CARBON TRANSITION INITIATIVE

Emerging Markets Investors Alliance

INDUSTRY BRIEF

AGRICULTURE AND FOOD SECTOR

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Executive Summary

Agri-food systems encompass interlinked activities including farming, harvesting, fishing, livestock-rearing, storing, processing, selling, buying, eating and disposing of food as well as non-food products that come from agriculture. The Food and Agriculture Organization (FAO) estimates that agri-food systems generated 21% of carbon dioxide emissions, 53% of methane emissions, and 78% of nitrous oxide emissions globally in 2019.**[1]** Four of the top five countries with the largest emissions from agri-food systems in 2019 were in emerging markets.

Farm-gate emissions (from crop and livestock activities) are the largest component of total agri-food emissions globally. Livestock activities accounted for two-thirds of farm-gate emissions in 2018, according to the FAO. Specifically, enteric fermentation and livestock manure were the main contributors, accounting for 39% and 20%, respectively, of total non-CO2 emissions from agriculture in 2018.**[2]**

There are a number of avenues to reduce the GHG emissions from agri-food systems. Waste reduction along the entire supply chain and including households can be an important driver of emissions reduction. Scientists have been working on innovative ways to reduce the enteric gas that comes from cow burps. By reducing production of meat and switching to plant-based and other alternative sources of protein, we can not only reduce the industry's Scope 1 emissions, but we can stop and reverse deforestation, using the newly available land for nature-based carbon removal and storage. One of the most obvious and frequently mentioned directions for sustainable agriculture is a shift to regenerative farming. Shifting to suppliers of renewable energy or developing on-site solar and wind generation is likely to both reduce GHG emissions and cut costs. Similarly, replacing fossil-fuel driven equipment with electricity-powered machinery is becoming more widely used in agriculture and other links of the food production value chain.

[1] The share of agri-food systems in total greenhouse gas emissions Global, regional and country trends 1990–2019 (https://www.fao.org/3/cb7514en/cb7514en.pdf)

[2] FAOSTAT ANALYTICAL BRIEF 18 Emissions due to agriculture Global, regional and country trends 2000–2018 (https://www.fao.org/3/cb3808en/cb3808en.pdf)

Investors should be mindful of the risks relevant to the agriculture industry even if they do not directly invest in farms. Owing to increasing attention to Scope 1, 2, and 3 GHG emissions, the entire supply chain should be in focus. According to Mighty Earth, the following list includes best practices that should be followed by companies working in the agriculture industry:

- Forest and natural habitats
- Regenerative farming
- Human rights
- Transparency and traceability
- Monitoring

By reducing production of meat and switching to plant-based and other alternative sources of protein, we can not only reduce the industry's Scope 1 emissions, but we can stop and reverse deforestation, using the newly available land for nature-based carbon removal and storage.

Introduction

Food production, and agriculture in particular, is a major source of GHG emissions. These emissions come from enteric fermentation of cattle, increasing use of land for grazing and growing feed for animal-sourced protein production, manure and chemical fertilizers, and other processes. Given the expected continuing growth of population, especially in developing countries, the need for more food is bound to increase, leading to additional strains on the industry. If the current trends continue, based on the currently utilized technologies and processes, limiting global warming to 1.5°C will be unattainable. At the same time, the warming itself has negative consequences for agriculture, where harvests are already impacted by droughts, floods, heat waves, deteriorating biodiversity, and other factors linked to climate change.

As a result of this position of the industry and its role, both mitigation and adaptation measures are critical. At the moment, the former are in focus, and we describe a number of approaches that aim to reduce emissions of methane and other GHGs. Different links in the food supply chain generated varying amounts of these gasses; therefore, some areas (such as meat and dairy production and deforestation) need utmost attention and can be the points of the most significant reduction of the emissions. We also highlight several challenges and opportunities that investors in the agriculture and food production companies are facing.

Key terms

Denitrification is the processing of nitrates by bacteria which releases N2O, a GHG, into the atmosphere.

Enteric fermentation is microbial fermentation that occurs in the digestive system of an animal (e.g., cattle, buffalo, sheep, goats, and camels), breaking down food into soluble products that can be utilized by the animal. Methane (CH4) is produced as a by-product of the fermentation and is exhaled or belched by the animal into the atmosphere.

Regenerative agriculture is an approach to farming that emphasizes health and restoration of soil and the surrounding ecosystem, as opposed to a focus on intensive industrial production.

Ruminants are a group of animals that digests the feed by first softening it in a first stomach called “rumen” and then regurgitating the resulting “cud” for additional chewing.

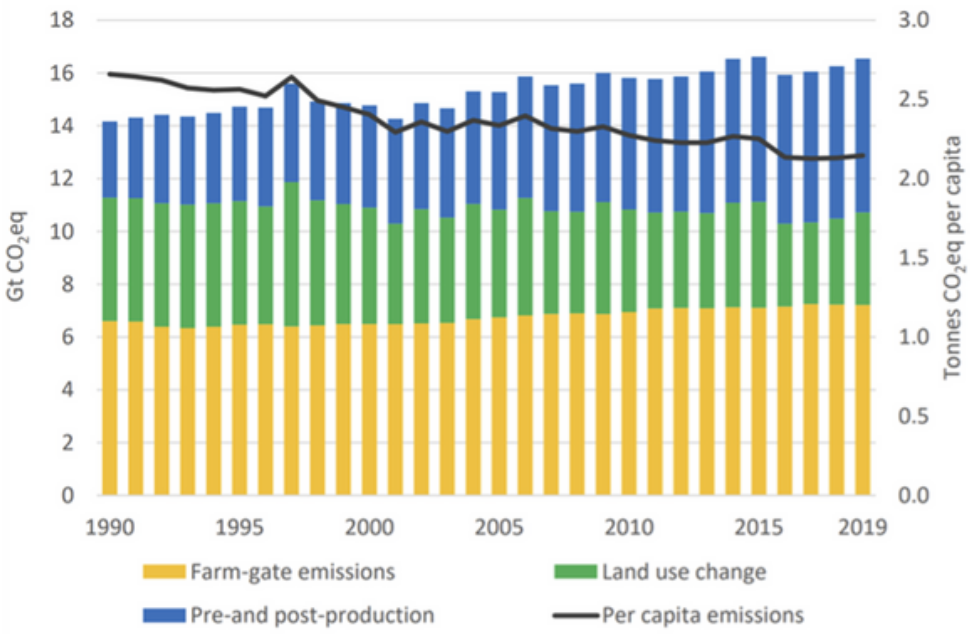
The Role of Food Supply Chain and its Elements in Global GHG Emissions

Agri-food systems encompass interlinked activities including farming, harvesting, fishing, livestock-rearing, storing, processing, selling, buying, eating and disposing of food as well as non-food products that come from agriculture, according to the Food and Agriculture Organization (FAO) of the United Nations. The agency noted that agri-food systems have a sizeable carbon footprint, contributing a significant amount to global greenhouse gas (GHG) emissions [i.e. 17 billion tonnes of carbon dioxide equivalent (CO2e) or 31% of total global anthropogenic emissions of 54 billion tonnes of CO2e in 2019].**[3]** Although the percentage of total emissions has decreased over time (e.g., down from 40% in 1990), the absolute amount of agri-food systems emissions has increased globally by 16% between 1990 and 2019. The agency also noted that agri-food systems generated 21% of carbon dioxide emissions, 53% of methane emissions, and 78% of nitrous oxide emissions globally in 2019.

Regarding specific components or sources of emissions from agri-food systems, farm-gate emissions is the largest component globally (i.e. 7.2 billion tonnes CO2e or 44% in 2019), followed by pre- and post-production processes (i.e. 5.8 billion tonnes CO2e or 35%) and then land use change (i.e. 3.5 billion tonnes CO2e or 21%). Notably, there is significant regional variability behind these average numbers.

[3] The share of agri-food systems in total greenhouse gas emissions Global, regional and country trends 1990–2019 (https://www.fao.org/3/cb7514en/cb7514en.pdf)

Fig. 1: Global agri-food system GHG emissions by life-cycle stage, and per capita emissions



Source: The share of agri-food systems in total greenhouse gas emissions Global, regional and country trends 1990–2019, Tubiello et al., 2021.

Farm-gate emissions are generated from crop and livestock production within the farm. Land use change emissions include carbon losses from land conversion processes for new cultivations (e.g., tropical deforestation and peatland degradation). Emissions from pre- and post-production processes include those related to transport, processing and input manufacturing, as well as from household consumption and waste. In Figure 2 (next page), the Food and Agriculture Organization of the United Nations (FAO) outlines which GHG emissions are produced by these three broad categories within the agri-food system and specific examples of activities in each category.

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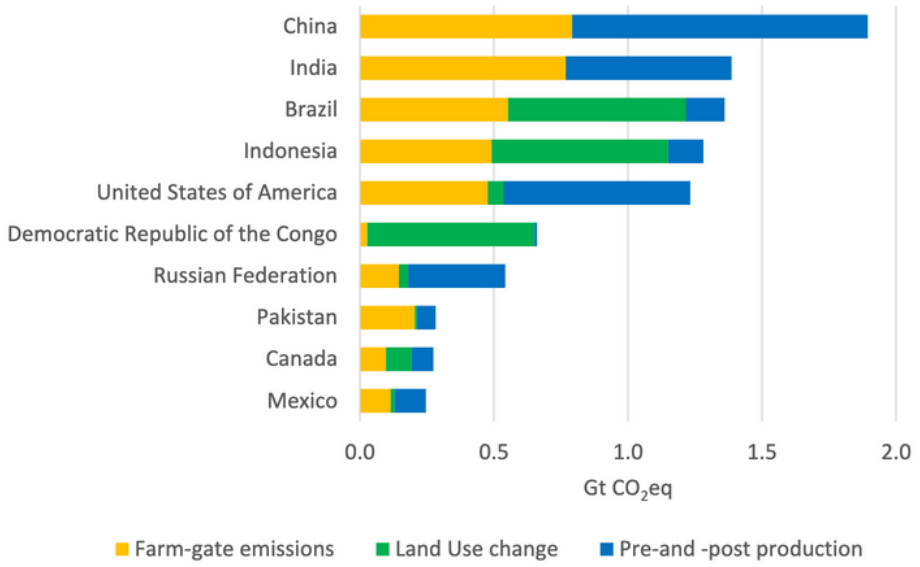
Fig. 2: Types of GHG emissions generated by Agri-food systems activities

Agri-food systems activity	GHG			FAO		
	CH_4	N_2O	CO_2			
Net forest conversion	x	x	x	LAND USE CHANGE	AGRICULTURAL LAND	AGRI-FOOD SYSTEMS
Tropical forest fires	x	x	x			
Peat fires	x		x			
Drained organic soils	x		x	FARM GATE		
Burning – Crop residues	x	x				
Burning – Savanna	x	x				
Crop residues		x				
Drained organic soils		x				
Enteric fermentation	x					
Manure management	x	x				
Manure applied to soils		x				
Manure left on pasture		x				
Rice cultivation	x					
Synthetic fertilizers		x				
On-farm energy use	x	x	x			
Fertilizer manufacturing	x	x	x	PRE- AND POST-PRODUCTION		
Processing	x	x	x			
Packaging	x	x	x			
Transport	x	x	x			
Household consumption	x	x	x			
Retail – Energy use	x	x	x			
Retail – Refrigeration	x	x	x			
Solid food waste	x					
Incineration			x			
Industrial wastewater	x	x				
Domestic wastewater	x	x				

Notes: IPCC (Intergovernmental Panel on Climate Change) LULUCF (land use, land use change and forestry)
Source: The share of agri-food systems in total greenhouse gas emissions Global, regional and country trends 1990–2019, Tubiello et al., 2021.

The FAO noted that four of the top five countries with the largest emissions from agri-food systems in 2019 were in emerging markets (i.e., China, India, Brazil, Indonesia) along with the United States. The main sources of agri-food systems emissions vary by country. Specifically, supply chain (pre- and post-production) was the main driver for the United States, China, and India in 2019 while land use change was the largest component in Brazil and Indonesia, according to the FAO.

Fig. 3: Agri-food systems emissions, top countries (2019)



Source: The share of agri-food systems in total greenhouse gas emissions Global, regional and country trends 1990–2019, Tubiello et al., 2021.

The FAO noted that four of the top five countries with the largest emissions from agri-food systems in 2019 were in emerging markets (i.e., China, India, Brazil, Indonesia) along with the United States.

Specific Sources of GHG Emissions Along the Food Supply Chain

As previously mentioned, farm-gate emissions (from crop and livestock activities) are the largest component of total agri-food emissions globally. Livestock activities accounted for two-thirds of farm-gate emissions in 2018, according to the FAO. Specifically, enteric fermentation and livestock manure were the main contributors, accounting for 39% and 20%, respectively, of total non-CO2 emissions from agriculture in 2018.**[4]**

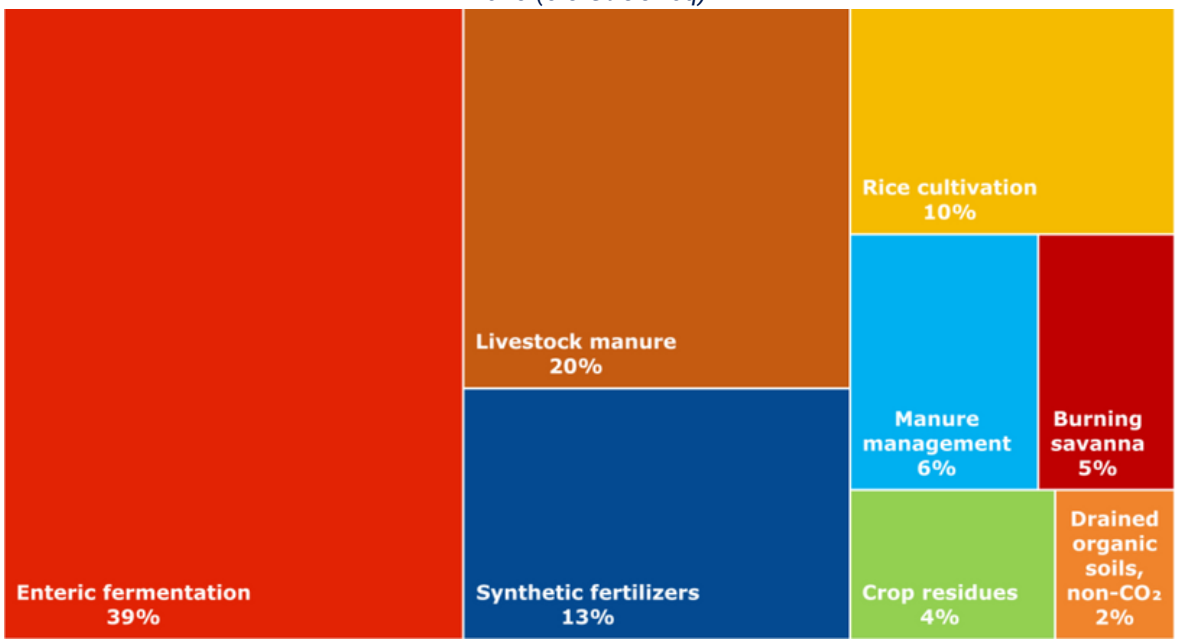
Enteric fermentation is microbial fermentation that occurs in the digestive system of an animal (e.g., cattle, buffalo, sheep, goats, and camels), breaking down food into soluble products that can be utilized by the animal. Methane (CH4) is produced as a by-product of the fermentation and is exhaled or belched by the animal into the atmosphere.

As reported in the same FAO report, "N2O emissions from livestock manure left on pastures by grazing animals and applications of manure to cropland contributed an additional 1 Gt CO2eq in 2018." The increase in livestock was the primary driver for the increase in the emissions from manure and from enteric fermentation (i.e. 20% and 13% in 2018 compared to 2000, respectively), according to the FAO.

Nitrogen pollution also comes from synthetic fertilizers such as artificial nitrogen. Production of the latter is a very energy intensive process. Furthermore, not all of the artificial nitrogen is incorporated into the biomass, with the remaining GHG being released into water or air in the form of N2O.

[4] FAOSTAT ANALYTICAL BRIEF 18 Emissions due to agriculture Global, regional and country trends 2000–2018 (https://www.fao.org/3/cb3808en/cb3808en.pdf)

Fig. 4: Contributions of crops and livestock activities to total non-CO2 emissions from agriculture in 2018 (5.3 Gt CO2eq)



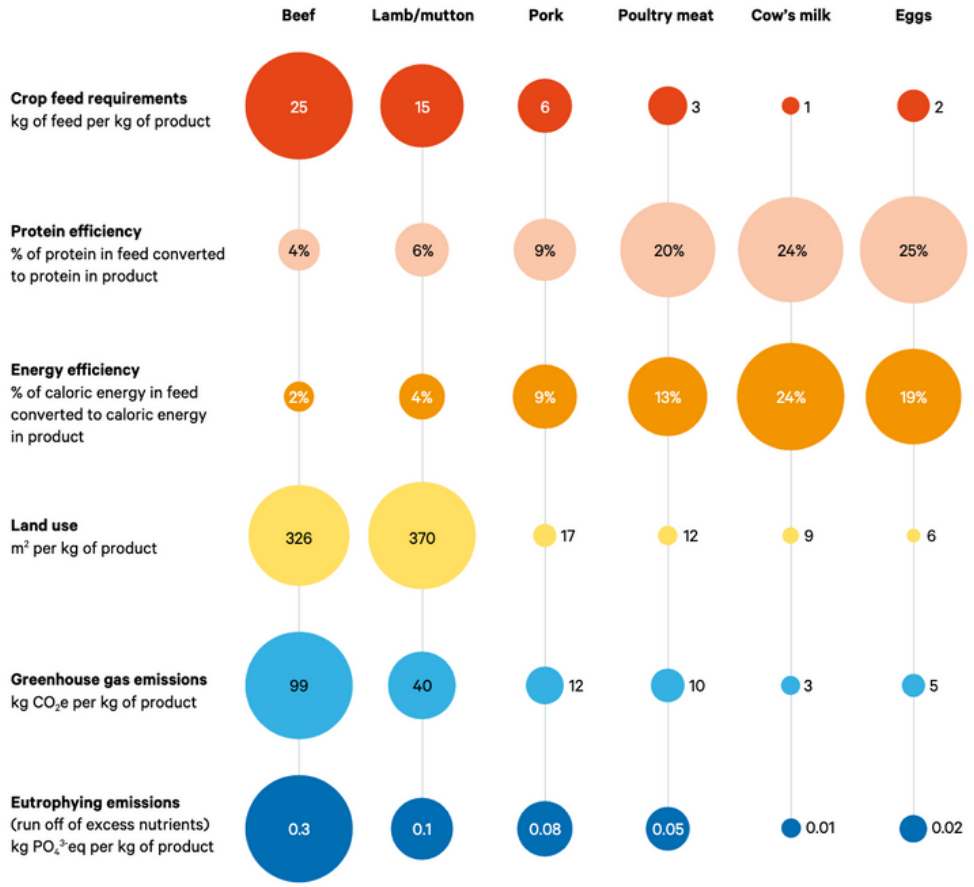
Source: FAOSTAT ANALYTICAL BRIEF 18 Emissions due to agriculture Global, regional and country trends 2000–2018.

...enteric fermentation and livestock manure were the main contributors, accounting for 39% and 20%, respectively, of total non-CO2 emissions from agriculture in 2018.

Meat and Dairy Production

Meat and dairy production have the highest environmental cost per unit of output (be it calories or proteins). For example, according to Mighty Earth,**[5]** 77% of all agricultural land globally is used for livestock, yet it generates only 18% of total consumed calories and 37% of protein. Furthermore, there are significant differences in the environmental cost among the various segments of this industry, i.e. animals differ in their conversion of feed energy intake into methane, as shown in the following figure.

Fig 5. Relative efficiencies and environmental impacts of animal-sourced foods ***[6]***



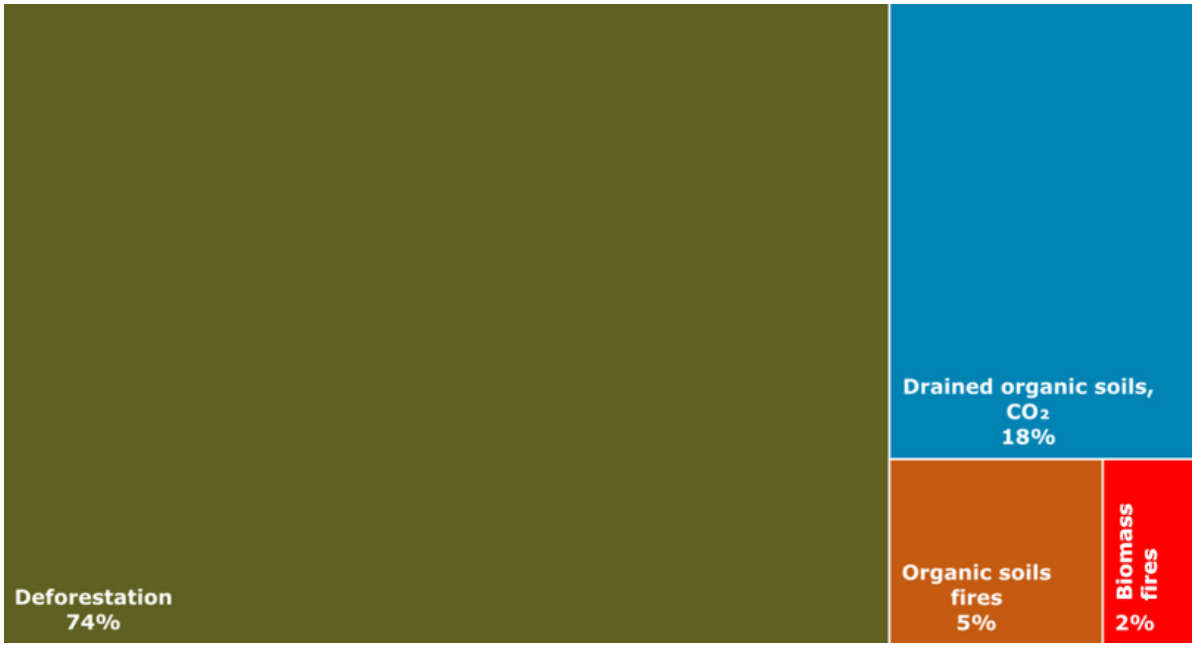
Source: Compiled by the authors from Alexander, P. et al. (2016), 'Human appropriation of land for food: The role of diet', *Global Environmental Change*, 41, pp. 88–98, http://www.sciencedirect.com/science/article/pii/S0959378016302370?via%3Dihub#bib0330; Poore and Nemecek (2018), 'Reducing food's environmental impacts through producers and consumers'.

[5] Data used by Mighty Earth in their presentation had been sourced from www.OurWorldinData.org.
[6] Chatham House, "Aligning food systems with climate and biodiversity targets" (https://www.chathamhouse.org/sites/default/files/2022-10/2022-10-14-food-systems-climate-biodiv)

Land Use and Deforestation

Agricultural land use and land use change are also meaningful contributors to total agri-food emissions globally. These emissions were nearly 4 Gt CO2 eq in 2018, according to the FAO. Deforestation (74%), drainage and burning of organic soils (18% and 5%, respectively, in 2018) were the contributing activities.

Fig. 6: Contribution of activities to total agricultural land use and land use change emissions in 2018 (3.9 Gt CO2eq)



Source: FAOSTAT ANALYTICAL BRIEF 18 Emissions due to agriculture Global, regional and country trends 2000–2018.

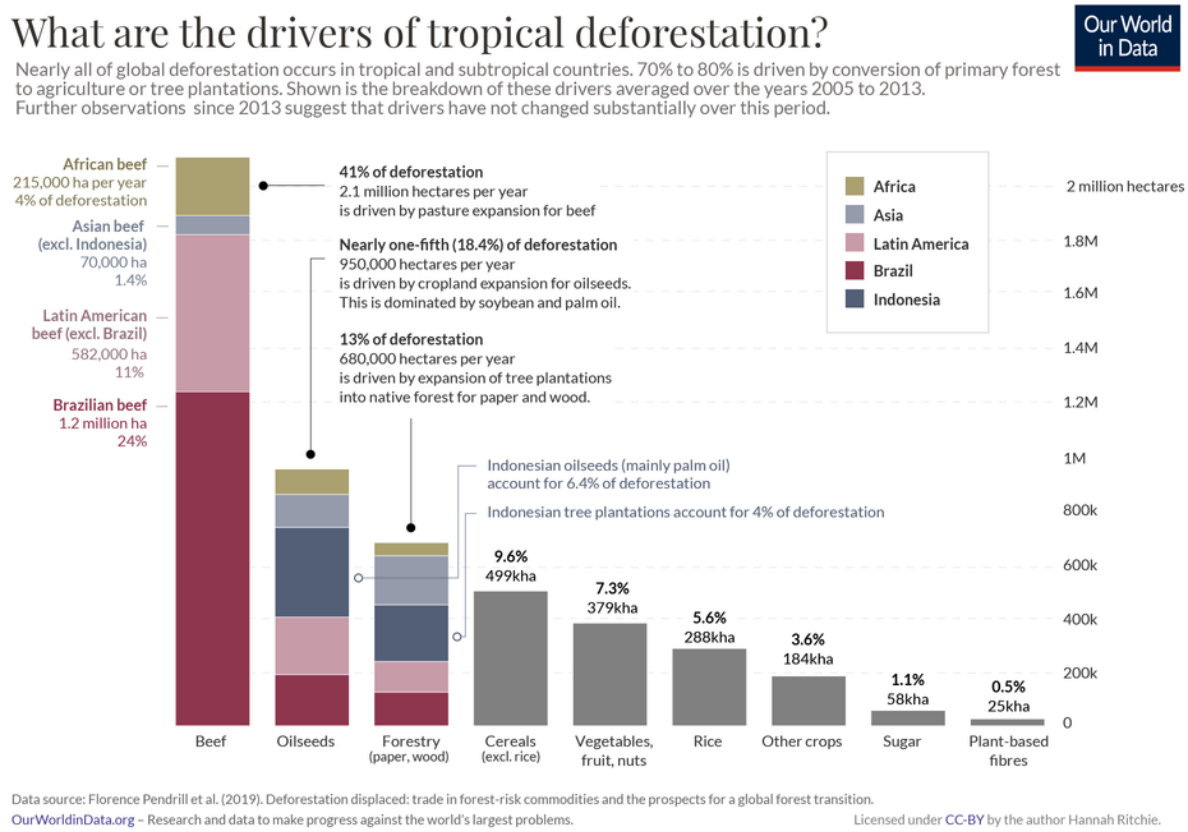
Agriculture-related deforestation is the purposeful clearing of forest land for agricultural expansion (e.g., space for crops, animal grazing, produce products). As trees and plants grow, they absorb carbon dioxide from the atmosphere and convert it into carbon and store it in their branches, leaves, trunks, roots and in the soil. Deforestation results in GHG emissions: carbon (mainly in the form of carbon dioxide) is released into the atmosphere when forests are cleared or burnt.

When ranking countries in terms of total emissions due to agriculture land use, Indonesia, Brazil, and Democratic Republic of the Congo were the top three emitters in 2018, according to the FAO. Our World in Data noted that the world lost 5.4 million hectares to deforestation in 2019, with Brazil and Indonesia accounting for 52% [one-third (1.8 million hectares) came from Brazil, and 19% (1 million hectares) from Indonesia].**[7]** The organization cited "the expansion of pasture for beef production, croplands for soy and palm oil, and increasingly conversion of primary forest to tree plantations for paper and pulp have been the key drivers of this."

[7] https://ourworldindata.org/drivers-of-deforestation

Historically, palm oil plantation was the largest driver of deforestation in Indonesia. **[8]** Deforestation in Brazil, which is home to the Amazon rainforest, reached a record high in 2022, according to the Council on Foreign Relations.**[9]** The agency noted that 17-20% of the Amazon has been destroyed over the past fifty years. As the largest exporter of beef and soy, land has been cleared primarily for cattle ranching and soy production.

Fig. 7. Drivers of tropical deforestation



Source: https://ourworldindata.org/drivers-of-deforestation.

[8] https://iopscience.iop.org/article/10.1088/1748-9326/aaf6db
[9] https://www.cfr.org/in-brief/deforestation-brazils-amazon-has-reached-record-high-whats-being-done

Available Solutions to Reduce Emissions in Agriculture and Food Production

Waste reduction along the entire supply chain and including households can be an important driver of emissions reduction. According to McKinsey,**[10]** one-third of all produced food is wasted before being consumed. By wasting less and helping their consumers do the same, the industry can cut costs and produce less, reducing land change requirements and lowering GHG emissions from all stages of food production. Investors can play a vital role by focussing the attention of investee companies' management to the problem of waste.

Production of animal-sourced food is the largest source of GHG emissions along the food supply chain, with the beef and dairy industry being the main contributor. One of the components of this contribution is enteric methane that comes from the cows' digestive process. The amount of methane that is generated depends on a number of parameters such as the physical and chemical characteristics of the feed, genetic factors, and a few other variables.**[11]** Scientists have been working on **innovative ways to reduce the enteric gas** that comes from cow burps. Studies have shown that addition of red algae and other supplements to their food can cut the outcoming methane by 80%. Other researchers have come up with ways to reduce methane emissions from manure. For example, anaerobic methane digesters can generate energy out of manure or extract such valuable elements as nitrogen, potash, or phosphorus which can then be used as fertilizers.**[12]**

Animal-sourced food production takes up massive amounts of land for grazing and other purposes. As the industry keeps growing, its increasing requirements for land are a leading cause of deforestation. By reducing production of meat and **switching to plant-based and other alternative sources of protein**, we can not only reduce the industry's Scope 1 emissions, but we can also stop and reverse deforestation, using the newly available land for nature-based carbon removal and storage. The human body can obtain protein from many sources, many of which have lower negative climate impact than red meat. Various methods to produce plant-based, fungi- and insect-derived, and cultivated proteins have been developed to a stage where they are widely offered to consumers at accessible prices.

[10] Feeding the world sustainably, McKinsey. (https://www.mckinsey.com/capabilities/sustainability/our-insig)
[11] https://www3.epa.gov/ttnchie1/ap42/ch14/final/c14s04.pdf
[12] Where's the beef? How food firms are innovating to cut methane emissions (https://www.reuters.com/business/sustainable-business/wheres-beef-how-food-firms-are-innovating-cut-methane-emissions-2022-11-02/?utm_campaign=ETH%2004NOV22%20Newsletter%20Database&utm_medium=email&utm_source=Eloqua)

Production of plant-based food by currently widely used technologies also contributes to carbon emissions. One of the most obvious and frequently mentioned directions for sustainable agriculture is a shift to regenerative farming. It will not only help to store carbon, but also provide benefits for biodiversity and water management, and help to restore soil organic matter.**[13]** According to Mighty Earth, the following list contains the most important priorities in regenerative farming:

- Protect and restore native habitat.
- Keep soil covered and minimize its disturbance.
- Shift to agroforestry**[14]** whenever possible.
- Plant cover crops.**[15]**
- Implement conservation tillage.**[16]**
- Precision fertilizer application (4R Method – Right source, Right rate, Right time, Right place).
- Crop diversification to include small grains (including wheat, barley, oats, buckwheat, flax, rye and other cereals that complete their life cycle in less than a year).

Opportunities to reduce Scope 2 emissions are already widely available and economically feasible. Shifting to suppliers of **renewable energy** or developing on-site solar and wind generation is likely to both reduce GHG emissions and cut costs.

Similarly, replacing fossil-fuel driven equipment by **electricity-powered machinery** is becoming more widely used in agriculture and other links of the food production value chain.

For investors who want to learn more about different ways to reduce GHG emissions in agriculture, we recommend the Reducing agriculture emissions through improved farming practices report by McKinsey.

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[14] "Agroforestry is the growing of both trees and agricultural / horticultural crops on the same piece of land. They are designed to provide tree and other crop products and at the same time protect, conserve, diversify and sustain vital economic, environmental, human and natural resources. Agroforestry differs from traditional forestry and agriculture by its focus on the interactions amongst components rather than just on the individual components themselves." – Agroforestry Research Trust (https://www.agroforestry.co.uk/about-agroforestry/)
[15] "A cover crop is a non-cash crop grown primarily for the purpose of 'protecting or improving' between periods of regular crop production." – Agriculture and Horticulture Development Board (https://ahdb.org.uk/cover-crops)
[16] "Conservation tillage is any method of soil cultivation that leaves the previous year's crop residue (such as corn stalks or wheat stubble) on fields before and after planting the next crop to reduce soil erosion and runoff, as well as other benefits such as carbon sequestration." – UN Climate Technology Centre & Network (https://www.ctc-n.org/technologies/conservation-tillage)

Investors: Challenges and Opportunities

Investors should be mindful of the risks relevant to the agriculture industry even if they do not directly invest in farms. Owing to increasing attention to Scope 1, 2, and 3 GHG emissions, the entire supply chain should be in focus. For example, even though public Brazilian meatpacking companies may not be directly involved in cow grazing, deforestation carried out by their suppliers is a cause for grave concern, and it is unlikely to be hidden for long. Similarly, banks that finance projects causing deforestation will feel pressure from various stakeholders, and investors should engage with them to avoid such harmful practices.

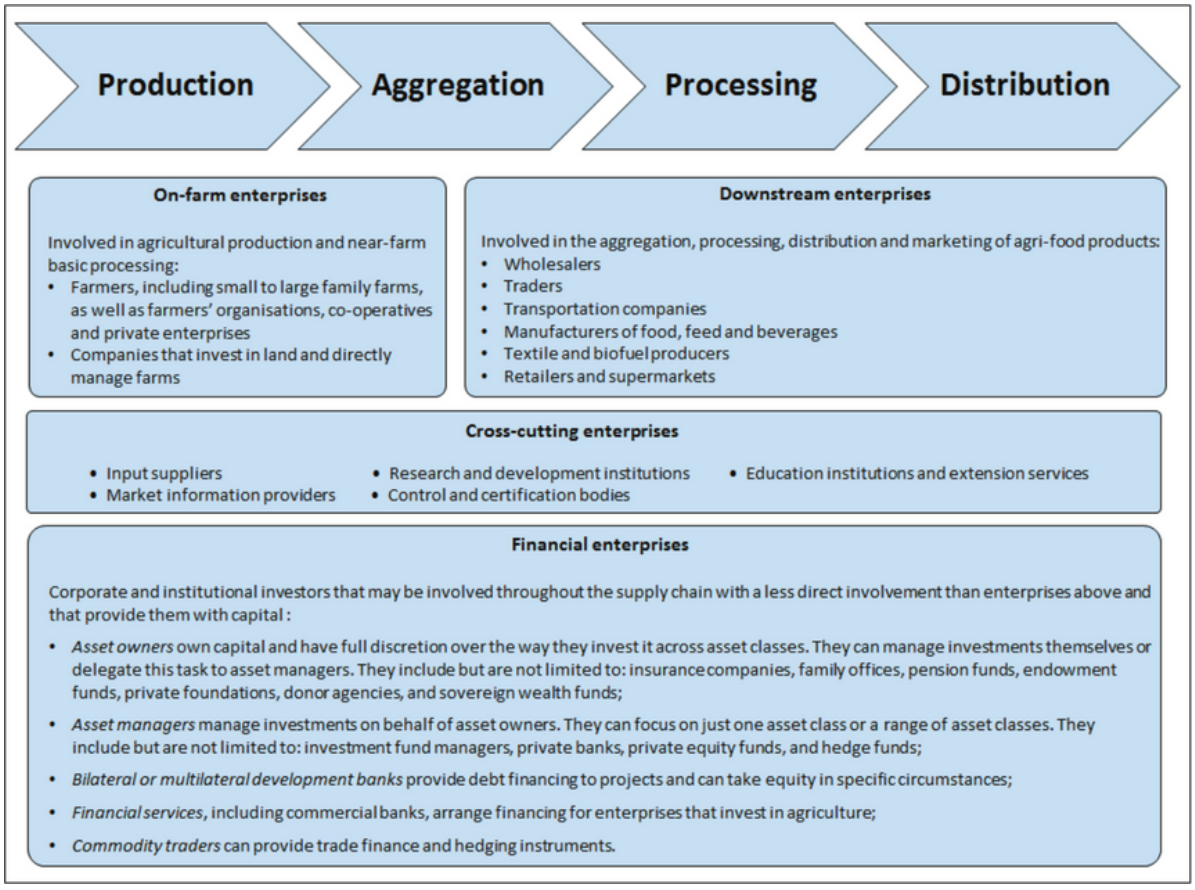
Agricultural Supply Chains

The Organisation for Economic Co-operation and Development (OECD) and Food and Agricultural Organization (FAO) of the United Nations published the "OECD FAO Guidance
for Responsible Agricultural Supply Chains." The report provides "guidance to help enterprises observe standards of responsible business conduct and undertake due diligence along agricultural supply chains in order to ensure that their operations contribute to sustainable development."**[17]**

As published in the report, "agricultural supply chains refer to the system encompassing all the activities, organisations, actors, technology, information, resources and services involved in producing agri-food products for consumer markets. They cover agricultural upstream and downstream sectors from the supply of agricultural inputs (such as seeds, fertilisers, feeds, medicines, or equipment) to production, post-harvest handling, processing, transportation, marketing, distribution, and retailing. They also include support services such as extension services, research and development, and market information."

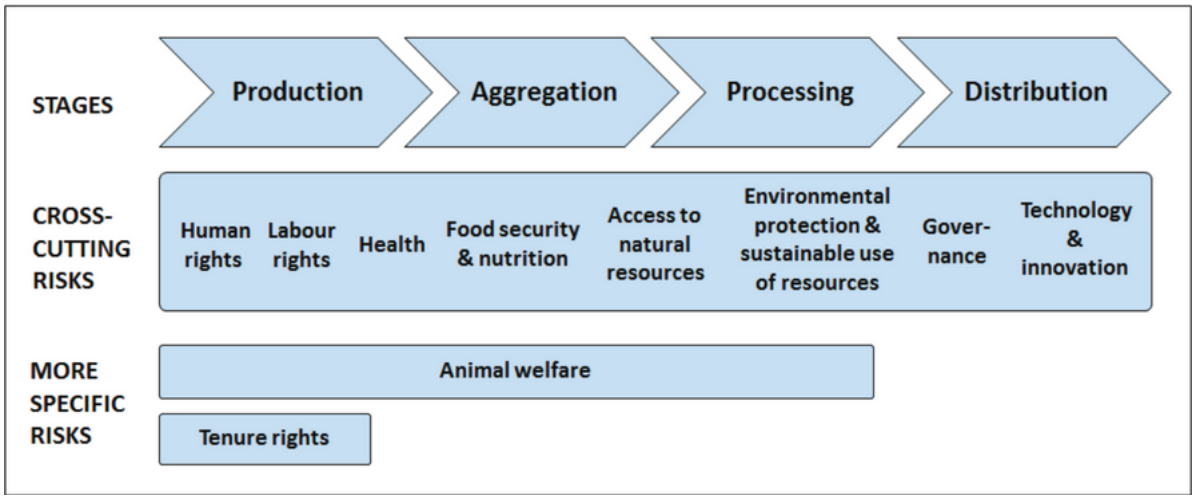
[17] https://www.oecd-ilibrary.org/docserver/9789264251052-en.pdf?expires=1674595926&id=id&accname=guest&checksum=51969D30BB4ED7789CD57032B72017F2

Fig. 8. Various stages of agricultural supply chains and enterprises involved



Source: https://www.oecd-ilibrary.org/docserver/9789264251052-en.pdf?expires=1674595926&id=id&accname=guest&checksum=51969D30BB4ED7789CD57032B72017F2

Fig. 9. Risks at various stages of agricultural supply chains



Source: https://www.oecd-ilibrary.org/docserver/9789264251052-en.pdf?expires=1674595926&id=id&accname=guest&checksum=51969D30BB4ED7789CD57032B72017F2

The guide includes the following Five-Step Framework for Due Diligence to address risks tied to agricultural supply chains:**[18]**

- *Step 1:* Establish strong enterprise management systems for responsible supply chains
- *Step 2:* Identify, assess and prioritize risks in the supply chain
- *Step 3:* Design and implement a strategy to respond to identified risks in the supply chain
- *Step 4:* Verify supply chain due diligence
- *Step 5:* Report on supply chain due diligence

There exist external providers that can help investors to verify carbon emissions and other sustainability factors along food supply chains. OpenSC is one example of such an organization that collects data and analyzes it to verify suppliers' sustainability claims.

Challenges

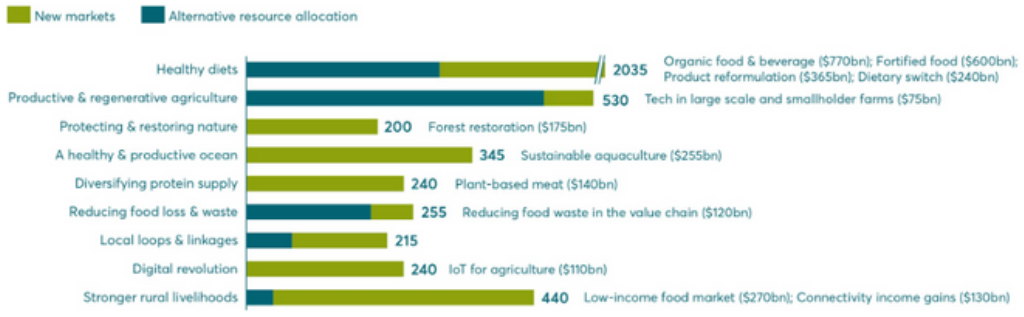
Scope 3 emissions are a very significant component of the total carbon footprint for many food companies. So far, there has been more progress made in reducing Scope 1 and 2 emissions in the industry as the upstream supply chain is often more difficult to control.

The farm is a key element in the food supply chain, and a great deal can be done at this level to decarbonize the industry. However, application of new technologies requires significant upfront investments, which can be particularly challenging for smaller farmers.

Opportunities

The following chart from the presentation by Mighty Earth at our recent webinar provides an estimate of the size of the largest business opportunities emerging in the agriculture and food industry.

Fig. 10. Potential revenues from new business opportunities in 2030, USD bln. (in 2018 prices)



[18] https://www.oecd-ilibrary.org/docserver/9789264251052-en.pdf?expires=1674595926&id=id&accname=guest&checksum=51969D30BB4ED7789CD57032B72017F2
OECD (2013), OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas: Second Edition, OECD Publishing, Paris, http://dx.doi.org/10.1787/9789264185050-en.

Development of new sources of energy such as biomass offers new opportunities for farmers to benefit from the trends of fuel decarbonization and plant-based protein growth.

Best Practices

According to Mighty Earth, the following list includes best practices that should be followed by companies working in the agriculture industry:

- Forest and natural habitats
  - Adopt no-conversion policy for all direct and indirect suppliers that protects all native ecosystems.
- Regenerative farming
  - Require use of regenerative on-field farming practices for all direct and indirect suppliers (crop specific) and agroforestry in the tropics and where appropriate.
- Human rights
  - Require suppliers to demonstrate Free Prior and Informed Consent from local communities regarding land use and protect land tenure.
- Transparency and traceability
  - Publicly report on supplier identity, location, and performance on sustainability metrics. Implement full supply chain traceability.
- Monitoring
  - Implement monitoring and verification system for supply shed.

Conclusion

Agriculture and food production are essential industries that generate significant amounts of GHGs. Reducing these emissions will require a lot of effort applied at various links of the value chain. It will necessitate behavioral changes, development and application of new processes and technologies, and engagement and oversight by governments and investors. In our report, we have attempted to paint a broad picture of the food supply chain, its impact on climate change, and potential solutions. We have also provided references to sources of useful information and recommendations.

Should you have any questions or comments, please do not hesitate to get in touch with Pavel Laberko, Director, Extractive Industries Program, EMIA, at plaberko@eminvestorsalliance.org.

Appendix: Additional Resources

Food and Agriculture Organization (FAO)
FAO is a UN agency whose mission is to defeat hunger. Environmental sustainability of agriculture is not the main focus of this organization, yet its website has a lot of resources with statistics, reviews, and other information about world food and agriculture.

Regeneration International (RI)
RI is a non-profit organization uniting farming and scientific communities, businesses, educational institutions and policy makers promoting the global transition to regenerative farming and land management. Their website is a large source of information for those interested to know more about this approach.

Science Based Targets initiative (SBTi)
SBTi helps companies to set and verify science based net zero targets aimed at achieving the Paris Agreement targets. It has developed guidance specifically for the food and agriculture industries.

The Carbon Transition Initiative aims to study the impact of climate change in emerging markets and identify best practices available to the investment community to help assess and manage climate- and transition-related risks and opportunities.
