF sector removals, corresponding to a 19% increase in carbon capture, the forestry sector having a total carbon capture of 95 $MtCO_2eq$/year
- 32.6% reduction in energy sector emissions
- 60.7% reduction in waste sector emissions
- 38.3% reduction in industry sector emissions

Several national documents support the implementation of Vietnam's NDC. The following documents cover activities related to food-systems:

- Law on Forestry (2017)
- National Climate Change Strategy to 2050 (2022)[45]
- National Strategy on Green Growth for 2021–2030 (2021)
- Vietnam's Forestry Development Strategy for 2021–2030 (2021)
- Methane Emission Reduction Action Plan to 2030 (2022)
- Scheme on Tasks and Solutions to Implement the Results of COP26 (2022)
- National Action Program on Sustainable Production and Consumption for 2021–2030 (2020)

45 The link does not direct to the official National Climate Change Strategy to 2050, but to an unofficial English translation of the strategy. The official document can be found here, in Vietnamese: https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Quyet-dinh-896-QD-TTg-2022-phe-duyet-Chien-luoc-quoc-gia-bien-doi-khi-hau-den-2050-523527.aspx

- Scheme on Development of Organic Agriculture for 2020–2030 (2018)
- Scheme on Sustainable Forest Management and Forest Certification (2018)
- Strategy for development of Vietnam's fisheries by 2030, with vision towards 2045 (Decision No. 339/QD-TTg, 11 March 2021).
- National Program on aquaculture development for 2021–2030 (Decision No. 985/QD-TTg, 16 August 2022)
- National action plan on development of Vietnam's shrimp industry by 2025 (Decision No. 79/QD-TTg, 18 January 2018).
- Plan for Implementation of the Paris Agreement on Climate Change (Decision No. 2053/QD-TTg, 28 October 2016, accessible in Vietnamese)
- Law on Fisheries, Law No. 18/2017/QH14, 21 November 2017 of the National Assembly
- National Climate Change Strategy to 2050 (2022) (Decision 896/QD-TTg, 26 July 2022)[46]
- National Action Programme on the Reduction of Greenhouse Gas Emissions through the reduction of Deforestation and Forest Degradation, Sustainable Management of Forest Resources, and Conservation and Enhancement of Forest Carbon Stocks (REDD+) by 2030 (Decision No. 419/QD-TTg, 5 April 2017)
- Decree on Mitigation of Green House Gas (GHG) Emissions and Protection of Ozone Layer (Decree No. 06/2022/ND-CP, 7 January 2022)
- Decision promulgating the lists of sectors and establishments emitting greenhouse gases subject to greenhouse gas inventory (Decision 01/2022/QD-TTg, 18 January 2022)

Measures in the updated NDC (Socialist Republic of Viet Nam 2022) to achieve the national emissions reduction targets span five economic sectors: energy (supply and demand), agriculture, LULUCF, waste and industry (IPPU).

The main measures for the agricultural sector are:

- Application of integrated crop management solutions
- Application of farming technologies such as alternating wet and dry irrigation, and systems of rice intensification (SRI) in areas with adequate infrastructure
- Mid-crop water withdrawal in rice cultivation
- Conversion of inefficient rice land into dry cropland or shrimp-rice land
- Modernization of watering and fertilizing practices for perennial plants
- Composting and organic agriculture
- Replacement of nitrogen fertilizers with slow-dissolving and slow-digesting fertilizers
- Improvement of ruminant rations
- Re-use of agricultural waste as organic fertilizer
- Development of biogas.

The 43% emissions reduction target for the agriculture sector is intended to be reached through several strategies, including the Action Plan to Respond to Climate Change of Agriculture and Rural Development for 2016–2020 with a vision to 2050. This plan promotes "agricultural restructuring, adopting smart agricultural solutions adapting to climate change and utilising advantages of tropical agriculture and developing organic agriculture".

At COP26 (Glasgow, UK, 2021), Vietnam committed to achieving 'net zero' by 2050 and became signatory of sectoral pledges related to coal phase-out, methane emission reduction, and forest loss and degradation halt. Methane emissions represent 21% of national GHG emissions, and come mainly from agriculture. Vietnam's government signed up for the Global Methane Pledge (GMP), an initiative of the United States and the EU "to catalyze global action and strengthen support for existing international methane emission reduction". The national Methane Emission Reduction Plan, published in August 2022, sets sector-specific goals for 2025 and 2030, namely limiting methane emissions to 42.2 metric tons from cultivation, 16.8 metric tons from animal husbandry, 21.9 metric tons from the waste sector, as well as 15.4 metric tons from other sectors. Collectively, these measures would contribute to reducing CH_4 emissions by 30% till 2030 as announced by Vietnam during COP26.

Vietnam's updated NDC (Socialist Republic of Viet Nam 2022) includes only one mitigation measure focusing on fisheries and aquaculture, that is: encouraging the conversion of inefficient rice

46 The link is not directing towards the Official National Climate Change Strategy to 2050 but to an unofficial English translation of the strategy. The official document can be found here, in Vietnamese: https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Quyet-dinh-896-QD-TTg-2022-phe-duyet-Chien-luoc-quoc-gia-bien-doi-khi-hau-den-2050-523527.aspx

land into more sustainable and more productive shrimp-rice farming systems (Tu et al. 2022). Nevertheless, fisheries and aquaculture suffer from significant performance gaps, meaning that there is potential to boost productivity in the sector, support livelihoods and enhance food security and nutrition, without increasing related GHG emissions and environmental footprints (Henriksson et al. 2021). Many options need to be explored, implemented and/or scaled up in the sector, including: species choice, genetic improvements, technological innovations in farming and processing, feed formulation, energy savings and renewable energy (e.g., sun-drying), spatial planning, mixed integrated farming systems, recirculating aquaculture systems[47], waste recycling and reuse (e.g., use of shrimp faeces compressors), regulation and financial tools (Henriksson et al. 2021; Le et al. 2022; Tu et al. 2022).

The main measures in the 2022 NDC for the LULUCF sector that affect food systems include:

- Protection of existing natural forest areas in mountainous areas, with priority given to hotspots of deforestation and forest degradation for food production
- Restoration of protection forests and special-use forests[48] from unproductive agriculture areas
- Improvement of the quality and carbon stocks of poor natural forests
- Scale-up of agroforestry models to improve carbon stocks and conserve soil.

The LULUCF sector is a net sink and, as such, is expected to play a large role in meeting the overall NDC target. The 2050 National Climate Change Strategy sets the target of reducing emissions by 70% and increasing absorptions by 20%, achieving a sink capacity of 95 $MtCO_2eq$/year by 2030. This will build on the 2017 Law on Forestry that regulates the management of forests, and the National Action Programme for REDD+ (Reducing Emissions from Deforestation and Forest Degradation, Sustainable Management of Forest Resources, and Conservation and Enhancement of Forest Carbon Stocks).

The main measures in the waste sector that affect food systems include:

- Management and reduction of solid waste generation
- Development and application of solid waste recycling technologies
- Recovery, burning and use of methane from solid waste landfills.

The *Climate Action Tracker* (CAT)[49] considers these sectoral targets to be "critically insufficient" and estimates that Vietnam's updated NDC, despite its stronger targets, is aligned with more than 4°C of warming and do not instigate further climate action. CAT analysis suggests that while Vietnam's current policies and actions will overachieve the NDC targets (resulting in lower emission levels), emissions will continue to fall in the range of 600-700 $MtCO_2eq$/year (excluding LULUCF) in 2030.

5.3 Assessing the alignment between our recommended priority actions and national policies

As mentioned above, based on FAO data, the main sources of GHG emissions in Vietnam's food system are, by decreasing order of importance: rice cultivation (34% of total food system emissions), enteric fermentation (12%), manure management (11%), synthetic fertilizers (10%), food system waste disposal (8%), and household food consumption (8%).

This suggests the following priorities for action to reduce food system emissions in Vietnam: (i) reducing emissions from rice production; (ii) addressing emissions from enteric fermentation and manure management; (iii) reducing emissions from synthetic fertilizer production and use; and (iv) improving the data situation to understand and to pinpoint the focus areas and address emissions from household food consumption and FLW.

47 Through water recycling and reuse of wastewater as fertilizer in agriculture, such systems can significantly reduce carbon and water footprints (Le et al. 2022).

48 'Special-use forest' (SUF) is one of the three forest categories, along with 'protected forest' and 'production forest', created by the Vietnamese government to protect forest and increase forest cover in Vietnam. SUFs have been established to maintain ecosystems, conserve biodiversity, provide opportunities for scientific research, and protect cultural and historical sites for outdoor recreation ecotourism. The SUF system is broken into five categories to provide different levels of protection of ecosystems: national parks, nature reserves, species and habitat reserves, landscape protected areas and scientific forests (Kim Dung et al. 2017).

49 https://climateactiontracker.org/countries/vietnam/

Reducing emissions from rice will have to rely on various approaches for the management of efficiency of water, fertilizer and residue use such as: alternate wetting and drying (e.g. Vo et al. 2023), aerobic rice cultivation ('dry rice'), systems of rice intensification, improved fertilizer management (e.g. slow-dissolving fertilizers), breeding of more resilient, less methane-emitting rice varieties, improved management of nutrients, cover crops and residues, and approaches such as conversion of unproductive rice areas into non-rice cropland or integrated rice-shrimp farming. Much of this is already part of Vietnam's updated NDC (Socialist Republic of Viet Nam 2022). More training and extension services integrating and supporting these approaches are needed. By way of co-benefits, these strategies could reduce emissions while also improving agricultural production efficiency and farm income as well as reducing soil degradation and water pollution.

Beyond reducing meat consumption and, hence, the number of living animals, a basket of approaches can be used to reduce livestock emission intensity and thus contribute not only to reduce emissions from enteric fermentation and manure management but also to improve productivity. These approaches include: improving feed quality and animal health, optimizing animal nutrition as well as manure and livestock management practices. The use of dietary supplements, such as feed additives, methane inhibitors, enzymes, probiotics, and essential oils, can help reduce enteric methane emissions, and alternative feed sources, such as legumes, can reduce the amount of methane produced from manure management. Manure management mitigation strategies also include anaerobic digestion, and composting. Manure emits GHG, but its sustainable use can replace synthetic fertilizers (see next paragraph). Such strategies could reduce emissions while also improving soil health, providing clean and renewable energy, and reducing fertilizer costs.

Reducing emissions from synthetic fertilizer manufacturing and application requires: improving production processes and reducing the use of synthetic fertilizer use by optimizing application and by increasing instead the use of organic fertilizers and promoting composting. Actions may include reducing the use of energy, hazardous chemicals and the amount of waste generated during production, implementing closed-loop systems, or capturing carbon dioxide and using it in other processes.

Addressing FLW across food value chains, from production to consumption, will require foremost a better assessment of the situation with primary, disaggregated data collection to enable the identification of priority areas on which to focus efforts. Based on more accurate data, it will become possible to devise technical solutions to reduce the largest FLW hotspots. Food loss and waste mitigation strategies shall also include improved storage, preservation and processing; composting food waste; and using food waste for animal feed. These strategies could reduce emissions, save money for producers and consumers, and reduce food insecurity. Technological, institutional and organizational innovations can help improve energy and resource-use efficiency at all stages of the food production chain.

Reducing emissions from household food consumption requires significant changes in consumption patterns. Information and education campaigns, labels and certification schemes, taxes and economic incentives, more efficient logistic and cold chain at retail and consumption stages, are all strategies that can contribute to change individual and collective behaviours and support more sustainable consumption patterns.

Some of these priority actions are already addressed in national documents supporting the implementation of Vietnam's NDC. For instance, reducing methane emissions from rice production is set as an objective in the National Climate Change Strategy to 2050. To implement this strategy, the Ministry of Agriculture and Rural Development (MARD) is the lead coordinator of provincial governments to carry out investments into irrigation, to implement mitigation options including alternate wetting and drying, sustainable rice intensification, and mid-season drainage practices to reduce methane emissions in rice production. The MARD also leads the development and implementation of a plan to mitigate emissions from agricultural production which includes converting inefficient paddy rice into other models (such as rice/aquaculture and diversification with fruit trees).[50] The National Climate Change Strategy to 2050 also holds the MARD responsible for developing an action plan for reducing methane emissions relating to crop and livestock production. The MARD is further tasked to issue guidelines on cattle feeding to "create a sustainable and productive livestock industry while reducing methane emissions".

Adjustments and shifts in the composition of livestock, crops, forestry and aquaculture production to increase quality, added value and competitiveness for more sustainable agriculture, are key aspects addressed in the National Strategy on Green Growth for 2021–2030. Restructuring livestock production is also identified as one of the tasks and solutions to mitigate and adapt to climate change in the 'Scheme setting out tasks and solutions for implementations of outcomes of the COP26'.

Reducing emissions linked to synthetic fertilizer production and use is not mentioned in the Vietnamese national documents supporting implementation of climate actions. However, the 'Scheme on developing organic agriculture for 2020–2030' includes important targets to: develop organic fertilizers; increase their percentage in total fertilizer output to 15% in 2025 through research and development; and strictly manage the input materials used in organic production.

The objectives of the mentioned 'Scheme' also align with the objective to reduce FLW, since this document tasks the Ministry of Natural Resources and Environment (MNRE) to research and propose measures on the reuse of organic waste and by-products in production. This Scheme will further promote the construction of organic gardens associated with waste collection. Actions targeting the waste sector are mentioned in most of the national documents, including the 'National Strategy', the 'Scheme', and the National Action Plan on Sustainable Consumption and Production (2021–2030). However, these policies mostly concern the management and technologies to handle municipal solid waste, including for energy production. The 'National Action Plan' supports implementation of circular economy models for waste in the agriculture and fisheries sectors.

Enhancing carbon sinks has also been identified as a priority in Vietnam's updated NDC (Socialist Republic of Viet Nam 2022). To do so, Vietnam can reduce deforestation, increase forest restoration, and foster sustainable land management practices that reduce pressure on forestland. Rehabilitating and protecting areas of natural forests, including mangroves along the coast and in the Mekong Delta are essential in Vietnam.

50 The Scheme on Development of Organic Agriculture for 2020–2030 (2018) mentions rice production, setting a target of 100,000–150,000 ha under organic farming before 2030 (which is a very small target given that harvested rice area in Vietnam amounted to 7.22 Mha in 2020).

6 Conclusions

This country profile aims to provide a first synthesis overview of Vietnam's land use, agriculture, FLW, diets and related GHG emissions, identifying perspectives on how to reduce these emissions. This analysis is based primarily on publicly available data such as those from FAOSTAT, with one purpose being to allow comparative analysis across four countries analysed in this study; besides Vietnam, similar analysis is available for Colombia, China and Kenya (Martius et al. 2023a, 2023b; Song et al. 2023), and we will develop comparative analysis across these four countries.

Based on the present analysis, Vietnam's food system emissions increased in absolute levels over the past decade (from 96 to 104 $MtCO_2eq$/year between 2010 and 2020), while their share in national emissions decreased (from 34% to 26%). The largest emission sources in the food system are, by decreasing order of importance, rice cultivation (34% of total food system emissions), enteric fermentation (12%), manure management (11%), synthetic fertilizers (10%), food system waste disposal (8%), and household food consumption (8%). Altogether, these six activities emitted 86.1 $MtCO_2eq$ in 2020 and accounted for 83% of all food system emissions.

Therefore, the priorities for action emerging in perspective are to reduce emissions from rice production, enteric fermentation and manure management, synthetic fertilizer production and use, and from household food consumption and FLW. These priority actions are quite well aligned with national priorities. They focus on reducing food system emissions while also supporting food security and nutrition, health and economic development. Our holistic food system perspective allowed us to identify some no-regret, promising but so-far neglected emission reduction pathways, such as reducing food loss waste fostering more sustainable consumption patterns.

Effective climate action planning should not only consider the size of sectoral emissions, but also the cost and feasibility (referred to as 'political economy') of implementing transformative measures. New light has been shed on GHG emissions related to food waste, household consumption and food transport – these are not the largest by size, but these sectors may provide accessible, viable, cost-efficient and effective emissions reduction pathways across food supply chains.

Avoiding and reducing emissions will require effective policy formulation, financial incentives, education and capacity building, technical and organizational innovations, and strong governance mechanisms involving multiple actors, sectors and scales. Vietnam already supports research and development of new technologies and practices to reduce emissions from all sub-sectors of the food system, and can collaborate with the Mitigate+ program to strengthen emission reduction in food systems.

These perspectives will need to be further analysed in light of available national data, by collecting additional primary data to identify priority areas for interventions, and putting them in the context of national efforts and plans. Such analysis will also need to better integrate forestry, the balance of emission sources and sinks, as well as to assess more accurately the amount of emissions from fisheries and aquaculture.

To explore these perspectives further, a thorough, comprehensive analysis is needed that scrutinizes them in the context of existing national data, in collaboration with national experts. This process will involve not only gathering supplementary data to pinpoint crucial areas necessitating interventions but also aligning these findings with national plans, needs and interests. Careful analysis along those lines will help national government and non-government actors shaping national strategies and plans, to ensure that food systems are efficient in producing sufficient and sufficiently nutritious food, and effective in reducing GHG emissions and stem the degradation of soil, water and biodiversity, the basic resources that must be maintained for a sustainable food production.

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Annex 1. FAOSTAT food system emissions: Definitions and boundaries

In FAOSTAT, food system emissions are disaggregated, as follows, in three main categories and 24 items. FAOSTAT food system emission data series have last been updated on 22 May 2023. New items have been introduced and some methodologies have been refined. In this report we are keeping data that have been extracted before that date. Extraction dates are given in all tables and citations.

1. **Land use change emissions**
    - *Fires in humid tropical forests.*
    - *Fires in organic soils.*
    - *Net forest conversion:* Net contribution of CO_2 sources and sinks due to deforestation, reforestation and afforestation activities within countries.

2. **Farm gate emissions**
    - *Burning – crop residues:* CH_4 and N_2O emissions resulting from the on-site combustion of a percentage of crop residues.
    - *Crop residues:* N_2O emissions resulting from the decomposition of crop residues returned to managed soils.
    - *Drained organic soils:* CO_2 and N_2O emissions.
    - *Enteric fermentation:* CH_4 emissions resulting from enteric fermentation, which is a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream of an animal.
    - *Manure applied to soils:* N_2O emissions from manure added to managed soils to enrich them.
    - *Manure left on pasture:* N_2O emissions from manure left on pasture by grazing livestock.
    - *Manure management:* N_2O and CH_4 emissions resulting from aerobic and anaerobic manure decomposition processes occurring during capture, storage, treatment, and utilization of animal manure.
    - *On-farm energy use.*
    - *Rice cultivation:* CH_4 emissions resulting from the anaerobic decomposition of organic matter in paddy fields.
    - *Savanna fires.*
    - *Synthetic fertilizers:* N_2O emissions resulting from synthetic fertilizers application to managed soils.

3. **Pre- and post-production emissions (beyond farm gate)**
    - *Fertilizers manufacturing:* CO_2 and N_2O emissions from energy use in fertilizer manufacturing. This item covers the main fertilizers products accounting for 85 of global fertilizer production quantity. Emissions from the extraction, transfer and supply of natural gas as input into the manufacturing (Haber-Bosch) process are not considered.
    - *Food household consumption:* CO_2, CH_4 and N_2O emissions resulting from energy consumption (electricity, fossil fuels, and non-renewable woodfuel consumption) in households (including small businesses and restaurants), for example for cooking, kitchen appliances and refrigeration. It is unclear whether this item includes emissions from four F-gases associated with domestic refrigeration.
    - *Food packaging:* CO_2, CH_4 and N_2O emissions resulting from energy consumption for the industrial production of glass, plastic aluminium, tin, pulp and paper products then used in food packaging. Energy used in facilities where food is packaged is not considered.

- *Food processing:* CO_2, CH_4 and N_2O emissions resulting from energy consumption in food processing (on-site combustion of fossil fuels and off-site electricity generation). It is unclear whether this item includes emissions from four F-gases associated with industrial refrigeration.
- *Food retail:* CO_2, CH_4 and N_2O generated by energy consumption in food retail facilities, such as for refrigeration and lighting. It is unclear whether this item also includes emissions from four F-gases associated with commercial refrigeration.
- *Agrifood systems waste disposal:* CO_2, CH_4 and N_2O emissions resulting from four categories of food systems waste disposal: (1) solid food waste disposed in landfills; (2) domestic wastewater; (3) industrial wastewater (generated by the production of food, nitrogen fertilizers and pulp production for paper products used in food systems); and (4) incineration of plastic and rubber materials used in food systems. Note that this excludes GHG emissions associated with the production, processing, or distribution of food products that are finally lost or wasted.
- *Food transport:* CO_2, CH_4 and N_2O emissions resulting from the combustion and evaporation of fuel for all domestic food transport (including domestic aviation, road transportation, railways, domestic water-borne navigation, and other transportation). This item excludes international transport (accounting for an estimated 2.5% of global food transport emissions). It is unclear whether this item includes emissions from four F-gases associated with food transport refrigeration.
- *On-farm electricity use.*
- *On-farm heat use.*
- *Pesticides manufacturing:* CO_2, CH_4 and N_2O emissions resulting from energy consumption during the energy-intensive processes of pesticide manufacturing.

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The global food system is responsible for 23 – 42% of total net anthropogenic emissions. This share is expected to increase in the future, driven by population and economic growth and changes in lifestyle, as other economic sectors are progressively decarbonized. Without rapid and radical transformations in food systems, the Paris Agreement targets will remain out of reach. The Initiative on Low-Emissions Food Systems (Mitigate+) aims to offer a comprehensive and evidence-based overview of national land use, agricultural production, diets and food system emissions in selected partner countries (China, Colombia, Kenya and Vietnam) and explore possible pathways that reduce emissions while enhancing food security, nutrition, livelihoods and preserving the environment in these countries. This document focuses on Vietnam.

Viet Nam's food system emissions increased in absolute level over the past decade (2010-2020) while their share in national emissions decreased. However, the food system emissions in 2020 still represent more than a quarter of total national emissions. The largest emission sources in Vietnam's food system are, by decreasing order of importance, rice cultivation (34% of total food system emissions), enteric fermentation (12%), manure (11%), synthetic fertilizers (10%), food system waste disposal (8%), and household food consumption (8%). Altogether, these six activities emitted 86.1 $MtCO_2eq$ in 2020 and accounted for 83% of all food system emissions.

This document thus highlights six priorities for action, well aligned with national priorities: (i) reducing emissions from rice production; (ii) addressing emissions from enteric fermentation and manure management; (iii) reducing emissions from synthetic fertilizer production and use; and (iv) improving the data situation to understand and to pinpoint the focus areas and address emissions from household food consumption and food loss and waste.

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