Sectoral Risk Briefings:
Insights for Financial Institutions

UN environment programme finance initiative

Climate Risks in the Agriculture Sector

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Acknowledgments

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Introduction

In the past few years, the global economy has been lashed by the COVID-19 pandemic, geopolitical conflict, supply chain disruptions, an energy crisis, and high inflation. These challenges are occurring against the backdrop of the mounting planetary emergency of climate change. Climate change can exacerbate all other challenges; increasing geopolitical conflicts over resources, crippling infrastructure and supply chains, extending the range of dangerous pathogens, and causing the collapse of the natural systems upon which we depend. As the US Pentagon presciently stated: "climate change is a threat multiplier". While the transition to a sustainable, net-zero future is critical, it demands fundamental shifts in nearly all economic sectors. These shifts are not without risk for companies and the communities impacted by them.

Financial institutions face an array of risks from this rapidly changing, and often chaotic, global context. Their clients are exposed to physical hazards as well as transition risks. These can have major credit, market, and operational implications. The prudent financial institution will explore these climate-related risks and prepare strategies to meet them. Ensuring resiliency and success in the future depends on making good decisions and thoughtful plans today.

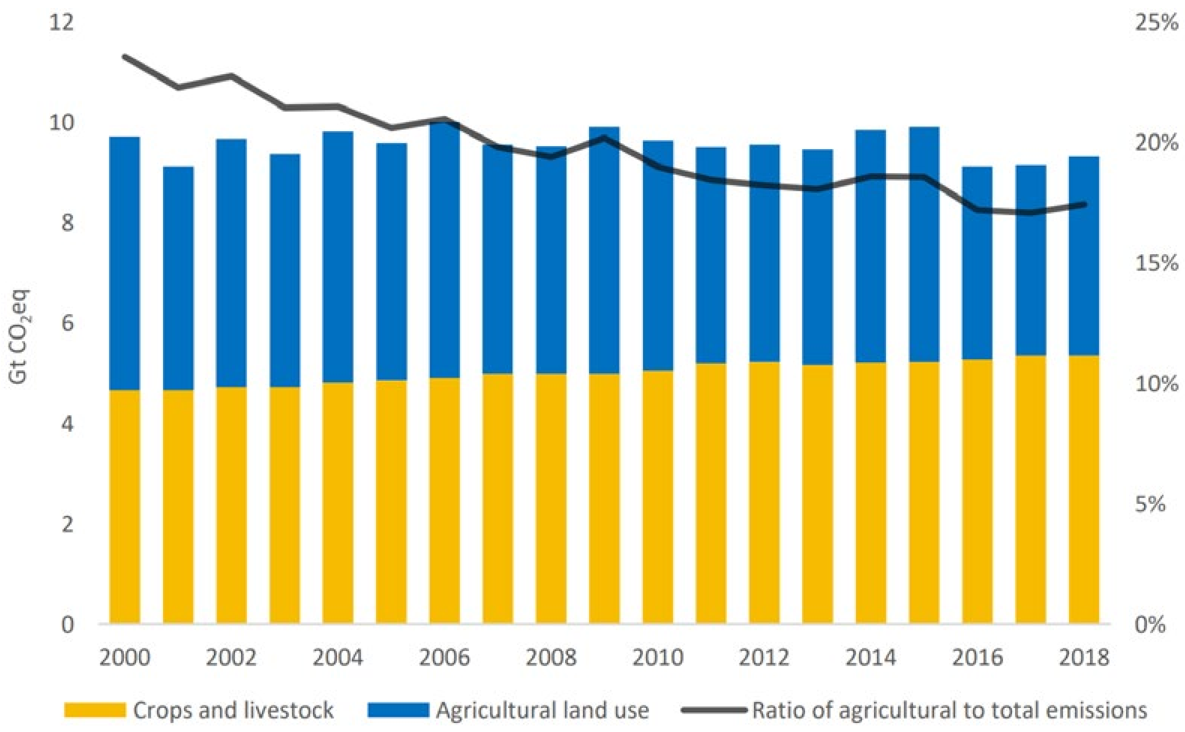
UNEP FI has been working at the intersection of sustainability and finance for over 30 years. Its programmes for financial institutions develop the tools and practices necessary to positively address the most pressing environmental challenges of our time. UNEP FI's Climate Risk and TCFD programme has now worked with over 100 financial institutions to explore physical and transition risks posed by climate change. Through this work, a need has been identified to provide financial institutions with a baseline understanding of climate-related risks and their manifestations across different sectors.

This brief is part of a series of notes that cover major economic sectors and their associated climate risks. UNEP FI intends for the resources and perspectives included within these notes to empower financial colleagues to communicate these risks throughout their institutions and across the financial sector more generally. The hope is that the communication process will not only enhance awareness of climate risks, but also begin conversations that will lead to tangible changes in strategy and operations. The extent to which these insights are integrated will be the truest test of this series' effectiveness. This particular brief covers the physical and transition risks facing the agriculture sector.

Agriculture overview

Emissions produced from the agriculture sector are driving the global temperature to rise at an alarming rate. The Food and Agriculture Organization (FAO) of the United Nations reported that emissions from agriculture and related land use account for 17% of global greenhouse gas (GHG) emissions (FAO, 2018). Agricultural activities and food production are associated with carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) emissions. Direct emissions from the sector are typically N_2O and CH_4 (Lynch *et al.*, 2021). Around one third of global methane emissions (32%) come from cows and other livestock due to the fermentation process during digestion. Methane emissions are also released during other agricultural activities, such as manure decomposition and rice cultivation (UN, 2022). Nitrogen fertilizers cause N20 emissions due to the excess amounts of nitrogen that they release in agricultural runoff (UN, 2022). The agriculture sector is also one of the main drivers of CO_2 emissions caused by land-use change, such as clearing land for crop production. Land use-related CO_2 emissions account for about 14% of annual CO_2 emissions. Of this 14%, the majority (71%) are directly linked to agriculture (Lynch *et al.*, 2021). The global food system is also the primary driver of biodiversity loss, with agriculture threatening 24,000 of the 28,000 species at risk of extinction (UNEP, 2021).

Figure 1: Emissions from agricultural activities and the share of agriculture in global GHG emissions (FAO, 2020)



In spite of the fertilizer effect of CO_2, higher temperatures will push many regions past optimal growing temperatures and yields. According to estimates by the United Nations, the global population is expected to rise to about 10 billion by 2050 (United Nations, 2021), which will add pressure on already strained food systems. As rainfall and weather patterns increasingly shift, crops may be damaged by the severe climate events resulting from these changes, such as floods, storms, and droughts (Colombia, 2022).

If global warming worsens, rising global temperatures and extreme weather events threaten to significantly affect agriculture production. According to the Globagri-WRR model, a global agriculture and land-use accounting system, agricultural land use will need to expand by over three billion hectares in order to meet the projected land demand for 2050. This massive increase in land use will result in major increases in GHG emissions (World Bank, 2020). As economies set climate targets, decarbonisation of the agriculture sector poses significant transition risks. Below, we explore in depth the key physical and transition risks faced by the agriculture (including aquaculture) sector (Table 1).

Table 1: Key climate risks for the agriculture (including aquaculture) sector

	Risk	Summary
Transition Risks	**Increasing carbon price**	Implementing carbon taxes could greatly impact the production and operating costs of carbon-intensive agriculture activities.
	Public policy restrictions	Governments can increase policy pressure through policies related to pasture reduction, deforestation, and oil palm expansion.
	Advancements in less carbon-intensive technology	Traditional agricultural producers can face pressure from producers that adopt the use of less carbon-intensive technologies.
	Shift in market preferences	Due to rising awareness of the large carbon footprint of the sector, consumers are increasingly willing to change eating habits and shift to other alternatives.
	Growing investor action	Due to the growing consideration of climate risks, investors are calling on countries and companies to reduce emissions produced from the sector.
	Rising reputational risk	Companies linked to agricultural activities that drive climate change, such as deforestation, are increasingly vulnerable to reputational risks due to criticism from investors, non-profit organisations, and consumers.

Physical Risks	**Droughts and heat stress**	Heatwaves and droughts can threaten livestock and feed supplies as well as causing changes in crop production, resulting in higher costs and agriculture loss.
	Extreme storms and flooding	Extreme storms and flooding can reduce the production and quality of feed grain, pastures, and crops. Such events can reduce the supply and quality of crops and livestock.
	Sea level rise	Sea level rises can impact biodiversity, decrease soil quality, induce more flooding, and increase saltwater intrusion and soil salinisation, causing production to fall and negatively impacting income and food security.
	Wildfires	Increased severity and frequency of wildfires can damage crops and livestock, resulting in losses for the forestry industry and infrastructure. Wildfires also create hazardous working environments for outdoor workers.
	Ocean acidification	Climate change is rapidly increasing the acidity of oceans. Rapid ocean acidification severely threatens marine biodiversity.
	Invasive species	Invasive species can reduce the resilience of agricultural systems and are one of the biggest drivers of biodiversity loss. The increased spread of invasive species can affect food security and livelihoods.

SECTION A:

Transition risks

Agriculture, including forestry, fisheries, and livestock, contribute to a fifth of GHG emissions. In order to achieve net zero by 2050, the sector needs to reduce emissions (FAO, n.d.). As a result, the agriculture sector is exposed to multiple transition risks, including policies and regulations, technological shifts, and changes in consumer preferences.

The transition risks facing the agriculture sector also pose a risk for workers and communities that rely on the the sector for jobs and income. It is therefore important to align financing with a just transition approach that considers the impact of the transition on groups at risk to operations in the agriculture sector, including workers, Indigenous Peoples and local communities.

1. Increasing carbon price

A carbon tax is an effective tool for lowering emissions. As policymakers and decision makers try to curb carbon emissions, the agriculture sector faces increasing risks from the implementation of carbon prices worldwide. In 2021, global carbon pricing revenue rose by 60% as compared to 2020, reaching approximately US$84 billion. Carbon prices are reaching record heights in markets such as the European Union (EU), California, New Zealand, Korea, Switzerland, and Canada (World Bank, 2022). The Organisation for Economic Co-operation and Development (OECD) projected that a carbon price of US$240 per ton of CO_2 equivalent emissions by 2050 would be consistent with a 1.5 climate target. Such a price point would serve to reduce net agriculture, forestry, and other land use (AFOLU) emissions by the 129% required to achieve the target, the OECD calculated (Ben Henderson *et al.*, 2021).

Implementing carbon taxes could greatly impact the production and operating costs of carbon-intensive agriculture activities (Schnitkey, Zulauf & Paulson, 2021). Research suggests that, on average, a carbon tax of US$144 per ton of CO_2 equivalent emissions could increase production costs for energy-intensive crops, such as corn and soya beans, by 27.45%. Increased production costs can be partially compensated through increased commodity prices. For example, a carbon tax of US$144 per ton can decrease returns for maize and wheat by 11.4% and 11%, respectively. Increased production costs of crops due to carbon taxes can cause a shift in production and trade patterns, potentially precipitating a reallocation of land use globally. For example, imposing a carbon tax on corn and wheat could increase preference for commodities such as barley, soya beans, and sunflowers by 1.2 to 8.8% (Dumortier and Elobeid, 2021). Carbon taxes also have a negative impact on the income of farmers. British Columbia introduced North America's first carbon tax in 2008, for instance. Initially set at CA$10 (US$7.5) per ton of CO_2 equivalent emissions, the tax rose annually by CA$5 (US$3.7). As a result, farmers experienced a decrease in net farm income-to-receipt ratios of between 8 and 12 cents per dollar of farm receipts. This decline in revenue correlated with increased commercial feed costs, labour costs, interest costs, and depreciation costs (Olale *et al.*, 2019).

Beyond carbon taxes, emissions trading schemes (ETSs)—commonly known as 'cap-and-trade' schemes—are also being implemented to limit carbon emissions. The United States, for example, is currently considering the adoption of such a scheme. The move follows the EU's decision back in 2005 to introduce its own ETS. In an ETS, the government puts a "cap" on the tons of GHG emissions generated per year by specific industries. Emission allowances are created, giving companies the right to emit one ton of CO_2 equivalent in a year (European Commission). While the main goal of cap-and-trade schemes is to limit emissions, they can also be used to generate additional income for businesses in the agriculture sector. The agriculture sector offers an abundant supply of emission credits. Farmers can effectively alter their farming practices to reduce emissions from the atmosphere while increasing their income. For instance, farmers can minimise or avoid using no-till practices to trap carbon stored in the soil, which is a natural carbon sink. Canada's carbon offset markets provide the "largest number of opportunities" globally for farmers, by the country's own reckoning (Government of Canada, 2022). In June 2022, the Government of Canada launched its Greenhouse Gas Offset Credit System, which gives farmers and foresters market-based incentives to undertake projects to reduce GHG emissions. These projects can create one tradeable offset credit for every ton of emissions reduced. The credit can then be sold to those who need to meet emission reduction goals or obligations under a carbon pricing scheme (Government of Canada, 2022). According to Indigo, a leading company in trading agricultural carbon credits, American farmers are estimated to generate 0.1 to 0.4 credits per acre in their first year. Their credit production is shown to increase over time. The quoted price per carbon credit is at least US$20, potentially increasing farmers' gross income by up to US$30 per acre every year (Indigo, n.d.).

Case study 1: Carbon price risk

ADM Annual Report 2021

An American multinational food processing company

Impacts of carbon pricing

The Company may be impacted by carbon emission regulations in multiple regions throughout the globe.

A number of jurisdictions where the Company has operations have implemented or are in the process of implementing carbon pricing programs or regulations to reduce GHG emissions including, but not limited to, the United States, Canada, Mexico, the European Union and its member states, and China. In particular, the State of Illinois recently enacted legislation intended to eliminate carbon emissions by 2050. The Company's operations located in countries with effective and applicable carbon pricing and regulatory programs, currently meet their obligations in this regard with no significant impact on the earnings and competitive position of the Company. It is difficult at this time to estimate the likelihood of passage, or predict the potential impact, of any additional legislation, regulations or agreements. Potential consequences of new obligations could include increased energy, transportation, raw material, and administrative costs, and may require the Company to make additional investments in its facilities and equipment. The Company has programs and policies in place to expand responsible practices while reducing its environmental footprint and to help ensure compliance with laws and regulations.

2. Public policy restrictions

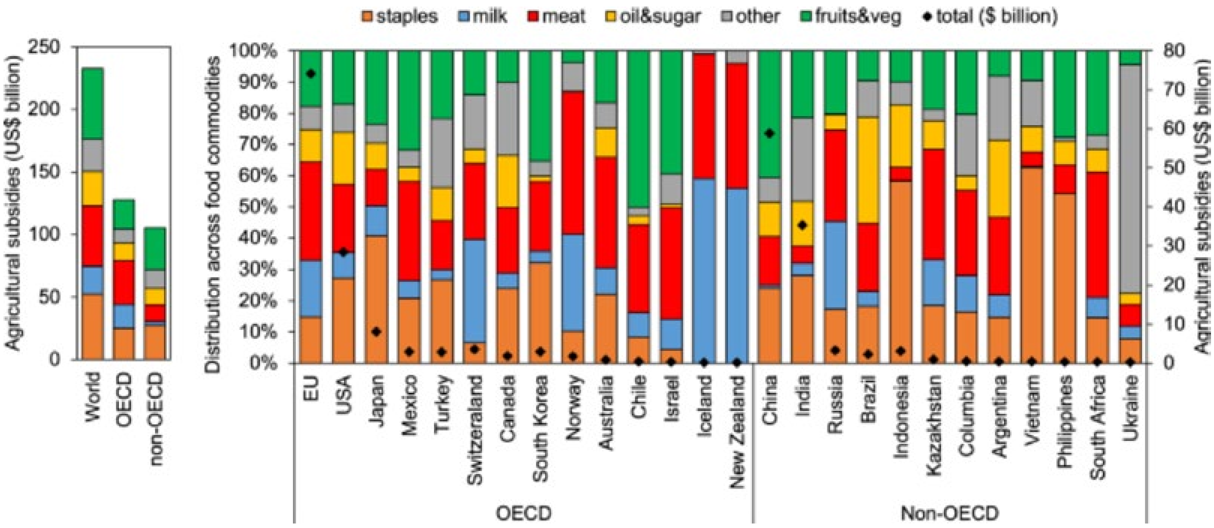
To reduce emissions from the agriculture sector, national governments are implementing other forms of policy pressure, such as policies related to pasture reduction, deforestation, nitrogen fertilizer, and oil palm expansion. For example, Norway is the first country to commit to no longer using any products that are linked to deforestation. Similarly, in 2021, at the Conference of Parties (COP) 26, over 100 countries pledged to halt and reverse forest loss and land degradation by 2030 with a backing of US$19 billion in public and private funds. Countries taking part in this agreement include Indonesia, Canada, Brazil, and Russia (COP26, 2021). The following year at COP27, more than 25 countries, including Japan, Pakistan and the United Kingdom, launched the Forest and Climate Leaders' Partnership to provide additional financing and to hold each other accountable for the pledge made at COP26 (UK Government, 2022). In 2020, the Dutch parliament approved a law to help reduce nitrogen emissions. The legislation mandates reductions in nitrogen emissions of up to 70% (increasing to 95% in a limited number of cases) with the goal of halving total nitrogen emissions by 2030 (USDA, 2021).

As part of the European Green Deal, the EU has set out the Farm to Fork Strategy (European Commission). The plan forms part of the EU's efforts to mitigate climate change by 2030 through the reduction of emissions in the agricultural sector (Figure 2). The strategy seeks to drive transition through regulatory and non-regulatory initiatives with common agricultural and fisheries policies. This includes the European Commission's intention to revise EU rules on information provided to customers to provide improved labelling information on nutrition, animal welfare, climate, and 'green' claims. The Farm to Fork strategy has also proposed a new business model for carbon sequestration by farmers. The model is based around rewards via the Common Agricultural Policy (CAP) or other public and private initiatives for farming practices that remove CO_2 from the atmosphere. The proposed carbon framing initiative would provide farmers with additional income sources while helping decarbonise the food chain. The strategy also emphasises clean technology to reduce the use of fossil fuels and improve energy efficiency (European Commission, 2020). However, this action plan by the EU has received some criticism. A study by the United States Department of Agriculture (USDA) found that implementing the strategy by 2030 in the EU would lead to a 12% reduction in agricultural production in the region and result in a 17% price increase in agricultural products across the trading bloc. The study claims that the strategy will reduce the EU's competitiveness in global trade markets, with exports decreasing by 20% and gross farm income decreasing by 16% (USDA, 2020).

Figure 2: Aims of the EU's Farm to Fork Strategy (European Commission).

The agriculture sector relies heavily on subsidies and other government support (Figure 3). It is estimated that agriculture receives around US$600 billion per year in global government support. From 2017 to 2019, the world's 54 major economies annually granted US$553 billion to the farming industry in market price support and direct subsidies. Governments commonly support the production of emission-intensive commodities, such as beef, dairy, and rice (Laborde *et al.*, 2021). As economies decarbonise, governments will increasingly consider restructuring agricultural subsidies to reduce emissions. For example, fertilizer subsidies have contributed to the overuse of nitrogen fertilizer worldwide, a major source of GHG emissions. From 1998 to 2016, China provided various subsidies to produce fertilizers, even offering fertilizer manufacturers special prices on electricity, natural gas, and transportation. However, by 2015, China began to phase out these subsidies and eliminated them permanently in 2017 (World Bank, 2020).

Figure 3: Overview of agricultural subsidies in 2017, by country and type of commodity (Springmann and Freund, 2022)



Removal of all agricultural support is possible. New Zealand eliminated its agricultural subsidies virtually overnight in 1986. Yet doing so brings trade-offs. In an extreme circumstance where all agriculture support was removed by 2030, GHG emissions would fall by an estimated 78.4 million tons of CO_2 equivalent according to the FAO. However, removing all government support is projected to decrease crop production, livestock farming production, and farm employment by 1.3, 0.2, and 1.27%, respectively. Eliminating agriculture-related fiscal subsidies would reduce 11.3 million tons of CO_2 equivalent globally by 2030. Removal of subsidies would affect consumers the most due to lower agricultural production and higher food prices. Decline in farm income due to the removal of subsidies would also push a portion of the sector in developing countries into poverty if not compensated (FAO, 2022). In addition, removal of government support can have mixed impacts on the sector, as agriculture production can shift between regions. Thus, were border measures to be removed in one country, for instance, GHG emissions may fall in that country but rise in other countries because of increased production to meet global demand. A recent study (Springmann & Freund, 2022) has shown that, for countries previously supported by subsidies, removing all agricultural subsidies by 2030 would reduce crop production by 1.1–2.8% in OECD countries and 0.8–1.2% in non-OECD countries. Regions with no subsidies would actually increase production. GHG emissions correlate to these changes in production, with emissions reducing by 1.8% in OECD countries and 0.1% in non-OECD countries, while increasing by 0.5% in non-subsidising countries.

Case study 2: Public policy risk

MOWI 2021 Annual Report

Norwegian seafood firm

Operating restrictions due to climate and biodiversity impacts

Some of our sites are located close to or within sensitive areas with respect to biodiversity. The effect of salmon farming on the environment and biodiversity is being intensively discussed and new regulations in this area could result in the closure of sites or require the implementation of costly measures. In addition, new regulations could result in restrictions to certain additives used in fish feed and in medication becoming prohibited at these sites if they are believed to have an adverse impact on the environment. Compliance with such laws, rules and regulations, or a breach of them, may have a materially adverse effect on our business and financial figures.

Mitigation Actions

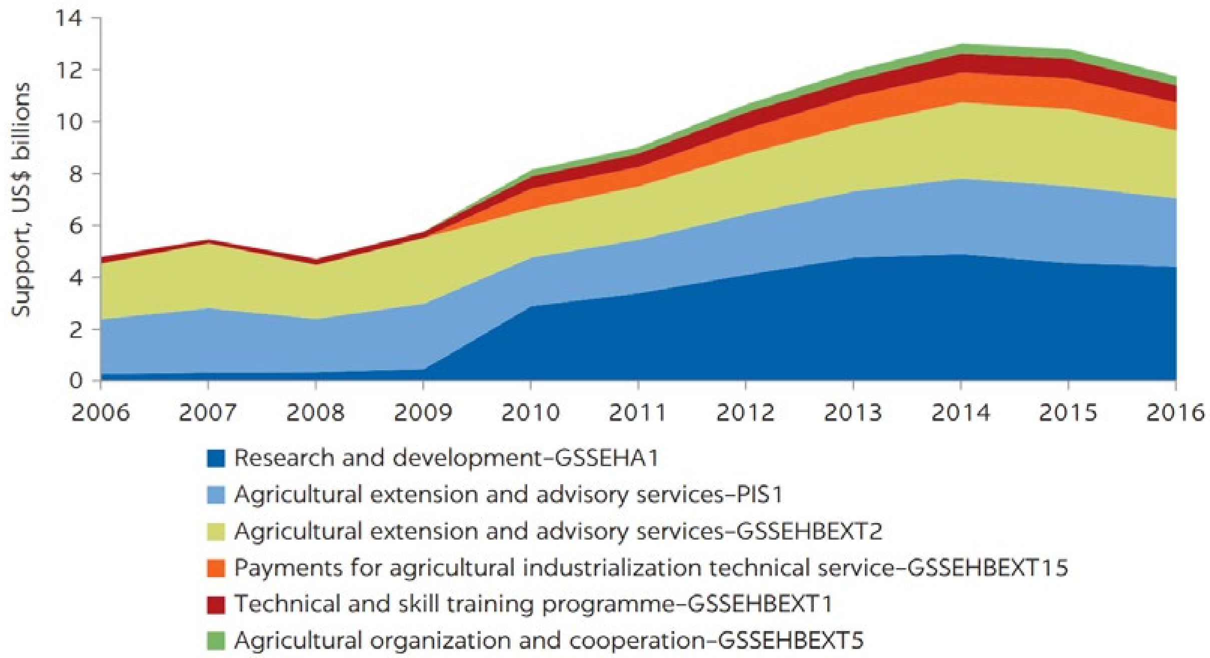
Continuous dialog with the authorities in the countries in which we operate to document that biodiversity is not adversely affected by our operations. Cooperation agreement with WWF. Norway for mutual exchange of ideas and information. Environmental testing and documentation to ensure that our operations do not leaving lasting footprint.

3. Advancements in less carbon-intensive technology

Traditional agricultural producers also face pressure from technological advancements to reduce emissions. Adoption of potential technologies includes dietary additives, improvement in feed quality, anaerobic digester technologies to reduce methane emissions, agronomic practices to reduce emissions from fertilizer use, and drainage management practices (Ben Henderson *et al.*, 2021). It is estimated that if EU farmers take up climate-smart actions (including various technologies) by 2030, the trading bloc could reduce its agriculture-linked GHG emissions by 6%. Such a move would also help restore soil health to over 14% of the EU's agricultural land. Farmers who take up such technologies could add anywhere between €1.9 billion and €9.3 billion in total accumulated income (World Economic Forum, 2022).

In 2020, the market for agricultural technology (known as 'agritech') was valued at US$9 billion and is expected to rise to US$22.5 billion by 2025 (Juniper Research 2020). Agritech can produce biotech crops that rely on fewer pesticides and require less frequent ploughing. Conservation tillage—made possible with biotech—can reduce carbon emissions by 7 to 35% compared to conventional tilling (Rutkowska *et al.*, 2018). Traditional farmers could be outcompeted by those who adopt biotechnology due to the latter's improved crop yields, reduced vulnerability to climate change, and more nutritionally enhanced produce. Since the 1980s, China has been supporting private enterprises to engage in developing biotechnology by investing millions of dollars into research and development (R&D). The government has also enacted policies that provide money from state-owned banks to private firms to encourage research. Through such policies, ChemChina, a state-owned enterprise, bought the Swiss agrochemical giant Syngenta for US$43 billion. The Government of China also initiated an R&D programme for biotechnology from 2008–2020 with a budget of US$3.5 billion (Deng *et al.* 2019). Figure 4 below shows China's expenditure on agricultural R&D (World Bank, 2020).

Figure 4: China's expenditure on agricultural R&D (World Bank, 2020)

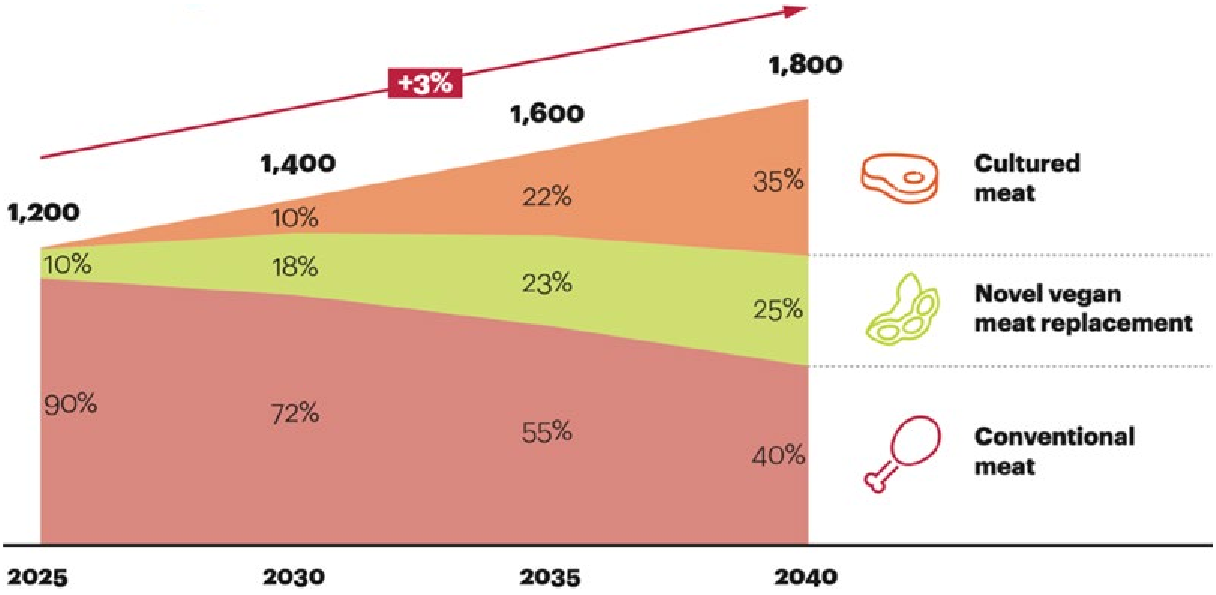


Source: OECD PSE and GSSE.

Innovative technologies to lower agriculture's carbon footprint, such as lab-grown meat and 3D-printed protein meat, could also put carbon-intensive agriculture practices at risk (Environmental Research Letters, 2021). In 2021, Nutreco, an animal nutrition company, and Mosa Meat, a food technology company, announced their Feed for Meat project. The project aims to bring lab-cultivated beef to the European market on a large scale. The European React-EU recovery assistance programme awarded the project a grant of €2 million (Nutreco, 2021). The first lab-made burger cost about US$325,000 to produce in 2012 but the price has since declined to US$9 (Forbes, 2022). With continued technological advances in the field, the costs of cultured meat are expected to become competitive with those of traditional meat.

In 2020, the global market revenue of plant-based meat was estimated at around US$6.6 billion and is expected to rise to US$16.6 billion by 2026 (Statista, 2022). Over the next few years, the global annual growth of plant-based alternatives is projected to rise by 20 to 30% (HBSB, 2021). Recently, cultivated meat has become an accepted form of protein, with Singapore approving the world's first lab-grown chicken meat in 2020. Eat Just, the company that develops cultivated chicken using animal cells, has raised over US$300 million and was last valued at US$1.2 billion. Cultured meat and other alternatives are projected to decrease the market share of traditional meat from 90% in 2025 to 40% in 2040 (AT Kearney, 2019). Figure 5 below highlights the global meat market forecast from 2025 to 2040.

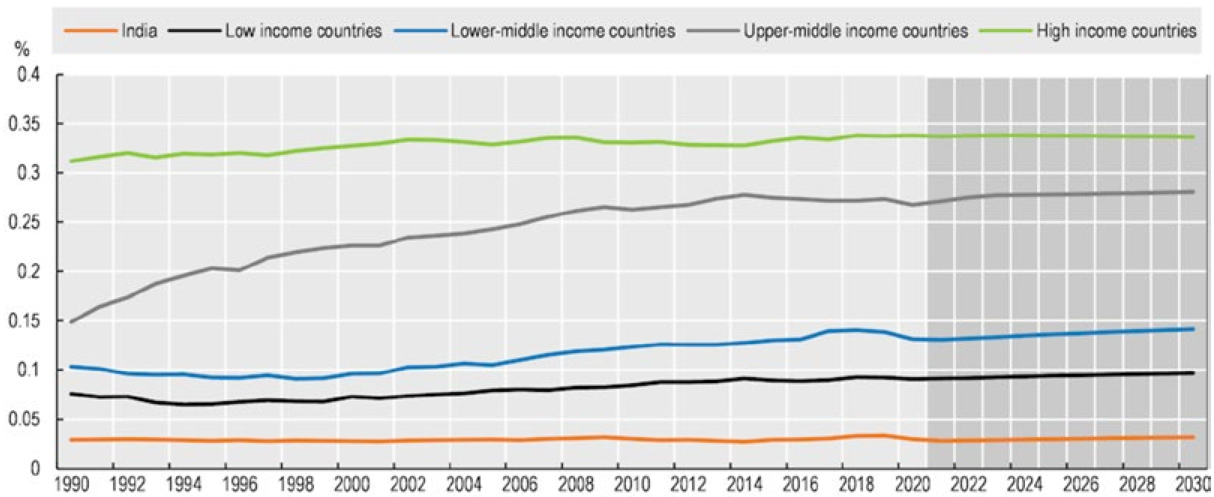
Figure 5: Global meat market forecast (in US$ billions) (AT Kearney, 2019)



4. Shift in market preferences

Global meat consumption is projected to increase by 14% by 2030, compared to 2018–2020 average levels. The growth in consumption will primarily be driven by growth in income and population. However, in high-income countries, meat consumption per capita is expected to level off due to changes in consumer preferences and slower population growth. By 2030, poultry is expected to represent 41% of global meat products, with beef representing 20% as shown in the figure below. Beef production is expected to grow by 5.8% in 2030, compared to the base period of 2018–2020 (OECD, 2021). The projected change in the composition of meat consumption for countries is illustrated in Figure 6.

Figure 6: Share of meat protein in total protein consumption from 1990 to 2030 (OECD, 2021)

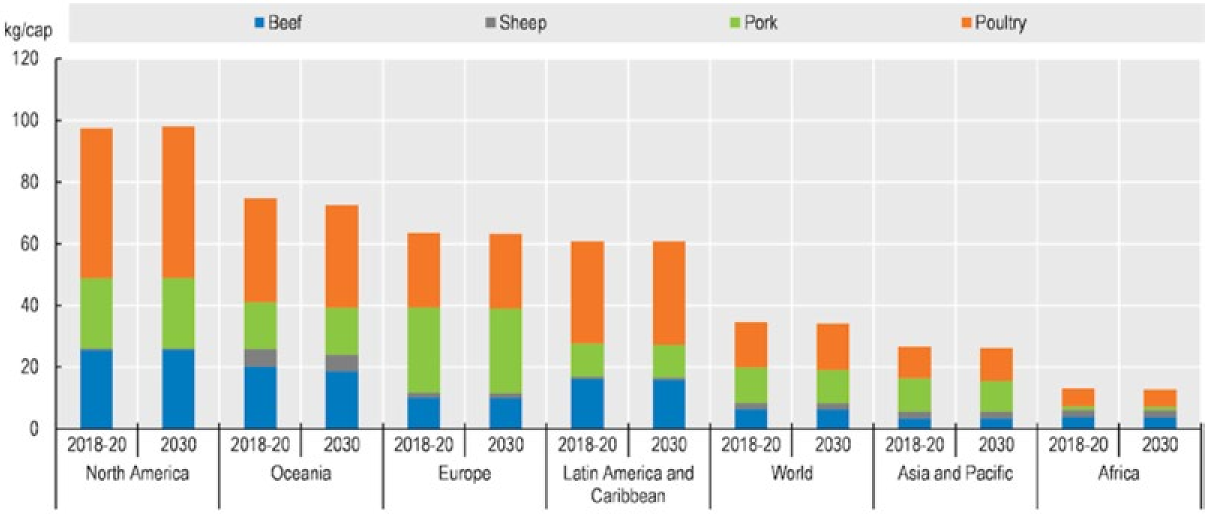


Note: The 38 individual countries and 11 regional aggregates in the baseline are classified into the four income groups according to their respective per-capita income in 2018. The applied thresholds are: low: < USD 1 550, lower-middle: < USD 3 895, upper-middle: < USD 13 000, high: > USD 13 000.The lower middle income category excludes India.

Source: OECD/FAO (2021), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

The shift in consumer preferences will comprise a strong driver of the slow growth of the beef industry. The OECD projects Asia and the Pacific as the only regions where per capita beef consumption is expected to increase by 2030 (see Figure 7 below). In China, the world's second-largest beef consumer, per capita consumption will increase by an estimated 8% by 2030—around four time lower than its growth rate of 35% over the last decade. Per capita consumption is also expected to fall in Argentina and Canada by 7% and in Brazil by 6%. Sub-Saharan Africa is projected to have the highest growth rate for beef production at 15% due to strong population growth. In comparison, beef production is expected to grow by 6% in North America. In Europe, beef production is expected to decrease by 5% (OECD, 2021).

Figure 7: Meat consumption per capita and a shift from beef to poultry (OECD, 2021)



Note: Per capita consumption is expressed in retail weight.

Source: OECD/FAO (2021), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

The large carbon footprint of agriculture products exposes the sector to transition risks arising from a shift in market preferences. Research shows that over half of consumers are willing to change eating habits to reduce the negative environmental impact of food products (IBM, 2020). Greater awareness of the emissions produced from agricultural activities and their impact is driving consumers to shift demand from carbon-intensive products to less carbon-intensive alternatives (EPA, 2021). As consumers understand the environmental impact of meat and dairy production through awareness-raising platforms such as social media, a growing number of consumers are preferring plant-based diets to meat diets. Rising costs due to taxes on carbon-intensive agricultural products, coupled with this growing awareness, could further discourage the consumption of meat and dairy products (AFN, 2021).

A shift in market preferences from traditional meat to plant alternatives can already be observed. In 2019, the retail food market grew by an average of 2.2%, but the plant-based food industry increased by 11.4%. In 2020, the industry grew by 27% in the United States, as compared to a 15% growth in general retail food sales (CBinsights, 2021). A survey by Gallup, a global analytics firm, showed that one in four Americans ate less meat in 2020 than in the previous year. One of the prominent factors that led to this reduction in meat consumption was environmental concerns, with 49% of respondents stating it as a major reason and 21% of respondents stating it as a minor reason (Gallup, 2020). The survey also showed that six in 10 Americans have tried plant-based meats. Of these respondents, most (60%) say they are "very likely" or "somewhat likely" to continue to eat plant-based meats in the future.

Consumers are also becoming increasingly aware of the carbon footprint of their groceries, with growing interest in carbon labelling on products. Carbon labelling is when a product label shows the quantity of emissions emitted during processes such as production, manufacturing, and transportation (Chilled Food Association, n.d.). A YouGov study of consumers across the United States, United Kingdom, Italy, Canada, Spain, the Netherlands, and Sweden indicated that more than two-thirds (66%) of consumers would feel more comfortable purchasing a food product if it demonstrated a recognisable carbon label (Carbon Trust, 2019). When information about a given product's carbon emissions is presented in terms familiar to consumers, they actively shift their purchase choices away from carbon-intensive to less carbon-intensive products (Camilleri *et al.*, 2018). Research has shown that carbon labelling has improved the carbon footprint of the average consumer's diet by about 5% compared to standard food labels (Vlaeminck *et al.*, 2014).

5. Growing investor action

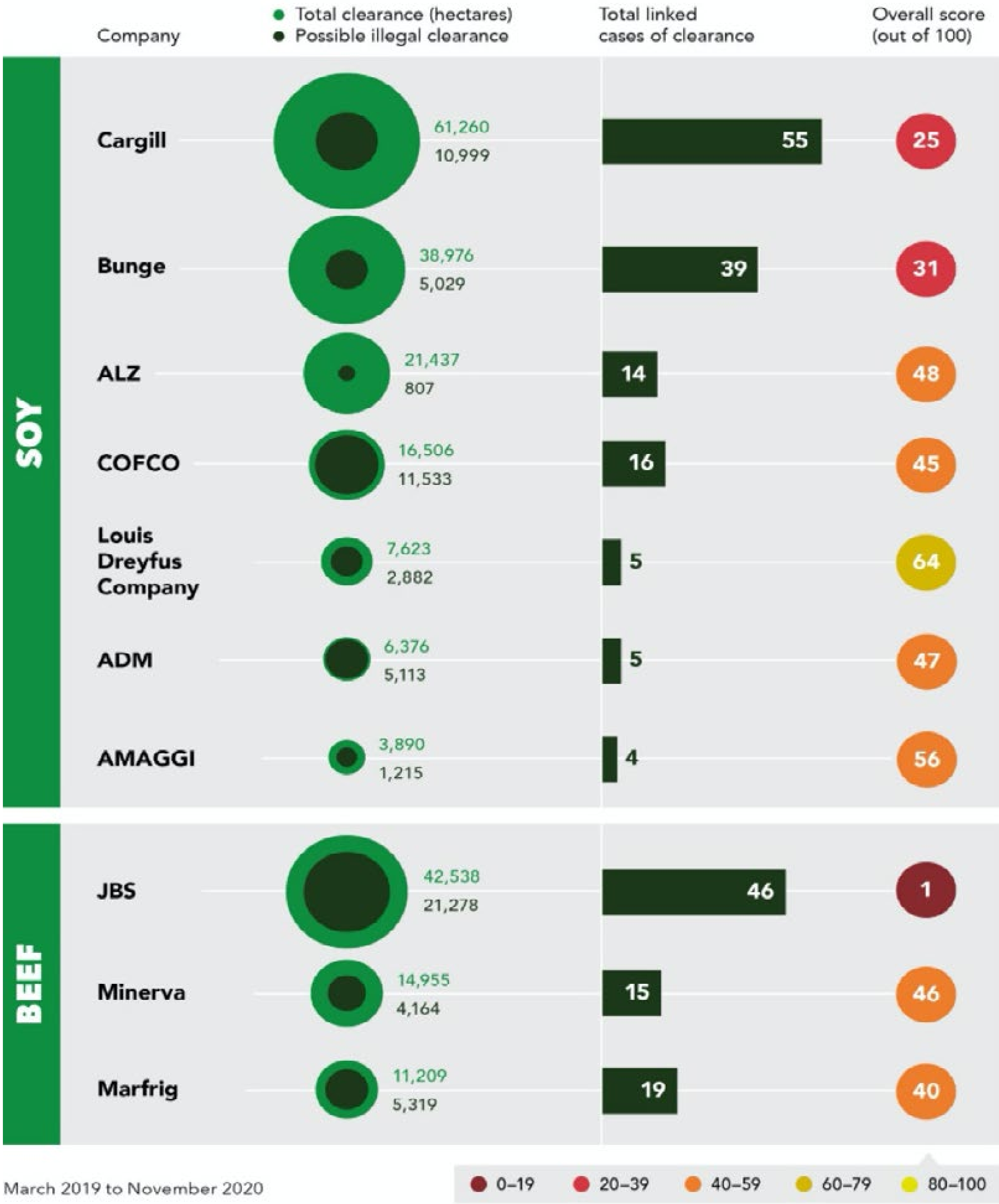
Investors are increasingly aligning their portfolios to consider climate risks in recognition of the financial risks that these pose to the food system. In recent years, investors have taken increasing action against countries and companies to reduce emissions produced from the sector. For example, at COP26, investors representing over US$12 trillion in collective assets called upon the G20 nations to disclose GHG emission reduction targets for the agriculture sector. In 2022, a group of investors covering US$14.6 trillion in assets under management released a statement calling on the UN's Food and Agriculture Organization (FAO) to develop a global roadmap to 2050 for the agriculture sector in order to limit global warming to 1.5, as well as protecting and restoring nature and providing food security (FAIRR, 2022). Over 30 financial institutions—representing more than US$8.7 trillion in assets under management—have also committed to eliminating agricultural commodity-driven deforestation risks in their lending and investment portfolios by 2025 (Race to Zero, n.d.). Prior to this, in 2020, a stewardship initiative made up of nine investors (including Fidelity International, Aviva Investors, and Nomura) called on companies to end deforestation in their supply chain and improve supply chain traceability. The initiative's first phase focused on palm oil producers in Malaysia and palm oil consumers. The initiative also plans to address beef and soya beans in Brazil and Indonesia (PRI, 2021).

In September 2022, the European Parliament voted on a deforestation law that would make it compulsory for companies to verify that goods sold in the EU have not been produced on deforested or degraded land. As part of the law, financial institutions will be expected to conduct due diligence to prevent them from financing activities that cause deforestation or land degradation, such as activities related to beef, soya beans, leather, palm oil, and corn (Responsible Investor, 2022).

6. Rising reputational risk

Companies that employ agricultural activities such as deforestation that drive climate change can find their reputations negatively impacted. Non-profit organisations and other entities have begun running campaigns against companies linked to the fuelling of deforestation. In light of increasingly high-profile campaigns about the impact of commodities-driven activities and in response to growing investor concerns about the economic implications of such reputational risks, companies have become quicker to take remedial actions. As far back as 2016, for example, Kellogg's and Mars were among 27 large palm oil buyers to suspend contracts with IOI Corporation, a major Malaysian producer of palm oil. The decisions followed claims that IOI had illegally cleared 45 square miles of forest and peatland in Indonesia. Following similar reports, Unilever suspended its purchases from Hayel Saeed Anam Group, a large conglomerate based in the United Arab Emirates that produces palm oil. In 2017, meanwhile, news that the South Korean trading company Korea Posco Daewoo had been involved in a deforestation programme prompted Dutch pension fund ABP to sell its shares in the firm (S&P Global, 2018). Cargill, a US-based commodities trader, came under fire following a report released by the NGO Mighty Earth in 2020 that accused the company of deceiving customers about its deforestation impacts. The report claimed that the company used an inaccurate accounting methodology to give an intentionally misleading picture of its practices in Brazil, Argentina, Paraguay, and Bolivia. Cargill's corporate customers include McDonald's, Burger King, Walmart, and Unilever (Mighty Earth, 2020) (Figure 8). Mondelēz International, a US-based multinational confectionery, has also come under pressure because of its link to palm oil suppliers causing deforestation in Southeast Asian forests. The financial impacts of such allegations are potentially profound. For example, United Cacao, formerly Latin America's largest pure play cocoa producer, could not pay its debts following legal and regulatory challenges due to illegal deforestation in Peru (S&P Global, 2018). This occurred after the media platform 'Confectionery News' published two articles in 2015 regarding the company's involvement in deforestation, which breached orders from the Peruvian government. In 2017, United Cacao secured US$700,000 in new capital but was delisted from the London Stock Exchange's Alternative Investment Market (Confectionary News, 2017).

Figure 8: Beef and soya bean companies linked to clearance and deforestation in Brazil ([Mighty Earth, 2020](#))



Note: Companies ordered by total clearance. Data from March 2019 to November 2020 using Mighty Earth Rapid Response reports. Clearance defined as "any land use change classified as loss of native vegetation by deforestation alert systems ". Possibly illegal clearance defined as "any deforestation that is inside a Legal Reserve or Permanent Preservation Area (APP)". Total cases illustrate an incident of deforestation or clearance flagged to the relevant trader associated with producer, owner or farm. For full methodology and data see: https://www.mightyearth.org/soy-and-cattle-tracker/

Box A: Amazon and Cattle Grazing

Brazil is the world's largest beef exporter, accounting for almost one fifth of global beef exports (Climate Policy Initiative, 2021). The Brazilian beef industry is worth US$124 billion, contributing 8% of the country's GDP (Amnesty International, 2020). The country also has the second largest cattle herd globally (Climate Policy Initiative, 2021).

The Amazon region has observed the largest growth in the Brazilian cattle industry, with the number of cattle almost quadrupling from 1988 to 2018. Estimates suggest that up to 70% of deforested land in the Amazon forest is for cattle ranching use (Climate Policy Initiative, 2021).

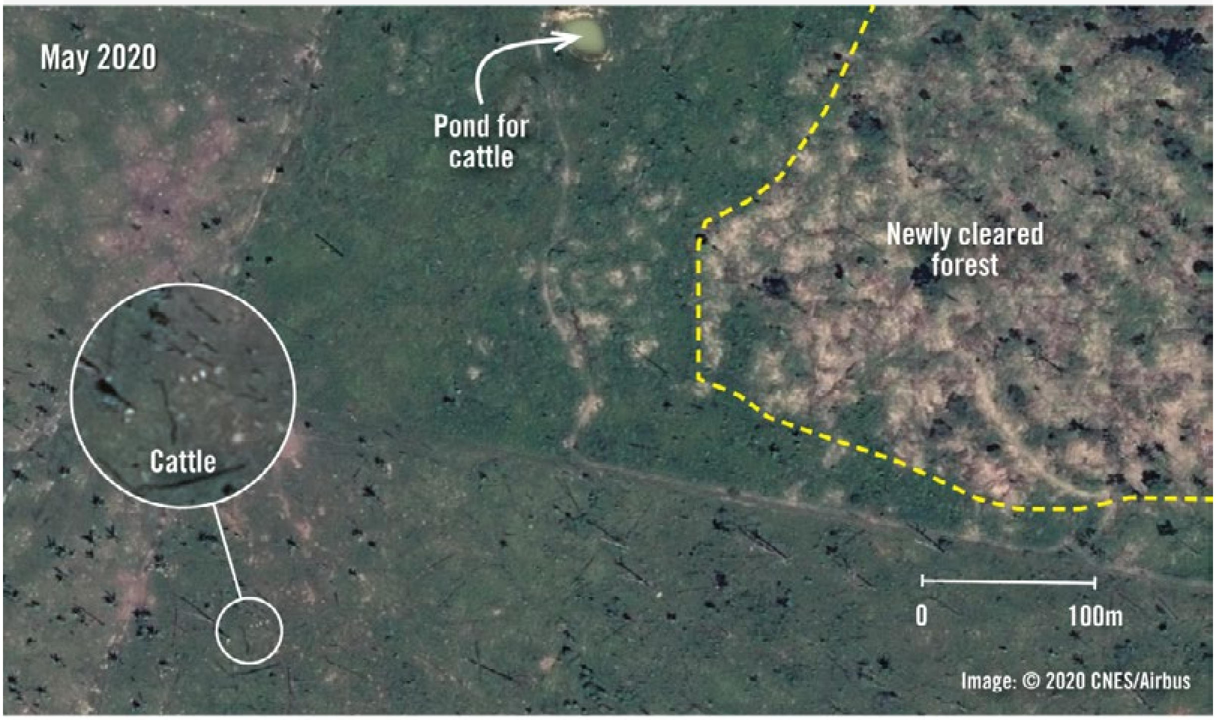
Illegal land seizures for cattle farming are driving deforestation in the Brazilian Amazon. Once plots of land are identified, trees are cut down and cleared, fires are lit, the grass is planted, and cattle are introduced. About two-thirds of the Amazon deforested in 1988 to 2014 (accounting for 500,000 square kilometres in total land area) was fenced, burned and converted to grazing pasture (Amnesty International, 2019).

An investigation on illegal land seizures prompted Amnesty International to start the petition, 'Say no to cattle illegally grazed in the Amazon' (Amnesty International, 2020). With more than 162,000 signatures, the petition called for Brazilian authorities to take more action (Amnesty International, 2019).

Despite signing two non-deforestation agreements with Brazil's Federal Public Prosecutor's office and with Greenpeace in 2009, JBS, the world's largest meat company, has not taken effective action to prevent illegal cattle grazing. Audits have shown that JBS does not monitor its indirect suppliers (Amnesty International, 2020).

In 2019, a Brazilian federal prosecutor noted: "Today, no company that buys in the Amazon can state that there isn't cattle coming from deforestation in its supply chain (…) No meat-packing company and no supermarket either." Amnesty International, 2020.

Figure 9: Satellite imagery highlighting the extent of deforestation in protected areas of the Amazon from 2019–2020 ([Amnesty International, 2020](#))



7. Transition risk guidance

Key transition risk questions for financial institutions to consider

1. **Gathering information**
   - Are there any new, government-imposed environmental requirements in our portfolio's footprint?
   - Are there markets for carbon credits and bioenergy production in our portfolio footprint? If so, do our clients participate in these markets?
   - How rapidly is the low-carbon transition progressing across our portfolio footprint?
   - What have our clients disclosed in their financial, sustainability, and climate reports regarding their transition risks?
   - Are any of our clients facing legal action related to deforestation, pollution, or other environmental issues?
   - How many of our clients have transition plans? Do they incorporate just transition considerations into these plans?
   - Do we have emissions data for our clients?

2. **Assessing the risks**
   - Have we looked at transition scenarios to see how those risks will evolve over time? Have we considered short-term, medium-term, and long-term risks?
   - What does our exposure to higher-risk clients look like? What are the terms of our financial relationship (e.g. debt/equity, tenor)?
   - How does the emissions intensity of our clients compare to regional averages for the commodities they produce?
   - What are the margins for our clients? How do they compare to regional averages for the commodities provided?
   - How much are our clients investing in low-carbon agricultural methods?
   - Which commodities will be most and least impacted in the low-carbon transition?
   - What potential sources of revenue would our clients be able to access related to carbon markets or bioenergy?

3. **Engaging with clients and updating strategy**
   - Do our senior leaders understand the transition risks of our clients?
   - How are we helping our clients to transition to a low-carbon future? How are we supporting their efforts to advance a just transition?
   - How will the transition risks identified and assessed influence our strategy in the agricultural sector?
   - What specific updates to risk management practices or business activities will be needed to appropriately consider these transition risks in our operations?

Recommendations for risk management

1. **Evaluate all GHGs, not just CO_2**
   - While CO_2 is the primary GHG driving climate change, a focus only on direct CO_2 emissions significantly underestimates the climate footprint of the agriculture sector. Methane (CH_4) from livestock, rice cultivation, and the decay of organic matter may be the predominant source of emissions from an agricultural firm. In addition, nitrogen fertilizers are a leading source of N_2O, a particularly potent GHG. Finally, land clearance and deforestation can also produce large quantities of GHGs. Financial institutions should familiarise themselves with the primary activities of their agricultural clients and determine emissions baselines for all GHGs. The GHG intensity of agricultural activities can provide investors with insights regarding a client's transition risks and the alignment of that client with their own emissions targets Information on emissions intensity can also enable comparisons between agricultural firms and suggest areas where the potential for emissions reductions is highest.

2. **Support regenerative agriculture and soil carbon sequestration**
   - Current agricultural practices have pushed many environmental systems to breaking point. In addition to climate impacts, modern agriculture has harmed biodiversity, increased nitrogen pollution, and reduced soil quality. Regenerative agriculture looks to break this cycle of increased fertilizer use and soil-exhausting monocultures. It actively looks to improve soil carbon content, enhance biodiversity, and expand ecosystem services. Financial institutions should explore agricultural firms that are applying regenerative methods as these methods can reduce transition risks and also improve resiliency to physical climate hazards. In addition, carbon sequestration in soils can play an important role in reducing atmospheric emissions. As carbon markets develop, credible sequestration schemes can also provide agricultural firms with an additional source of revenue. Over time, nations can be expected to enact stronger policies around issues such as deforestation, fertilizer use, and GHG emissions. As such policies come into force, the economic case for regenerative agricultural will grow, as will its role as a mitigant of transition risk.

Adaptive and mitigating actions of clients

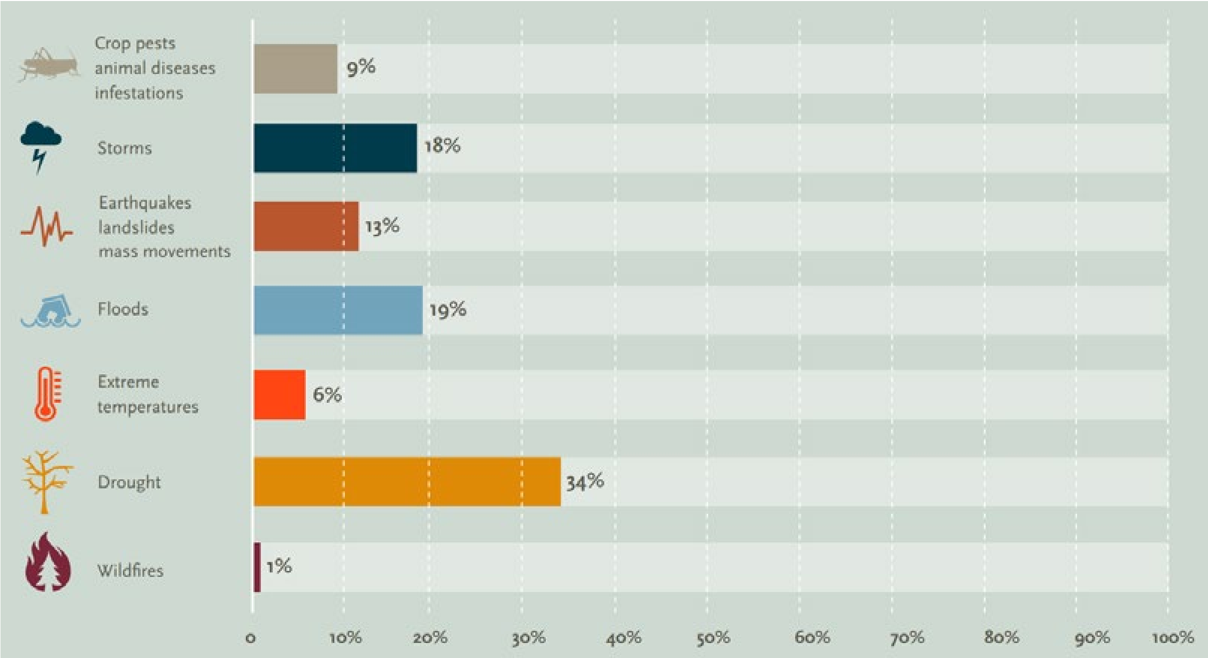
1. **Investing in low-carbon and nature-positive operating models**
   - Many large agricultural firms have significant environmental footprints: from fertilizer use to the production of carbon-intensive food sources. Reducing the negative impacts on the climate and on nature begins by investing in low-carbon and nature-positive operating models. These models may mean using lower quantities of synthetic fertilizers and switching grazing methods for livestock. Changes can also be made in selecting more sustainable crops or livestock to produce. The process of "going green" involves investing in necessary capital assets and considering the impacts of sustainable choices on yields and costs. Agricultural firms should develop a transition plan to outline their journey to sustainability and specify how different parts of their operations will evolve during this transition.

2. **New revenue from carbon storage and bioenergy**
   - The growing emphasis on reducing atmospheric carbon has created a set of opportunities for the agricultural sector. Increasing carbon prices around the world and the emergence of global carbon markets are helping to incentivize the uptake and sequestration of carbon. At the same time, renewable energy mandates often contain incentives for the use of biofuels. Agricultural firms are in a prime position to benefit from these developments. They can even convert land used for high-emitting commodities into forests (afforestation) or switch production to crops that can be turned into biofuels. Other methods of carbon capture may also be considered, such as enhanced weathering, where finely ground-up rocks are dispersed over a field. With rising demand for carbon-neutral fuels and carbon dioxide removal, these opportunities may present a revenue source that can shield some agricultural firms from transition risk.

SECTION B:
Physical risks

Food security is a rising challenge, with almost 9% of the global population going hungry. This is expected to intensify further as the global population peaks at around 10 billion in 2050 (United Nations, 2021). The worsening situation of food security is not just because of population growth. Climate change is also anticipated to play a role due to its negative effects on crop quality, yield, and food safety. The agriculture sector is vulnerable to various physical hazards, including temperature rise, extreme storms, water stress, flooding, wildfires, and invasive crops and pests (World Bank, 2021) (Figure 10). Physical hazards disrupting agricultural operations can lead to significant economic losses for businesses and economies that rely on agriculture.

Figure 10: Crop and production loss per type of physical hazard in the Least Developed Countries (LDCs) and Lower-middle Income Countries (LMICs) from 2008–2018 (FAO, 2021).



Case study 3: Food security risk

BRF Annual Report 2021

A Brazilian Food Processing Company

Overall physical risk impacts

We consider the potential effects of climate change in our operations and in the supply chain and we recognise the vulnerabilities associated with the natural resources and agricultural products that are essential to our activities. The principal risks tied into this matter relate to shifts in the temperature and rain patterns, including droughts and natural disasters, that could affect agricultural productivity, animal welfare and the availability of water and energy. These factors can adversely affect our costs and operational results.

Climate-related strategy measures

We have assumed public commitments to maximize our contribution to the combating of climate change. As well as the commitment to be coming net zero by 2040, we have targets relating to energy consumption, using clean sources and reduction in our use of water, we have improved our means of controlling and traceability of grains originating from the Amazon and Cerrado regions, and we are pursuing actions in a value chain. We periodically analyze the water vulnerability of our industrial plants, as well as the micro and macro drainage basins in the regions, where we operate. We also strive to make an efficient use of hydro energy resources in our operations.

1. Drought and heat stress

Drought due to climate change is one of the leading causes of reduction in agricultural productivity and yield. The agriculture sector absorbs 82% of the total economic impact of droughts (FAO, 2021). Along with heatwaves, droughts have the potential to threaten livestock and feed supplies as well as cause changes in crop production. They are consequently highly costly for the sector. The same is true for heat stress. Agricultural losses account for 26% of the economic losses caused by climate events, increasing to 83% in developing regions that are vulnerable to drought, according to the FAO (FAO, 2019). Between 1991 and 2017, rising temperatures have resulted in an estimated US$27 billion in insurance payments to farmers (Diffenbaugh *et al.*, 2021). Warmer weather can allow certain parasites and pathogens, such as ticks, to survive more easily and expand their range. (EPA, 2017) (For more information, see the sub-section on invasive species.)

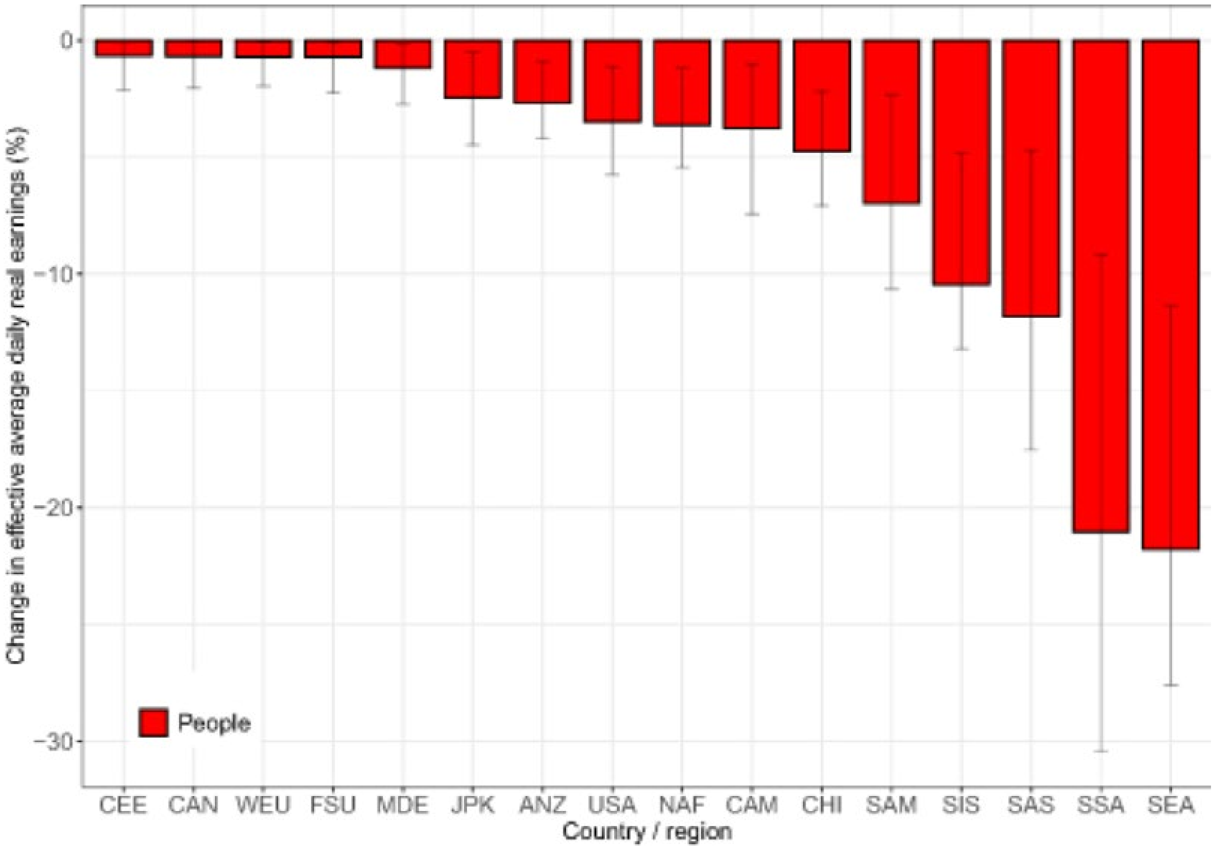
In LDCs and LMICs, droughts cost the agricultural sector over US$37 billion, with 34% of crop and livestock production being lost from 2008 to 2018 (FAO, 2021). In 2020, for instance, temperatures in Iraq hit record heights, with the 2021 rainfall season being below average. The country experienced its second driest period in 40 years (UNICEF, 2021). The induced droughts directly led to significant crop losses and failures. Thirty-seven per cent of farmers reported losing most (i.e. over 90%) of their expected wheat harvest. Crop failures such as these resulted directly in income reduction. More than half of the households in the cities of Anbar, Basra, and Kirkuk recorded income levels that were just over half of what is required to meet their monthly expenditure. While 440,000 IQD (US$302) is needed for subsistence, households earned 263,000 IQD (US$180) during droughts (Norwegian Refugee Council, 2021).

Heatwaves and droughts have the potential to significantly reduce agricultural production, which leads to price increases—especially when demand is rising, as at present. Canada provide a clear example of this dynamic. Droughts in 2021 caused the country's canola production to fall to its lowest level since 2007 (Statistics Canada, 2021), resulting in consumers experiencing a price hike of 4.7% for bakery products (Statistics Canada, 2022). In a similar way, South Africans witnessed rapid increases in food prices after droughts in 2015. The price of beef increased by over 30% (Hitachi, 2017). Rising food prices particularly impact low-income households, who typically spend a larger share of their household income on food. Studies have shown that increasing prices make high-quality food challenging to afford for low-income families, causing them to rely on cheaper and less nutritious alternatives (Mkhawani, 2016).

Temperature rise also affects aquatic biodiversity due to the impact of higher temperatures on marine disease outbreaks, reproduction, and migration of aquatic species (EPA, 2017). Future fishing areas in the tropics are predicted to see declines of up to 40% in potential seafood catch by 2050 due to climate change, posing significant problems for global food supply (Marine Stewardship Council, 2021). Changes in the populations of aquatic species will lead to changes in how "local seafood" is defined in the coming decades, impacting businesses reliant on local catches. For example, between 1999 to 2017, a gradual rise in the temperature of the Gulf of Maine caused lobster hauls to decrease from over eight million pounds to two million pounds (Atlantic States Marine Fisheries Commission, 2018). Similarly, the economy of Namibia is heavily dependent on the fisheries sector, contributing about 3.4% to the nation's total income. However, as one of the driest countries in sub-Saharan Africa, the country is extremely vulnerable to rising temperatures. As ocean temperatures rise, lobsters are becoming scarcer in the area. This has increased the cost of fishing operations, such as fuel and bait, as fishermen must spend more days in the ocean to catch the same amount of lobsters as before. Many companies that relied on lobster stocks have been forced to spend their financial reserves to survive the decrease in catch sizes (Sauer *et al.*, 2021).

Extreme heat also poses rising risks to employees' health and safety in the sector due to the physical exertion of working outdoors for long hours. A study has estimated the number of unsafe hot workdays is expected to double by 2050 (Agriculture Economic Insights, 2021). A study determined that a single additional day with a higher temperature of 35 increased the annual mortality rate by 0.7% in rural India, attributed to a high dependency on outdoor agricultural activities. The effect was practically negligible in urban India and the United States, where individuals are less likely to undertake outdoor agricultural activities (Burgess *et al.*, 2017). Hotter weather can also be linked to decreased labour capacity and agricultural yield. Heat stress may force workers to only work a fraction of their current hours, leading to a reduction in agricultural output and an increase in prices. Some areas might be able to adjust their working hours to avoid peak temperatures during the day. In regions such as the tropics, this has already occurred. Heat stress due to a global temperature rise of 3°C can reduce agriculture labour capacity in sub-Saharan Africa and Southeast Asia by 30 to 50%, which can cause crop prices to rise. Reduced working hours due to high temperatures can also impact hourly wages of employees. Notably, for example, real earnings of unskilled agricultural workers are expected to decline by 20% in both sub-Saharan Africa and Southeast Asia (Figure 11) (Lima *et al.*, 2021).

Figure 11: Change in average, daily agricultural real incomes due to a global temperature rise of 3°C compared to pre-industrial levels (Lima *et al.*, 2021)



Note: CEE: Central and Eastern Europe; CAN: Canada and Rest of North America; WEU: Western Europe; FSU: Former Soviet Union; MDE: Middle East; JPK: Japan and South Korea; ANZ: Australia and New Zealand; USA: United States of America; NAF: North Africa; CAM: Central America; CHI: China-plus (China, Hong Kong, North Korea, Macau, Mongolia); SAM: South America; SIS: Small Island States; SAS: South Asia; SSA: sub-Saharan Africa; SEA: Southeast Asia.

Case study 4: Drought and heat stress

John Deere TCFD Report 2021

An American corporation manufacturing agricultural machinery

Increased severity and frequency of extreme weather events such as heat waves and storms

Risk type: Acute

Description: The IPCC assessment reports find extreme weather conditions will worsen as a result of climate change. Under a high emissions scenario (RCP 8.5), we assume a nine times increase in frequency of heatwaves, 30 percent increase in severity of heavy rain storms, and a 35 percent increase globally in high fire danger. Under a low emissions scenario (RCP 2.6), extreme weather is still expected to increase though not to the extent of the high emissions scenario. As a result, farmers may see reduced crop yields over time due to extreme weather events. Crop insurance can mitigate the direct financial impact of lost yields to farmers, but insurance premiums could rise and reduce profit margins for farmers. These potential changes in revenue and profit margins could result in decreased cash on hand for John Deere products. This analysis considered a long-term view of four years or greater, in alignment with John Deere's strategic planning.

Impact

Time horizon: Long-term

Likelihood: Likely

Magnitude of impact: Medium

Primary potential financial impact: Decreased revenues due to reduced farmer spending

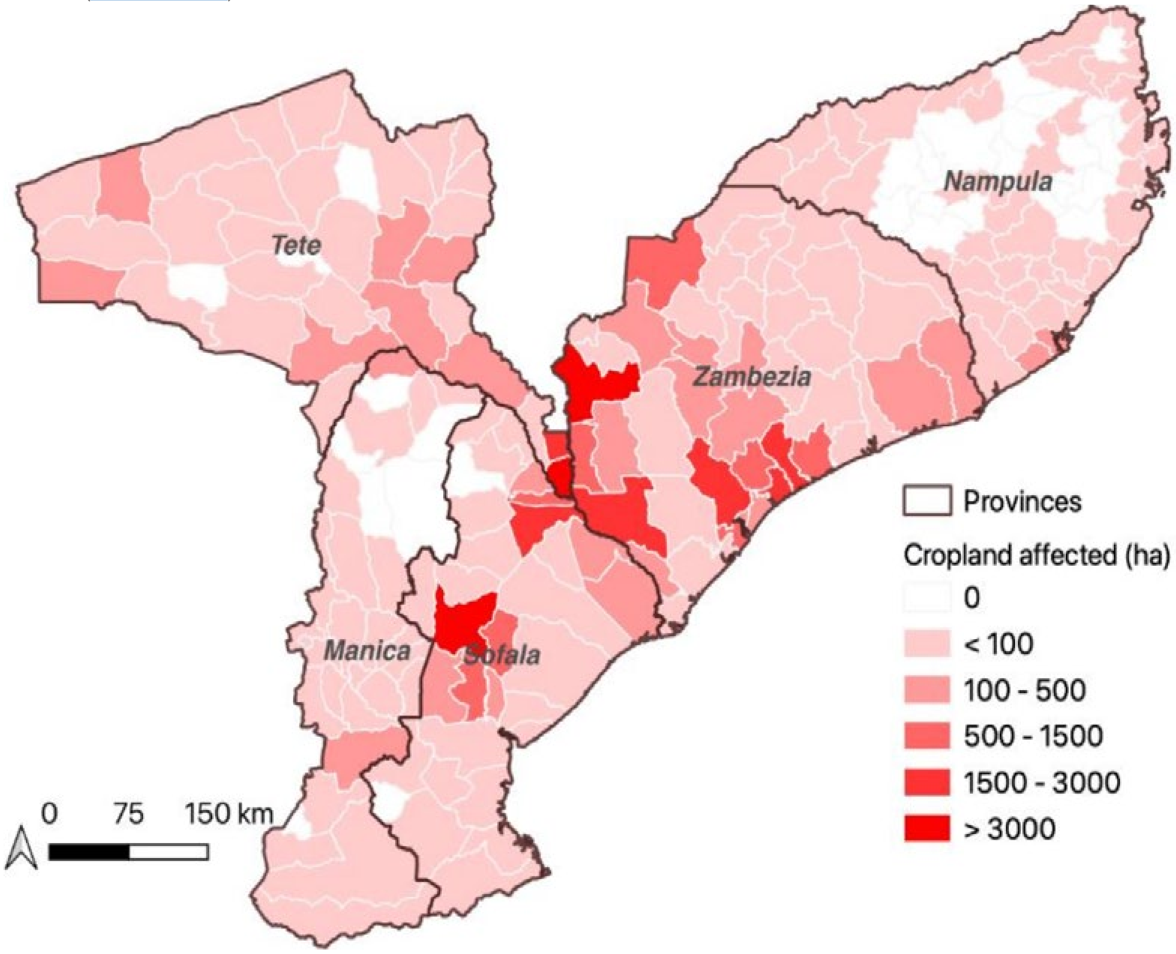
Opportunities for climate mitigation

As farmers look for ways to reduce emissions, especially under a low emissions scenario, John Deere has the opportunity to help farmers meet the emission reduction and sustainability goals, through new equipment and services. John Deere products could support regenerative agriculture practices such as cover cropping, hasten outdated equipment, through performance upgrades or retirement, and supply soil carbon measurement products (similar to nitrogen, sensing product lines).

2. Extreme storms & flooding

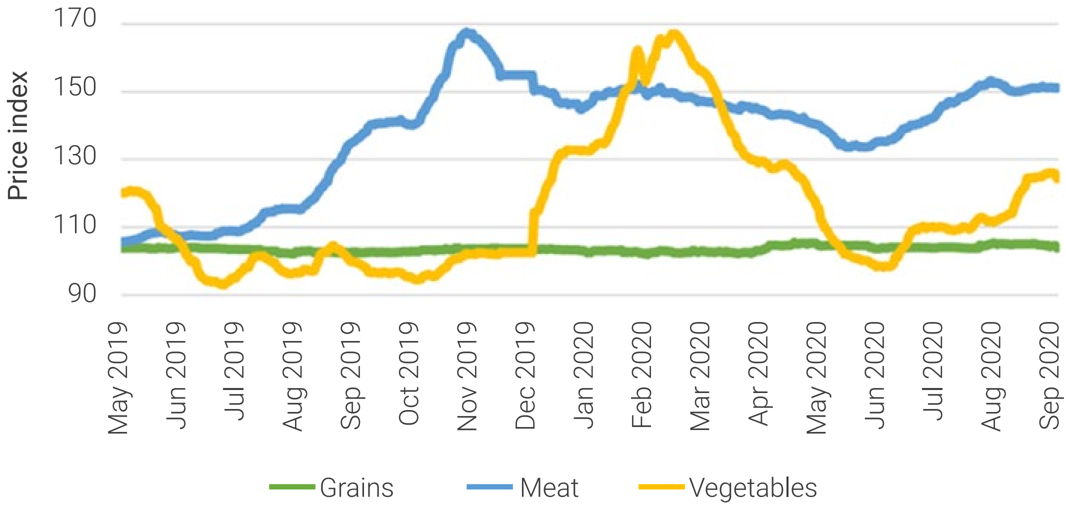
Extreme storms and heavy wind, such as tropical hurricanes and cyclones, pose a significant threat for agriculture production. From 2008 to 2018, severe storms have caused more than US$19 billion in production loss (FAO, 2021). Extreme storms and flooding can reduce the production and quality of feed grains, pastures, and forage crops as well as exposing crops to heavy metals, chemicals, and other contaminants (FDA, 2022). Such events can reduce the supply and quality of crops and livestock. Recovery from storms and floods can be extremely costly. In Mozambique, for instance, agriculture accounts for 25% of the country's gross domestic product (GDP) and employs 80% of the workforce (FAO, 2017). In 2022, tropical storm Ana flooded 42,406 hectares of cropland (Figure 12), and more than 1,000 farmers reported livestock losses. The cost of restoration of agriculture-based activities was estimated at around US$5.3 million (FAO, 2022).

Figure 12: Cropland affected by flooding from tropical storm Ana from 24–28 January 2022 (FAO, 2022)



Decreased crop yields and difficulties in food transportation from extreme storms and flooding can further strain the food supply, resulting in price increases. In 2019, floods in the Upper Midwest and the Mississippi River Valley drastically impacted the food market in the United States, with prices of corn, soya beans, and wheat increasing by 8.5, 21.4, and 18.4%, respectively (Federal Reserve Bank of St. Louis, 2019). Between June and July 2020, meanwhile, southern China was severely struck with heavy rainfall and extreme flooding. The flooding destroyed 6.03 million hectares of cropland and resulted in 1.14 million hectares of crop failure. Destruction from the extreme weather resulted in a direct loss of US$26 billion, accounting for 0.21% of China's 2020 GDP (GOV China, 2020). The financial loss partly contributed to increased food prices. The price indexes shown below (Figure 13) (consisting of data from May 2019 to September 2020) demonstrate that the Chinese price indexes for meat and vegetables steadily increased from June to August 2020, coinciding with the floods (Iowa State University, 2020). Production shortfalls and higher prices can reduce the competitiveness of agricultural products from vulnerable regions when compared with products from regions not prone to extreme storms and flooding.

Figure 13: Chinese Consumer Price Index for meat, grains, and vegetables from May 2019 to September 2020 (Iowa State University, 2020)



Case study 5: Cyclone and flood risk

ADM Annual Report 2021

An American multinational food processing company

Climate physical risks

Increased severity and frequency of extreme weather events such as cyclones and floods could lead to increased direct costs from the disruption of supply chains and impair our ability to deliver products to customers in a timely manner.

Increased severity and frequency of extreme weather events such as cyclones and floods could lead to increased sourcing costs due to limited availability of agricultural commodities and impact ADM's ability to produce goods, which would directly affect sales and revenue.

Climate-related strategy measures

The company aims to mitigate climate change to renewable products and process innovation is, supply chain commitments, and a strategic approach to operational excellence, with a focus on enhancing the efficiency of ADM's production plants throughout its global operations. Ag Services and Oilseeds is focused on traceability of sourcing in different station and working with grows on low carbon agricultural products. Carbohydrate Solutions is focus on decarbonization as a business and buy solutions and buy materials, including fuel and solutions from agricultural products to replace petroleum-based products. Nutrition is focused on developing alternative proteins that can reduce the amount of animal-based proteins that are sources of methane a greenhouse gas emissions. The company anticipate spending between US$170 million–US$300 million on capital projects to achieve the Strive 35 targets. In 2021 15 million was spent on products in support of these goals.

3. Wildfires

Wildfires are another source of climate risk for the agriculture sector. Along with their impact on agricultural production systems through crop and livestock production damage, wildfires can also result in losses in the forestry industry, such as timber (FAO, 2021). Beyond direct flames, smoke from wildfires can damage the quality of crops that are not directly affected. The direct fires, radiant smoke, and heat could also incur extra economic costs to producers by damaging surrounding infrastructures, such as fences and sprinklers (Agriculture Climate Network, 2021). The average annual acreage of land affected by wildfires in the United States has been increasing year on year. In 2021, wildfires destroyed four million acres of farmlands and crops in the Western states of the country. Damage to farming lands can result in a loss in profits for farmers. Furthermore, with the increasing risk of wildfires in California, farmers are facing challenges in the insurance market. In some cases coverage costs have risen, while in others farmers have been dropped by their insurance providers altogether. California has also signed a law to provide limited coverage to farm buildings with a cap much under the value of many farms and with no cover for crop damage (Agriculture Economic Insights, 2021). The increasing frequency and severity of wildfires are also making the working environments for outdoor workers more hazardous. Continued exposure to wildfire smoke can result in heart-related illnesses and respiratory conditions (Agriculture Economic Insights, 2021).

Figure 14: 2019–2020 wildfires in Australia (UNEP, 2020)

Similarly, the 2019–2020 wildfires in Australia led to an economic loss to the Australian food system of AU$4–5 billion (US$2.7–3.3 billion), equivalent to 6–8% of the country's national output for the same period. It is estimated that the wildfires directly damaged AU$2–3 billion (US$1.3–1.9 billion) worth of property, infrastructure, and land. Food production losses account for about AU$2 billion (US$1.3 billion). Health impacts on farmers and other workers in the sector from the wildfires were estimated at around AU$279 million (US$176 million). The wildfires also led to an increase in food prices and a rise in the unemployment rate in affected regions. These impacts passed through the entire food system, from producers to processors, distributors to consumers. Though the effects on food prices were short-lived, the impact on employment was much more long-lasting and significant. These economic losses were only partly compensated through insurance pay-outs and government subsidies, with farmers and other food-related businesses receiving only 20% of economic recovery grants provided by the government in response to the wildfires. The total funding for the recovery of Australia's food and agriculture sector is estimated to be about AU$1.6 billion (US$1 billion) (WWF, 2021).

4. Sea level rise

Rising global sea levels due to climate change also threaten agricultural production. Sea level rise can impact the biodiversity of coastal regions and damage farmlands, especially when accompanied by more frequent tropical storms and high tides. Among the primary impacts of higher sea levels are greater soil erosion, more frequent flooding, increased soil salinity, and lower crop production. These effects can reduce the incomes of farmers and agricultural companies, as well as making global food security more vulnerable (Abia *et al.*, 2021). In Bangladesh, for example, it is estimated that rising sea levels could sink 40% of total farm land and force 200,000 coastal farmers inland (Ohio State University, 2018). In Vietnam, meanwhile, agriculture contributes about one fifth of the country's GDP and employs over one in three (35.6%) of working adults (Nghia, 2017). However, research suggests that a rise in sea levels of one metre could result in the country losing two million hectares of land for rice cultivation, around half of its current size (Huynh *et al.*, 2020). Even though Vietnam's economy is expected to grow at an average annual rate of 5.4% till 2050, rising sea levels are projected to curtail its GDP between 2046 and 2050 by up to 2.5%.

5. Ocean acidification

The ocean absorbs 30% of CO_2 from the atmosphere (NOAA). Due to anthropogenic activities, the concentration of CO_2 emissions in the atmosphere has rapidly increased. As a result, the ocean has absorbed about 29% of additional carbon (USGCRP, 2017). The absorption of CO_2 in the ocean causes an increase in hydrogen ions and a decrease in carbonate ions, which results in ocean acidification (UCSUSA, 2019). Ocean acidity has increased by an estimated 30% since the start of the industrial era (NOAA). Ocean acidification is occurring at its fastest rate in over 66 million years (Zeebe at al., 2016). At the current rate of carbon emissions, estimates suggest that ocean acidity could double by 2100 as compared to the end of the previous century.

Ocean acidification threatens marine biodiversity, especially for marine species that require carbonate ions to build skeletons such as, clams, mussels, crabs, and corals. As a result, increasing ocean acidification can threaten the survival of commercial shellfish businesses. For example, ocean acidification could reduce Dungeness crab populations on the Pacific Coast of the United States, which are the highest-revenue fishery in Oregon and Washington (UCSUSA, 2019). Multibillion-dollar fisheries such as the Alaska king crab and New England sea scallops are also at risk (NOAA, 2020; Scientific American, 2020).

In 2022, the Alaska snow crab harvest was cancelled for the first time due to a substantial decline in snow crab populations in the Bering Sea. The snow crab population decreased from eight billion in 2018 to one billion in 2021. This rapid decline meant that in 2022 the fishery failed to meet the regulatory threshold to open. The population collapse can be partly attributed to stresses from increased water temperatures, which has now sparked trouble for the Alaskan crab fisheries and the communities that depend on them (CNN, 2022; The Guardian, 2022). The Alaskan seafood industry employs more than 50,000 people, pays US$2 billion annually in wages, and includes the country's most significant and most valuable crab fishery (NOAA, 2020; Scientific American, 2020).

Without further mitigation efforts to curb CO_2 emissions, it is expected that annual supplies of clams in the United States will decrease by 35% by the end of the century. Oyster and scallop supplies are set to fall even faster, by 50% and 55%, respectively (UCSUSA, 2019). The shellfish industry could experience a loss of over US$400 million annually in the United States and up to US$100 billion globally by 2100 (Massachusetts Special Legislative Commission on Ocean Acidification, 2021). Similarly, research has shown that ocean acidification could reduce shellfish production by 14 to 28% in the UK by 2100 (Mangi *et al.*, 2018). This could lead to a total loss of £23–88 million (US$27–104 million) to the UK economy due to reduced shellfish production and consumption. Similarly, coral reefs in Florida (valued at US$8.5 billion) are also vulnerable to ocean acidification (NOAA, 2020; Scientific American, 2020). The United States could lose

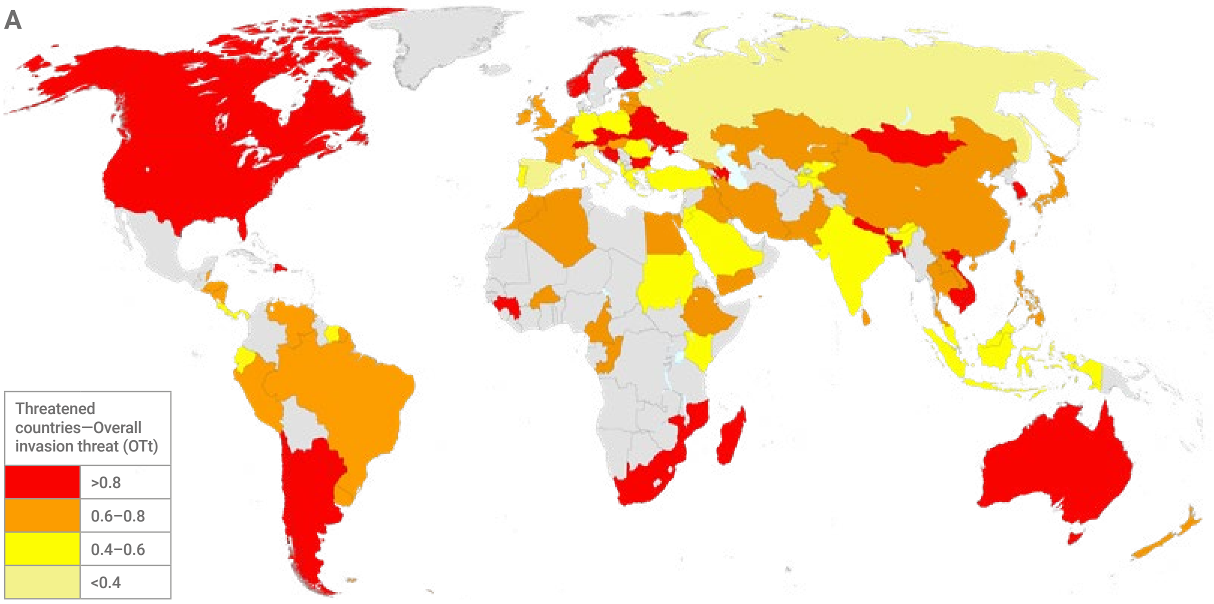
US$140 billion in recreation benefits from coral reefs (UCSUSA, 2019). Florida Keys, Puerto Rico, and the US Virgin Islands are among the regions at most risk to ocean acidification within the United States (NOAA, 2020; Scientific American, 2020).

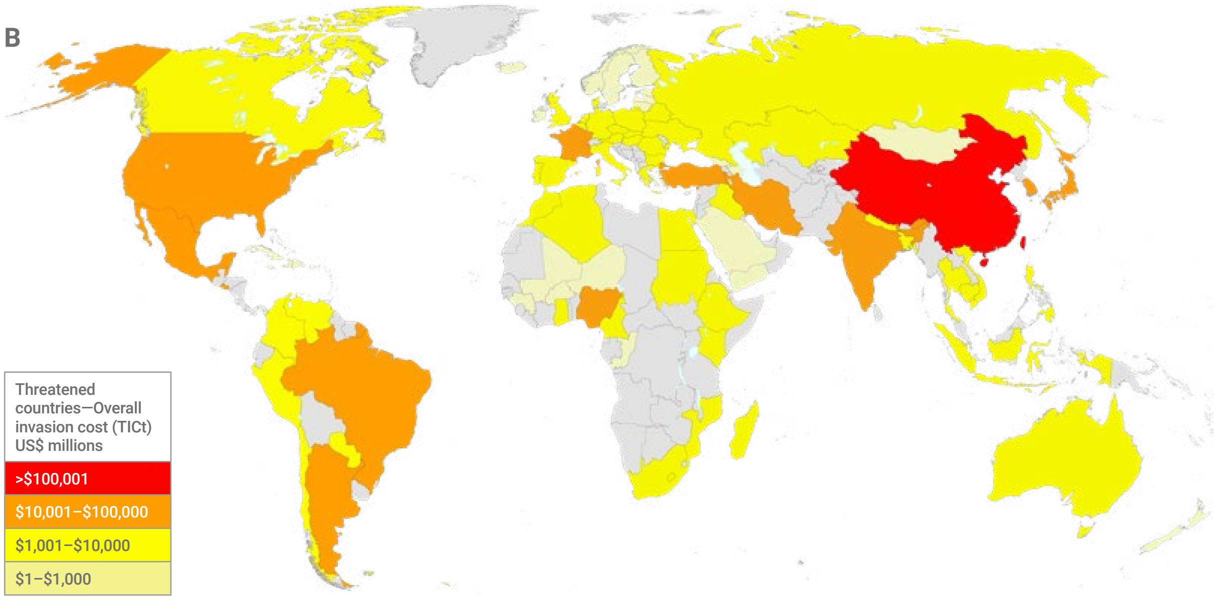
6. Invasive species

Climate change will also exacerbate the spread of invasive species. Extreme events, like droughts, floods, and hurricanes, can introduce invasive species to new regions. As the global temperature rises, invasive species can expand to higher altitudes due to warmer winters, increasing the chance of their survival. The melting of Arctic ice caps will also reduce the duration of the journey between Europe and Asia. It is estimated that the number of established alien species will rise by 36% during the period 2005–2050. Invasive species can reduce the resilience of natural ecosystems and agricultural systems to climate change. These species are one of the main drivers of biodiversity loss and comprise a major threat to global food systems. The increased spread of invasive species will have strong implications for food security and livelihoods (IUCN, 2021).

Invasive species can reduce crop and animal health, impacting agricultural systems (IUCN, 2021). Large agricultural producers, such as the United States, China, India, and Brazil, have the highest potential costs from invasive species (PSU, 2016). Annually, invasive species cost the global economy more than US$70 billion (IUCN, 2021). In the United States, losses in crop and forest production from invasive insects and pathogens account for about US$40 billion annually (Paini *et al.*, 2016). Figure 15 illustrates invasion threats to countries and their total invasion costs.

Figure 15: (A) Overall invasion threat to countries; and (B) Total costs of invasions to countries (Paini et al., 2016)





The Desert Locust is one of the most damaging migratory pests in Africa, Asia, and the Middle East (Figure 16). A small swarm can be made of up to 80 million locusts. In a single day, a swarm of this size can consume enough food to feed 35,000 people. Large swarms are even more destructive, consuming up to 1.8 million metric tons of vegetation at a time (sufficient for 81 million people). In 2019/2020, swarms of locusts infected crops in 23 countries. This was the worst infestation recorded in Ethiopia and Somalia for 25 years, in India for 26 years, and in Kenya for 70 years (World Bank, 2020). Pasture and croplands in Ethiopia, Kenya, and Somalia suffered enormously, resulting in potentially severe consequences in a region where about 12 million people already face food insecurity. Impacts on food security can also threaten livelihoods, increase food prices, and elevate poverty (FAO, 2020). Another country where the upsurge in locust outbreaks has been devastating is Pakistan. Agriculture accounts for 20% of Pakistan's GDP and provides livelihoods for 61% of its population. During the 2019/2020 outbreak, the FAO estimated that 25% of growing crops were damaged, with losses reaching around US$5.7 billion (Sultana *et al.*, 2021). The Government of Pakistan has estimated that desert locusts caused financial losses of US$3.4 billion to US$10.21 billion in 2020 and 2021 (UN, 2020). As a result of the major outbreak, the cost of sugar doubled and flour prices increased by 15% in 2020 (Showler *et al.*, 2022).

Figure 16: Desert locust swarms in Kenya (National Geographic, 2020)

Box B: Physical risks impact the Mexican Agriculture sector

Mexico's geographic location makes it vulnerable to climate change. In some farming regions, the temperature is expected to rise more than the global average. In 2020, the director of the Agriculture Ministry's climate change group claimed that 75% of soil in Mexico had become too dry to cultivate crops (Al Jazeera, 2020).

In 2021, two-thirds of the country was threatened by a long-term drought and high temperatures, resulting in crop loss and water shortages, impacting 70% of Mexico. In some key farming regions, the temperature rose to up to 40°C. An estimated 20% of the country was experiencing an extreme drought, four times the annual average for the previous decade. Severe droughts prompted the government to seed clouds with silver iodine in the farming states of Sinaloa, Sonora, and Chihuahua (Reuters, 2021).

Mexico is the world's second-largest importer of maize. However, climate change poses a significant risk given the increase in droughts and changing rain patterns that it causes. Maize cultivation in the region of Tehuacán decreased by 18% (40,000 hectares) between 2015 and 2019. Farmers have noted a decrease in corn yield, with one hectare of land now producing just about 700 kilograms of corn compared to four tons previously. Tehuacán farmers and officials have blamed climate change for the decrease in production. According to the Washington DC-based National Academy of Sciences, corn yield is expected to fall significantly due to climate change, especially in countries like Mexico that are situated in the tropics (Al Jazeera, 2020).

An increase in the frequency and duration of droughts are causing farmers to switch the types of crops they produce. For example, many farmers are switching out of corn and cereals in preference for crops that require less water, such as pistachio nuts and cacti (Al Jazeera, 2020).

7. Physical risk guidance

Key physical risk questions for financial institutions to consider

1. **Gathering information**
   - What are the most prevalent physical risks across our portfolio footprint?
   - What impact have past physical hazards had on agricultural production across out portfolio footprint?
   - What have our clients disclosed in their financial, sustainability, and climate reports regarding their physical risks?
   - How many of our clients have business resiliency plans?
   - Do we have locational data on the major assets of our clients?

2. **Assessing the risks**
   - How much of our portfolio operates in areas of high physical risk?
   - What does our exposure to higher-risk clients look like? What are the terms of our financial relationship (e.g. debt/equity, tenor)?
   - Have we looked at physical risk scenarios to see how these risks will evolve over time? Have we considered short-term, medium-term, and long-term risks?
   - How would physical hazards disrupt our clients' production and distribution activities?
   - How long might disruption last? What might be the potential loss in revenue?
   - How might insurance markets (and insurability) change in the face of worsening physical risks to agricultural assets?
   - Have we explored if local adaptation measures are being taken and, if so, how they will increase the resilience of assets to climate change?
   - How much are clients investing in adaptation and resiliency measures?

3. **Engaging with clients and updating strategy**
   - Do our senior leaders understand the physical risks of our clients?
   - How are we helping our clients to transition to more resilient infrastructure?
   - How will the physical risks identified and assessed influence our strategy in the agricultural sector?
   - What specific updates to risk management practices or business activities will be needed to appropriately consider these physical risks in our operations?

Recommendations for risk management

1. **Consider global events and supply chains**
   - Many agricultural products (maize, soya beans, wheat, etc.) are global commodities. While financial institutions have explored direct physical risks to agricultural clients, the implications of physical hazards in other parts of the world are not always considered. A key example occurred ahead of the Arab spring in 2010 and 2011 when poor harvests in Russia and across Asia drove up global grain prices, precipitating major consequences for Middle Eastern societies. Financial institutions should not only monitor the direct physical impacts of climate-related events; they should also be aware of the potential impacts of such events on agricultural markets in other parts of the world. Financial institutions should also understand the supply chains of their agricultural clients and work to identify their potential vulnerabilities. From agricultural production and processing through to transportation and sale, climate-related risks can manifest themselves in diverse ways. An evaluation of supply chain vulnerabilities can help build resilience both on the part of agricultural clients and in financial portfolios.

2. **Integrate productivity losses into forecasts**
   - Existing agricultural research has extensively explored the impact on crop yields of both temperature and precipitation, two variables directly affected by climate change. This research may not be well-known to financial institutions with agricultural exposures, but it can provide useful insights into emerging risks. By understanding optimal growing conditions for agricultural products and comparing deviations in these conditions under climate scenarios, financial institutions can quantify potential productivity losses with direct revenue implications. Given that extreme events such as floods and heatwaves negatively affect labour productivity, the rising costs of labour and the direct damages from acute events should also be factored into financial projections.

Adaptive and mitigating actions of clients

1. **Selecting for resilience**
   - As climatic conditions worsen, agricultural productivity is increasingly under threat. Not only do warming temperatures exceed optimal growing conditions for many crops in regions around the world, but extreme weather (both floods and droughts) has the ability to destroy harvests. Despite the increasing risks, agricultural firms can select for resilience in the commodities they produce and in their methods of production. This process begins by evaluating which crops are going to be less dependent on scarce resources, such as water in dry regions, and which are more tolerant of weather events. Sometimes, this means selecting varieties of crops or livestock that are able to survive sudden heatwaves or cold spells; at other times, it may mean selecting different products that are better adapted to the new climate of the region. Agricultural science can also play a supporting role in enhancing resilience as firms can purchase drought or pest-resistant strains of crops.

2. **Improved resource management and circularity**
   - As discussed above, agricultural firms can mitigate some of their physical risks by selecting products that are less resource intensive and more resilient. Being mindful about resources should also extend to growing and production operations. Critical assets such as high-quality topsoil or underwater aquifers are becoming depleted in many areas, with potentially dire consequences for agricultural output. To avoid ever-worsening conditions, the agriculture sector should adopt the principles of circularity in its treatment of resources. Examples of this approach come from regenerative farming methods, elimination of purely monoculture fields, and improved nutrient cycling. These tactics, along with numerous others, can provide resilience in an increasingly uncertain climatic future.

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