Climate Risk & Adaptation in Global Food

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First Sentier MUFG
Sustainable Investment Institute

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This report was authored by Shuayb Ismail (Director, Baringa) and Zdravko Slavov (Senior Manager, Baringa).

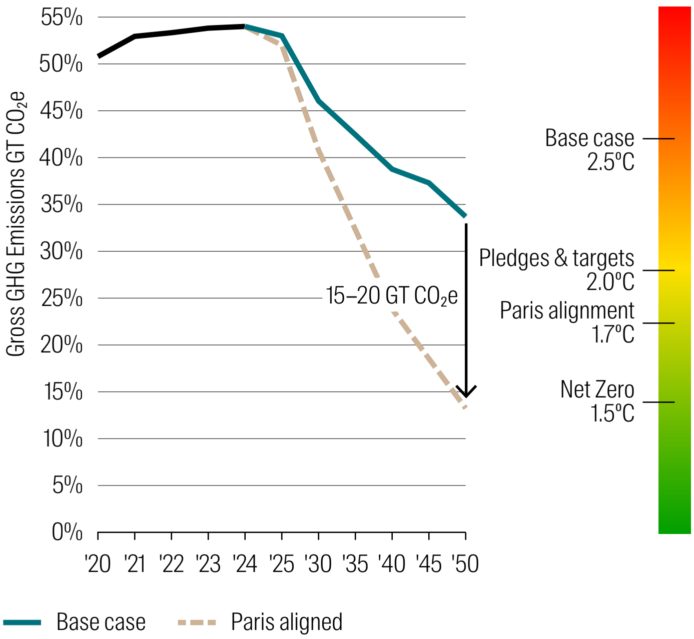
Image caption

Executive summary

1 The purpose of this report is to **highlight the major climate change and extreme weather impacts on global food supply chains** through to 2050 and propose actions which businesses and investors can take to support food security, food system resilience, and commercial returns.

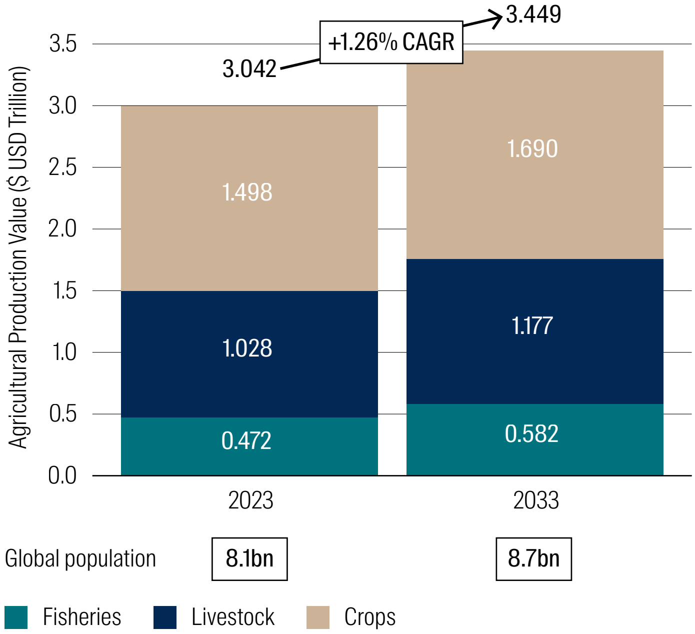
2 The world is **on track for 2.5 degrees global warming by 2050 at the rate of current policies and climate action,**[1] with an expected deficit of 15-20 GT CO2e according to Baringa's modelling. The Intergovernmental Panel on Climate Change (IPCC) has confirmed positive correlations between increased emissions and increased occurrence of extreme weather hazards. This means that both direct and indirect investors across globally integrated supply chains like food will continue to face exponentially increasing climate risks and extreme weather hazards over the next several decades.

Figure 1. Baringa GHG emissions base case (2020–2050)[1]



Source: Baringa analysis based on global energy and industry emissions (2024).

Figure 5. Global agricultural growth (2023-2033)[2]



Source: US Energy Information Agency as at 20 March 2024.

3 Global food **demand is expected to grow at 1.26% CAGR over the next decade, driven by population, economic, and urbanisation growth**. Importantly, agricultural production value is growing in almost every region at a faster rate than the population (0.7% CAGR) especially driven by economic growth and changing diets. Moreover, this demand will happen in a highly integrated global food system where food can travel 1,000s of miles and multiple processing steps before it reaches the table.

4 Supplying this demand will face significant climate risks and extreme weather hazards leading to a higher likelihood of increased insecurity and commercial losses across the food system.

5 **The global food system faces six key extreme weather events** (temperature extremes, heavy precipitation, flooding, droughts, extreme storms, and compound events) which have the potential to cause significant impact against infrastructure, food value chains, and wider natural ecosystems with a projected cost of up to $38 trillion in damages by 2050.[3]

1 "Baringa Base Case", Baringa (2024); this considers full Greenhouse Gas Emissions from energy, industry, agriculture, and land use change & forestry, and is informed by the outcome of the latest climate policies, pledges, and their deliverability.
2 "World Population Prospects", United Nations (2024) and "Agricultural Outlook", OECD-FAO (2024).
3 "Emissions Gap Report", UNEP (2024) and "The economic commitment of climate change", Koz et al., Nature (2024).

6 The global food system also has **a range of measures proven to mitigate or adapt to climate change leading to increased climate resilience and protected food system assets**. For example, these include responsible soil management (e.g. through conservation tillage, biochar application, or crop rotations), precision farming to optimise fertiliser usage, and livestock and fishery breeding aimed at ensuring the ability of animals to better withstand climate change impacts (e.g. improved heat resilience or adapted to lower quality feed).

7 Climate risks and extreme weather impacts will continue to be a recurring feature of the changing climatic system leading to a rebalancing of the market. **5 key market shifts will define the new agricultural realities:**

Shift in geographic viability
Changing climate patterns and demand for 'locally sourced' is increasing the commercial viability of higher value and volume products for previously too cold regions (e.g. Northern Europe)

Shift to climate resilient species
Temperature spikes and increasing droughts are changing both crop and livestock farming towards species that are more heat or cold resilient (e.g. from cattle to goat and camel farming)

Shift in technology innovation
Technology innovation is accelerating including the use of data analytics and AI to increase farming yields through up-to-date meteorological data on weather patterns to optimise inputs

Shift in consumer preferences
Dietary choices are changing across markets with a greater emphasis on linkages to health and sustainability in high-income countries, and rising livestock intake in key emerging markets

Shift in agricultural trade
Geopolitical and climate changes can mute agricultural trade in the coming decade compared with previous years requiring corporates to ensure diversified supply chains and markets

8 Ultimately, the world remains on track towards a 2.5° scenario by 2050 unless we can course correct and fast. **Investors can facilitate this by engaging with their portfolio companies, wider sectors, policy makers, and civil society** to shape agricultural value chains towards mitigating the harmful impacts of current practices and adapting to changing weather patterns and consumer demands.

There are three key recommendations for investors to:

8.1 **Incorporate physical climate risk into their investment decision making** including through updating due diligence processes to consider cross-value chain climate impacts (e.g. on upstream commodity input prices).

8.2 **Support companies to consider and disclose (to the board and/or publicly) on 10 areas** that can help them to assess their climate risks and opportunities. These include:

i. **Value chain maps** especially outlining core partners and regions that account for over 20% of either supply or offtake;

ii. **Climate risk scenarios over at least 10 years** across all key extreme weather hazards for themselves and core supply chains;

iii. **Input price scenarios over 5 years** including identifying key drivers for volatility;

iv. **Nutrient density trends across key products** linked to key drivers (e.g. reduction in wheat protein density due to drought);

v. **Emissions trajectories across scope 1–3 for their operations** (including breakdowns between different emission types if possible);

vi. **Natural resource consumption across direct and indirect operations** (e.g. spatial footprint of land controlled, land use change, water consumption) and opportunities to minimise resource usage;

vii. **Priority and material ESG factors impacted or impacting direct and dependent operations** (e.g. water, biodiversity loss, soil health, worker welfare);

viii. **Impacts of current and projected carbon taxes (and other relevant taxes like sugar taxes)** on their operations impacting both economics as well as product mix;

ix. **Market demand trends at the end of their agricultural value chains** that could change customer and consumer demand (e.g. towards health, sustainability, or higher protein foods); and

x. **Operational, product, and investment plans** to decarbonise operations, improve material impacts, and hedge towards future consumer demand.

8.3. **Formulate and pursue an engagement strategy covering portfolio companies, other investors, the wider industry, and civil society** that leverages their influence, convening power, and financial resources to steward their portfolios away from significant climate risk and towards a more resilient future.

Detasseling corn in Illinois, USA.

1.0 | Introduction

1.1 The current climate trajectory

The world is on track for 2.5 degrees global warming by 2050 at the rate of current policies. This means both direct and indirect investors across globally integrated value chains like food will continue to face exponentially increasing climate risks and extreme weather hazards to their investments over the next several decades.

> *"Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020."*[1]

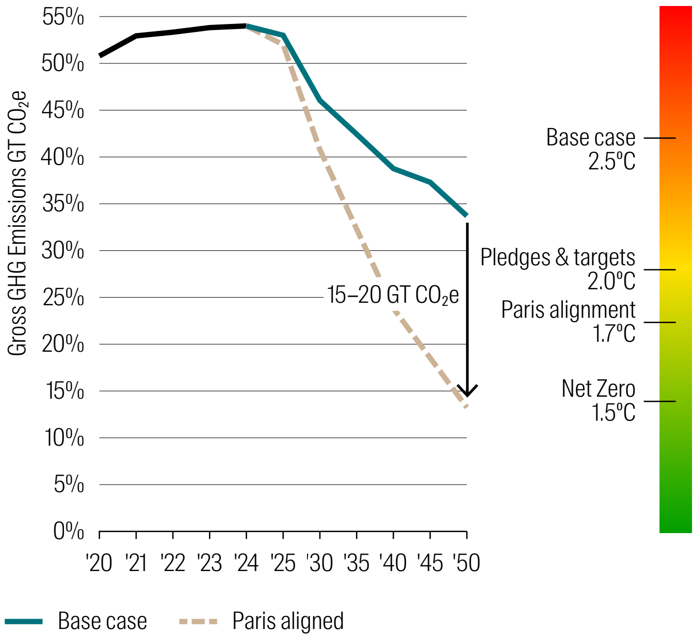
This has led to an increased frequency and intensity of climate risks and extreme weather hazards. Baringa models the outcomes of the latest climate policies and their deliverability to inform a realistic 'Base Case' for global emissions reduction. Where the Paris Agreement set a goal to limit warming to 1.5 degrees by 2050, Baringa's 'Base Case' sees a deviation of 15-20 Gt CO2e at the current trajectory with a likely scenario of 2.5 degrees by middle of the century.[2]

These increased emissions are a trigger for the broader challenge of climate change. The Intergovernmental Panel on Climate Change (IPCC) has confirmed positive correlations between increased emissions, enhanced radiative forcing,[3] global warming, and the associated climate feedback in the form of extreme weather hazards.[4] It is this feedback that causes the most immediate damage. **In fact, the existing emissions and global warming trajectory could result in up to US$38 trillion in damages across infrastructure, food value chains, and wider natural ecosystems.**[5]

This is especially so as the world races towards crossing climate tipping points. These are defined as a threshold beyond which a system cannot return to its previous equilibrium. Tipping points exist in the cryosphere, oceanosphere, biosphere, and atmosphere. Examples include the collapse of the West Antarctic Ice Sheet, the slowdown of the Atlantic Meridional Overturning Circulation (that circulates currents and heat in the Northern Atlantic), or the destruction of rainforests or coral reefs. These tipping points threaten significant impacts on global agricultural systems by escalating impacts (e.g. leading to a >50% reduction in land suitable for wheat and maize production).[6]

'Extreme weather' refers to a singular occurrence of a rare event for that place or time (such as the hottest day on record or an unprecedented level of rainfall). In contrast, 'climate risk' refers to a continued pattern of extreme weather over longer periods. There are 6 key hazards modelled by both Baringa and the IPCC with the potential to reduce agricultural yields up to 20% in a 2.5° scenario (see *Figure 2*).[7]

Figure 1. Baringa GHG emissions base case (2020–2050)[8]



Source: Baringa analysis based on global energy and industry emissions (2024).

1 "Climate Change 2023 Synthesis Report", IPCC (2023).
2 "Baringa Base Case", Baringa (2024); this considers full Greenhouse Gas Emissions from energy, industry, agriculture, and land use change & forestry, and is informed by the outcome of the latest climate policies, pledges, and their deliverability.
3 Radiative forcing refers to a change in the net balance of solar energy remaining within the Earth.
4 "Weather and Climate Extreme Events in a Changing Climate", IPCC (2021).
5 "Emissions Gap Report", UNEP (2024) and "The economic commitment of climate change", Koz et al., Nature (2024).
6 "Climate Tipping Points", OECD (2022).
7 "Climate Change 2023 Synthesis Report", IPCC (2023).
8 "Climate Change 2023 Synthesis Report", IPCC (2023).

Supercell thunderstorm in Texas, USA.

Figure 2. Extreme weather hazards across climate scenarios[9]

	Extreme weather	Description	Impact	Example recent occurrence
	Temperature extremes	Prolonged periods of extreme heat or cold	Reduced crop and livestock yield due to heat stress and increased water demand	Heat waves in France in 2022 led to losses for livestock farmers across the country estimated at $2-4.5 billion[10]
	Heavy precipitation	Intense rainfall leading to water saturation	Soil erosion, crop damage, delayed farming, and waterlogging of fields	Heavy rains and hurricanes across the US caused 18% of the total c.$22 billion in crop losses from extreme weather[11]
	Flooding	Overflowing of water bodies onto land and coastal regions	Destruction of crops, contamination of freshwater supplies, and loss of land	Floods in Pakistan in 2022 destroyed 2.2 million hectares of crop land with losses of $3.7 billion[12]
	Droughts	Prolonged periods of low rainfall, leading to water scarcity	Crop failures, livestock loss, and reduced water availability for irrigation	Drought in Ethiopia in 2022 led to 4 million livestock deaths worth over $700 million[13]
	Extreme storms	Powerful storms, such as hurricanes, typhoons, or cyclones	Damage to infrastructure, disruption of food supply chains, and loss of crops	Typhoons in the Philippines in 2022 caused $33 million of agricultural damage especially in fishery businesses[14]
	Compound events	Multiple hazards occurring concurrently or in quick sequence	Increased vulnerability of food systems overwhelming adaptive capacity	Sequential droughts and floods in Australia in 2022 devastated crops and livestock with losses of $3 billion[15]

9 Baringa analysis.
10 "'Absolute emergency': 'Billions' needed to compensate drought losses in France", euronews (2022).
11 "Major Disasters and Severe Weather Caused Over $21 Billion in Crop Losses in 2023", Farm Bureau (2024).
12 "Pakistan: Flood Damages and Economic Losses Over 30 billion and Reconstruction Needs Over 16 billion", World Bank Group (2022).
13 "The Horn of Africa is facing an unprecedented drought. What is the world doing to help solve it?", WEF (2022).
14 "Flash Update No3: Philippines: Super Typhoon Noru/Karding", OCHA (2022).
15 "The Great Deluge: Australia's New Era of Unnatural Disasters", Climate Council (2022).

Figure 3. Example impact flows for extreme weather hazards on the food system[16]

Extreme Weather Hazards	Temperature extremes	Heavy precipitation	Flooding	Droughts	Extreme storms	Compound events
First Order Impacts	Soil degradation	Water scarcity	Labour shortage	Biodiversity loss	Energy price Inflation	Warming waters
			Nutrient cycling decline	Pollination service decline	Pest control disruption	Loss of genetic diversity
Production Impacts	Farmland damage	Inputs reduction	Feed shortage		Wild capture migration	Aquaculture facility damage
	Crop yield reduction		Livestock injury, stunting & mortality		Fishery stock decline	
Value Chain Impacts	Agricultural output fall	Low plant productivity	Transport disruption	Market shortages	Increased food loss (incl. from perishables lost in transport)	
Societal Impacts	Lower food resilience		Greater food insecurity		Social unrest	
Investor Impacts	Heightened risk profiles and insurance premiums	Increased capital and operational expenditures	Increased price volatility	Market turbulence	Long-term decline in yields	Increased stranded asset risks

Biodiversity impacts

Figure 3. demonstrates the flow of impact from extreme weather hazards through first order, production, and wider value chain effects. Weather hazards can occur singularly or concurrently as a compound event. These not only impact energy prices and labour (e.g. blocking transport routes or inhibiting productivity in heatwaves), but they also have a direct impact on the natural environment including soil, water, and biodiversity.

For example, the global food system is already one of the leading causes of biodiversity loss, with agriculture responsible for endangering 86% of the 28,000 species currently at risk of extinction[17]. This will only get worse if we cannot mitigate or adapt to rising global temperatures and extreme weather to reduce its first order impacts. These first order effects lead to production impacts lowering yields across crops, livestock, and fisheries. This reduced agricultural output also, in turn, lowers plant productivity. There are also wider effects from extreme weather hazards on transport and markets, leading to increased food loss. Ultimately, this results in wider societal and investment impacts such as heightened risk profiles, increased operational costs, and increased stranded asset risks especially if extreme weather hazards convert into longer term climate risks.

Case Study 1. Compound event agricultural losses in Texas

In 2023, a series of extreme weather events hit Texas starting with widespread rains in May and June followed by the driest summer on record.[18] In addition to heat-related stress to agricultural labour and land, this also caused significant water scarcity impacting irrigation systems and contributed to an active wildfire season with more than 1,000 fires across the state. Ultimately this led to US$4.8 billion in losses including $2.3 billion in cotton and $1.5 billion in forage and range land.[19] In addition to lower agricultural output, this also spiked crop insurance claims (both public and private).[20]

16 Baringa analysis.
17 “Climate Risk in the Agriculture Sector”, UNEP FI (2023).
18 “Texas drought has deepened amid this year’s brutal heat”, The Texas Tribune (2023).
19 “Major Disasters and Severe Weather Caused Over $21 Billion in Crop Losses in 2023”, Farm Bureau (2024).
20 “Amid heat waves and drought, crop insurance costs skyrocket”, Houston Chronicle (2023).

1.2 | Growth in the global food system

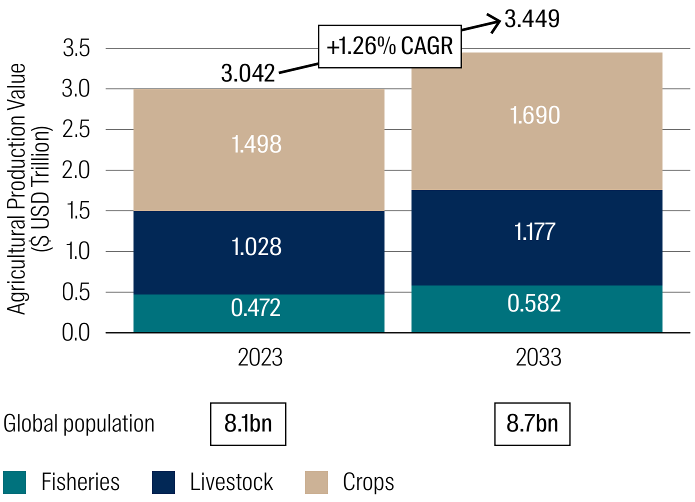
The backdrop to these risks is the growth in global food demand driven by population, economic, and urbanisation growth. This demand will happen in a highly integrated global food system where climate risks in one part of the world can lead to lower yields and greater prices elsewhere, impacting indirect investors.

The world population is forecast to increase by 600 million people through to 2033 with a corresponding average global GDP growth of 2-3% p.a.[21] Whilst the fastest growing regions will continue to be Africa and Asia (responsible for over 90% of total net population growth and whose GDP growth is expected to be 1-2% higher than the global average), the aggregate effect of this increase will be additional pressure on agricultural demand and its downstream sectors. This includes food, but also chemicals, energy, pharma, and textiles.

The food system can be divided between three distinct groups: crops, livestock, and fisheries. Collectively, these three groups held a net production value of over $3 trillion in 2023 with growth expectations of 1.26% compound annual growth rate (CAGR) over the next decade. There are several trends driving this growth including increased productivity from improved farming techniques and economic growth driving demand for premium foods such as sugars, high-value dairy, and other protein products.[22]

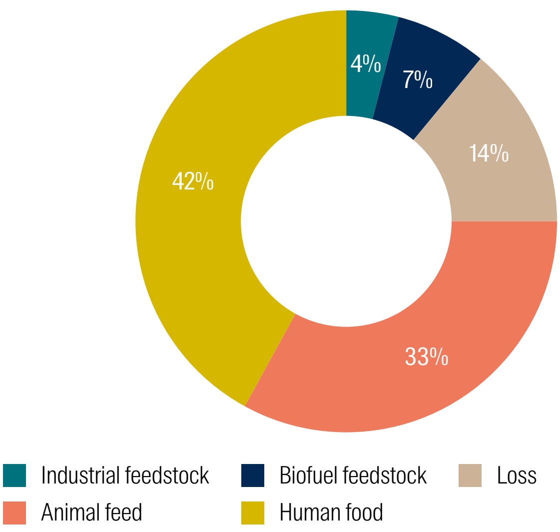
Another layer to this demand view is also the distinction between different demand use cases. Crops represents the largest share of agricultural production, accounting for 45% of total output value. However, not all this goes directly for human consumption. 42% is used for human food whilst a further third goes to animal feed (especially grains such as corn and soya). The remainder is focused on feedstock for energy and industry or is lost through the value chain.

Figure 5. Global agricultural growth (2023–2033)[23]



Source: US Energy Information Agency as at 20 March 2024.

Figure 4. Average crop consumption share (2023)[24]



21 "World Population Prospects", United Nations (2024) and "Agricultural Outlook", OECD-FAO (2024).
22 "Agricultural Outlook", OECD-FAO (2024), "Pathways towards lower emissions: A global assessment of the GHG emissions and mitigation options from livestock agrifood systems", FAO (2023), "Statistical Yearbook", FAO (2023), and "The State of World Fisheries and Aquaculture", FAO (2024).
23 "Agricultural Outlook", OECD-FAO (2024).
24 "World Population Prospects", United Nations (2024) and "Agricultural Outlook", OECD-FAO (2024).

Figure 6. Population and agricultural production value growth by region (2023–2033)[25]

Europe and Central Asia (incl. UK, European Union, Türkiye, and Central Asian states)

Population (Bn)

2023		2033
0.93	+1%	0.94

Agricultural production value ($ USD Bn)			
Crops	176.30	+8%	190.80
Livestock	225.00	+6%	237.80
Fisheries	53.30	+10%	58.60

Latin America and Caribbean (incl. South and Central America, and Caribbean states)

Population (Bn)

2023		2033
0.66	+8%	0.71

Agricultural production value ($ USD Bn)			
Crops	183.80	+14%	210.30
Livestock	152.90	+12%	171.40
Fisheries	49.00	+23%	60.40

North America (incl. Canada and the United States)

Population (Bn)

2023		2033
0.38	+6%	0.40

Agricultural production value ($ USD Bn)			
Crops	140.8	+15%	162.20
Livestock	132.90	+8%	143.80
Fisheries	16.00	+7%	17.10

Near East and North Africa (incl. North Africa and Middle East such as Algeria, Egypt, UAE)

Population (Bn)

2023		2033
0.45	+19%	0.53

Agricultural production value ($ USD Bn)			
Crops	26.30	+25%	32.80
Livestock	39.50	+26%	49.80
Fisheries	17.10	+8%	18.50

25 "World Population Prospects", United Nations (2024) and "Agricultural Outlook", OECD-FAO (2024).

South and Southeast Asia (Asian markets excl. Developed and East Asia)

Population (Bn)

2023		2033
2.74	+10%	3.02

Agricultural production value ($ USD Bn)			
Crops	377.10	+17%	442.30
Livestock	199.10	+38%	274.70
Fisheries	158.10	+12%	177.80

Developed and East Asia (incl. China, Japan, Republic of Korea, Australia, and New Zealand)

Population (Bn)

2023		2033
1.63	–1%	1.61

Agricultural production value ($ USD Bn)			
Crops	446.90	+3%	461.90
Livestock	242.90	+5%	254.30
Fisheries	199.80	+13%	254.30

Sub-Saharan Africa (all sub-Saharan states incl. Ethiopia, Nigeria, and South Africa)

Population (Bn)

2023		2033
1.15	+30%	1.50

Agricultural pproduction value ($ USD Bn)			
Crops	147.00	+25%	190.00
Livestock	36.00	+26%	45.00
Fisheries	23.00	+8%	25.00

Agricultural production value is growing in almost every region at a faster rate than the population. A key driver of this is shifting dietary preferences and rising per capita calorie intake linked to economic growth, especially in emerging markets. Per capita intake of sweeteners (in crops) and fats (in livestock and fisheries) is expected to increase especially in India, Southeast Asia, and Latin America[26].

Whilst there is still an economic distinction between countries, in general there will be greater transition from staples to higher-value food products. This push away from staples adds further complexity, especially as it means greater processing of commodities. This will result in lengthened value chains across regions, thereby compounding the impact of climate risk and extreme weather hazards.

The wider food system can be understood as a complex network of drivers, mechanisms, and industries (see *Figure 7)*. Between farm and fork, food typically is processed through 7 key stages along the value chain. Amongst these, production and processing account for 35-60% of total economic value (lower for crops and higher for fishery businesses).

Food trade is global where inputs from one continent often support production in another, to be processed in a third, and finally marketed and consumed in a fourth. An example is the soya bean market (see Case Study 2). In this way, downstream investors of agribusiness or food companies are indirect holders of climate risks upstream in inputs, production, processing, and distribution.

26 "Agricultural Outlook", OECD-FAO (2024).

Dairy cows, Bega Valley, Australia

Figure 7. Integrated food value chain and cross-cutting drivers[27]

Value Chain	1. Inputs	2. Production	3. Processing	4. Distribution	5. Marketing	6. Consumption	7. Waste/recycle
Description	Production of seeds, feed, water, fertiliser, energy, machinery and labour	Farming crops, animal husbandry, and wild or aquaculture fishery operations	Aggregation and transformation of raw products (e.g.. milling or slaughtering)	Transportation of products to consumption markets incl. for exports	Wholesale and retail activities (e.g.. packaging and promotional activities)	Purchase and final consumption of agricultural products	Collection, disposal, or processing of agricultural and biogenic waste
Economic share	10–15%	20–35%	15–25%	10–15%	5–10%	N/A	N/A
Key actors	Input agents Energy firms Agronomists	Farmers Rancher Fisherman	Processer Butcher Technologist	Cold chain operator Logistics agent	Marketer Wholesaler Retailer	Restaurant chef Consumer	Waste specialist Circular business owner
Cross-cutting drivers	**Socio-Economic Drivers** (e.g.. Population, economy, industrial demand, income levels, investment, dietary changes)						
Strong impact	**Climate Risks & Weather Hazards** (e.g.. temperature changes, water availability, soil health)						

27 Baringa analysis.

Case Study 2. The global journey of soya beans

Brazil represents the largest single producer of soya beans in the world with 35% of global production (surpassing the USA at 33%).[28] It is also the largest exporter of soy products in the world representing a 42% market share measured by volume weight.[29] However, these two statistics obscure the globally interconnected nature of the agricultural value chain for soy production.

Upstream, Brazil is highly dependent on other countries. Most soy crops in Brazil are transgenic using genetically modified (GMO) soy seeds typically developed by large agrichemical businesses in the US or Europe. Brazil as a market is also a net importer of fertiliser products and dependent on 80% imports from abroad with a sizeable portion of these coming from Canada, Russia, and Belarus.[30]

Downstream, soy production in Brazil is split with 63% directed to international markets. The primary market for Brazil is China, accounting for 70% of all soy exports over the last several years[31]. In China, the majority of this domestically goes to livestock feed and edible oil production (whilst domestically produced soya beans are typically used for tofu, milk, and soy sauce).[32] Whilst China is a net importer of most agricultural products, it also exports over $13.5 billion of animal products with Japan, the USA and Europe being key trading partners.[33]

Ultimately, this journey for soya beans is typical of a globally integrated food value chain where inputs, production, processing, distribution, marketing, and consumption can all criss-cross multiple geographies. This is especially true for crops compared to other agricultural commodities. Importantly, it also means that climate risks do the same too. For example, the 2021 severe droughts in Canada had a knock-on effect on its fertiliser exports including to Brazil which had to find other markets to supply inputs for its soya bean demand.[34] Together with wider droughts across the value chain, this led to a production fall in 2021 and a supply shock to the wider market leading to follow-on price spikes in associated downstream soya sectors.[35]

The same is also true in reverse. Droughts in Brazil last year led to a hold-up in soybean planting which in turn reverberated through fertiliser markets. As an example, this led to a 25% fall in booked fertiliser demand with YoY retail potash prices (a key component in fertilisers) being quoted as 36% lower[36]. The integrated nature of food value chains means that climate risks in one part of the world can lead to lower yields and greater prices elsewhere, thereby impacting indirect investors.

28 "FAO Stat", FAO (2024).
29 "FAO Stat", FAO (2024).
30 "Soybean in Brazil", CZ (2023).
31 "Massive Brazilian soybean exports too heavily leaning on China?", Reuters (2023).
32 "Interdependence of China, United States, and Brazil in Soybean Trade", USDA (2019).
33 "World Integrated Trade Solution", World Bank (2022).
34 "Impacts and Repercussions of Price Increases on the Global Fertilizer Market", USDA (2022) and "Confronting Urgent Challenges and Building the Resilience of the Canadian Food Supply Chain", House of Commons Canada (2022).
35 "Agriculture Industry Is Still Sweating This Year's Droughts", S&P Global (2022).
36 "Brazilian drought slows fertilizer purchases, affecting global suppliers", Fertiliser Daily (2023) and "Fertilizer Outlook: Global dynamics to influence 2024 fertilizer prices", Farm Progress (2023).

1.3 | About this report

The purpose of this report is to highlight the major climate change and extreme weather impacts on global food supply chains.

It is critical to identify the risks, opportunities, and actions that food system actors need to take to mitigate and adapt to the expected increased prevalence of climate risks and extreme weather impacts on the global food system. Not only is this about preserving commercial returns, but also ensuring food security and system resilience to support growing populations and economies around the world. Further, the highly integrated nature of the food value chain requires joined up and systemic action.

As such, this report focuses on three core questions:

1. **What will be the major climate risks and extreme weather impacts** on global food commodities over the decade (Section 2–5)?
2. **What mitigation and adaptation measures exist** to tackle these impacts to support food system security, resilience, and commercial returns (Section 2–5)?
3. **What are the opportunities for investors** to engage and support agricultural and food companies (Section 6)?

Ultimately, this report aims to support investors by:

1. **Deepening awareness of the causes, risks, and impacts** of climate change in high volume agricultural sectors across crops, livestock, and fisheries.
2. **Outlining example proven mitigation and adaptation initiatives** that can enhance food security, food system resilience, and commercial returns.
3. **Informing investor decision-making and engagement strategies** concerning agricultural and food system companies and the wider stakeholder community on key climate risk issues including disclosures.

2.0 | Crop value chains

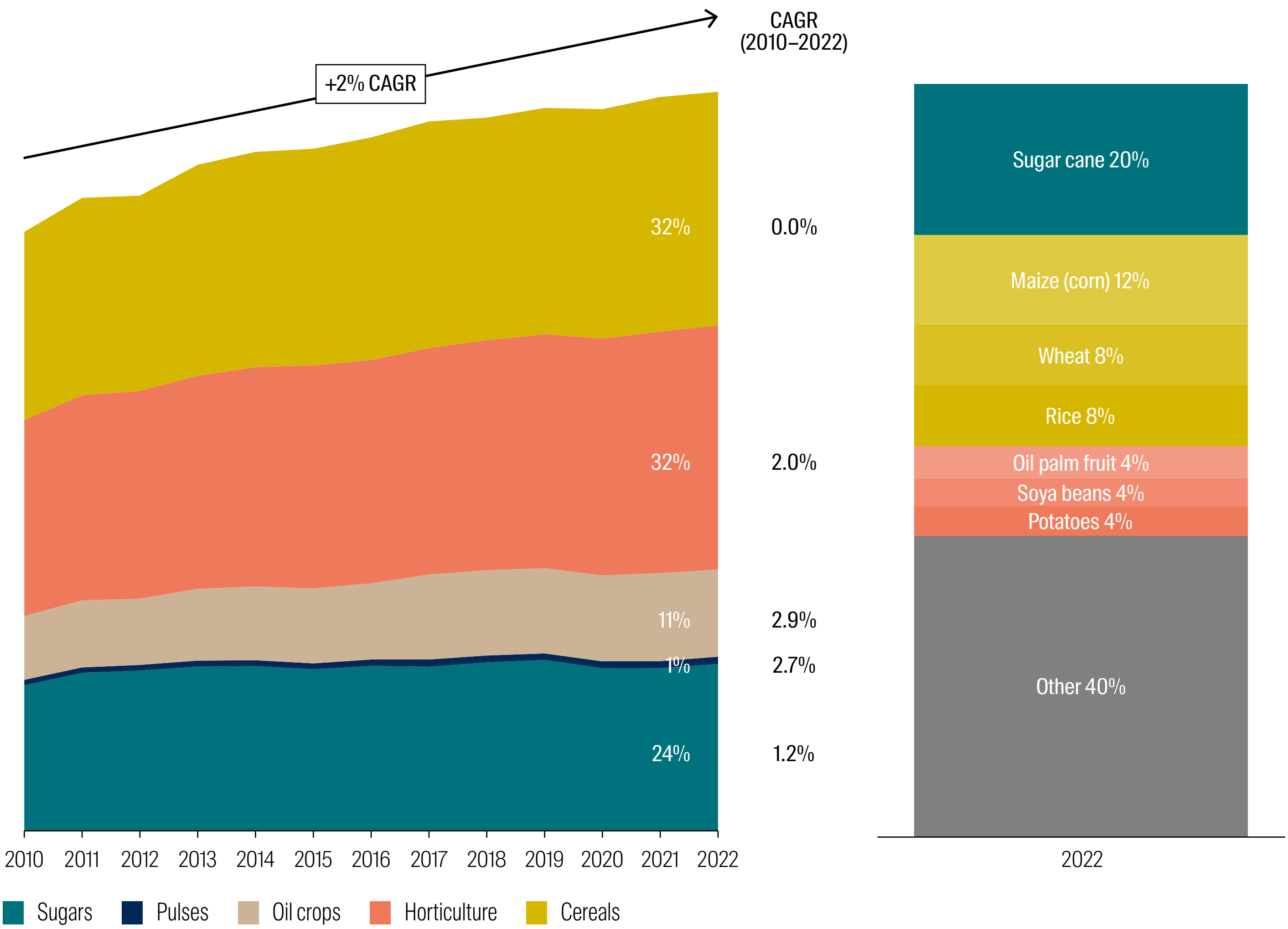
2.1 | Global value chain structure

Global crop value chains can be highly integrated crossing multiple regions and thus aggregating climate risk and weather hazard impacts across each segment. This is especially true for upstream segments such as inputs and production where the market faces greater consolidation than downstream consumption.

Crops focused on food and feed accounted for $1.13 trillion in 2023 with c.10 billion tonnes of production.[1] These crops segment between 5 key categories including cereals, horticulture (including fruit, vegetables, roots, and nuts), oil crops, pulses, and sugars. Crop production growth has seen a 2% CAGR since 2010 and is forecast to continue to grow through to 2033 with the largest absolute growth coming from cereals, horticulture, and sugars.[2]

A key component of this growth will come from increased demand of core commodities such as sugarcane, maize and wheat representing 40% of the total crop production in 2022.[3] This is especially driven by population growth and shifting dietary trends (e.g. higher demand of maize for livestock feed or increased sugar demand from India and Southeast Asia resulting from rising incomes).

Figure 8. Crop production volume growth (2010–2022)[4]

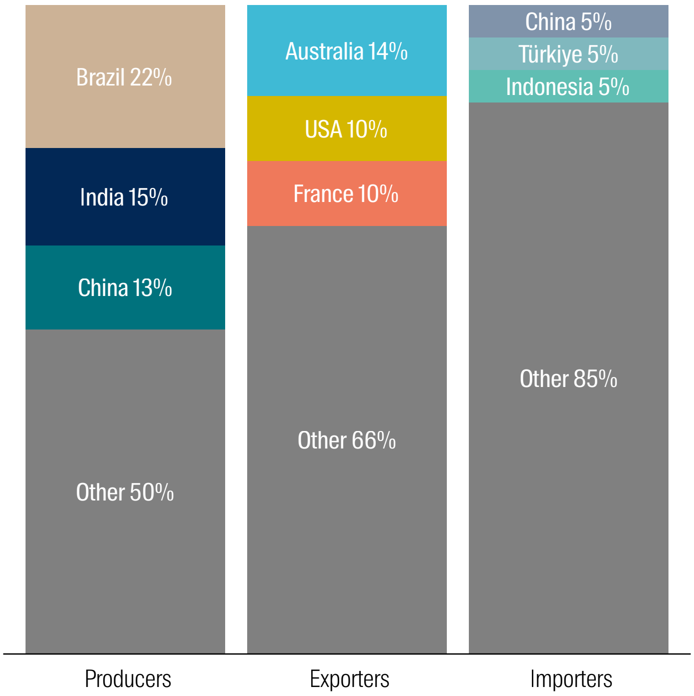


1 "Agricultural Outlook", OECD-FAO (2024) and "FAO Stat", FAO (2024); this is 75% of the total $1.498 trillion of crop production value in 2023.
2 "World Projections", OECD (2023) and "FAO Stat", FAO (2024).
3 "Agricultural Outlook", OECD-FAO (2024) and "FAO Stat", FAO (2024).
4 "Agricultural Outlook", OECD-FAO (2024) and "FAO Stat", FAO (2024).

Figure 9. Highest volume crop: production and trade (2022)[5]

Class	Commodity	% share of production	Largest producers	Largest exporters (of raw and processed)	Largest importers (of raw and processed)
Sugars	Sugarcane	20%	1. Brazil (38%) 2. India (23%) 3. China (5%)	1. Brazil (37%) 2. India (17%) 3. Thailand (9%)	1. Indonesia (9%) 2. China (8%) 3. USA (6%)
Cereals	Maize	12%	1. USA (30%) 2. China (24%) 3. Brazil (9%)	1. USA (28%) 2. Brazil (20%) 3. Argentina (16%)	1. China (10%) 2. Mexico (8%) 3. Japan (7%)
Cereals	Wheat	8%	1. China (17%) 2. India (13%) 3. Russia (13%)	1. Australia (14%) 2. USA (10%) 3. France (10%)	1. China (5%) 2. Türkiye (5%) 3. Indonesia (5%)
Cereals	Rice	8%	1. China (27%) 2. India (25%) 3. Bangladesh (7%)	1. India (39%) 2. Thailand (14%) 3. Viet Nam (10%)	1. China (11%) 2. Philippines (6%) 3. Iraq (4%)
Oil crops	Oil Palm Fruit	4%	1. Indonesia (60%) 2. Malaysia (22%) 3. Thailand (4%)	1. Indonesia (56%) 2. Malaysia (27%) 3. Netherlands (2%)	1. India (16%) 2. China (11%) 3. Japan (6%)

Market Concentration across top 3 highest volume commodities



The table and graph shown in *Figure 9* demonstrates crop market consolidation especially in upstream value chains. Here, sugarcane, maize, and wheat account for 40% of total crop volumes produced globally, and 50% of this volume from just three countries namely Brazil, India, and China.[6] This concentration of production also represents a concentration of climate risk as extreme weather impacts in these three countries reverberates downstream across processing exporters and finished good importers.

As such, *Figure 9* also demonstrates the complex and integrated nature of crop value chains. Compared to livestock, crops demonstrate greater market concentration in production systems than downstream processing and marketing (demonstrated by proxy through process exporters and importers).

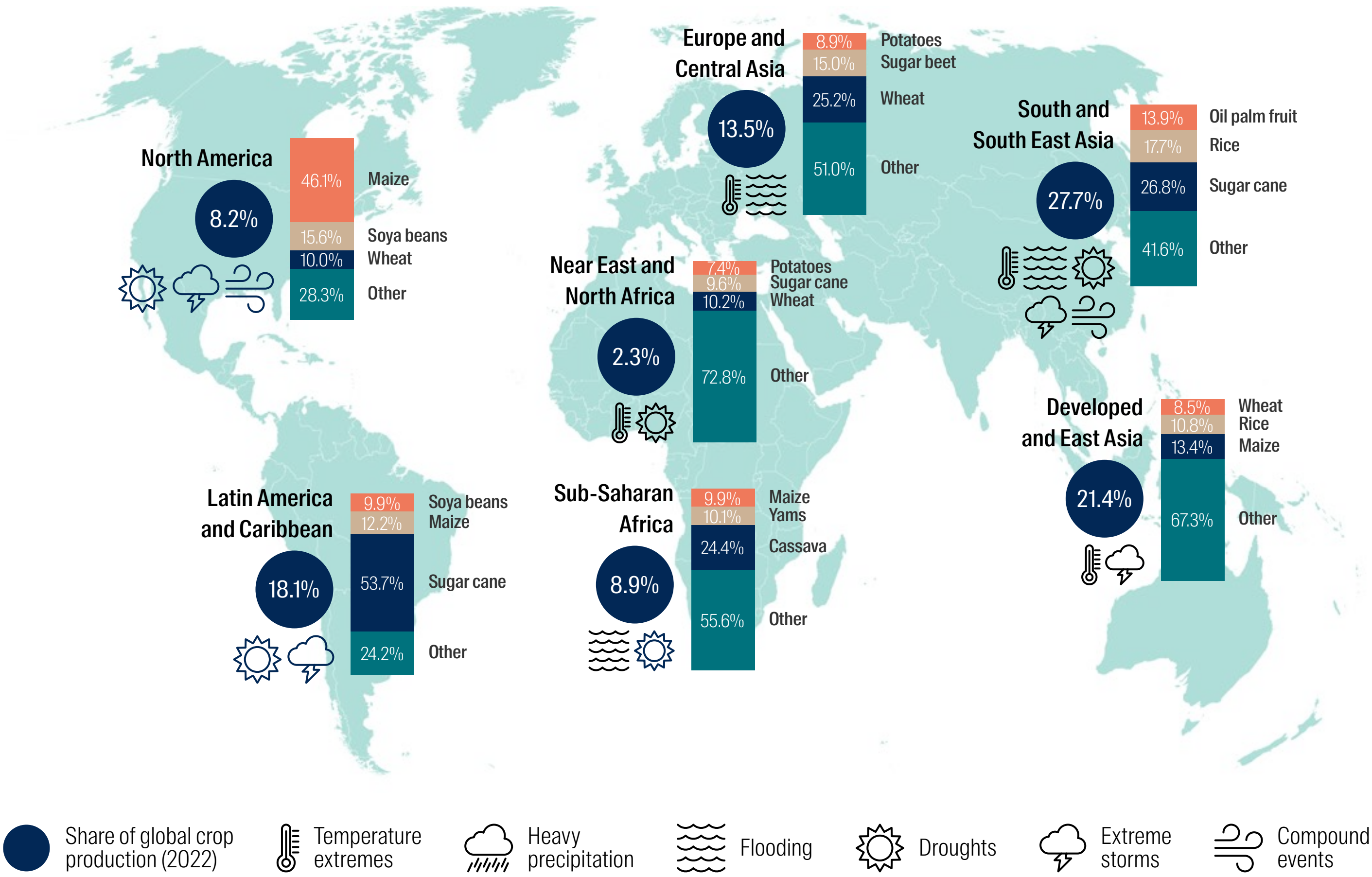
The typical value chain for crops crosses 7 segments and up to 31 steps between inputs and waste. This is shown in *Figure 10*. Some crop inputs originate within production countries whilst others such as energy, fertilisers, and pesticides, also have their own global supply chains. Postproduction, processing, distribution and marketing can often span multiple geographies before ultimately arriving at the table (see *Case Study 2* as an example of the journey for Soya Beans). This complex value chain for crops is a key factor that drives climate risk in our global food value chain.

5 "FAO Stat", FAO (2024).
6 "FAO Stat", FAO (2024).

Figure 10. Typical crop value chain activities

1. Inputs	2. Production	3. Processing	4. Distribution	5. Marketing	6. Consumption	7. Waste/recycle
• Water • Energy • Labor and mechanisation • Seeds • Fertilizers • Pesticides	• Land preparation • Planting • Irrigating • Fertilizing • Pest control • Harvesting	• Dry milling • Wet milling • Shelling and drying • Sorting and grading • Specialised processing • Packaging	• Trading • Export • Transportation	• Product labelling • Pricing • Advertising • Distribution	• Direct food consumption • Livestock feed	• Animal feed production • Biofertilizers production • Biofuel production • Bioplastic production
Example actors • Bayer • Syngenta	• Commercial Farms • Small Holders	• Tereos • Cargill	• Cosan • LDC	• Walmart • Sainsbury's	• People • Livestock	• Braskem • Bioenergy Devco

Figure 11. Global crop production and most common extreme weather hazards by region (2022)[7]



7 "FAO Stat", FAO (2024).

2.2 | Crop climate risks and extreme weather impacts

Across all agricultural products, crops have distinct vulnerabilities to climate change and extreme weather driven by their environmental dependencies and immobility. These underline the vulnerability within their seasonal growth stages that lead to key direct and indirect investor impacts.

Each crop has distinct and high reliance on water, soil, and temperature patterns suited to their specific requirements. For example, sugarcane requires four times as much water as wheat and over a longer growth cycle, whilst potatoes grow better in a higher soil acidity than corn. These distinct growing requirements highlight 6 unique vulnerabilities of crops (see *Figure 12*) that makes them especially susceptible to extreme weather hazards impacting their growth and development.

Figure 12. Crop vulnerability to climate risks and extreme weather impacts

Extreme weather	Description
Water	Different crops have specific water requirements that support optimal growing conditions with distinct nutrient needs; changes in the volume and composition of its water not only results in lower yields but also lower quality (e.g.. wheat with lower protein levels under drought conditions or potatoes that are more susceptible to disease in uneven water conditions)
Temperature	Crops grow under distinct temperature conditions and are highly seasonal as a result (e.g.. wheat grows best in 10-24 degree environments vs. maize that requires higher temperatures of 18-27 degrees); changes in temperature during growing periods can inhibit crop growth, reduce nutrient balances, or lead to mass spoilage (e.g.. maize that suffers from kernel shrinkage in heat stress)
Soil	Soil conditions are a key component for crop growth as it provides the delivery and drainage for water and nutrient supply as well as support and buffering for root systems; in this way, soil is a buffer against climate and weather extremes to protect crop growth (e.g. sugarcane has lower sucrose content due to heightened soil salinity from rain runoff)
Pest and disease	Crops have different pests and disease risks unique to themselves and their environments; climate risks and extreme weather hazards have the potential to shift seasonal patterns or introduce new pests and diseases impacting crop development (e.g.. expanding potato beetle populations due to warmer weather lowering potato yields)
Immobility	Each of the above four vulnerabilities are made worse by the inability to move crop production once planted; this is especially an issue as weather patterns become unpredictable and the heuristic tendency in agricultural production to rely on generation old planting, fertiliser, and harvest patterns which may have shifted due to climatic changes in weather and soil
Post-harvest deterioration	Post-harvest losses have been increasing especially due to warmer and wetter conditions that have increased contamination risks and spoilage (e.g.. high moisture environments during post wheat harvest reduced grain quality, whilst delays in sugarcane transport reduces sugar recovery by up to 30%)

Each of these unique vulnerabilities are triggered or exacerbated by the six extreme weather hazards outlined in *Figure 2*, especially along the strong impact components of the value chain (inputs, production, processing, and distribution). The correlation of weather hazards on these vulnerabilities undermines crop yields leading to direct asset and investor impacts, as well as the indirect impacts across the rest of the integrated value chain. These result in lower asset valuations due to reduced productivity and higher stranded asset risks due to worsening environmental conditions.

Figure 13. Example extreme weather hazards and asset and investor impacts across crops[8]

Value chain segment	Example extreme weather impacts	Asset and investor impact	Example occurrence
Inputs	• Temperature fluctuations impacting labour productivity • Saline intrusion from coastal flooding impacting soil health and seed-soil suitability	• Higher opex costs (e.G. Transgenic seeds, specialist fertilisers, and labour costs)	• GM seed prices for maize and soya beans rose 463% between 1990 and 2020 due to high demand, higher than returns from crop sales[9]
Production	• Temperature fluctuations impacting seed germination • High rainfall causing fertiliser run-off	• Greater yield losses especially at required quality levels • Potential stranded asset risks (e.g. due to wildfires, droughts, or flooding)	• Temperature extremes since 2000 in Japan has led to a deterioration in rice nutrients with studies demonstrating reductions of 10% in protein, 8% in iron, and 5% in zinc[10]
Processing	• High humidity increasing contamination from spoiled crops • Power outages impacting processing facilities	• Reduced productivity leading to lower outputs and profitability	• Heavy rains in 2022 in Kenya led to increased aflatoxin contamination in maize post-harvest processing with 35% of samples exceeding the regulatory limit (linked to increased liver cancer risks)[11]
Distribution	• Flooded roads blocking transport and increasing spoilage • Heightened temperatures stressing cold-chain infrastructure	• Higher prevalence for food spoilage in transport • Higher transport costs (including for cold chain)	• Cyclone Jasper in 2023 hit Australia causing more than 1 million tonnes of sugarcane losses, equivalent to 3% of total production, especially with sugar milling and cane rail infrastructure damage[12]

8 Baringa analysis.
9 "Prices for genetically modified seeds have risen much faster than non-GM seeds", USDA (2023).
10 "Carbon dioxide (CO2) levels this century will alter the protein, micronutrients, and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries", Science Advances (2018) and "Warming Leads to Lower Rice Quality in East Asia", Geophysical Research Letters (2024).
11 "Aflatoxin Contamination of Maize from Small-Scale Farms Practicing Different Artisanal Control Methods in Kitui, Kenya", Journal of Food Quality (2023).
12 "North Queensland flooding has significantly impacted farming communities and supply chains", Queensland Farmers' Federation (2023).

2.3 | Mitigation and adaptation measures

In response, corporates and their investors should ask themselves 4 key questions as they plan mitigation and adaptation actions to protect their investment, enhance food system resilience, and strengthen commercial returns against extreme weather hazards.

The distinction between mitigation and adaptation is critical when considering responses to climate change and extreme weather events. Mitigation is about preventing long-term climate risk, whilst adaptation concerns managing and adapting to its effects. Both are important especially to improve crop value chain resilience. Each has numerous levers open to companies and investors (see *Figure 14*).

Figure 14. Example mitigation & adaptation levers for crops[13]

	Example lever	Potential impacts
Mitigation	**Responsible soil management** to protect soil health (e.g. through conservation tillage, biochar application, or crop rotations)	• Improved agricultural output • Reduced OpEx on inputs (e.g. lower fertiliser needs)
	Precision and organic fertilisers to minimise chemical pollution, support soil health, and prevent contamination from water run-off	• Reduced OpEx on inputs (e.g. lower fertiliser needs though might be offset due to higher unit costs)
	Nature based solutions such as agroforestry that integrate trees and shrubs into farms to support carbon storage and improve extreme weather resilience (e.g. through microclimate regulation from treeline wind breaks or shade during heatwaves)	• Improved agricultural output • Lower production losses • New revenue streams from sustainable wood production or carbon credits
	Renewables and clean energy fuels to reduce agricultural emissions from mechanisation and transport (responsible for 10-20% of food emissions[14])	• Lower OpEx from fuel and maintenance • Alignment to ESG expectations supports low-carbon expectations (with partners and consumers)
Adaptation	**Crop breeding** that identifies higher productivity crop breeds that can withstand extreme weather impacts and low-tech post-harvest stresses (e.g. with high tolerance for heat and drought)	• Improved agricultural output • Lower risk profiles from greater resilience to extreme weather • Reduced OpEx on inputs (e.g. irrigation)
	Digital technology that supports early warning systems for farmers to monitor soil health and changing climate patterns to inform farmers of changes to planting, fertiliser, and harvest patterns	• Improved agricultural output • Reduced OpEx on inputs (e.g. usage of right-time fertilisers to maximise outputs)
	Landscape breakers to protect agricultural lands from extreme weather (e.g. building rock walls that protect against severe wind or wildfires)	• Improved agricultural output • Lower risk profiles from greater resilience to extreme weather
	Insurance to protect farmers, processors, distributors, and markets including through weather-index based policies that payout against weather thresholds (e.g. from extreme heat, rain, humidity)	• Reduced financial risk and volatility • Improved risk profile for capital raising

13 Baringa analysis.

14 "Reducing food's environmental impacts through producers and consumers", Science (2018) and "Field to fork: global food miles generate nearly 20% of all CO2 emissions from food", EC (2023).


Rice farming in Tamil Nadu, India.

Ultimately, corporates and investors across the food system have numerous mitigation and adaptation measures open to them to support more sustainable, resilient, and productive agribusinesses. Identifying the right mix requires a full understanding of the relevant value chain, environmental context, and climate trends. This should start by asking 4 key questions:

1. What is my upstream supply chain understanding geographic, crop, and climate zone concentration?
2. What is the forward 10-year trend of climate risks and extreme weather hazards impacting my supply chain and operations, and how will this impact crops yields, quality, and market demand?
3. Which mitigation and adaptation measures can lower my risk profile and drive improved agricultural output at the required quality levels?
4. What ESG and climate risk disclosures do we need to support on climate-resilient and sustainable agricultural investments?

These questions will support food value chain actors to understand their value-chains, risk profiles, mitigation measures and prioritisation criteria to support a more resilient and rewarding crop system. Section 6 details further opportunities for investors to engage their companies and wider stakeholders.

Case Study 3. Conservation tillage as climate change mitigation in India

India, as the second largest agricultural producer after China, is increasingly facing extreme weather events which are damaging its agricultural ecosystem. Heatwaves, droughts, heavy precipitation, and compound events have led to significant agricultural damages with the loss of 33.9 million hectors of farmland due to floods and 35 million hectares due to drought between 2015 and 2021[15] (an area larger than Japan and the UK combined). Meeting continued yield expectations is requiring higher input costs to mitigate extreme weather impacts.

Responsible soil management practices, especially conservation tillage, have been introduced over time in different Indian farming communities to support more efficient and sustainable agricultural practices. Whilst not suited to all locations, this practice is effective in drier climates to support rain-fed crop productivity.[16] Conservation tillage typically involves three principles including 1) minimising mechanical soil disturbance; 2) maintaining soil mulch (e.g. through cover crops); and 3) diversifying crop systems (e.g. through crop rotations) to improve soil health.

An analysis of 1,353 field studies in 2020 demonstrated significant benefits from conservation tillage practices especially for crops such as wheat and maize and their corresponding climate impacts[17]. This demonstrated a 5.8% increase in yield, a 12.6% increase in water efficiency, 25.9% increase in net economic returns, and a 12-33% decrease in emissions. These returns, whilst contextual to their specific regions, demonstrate the potential benefits for mitigation actions to contribute to yield resilience, commercial, and sustainability outcomes.

15 "UNDP India partners with Absolute Foods to further sustainable agriculture practices in the country", UNDP (2023).
16 "Productivity limits and potentials of the principles of conservation agriculture", Nature (2015).
17 "Conservation agriculture for sustainable intensification in South Asia", Nature Sustainability (2020).

Floriculture and horticulture farming in Taiwan.

Case Study 4. Successful flood adaptation measures in Taiwan's Dajia River basin

On average each year the economic losses from torrential rainstorms and typhoons causing floods in Taiwan amount to $400 million.[18] Typhoon Morakot in 2009 was one of the deadliest typhoons to hit the island in the past 50 years causing an estimated loss of $3.4 billion.[19] The typhoon submerged extensive farmlands and highlighted the need for more comprehensive adaptation strategies. Three adaptation strategies subsequently implemented in Taiwan's Dajia River Basin have successfully improved crop resilience and minimised losses:

1. **Heightened farmland ridges** around crop fields help control water flow and prevent lengthy waterlogging that leads to high spoilage. This measure has shown 25% reduction in flooded areas for sweet potato crops.[20]
2. **Flood-resistant crop varieties** with shorter growing seasons and higher water tolerance increase output resilience by reducing their vulnerability to waterlogging, thus increasing yield stability.
3. **Disaster early warning system** provides fine-scale weather forecasts, real-time disaster alerts via push notifications and a crop disaster calendar for the 76 most important crops. The efficiency of the system is driven by an increased density of weather stations (from 17 in 1986 to 176 stations in 2021) providing higher quality and quantity prediction data.[21]

Combining engineering solutions (heightened farmland ridges), agricultural resilience strategies (flood-resistant crop varieties) and technology-driven solutions (disaster warning systems) has proven to be an effective way to adapt to increasing extreme weather risks posed by severe flooding in Taiwan.

18 "A Case Study on Flooding in the Southern Taiwan during Typhoon Morakot and Typhoon Fanapi", Natural Hazards and Earth System Sciences (2022).
19 "Typhoon Morakot Situation Report No. 1", OCHA (2009).
20 "Agriculture Adaptation Options for Flood Impacts under Climate Change", Sustainability (2021).
21 "Agricultural Disaster Prevention System: Insights from Taiwan's Adaptation Strategies", Atmosphere (2021).

Organic horticulture farming in California, USA.

Case Study 5. Investing in organic production as a natural hedge in the USA

Whilst agricultural commodity prices face significant volatility due to the reasons outlined in this paper – including fluctuating input prices, yields, and production quantity due to extreme weather hazards - some investors have turned to organic agriculture as a natural hedge. This works through leveraging organic premiums to stabilise returns and support mitigation and adaptation mechanisms, especially where organic farming can form part of a regenerative agricultural practices to rehabilitate depleted soils.

The global organic market has seen substantial growth over the last several decades growing at 8% CAGR since 2010 to reach a global size of $134.8 billion in 2022.[22] The largest market is in the US accounting for 43% global market share by value. Whilst this growth has led several corporates and real estate investment trusts (REIT) to focus on organic farming, farmers have often struggled. This is especially due to the 'valley of death' where it takes up to three years for individual farmers in the US to transition from conventional to organic farming before they can market under USDA certified organic labels (and thus claim organic premiums).

One American REIT is focused on solving this challenge through deploying patient capital to support farmers to jump the 'valley of death' and implement more regenerative farmer practices. They have raised and deployed $120 million across more than 116 investments.[23] Amongst different mechanisms, they issue flexible private lending solutions including through a 'Soil Restoration Note' as a 5-year 2.5% unsecured private debt instrument. This especially supports farms to make the transition from conventional to organic farming where a three-year transition process is required before farms can market their certified organic labels to carry an organic premium.[24] Ultimately, with a long-term outlook on returns, they have found significant success helping farmers to de-commoditise their offerings through breaking into the organic market, supporting higher quality crop production alongside improved food system resilience.

Another American investment fund is working to capitalise on regenerative agriculture as a natural hedge against market volatility and price inflation. Founded in 2009, they have more than $300 million in assets and focus on acquiring and converting conventional farmland into sustainable operations.[25] Their approach has not only helped to support soil regeneration, sequestering 16,000 tonnes of CO2 and avoiding 3.1 million tonnes of synthetic fertiliser[26], they have also delivered post-tax returns of 113% to investors from their first fund.[27] The success of using regenerative agriculture to tap into organic premiums and boost long-term yields through improving farmland health has paid off, with the investment fund now on their third fund targeting $250 million.

22 "The World of Organic Agriculture", IOFAM (2024).
23 "Public Benefit Report", Iroquois Valley Farmland REIT (2023).
24 "Farm Grows 'Organic' Returns for Impact Investors", Real Leaders (2022).
25 "About Us", Farmland LP (2024).
26 "Impact", Farmland LP (2024).
27 "Farmland LP Launches $250M Third Fund Focused on Organic and Regenerative Agriculture", PR Newswire (2023).

3.0 | Livestock Value Chains

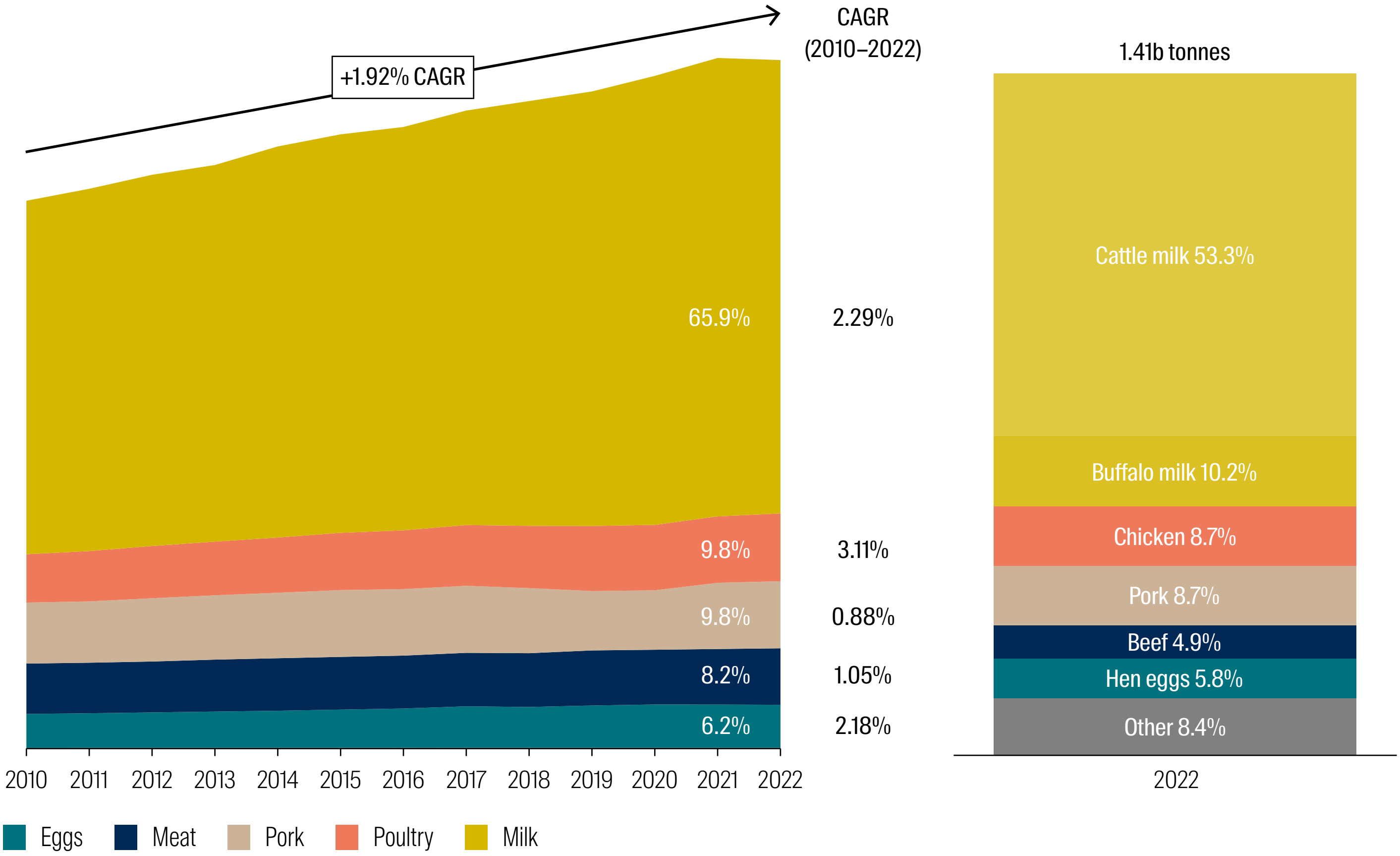
3.1 | Global value chain structure

Similar to crops, global livestock value chains are also highly integrated and interdependent crossing multiple regions. However, in contrast to other agricultural commodities, livestock production has three unique characteristics including its dependence on crop feed production, development through longer growth cycles, and its lower market concentrations across producers.

Livestock accounted for just over $1 trillion in production value in 2023 with c.1.41 billion tonnes of production grouped in 5 key categories: milk, poultry, pork, meat, and eggs.[1],[2] Production has grown by 1.92% CAGR since 2010 and is forecasted to continue to grow through to 2033 with the largest absolute growth coming from dairy, poultry, and meat.

A key driver of this growth will be rising supply and demand from emerging economies. For dairy, India and Pakistan will account for over 30% of supply by 2033 representing the largest absolute increase over the decade. This primarily is a factor of significant population and economic growth in South Asia. The next fastest growing livestock classes are poultry and meat, expected to grow over the period by up to 16% and with 79% of this generated from middle-income countries . Where trends in dairy and meat alternatives may continue in some countries, this will be offset by higher demand from emerging markets.

Figure 15. Livestock production volume growth (2010–2022)[3]



1 This excludes non-food products such as hides, skills and beeswax which accounting for 14.8 million tonnes production in 2022. Honey is also not shown which accounts for 0.1% of total production share by volume.
2 "Agricultural Outlook", OECD-FAO (2024), "Pathways towards lower emissions: A global assessment of the GHG emissions and mitigation options from livestock agrifood systems", FAO (2023), and "FAO Stat", FAO (2024).
3 "Agricultural Outlook", OECD-FAO (2024) and "FAO Stat", FAO (2024).

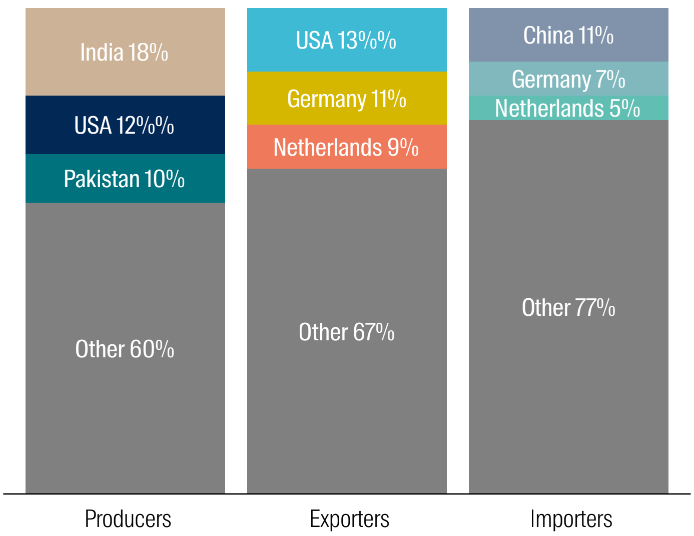
The table and graph shown in *Figure 16* demonstrates livestock market consolidation whilst the diagram in *Figure 17* portrays a typical livestock value chain. This crosses 7 segments and up to 32 steps between inputs and waste. Whilst livestock value chains have a similar level of complexity to crops, they also have unique characteristics. Further, in contrast to crops, livestock offers slightly lower market concentration in production systems.

The first distinction for livestock is its own dependence on crop production for feed. The most common feed crops are cereal grains and grasses such as maize, barley, and oats. Poultry, Pork, and Beef account for 22.3% of global livestock tonnage but relies in turn on maize production where corn accounts for 60–90% of animal feed especially in the US as a key production and export market.[4] This feed requirement translates to a wide surface area risk. As such, livestock production carries forward supply chain and climate risks from input production which can have much more concentrated markets.

Figure 16. Highest volume livestock: production and trade (2022)[5]

Class	Commodity	% Share of Production	Largest Producers	Largest Exporters (of raw and processed)	Largest Importers (of raw and processed)
Milk	Cattle and buffalo milk	63.5%	1. India (23%) 2. USA (11%) 3. Pakistan (7%)	1. Germany (13%) 2. Netherlands (9%) 3. New Zealand (8%)	1. Germany (12%) 2. China (8%) 3. Netherlands (8%)
Poultry	Chicken meat	8.7%	1. USA (16%) 2. Brazil (12%) 3. China (12%)	1. Brazil (26%) 2. USA (23%) 3. Poland (8%)	1. China (10%) 2. Mexico (6%) 3. Netherlands (5%)
Pork	Pork meat	8.7%	1. China (45%) 2. USA (10%) 3. Brazil (4%)	1. Spain (15%) 2. USA (15%) 3. Germany (12%)	1. China (13%) 2. Mexico (7%) 3. Japan (6%)
Eggs	Hen eggs	5.8%	1. China (36%) 2. India (8%) 3. USA (8%)	1. Netherlands (16%) 2. Poland (11%) 3. Türkiye (9%)	1. Netherlands (14%) 2. Germany (14%) 3. Belgium (8%)
Meat	Beef	4.9%	1. USA (19%) 2. Brazil (15%) 3. China (10%)	1. Brazil (16%) 2. USA (10%) 3. India (9%)	1. China (20%) 2. USA (8%) 3. Japan (4%)

Market Concentration across top 3 highest volume commodities



4 “Feed Grains Sector”, USDA (2023).
5 “FAO Stat”, FAO (2024).

Figure 17. Typical livestock value chain activities[6]

1. Inputs	2. Production	3. Processing	4. Distribution	5. Marketing	6. Consumption	7. Waste/recycle
• Water • Energy • Labor • Feed and fodder • Genetics • Veterinary services	• Feeding • Rearing • Milking • Reproduction • Environmental Management	• Slaughtering • Cutting / deboning • Pasteurisation/ homogenisa-tion • Sorting and grading • Specialised processing • Packaging	• Cold chain logistics • Transportation • Trading • Export	• Product labelling • Pricing • Advertising • Distribution	• Direct food consumption • Livestock feed	• Waste management • Animal feed production • Biofertilizers production • Biofuel Production • Composting
Example actors • Cargill • Zoetis	• BRF • Tyson Foods	• Nestle • JBS	• Buitelaar Group • Cold Chain Logistics	• Costco • Carrefour	• KFC • People	• Darling • BioCNG

The second distinction for livestock is that they can have more varied and longer growth cycles than crops. Maize, wheat, rice, and most other crops have growth timeframes of 2-5 months (with exceptions for sugarcane and oil palm fruit which can take 1-1.5 and 3-4 years respectively to mature but then can be harvested every 10 days). In contrast, livestock production ranges from 2-24 months depending on if you are looking at chicken (2-3 months depending on breed and if it is organic), eggs (4-5 months from birth), pork (5-6 months), or beef (18-24 months). This longer gestation period represents a wider temporal surface area for climate risk to impact production and greater care required to protect livestock value.

The third distinction concerns market concentration. Crop value chains are relatively consolidated in production segments with the largest three producing countries accounting for 50% market share of the top 40% of crop production by tonnage. In contrast, the top three livestock commodities account for 80% of global livestock tonnage. However, the largest three producing countries for these commodities only hold a 40% market share on production with the majority of this domestically consumed. As such, the key driver for this lower market concentration is shorter routes from farm to table.

6 Baringa analysis.

Case Study 6. Short value chains for milk in India, Germany, and Australia

Cattle and buffalo milk, as the largest livestock commodity accounting for 63.5% of global livestock volume, offers a good example of the impact of lower market concentration in livestock value chains especially representing shorter routes to the consumer. India has the largest market share with 23% of global production. Inputs for milk are typically locally sourced and integrated into smallholder farmer systems.[7] Raw milk is then processed in local cooperatives to produce processed dairy products like ghee, cheese, and yoghurt. This is channelled to retail outlets where marketing focuses on affordability and tradition, with local and domestic brands playing a key role. This localised value chain is typical for many emerging market economies for staple dairy products.

In contrast, Germany and Australia are industrial dairy processors and are consequentially one of the largest importers and exporters of dairy products. However, even then its supply chains are short. Germany is the largest producer of milk in the EU with high production standards and mechanised farms ensuring uniform quality across the sector. Over 90% of its dairy imports come from neighbouring EU countries and are focused on meeting its processing demand.[8] German processors in turn are export focused and dominated by large multinationals and cooperatives producing a wide array of dairy products with over 70% of exports going back to EU countries and the largest international markets being China (14%) and Mauritania (2%).

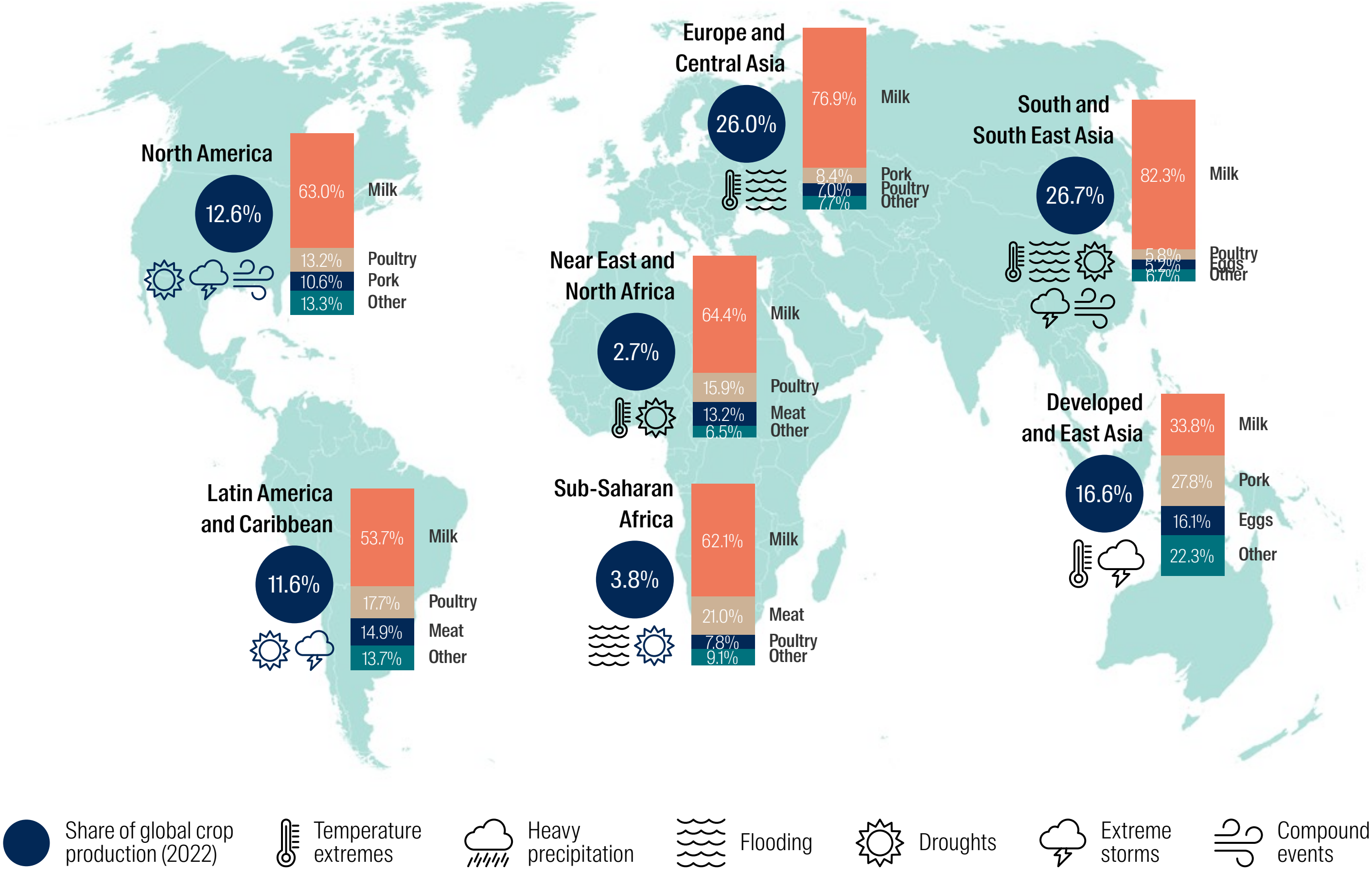
Australia offers a similar perspective. 85% of dairy imports for Australia originate from New Zealand channelled to large multinational industrial processors. These focus on products such as milk powder and cheese, which are marketed under Australia's food safety certifications to demonstrate high quality and generate premium returns. Export markets then focus on East Asia with more than 80% of exports going to 4 countries including China (51%), Singapore (14%), Philippines (8%), Malaysia (7%). Both Germany and Australia demonstrate that, even for industrialised nations, value chains for livestock products can be much shorter than for crops and can typically be regionally bounded.

Ultimately, the generally shorter value chains for milk across global markets correlate to several key impacts from extreme weather events. This includes faster impact transmission especially due to the higher perishability of milk products coupled with a preference for local sourcing. Where this means single extreme weather events can have an effect across entire local supply chains, it also means there is a lower chance to supplement diminished local supply through global imports especially for fresh milk products. This distinction is unique to milk products as opposed to wider livestock, crop, or fishery commodities.

7 "FAO Stat", FAO (2024) and "India's White Revolution", Niti Aayog (2023).

8 "UN Comtrade Database", UN (2024).

Figure 18. Global livestock production and most common extreme weather hazards by region (2022)[9]



9 "FAO Stat", FAO (2024).

Drought facing cattle farms in Australia.

5.2 | Livestock climate risks and extreme weather impacts

Five characteristics of livestock production represent distinct impact vulnerabilities from extreme weather, including carrying forward risk from climate impacts on crop production and longer recovery times.

Livestock production has a high reliance on water both for feed as well as the livestock themselves. Temperature spikes and increasing droughts are leading to growing water scarcity with wide ranging impacts across the livestock sector including reducing egg size, inhibiting fertility, stunting growth, and increasing the risk of disease. Water scarcity also lowers both the quality and volume of feed production which compounds these effects.

Alongside shared vulnerabilities to crop production, livestock also incur wider climate risks from temperature changes especially as many animals lack efficient cooling systems. This can increase the spread of disease including by impacting animal immune systems. Ultimately, compared to the relative ease to clear soils and replant crops, recovery times for livestock farms is typically longer especially due to their heavier investments required in growth cycles, infrastructure, and supply chains.

Figure 19. Livestock vulnerability to climate risks and extreme weather impacts

Extreme weather	Description
Water	Livestock require large amounts of water for drinking, feed, and cooling; water scarcity puts animals at risk of dehydration, especially in arid areas, impacting their health and productivity (e.g.. reducing egg size, inhibiting fertility, stunting growth, and increasing the risk of disease)
Crop changes	All livestock have a strong dependence on crop feed for food especially cereals and grasses; as such, extreme weather hazards impacting crop production has a follow-on effect on livestock especially due to lower production or quality outputs (e.g. dairy farms experiencing reduced milk yield due to lower protein intake by cattle from lower-quality feed)
Temperature	Livestock are highly sensitive to temperature changes as they lack efficient cooling mechanisms like sweating; higher temperature causes heat stress and reduces feed intake, growth rates, milk production, and reproductive performance, particularly in dairy cattle and poultry
Disease	Disease spread by vectors like ticks and mosquitoes, whose populations increase with warmer temperatures and higher rainfall, can be accelerated by livestock living in larger herds and warming temperatures (i.e. leading to heat stress and immune suppression among certain animals at the same as warmer environments support vector populations)
Longer recovery	Production investments for livestock can be intensive in terms of growth cycles, infrastructure, and supply chains; in contrast to crops which can be replanted relatively cheaply, injury from extreme weather can lead to long recovery times for animals, whilst mortality can result in a significant loss of breeding stock

Each of these distinctive vulnerabilities is triggered or aggravated by the six extreme weather impacts outlined in *Figure 2*. This leads to significant risks for both immediate term livestock yields as well as longer-term productivity and agricultural output. These result in lower food resilience, greater food insecurity, and ultimately lower commercial returns for both corporates and direct and indirect investors. Whilst this can impact short-term valuations and insurance costs, in the longer term it can completely change investment business cases.

Figure 20. Example extreme weather hazards and asset and investor impacts across livestock[10]

Value chain segment	Example extreme weather impacts	Asset and investor impact	Example occurrence
Inputs	• Water scarcity lowering irrigation for pasture and feed production • Extreme heat reducing labour productivity and availability	• Higher OpEx costs (e.g. higher feed costs due to reduced feed quality and increased labour costs)	• Extreme weather in the UK through 2022 saw feed costs reach a 10-year high impacting livestock farmers with 2023 prices increasing by 33% YoY.[11]
Production	• Flooding causing significant damage to pastures, shelters, and water sources for livestock leading to injury or mortality including due to more frequent disease outbreaks	• Reduced productivity and quality levels • Higher OpEx costs (e.g. temperature-controlled shelters and disease control)	• Flooding in Australia in 2019 lead to $3.7b in losses including 500,000 livestock deaths.[12]
Processing	• Heatwaves increasing refrigeration demand • Power outages impacting processing facilities	• Higher OpEx costs (e.g. cold chain storage, energy)	• Heat waves in British Columbia in 2021 led to the deaths of 661,00 poultry and lost milk production of 2.5m litres including due to lack of sufficient cold storage.[13]
Distribution	• Storm flooring leading to port closures and roadblocks • Heightened temperatures stressing cold-chain infrastructure	• Higher OpEx costs (e.g. transport) • Higher prevalence for food spoilage in transport	• Typhoon Maysak off the coast of Japan in 2020 caused the sinking of a livestock cargo ship with the deaths of 43 crew and 6,000 cattle.[14]

10 Baringa analysis.
11 "Extreme weather and its impact on farming viability in Wales", Farmlytics (2024).
12 "Multi-week prediction of livestock chill conditions associated with the northwest Queensland floods of February 2019", Nature (2022).
13 "The Case for Adapting to Extreme Heat", Canadian Climate Institute (2023).
14 "Cargo ship with 43 crew and nearly 6,000 cattle sank off Japan, survivor says", The Guardian (2020).

3.3 | Mitigation and adaptation measures

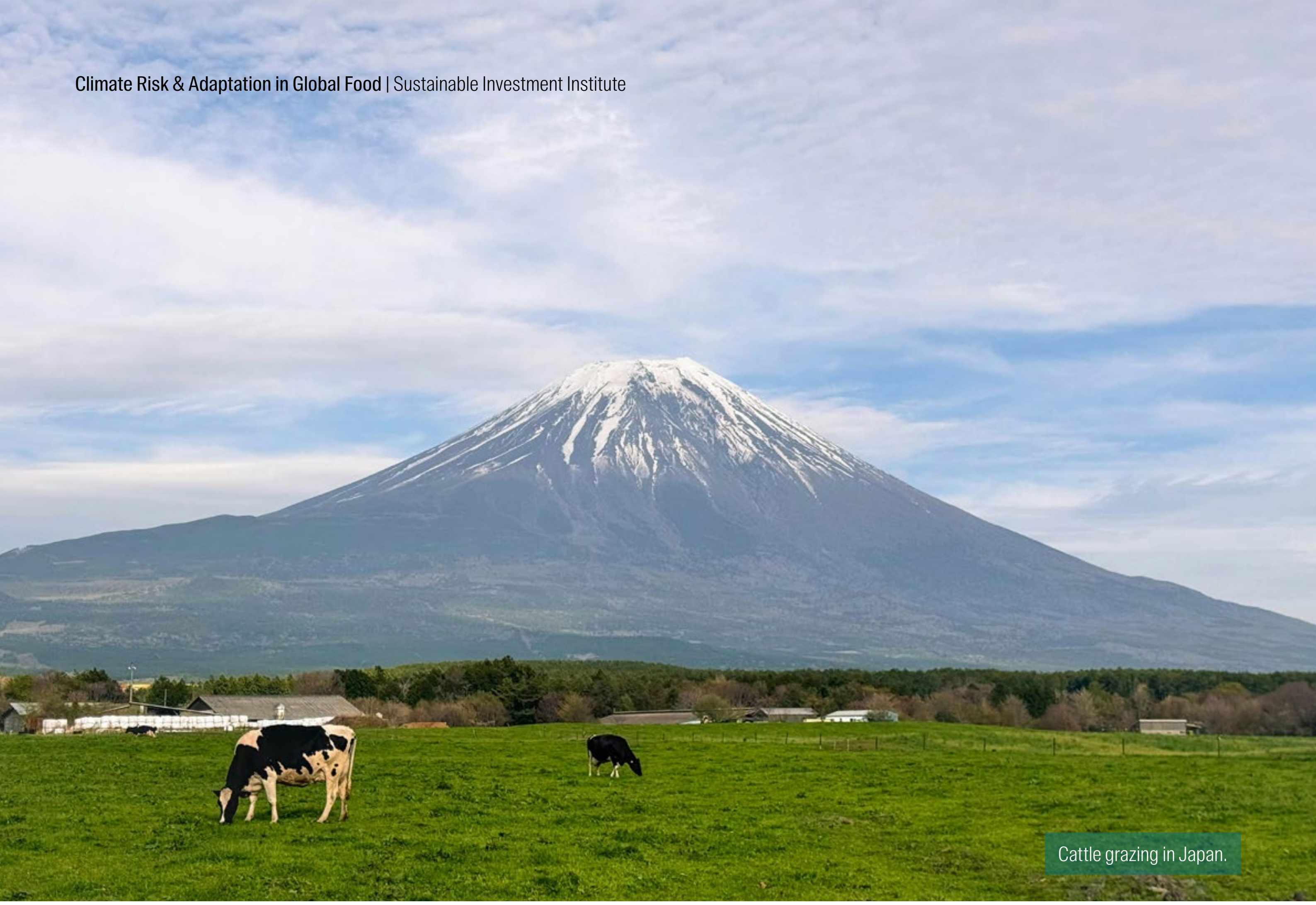
In response, corporates and their investors should ask themselves 4 key questions as they plan mitigation and adaptation actions to protect livestock food system investments, enhance food system resilience, and strengthen commercial returns against climate risk and extreme weather hazards.

Operators across the livestock value chain have numerous levers open to them to both reduce their contributions to climate change as well as adapt to the impacts from increasing extreme weather. This starts by taking stock of their wider value chains and resource usage to both drive efficiency and lower resource needs. Such measures are designed to increase resilience to extreme weather whilst maintaining animal welfare and operational sustainability to support commercial stability and growth.

Figure 21. Example mitigation and adaptation levers for livestock[15]

	Example lever	Potential impacts
Mitigation	**Methane reduction strategies** such as using feed additives (e.g. seaweed) and converting manure into biogas (e.g. installing biogas digesters)	• Reduced OpEx on inputs (e.g. biogas used in own operations) • New revenue streams (e.g. biogas sold on the market)
	Increase feed efficiency by optimising feed composition to improve digestion and feed used to reduce nutrient excretion and emissions and improve productivity (e.g. precision feeding systems or protein-rich additives)	• Reduced OpEx on inputs (e.g. lower quantities of feed required) • Improved livestock yields • Alignment to ESG expectations for emissions reduction
	Nature based solutions such as agroforestry integration into livestock farms by planting trees and shrubs to support carbon storage and improve extreme weather resilience (e.g. through microclimate regulation from treeline wind breaks or shade to protect animals)	• Improved agricultural output • Lower production losses • New revenue streams from sustainable wood production or carbon credits
	Renewables and clean energy fuels to reduce emissions from mechanisation and transport (e.g. solar panels on barns or coops to power operations)	• Lower OpEx for fuel and maintenance • Alignment to ESG expectations for emissions reduction
Adaptation	**Livestock breeding** aimed at creating breeds that better withstand climate change and extreme weather (e.g. increased heat resiliency or adapted to lower quality feed)	• Improved agricultural output • Lower risk profiles with greater resilience to extreme weather
	Diversified feed sources to enhance resilience to climate-induced feed shortages (e.g. drought-tolerant forage and feed crops)	• Improved agricultural output • Reduced OpEx on inputs (e.g. price spikes on feed to be used in addition to futures contracts)
	Enhanced infrastructure to better protect farms from the impacts of climate change effects and extreme weather such as droughts or storms (e.g. elevated barns and processing units in flood-prone regions)	• Maintain agricultural output • Lower risk profiles with greater resilience to extreme weather
	Digital technology that supports early warning systems to enable farmers to anticipate extreme weather and protect livestock assets	• Improved risk profile with greater resilience to extreme weather

15 Baringa analysis.



Cattle grazing in Japan.

Ultimately, corporates and investors can plan and prepare for increase climate risk to protect their livestock assets or downstream processing units. This should include asking 4 key questions:

1. What is my upstream supply chain for all key inputs including feed, and what options do I have to hedge concentrated risk (including through feed diversification and water storage in droughts)?
2. What is the forward 10-year trend of climate risks and extreme weather hazards impacting my value chain, and how can I adapt to changes including through infrastructure investments in shelters?
3. What disaster scenario and contingency plans exist to maintain operational resiliency (e.g. to maintain cold storage during power outages)?
4. What technologies and data does the company have and need to monitor weather conditions, livestock health, and resource availability?

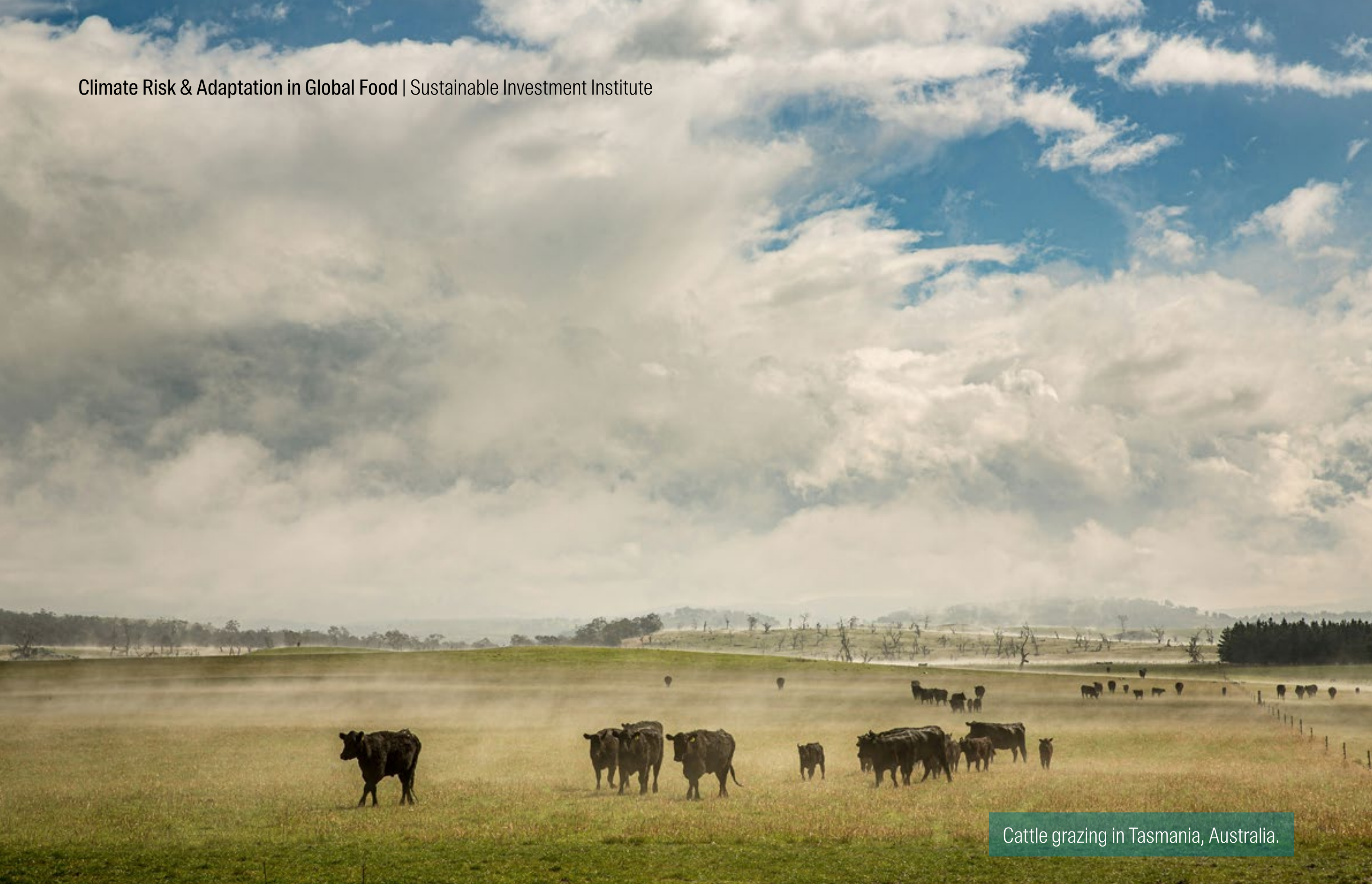
These questions will support livestock actors to understand their value-chains, risk profiles, mitigation measures and prioritisation criteria to support a more resilient system.

Case Study 7. Working with upstream suppliers to map emissions in Japan

Enteric emissions from cattle are the largest contributor of agricultural methane, responsible for up to 3% of global CO_2e emissions. This is a concern for all actors across the value chain especially with a growing focus on scope 3 reductions. Identifying the carbon footprint for upstream supply chains is a starting activity to design mitigation plans.

One large Japanese food company sought to tackle its scope 1–3 emissions and started by producing a carbon footprint assessment of their products. As well as mapping their own emissions, they also dispatched staff to work with dairy suppliers to compile annual data on energy inputs, feed composition, and feed consumption. This enabled them to identify that 91% of their own total carbon footprint came from their upstream supply chains, with over 58% coming from enteric methane in the cows .

The benefit of their approach was two-fold: firstly, it located and quantified the source of their emissions challenge, giving them a target to reduce their overall footprint. Secondly, through engaging their upstream suppliers at the beginning, they built buy-in and momentum to support their decarbonisation journey transitioning from transactional relationships to true partnerships.



Cattle grazing in Tasmania, Australia.

Case Study 8. Producing eco milk in Australia
One of the most important ways to reduce methane emissions without impacting overall production volume is to tailor feed to better suit livestock diets. Feed tailoring can cattle emissions by up to 90%. Whilst still at early-stage pilots, Numerous producers and food restaurant chains are exploring integrating improved feed products into their businesses.

In 2024, a dairy farm in Tasmania started producing milk with 500 cows being fed an oil containing a specialised seaweed extract proven to reduce cattle methane emissions[16]. This trial achieved a 25% reduction in emissions.

The cows produced around 10,000 litres of milk a day with a significant portion being packaged under a new eco-brand to be sold in large local retailers. The brand marketed a 5% premium against other full cream milk receiving positive market results, whilst the company producing the seaweed extract was a 2023 Finalist for the Earthshot Prize.

Case Study 9. Reducing heat stress mortality for poultry in India
Poultry accounts for 9.8% of global livestock production volume, and 30% when you discount milk. Chicken is the largest share of the poultry market representing almost 90% of total tonnage. However, where chickens thrive in an optimum temperature of 15–25°C, increasing temperature spikes in traditional farming regions are causing significant heat stress. A key driver of this is that chickens lack sweat glands enabling them to regulate their internal temperature. As such rising temperatures leads to heat build-up within the animal leading to poorer welfare, growth, productivity ultimately leading to chicken mortality.

One rural chicken farmer in India found 10–15% of their chicken flock had suffered heat stress-related death in one night in 2020. The impact of this was not just commercial, but also emotional on the flock, farmer, and family.
In response, they invested in their coop design to better adapt to rising temperatures. They installed solar-powered cooling systems whilst neighbouring farms also invested in more airy sheds with thick thatched roofs to offer low-tech cooling solutions. Ultimately, solutions such as these increased market returns by up to 20% due to healthier chickens with higher weight gain.[17]

16 "Tasmanian 'Eco-Milk' Tests Shoppers' Thirst for Climate-Friendly Dairy", ESM (2024).
17 "Experimenting with shed design to reduce heat stress in livestock, poultry", Mongabay (2024).

4.0 | Fishery value chains

4.1 | Global value chain structure

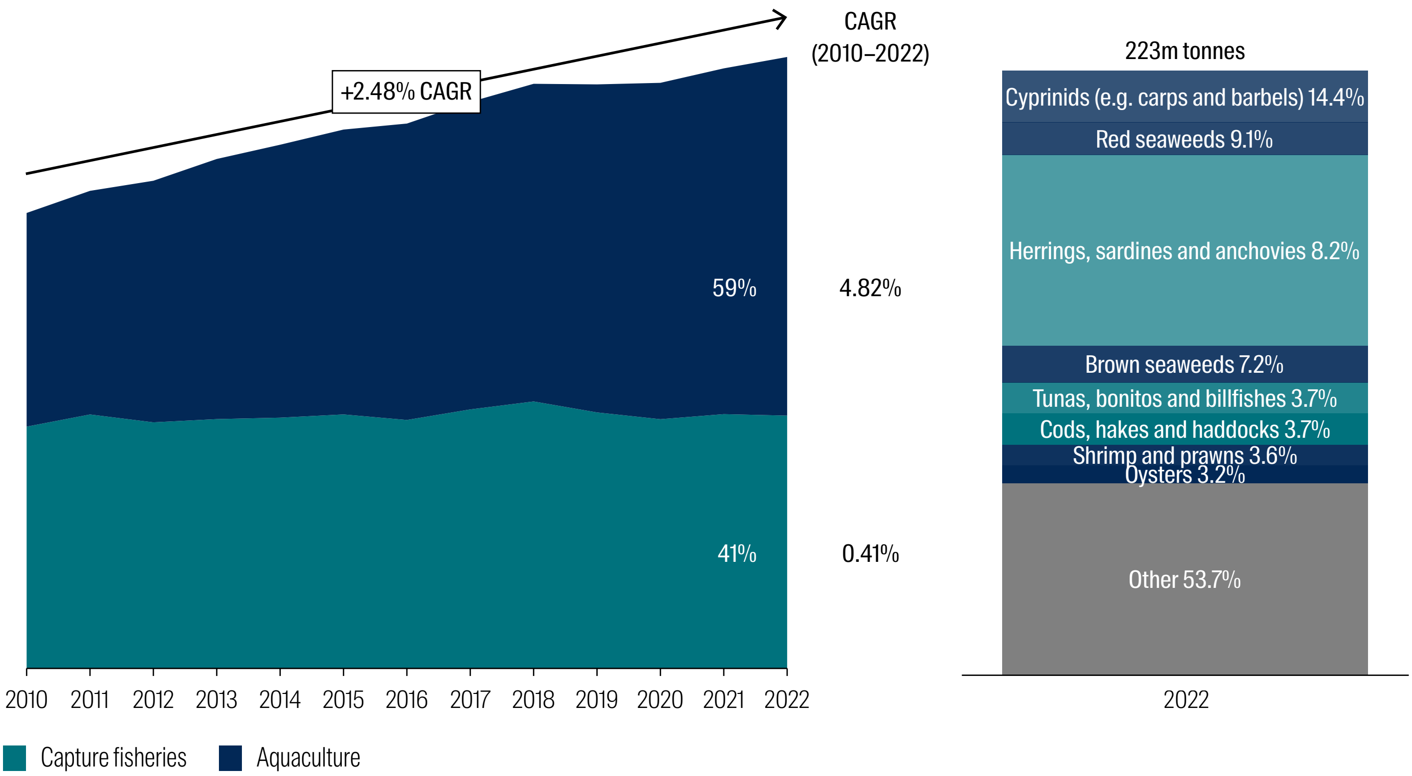
Fisheries, where demand has grown by 2.48% CAGR over the last 15 years, is naturally a distinct segment of the wider food system with unique dependencies related back to its marine ecosystem. For example, the high-water content and delicate tissue of fishery products means they have shorter shelf lives post capture requiring more robust storage infrastructure across the value chain.

Global production of marine products has grown faster since 2010 than other crop or livestock systems driven by two key factors: increasing worldwide per capita consumption and the significant growth in farming techniques. Fishery production can be segmented into two broad categories based on the cultivation and sourcing of aquatic species. Where capture fisheries refer to 'wild catching' from water bodies (such as oceans, rivers, or lakes), aquaculture involves farming fish species in controlled water bodies for the specific purpose of food production.

Aquaculture has been the driving force behind fishery growth seeing a 4.82% CAGR since 2010 with expectations to continue this growth, though at a slower pace, over the next decade. Growing demand for seafood (due to population growth and shifting dietary preferences) coupled with declining wild fish stocks are some of the core reasons underpinning growth in aquaculture markets. However, the key factor has been advancements in farming techniques.

Innovations in breeding and feed delivery amongst others has enabled fish farming to grow at scale by producing healthier, larger, and more sustainable fish at faster rates. This has enabled aquaculture to account for 59% of total fishery markets today, with aquatic animals responsible for 72% of total aquaculture farming producing 130.9 million tonnes and expected to reach 205 million tonnes by 2032.[1]

Figure 22. Fishery production volume growth (2010–2022)[2]



1 "The State of World Fisheries and Aquaculture", FAO (2024).
2 "The State of World Fisheries and Aquaculture", FAO (2024).

The table and graph shown in *Figures 23* and *24* demonstrates the market consolidation for production and trade of fishery products.[3] The 3 largest produced fishery commodities account for 31.7% of total volume, with 77% of total production coming from just three countries in Asia. This is typical of global fishery markets especially where Asian diets and population growth are driving higher fishery demand.

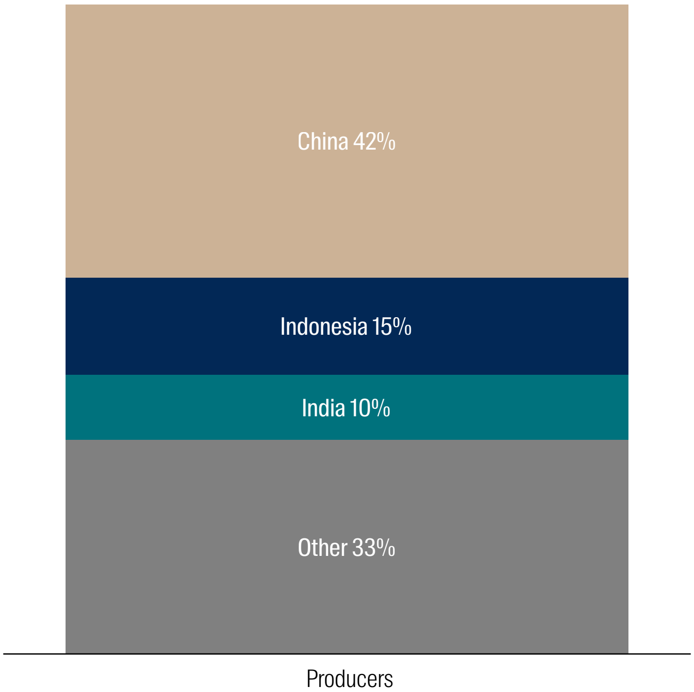
In contrast, whilst aggregate production of fishery products is dominated by a few key markets, trade is relatively fragmented with the largest 3 export and import markets occupying 23% and 27% of trade respectively. This demonstrates several key factors unique to fishery markets compared with crops and livestock:

1. Dietary preferences in most markets tend to favour locally caught fish representing high barriers to entry for 'foreign fish' and reducing the need for high cross-border trade;
2. High perishability of fishery products increases distribution and storage costs leading most suppliers to favour proximate demand; and
3. High regulatory requirements for fishery trade (e.g. on quality, safety, and sustainability) can be costly to meet making it easier to supply domestic markets.

These three factors indicate that most broader value chain risks can be localised to specific regional boundaries. However, the interconnected nature of aquatic ecosystems especially for ocean sourced fishery products still means climate risks are shared across regional systems.

Figure 23. Highest fishery volume: production (2022)[4]

Class	Commodity	% share of production	Largest producers
Aquaculture	Cyprinids (e.g.. carps and barbels)	14.4%	1. China (64.2%) 2. India (20.4%) 3. Bangladesh (4.5%)
Aquaculture	Red seaweeds	9.1%	1. Indonesia (45.2%) 2. China (40.7%) 3. Philippines (7.6%)
Capture fishery	Herrings, sardines, and anchovies	8.2%	1. Peru (22.6%) 2. Morocco (5.6%) 3. Chile (5.4%)
Aquaculture	Brown seaweeds	7.2%	1. China (88.3%) 2. Rep. Korea (7.3%) 3. DPRK (3.8%)
Capture fishery	Tunas, bonitos, and billfishes	3.7%	1. Indonesia (19.8%) 2. China (6.3%) 3. Viet Nam (5.7%)



3 "FishStat", FAO (2024).
4 "FishStat", FAO (2024).

Figure 24. Highest fishery volume: trade (2022)[5]

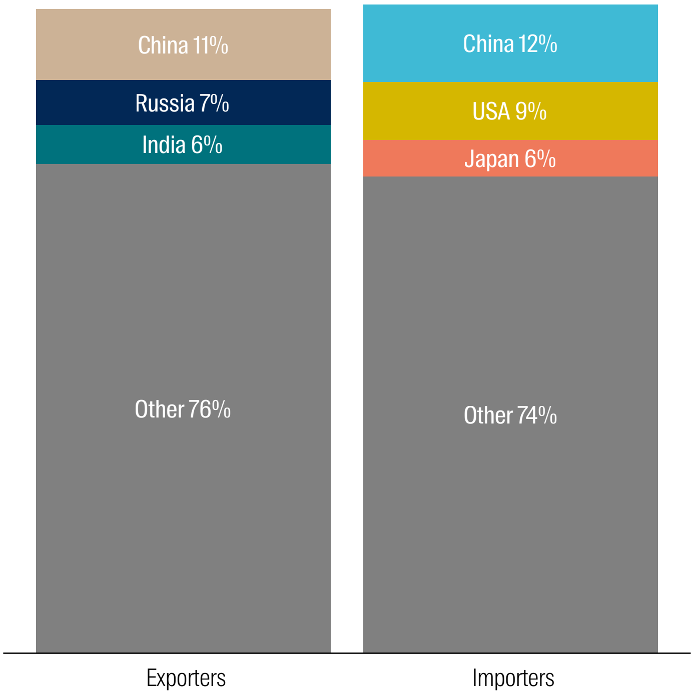


Figure 25. Typical fishery value chain activities[6]

1. Inputs	2. Production	3. Processing	4. Distribution	5. Marketing	6. Consumption	7. Waste/recycle
• Fishing gear • Boats • Energy • Labour • Aquaculture inputs (e.g. feed, water treatment, broodstock)	• Feeding • Fishing • Cleaning • Chilling • Environmental management	• Sorting & grading • Cleaning and gutting • Filleting • Specialised processing • Preserving • Freezing • Packaging	• Cold chain logistics • Transportation • Trading • Export	• Product labelling • Pricing • Advertising • Distribution	• Direct food consumption • Fishmeal and oils • Industrial use • (e.g. fish glue)	• Waste management • Animal feed production • Biofertilizers production • Biofuel production
Example actors • Skretting • AKVA Group	• Pacific Seafood • MOWI	• SAFCOL • NISSUI	• Sysco • Trident Seafoods	• Thai Union • Maruha Nichiro	• Costco • KURA	• Biomega • Fujimitsu

5 "FishStat", FAO (2024).
6 Baringa analysis.

4.2 | Fisheries climate risks and extreme weather impacts

Where fishery value chains share the same extreme weather hazards as the broader food ecosystem, they also manifest into unique impacts especially for ocean habitats and migratory patterns. In addition to stress in aquaculture farming, these have placed major strain on capture fishery potential, leading to a 40% decline in fishable ocean products by 2100.[7]

Extreme weather hazards impact fishery systems in distinct ways due to the unique characteristics of aquatic ecosystems and life cycles. For example, heatwaves, flooding, and storms can severely damage coral reefs and seagrass beds, which house upwards of 25% of all ocean species as the 'rainforests of the sea'.

Similarly, whilst droughts can dry up inland water bodies, heavy precipitation can lead to stormwater runoff which alters the salinity of coastal water regions. This either injures fish or forces them to migrate. In all these cases, the impact to the fishing industry can be severe and long-lasting.

A key climate risk occurring to oceans is acidification. Whilst this sits aside from extreme weather impacts, it is exacerbated by them. Ocean acidification concerns the absorption of atmospheric CO2 into seawater that results in carbonic acid that ultimately has different impacts on ocean life including the prevention of corals, molluscs, and certain plankton to build calcium carbonate shells and skeletons. This damages fish nurseries and disrupts aquatic food chains ultimately leading to material declines in commercially significant fish such as carp, salmon, and cod. As a result, ocean acidification can be a significant and unique compound effect with wide reaching impacts.

There are 5 key vulnerabilities that underpin the impact climate risk and extreme weather hazards have on aquatic life. These are outlined in *Figure 26*. Further impacts across other key elements of the value chain are outlined in *Figure 27*.

Figure 26. Fishery vulnerability to climate risks and extreme weather impacts

Extreme weather	Description
Temperature	Fish are ectothermic (cold blooded) and as such their metabolism, growth, and reproduction are directly influenced by the water temperature; heatwaves and temperature fluctuations can significantly impact fish biological cycles causing early migrations or resulting in fish mortality (e.g. salmon die-offs in the Pacific Northwest)
Water chemistry	Fish are highly sensitive and dependent on water nutrient levels including for oxygen, carbon, and salinity; heavy rainfall or flooding can reduce salinity forcing fish to migrate, whilst storm runoff can lead to algal blooms that deplete oxygen levels resulting in areas which are lethal to fish (e.g. certain areas in the Gulf of Mexico are referred to as 'dead zones')
High mobility	Compared to other agricultural systems, fish are highly mobile and respond to environmental changes by migrating relatively easily to more favourable conditions; fish also take migratory cues from their environment due to the perceived predictability of ocean currents during certain seasons with significant impacts when these change (e.g. tuna and mackerel migrate during warming waters)
Breeding cycles	Breeding or spawning occurs in seasonal cycles of fish informed by environmental patterns such as ocean temperatures; warming oceans or altered water chemistry can either spark early, but ill-prepared, breeding seasons, disrupt season spawning, or reduce egg viability (e.g. rising temperatures are damaging cod eggs and reducing populations)
Complex food webs	Fish are reliant on complex food changes where impacts to one species can reverberate across wider chains (e.g. ocean acidification leads to numerous impacts including reducing plankton populations which have follow-on effects for the flow of nutrients across the ocean as well as the many fish that feed on plankton species such as herring, anchovies, sardines, mackerel, salmon, and cod)

7 "The Impact of Disasters on Agriculture and Food Security", FAO (2023).

Herring and sardine schools in Monterey, USA.

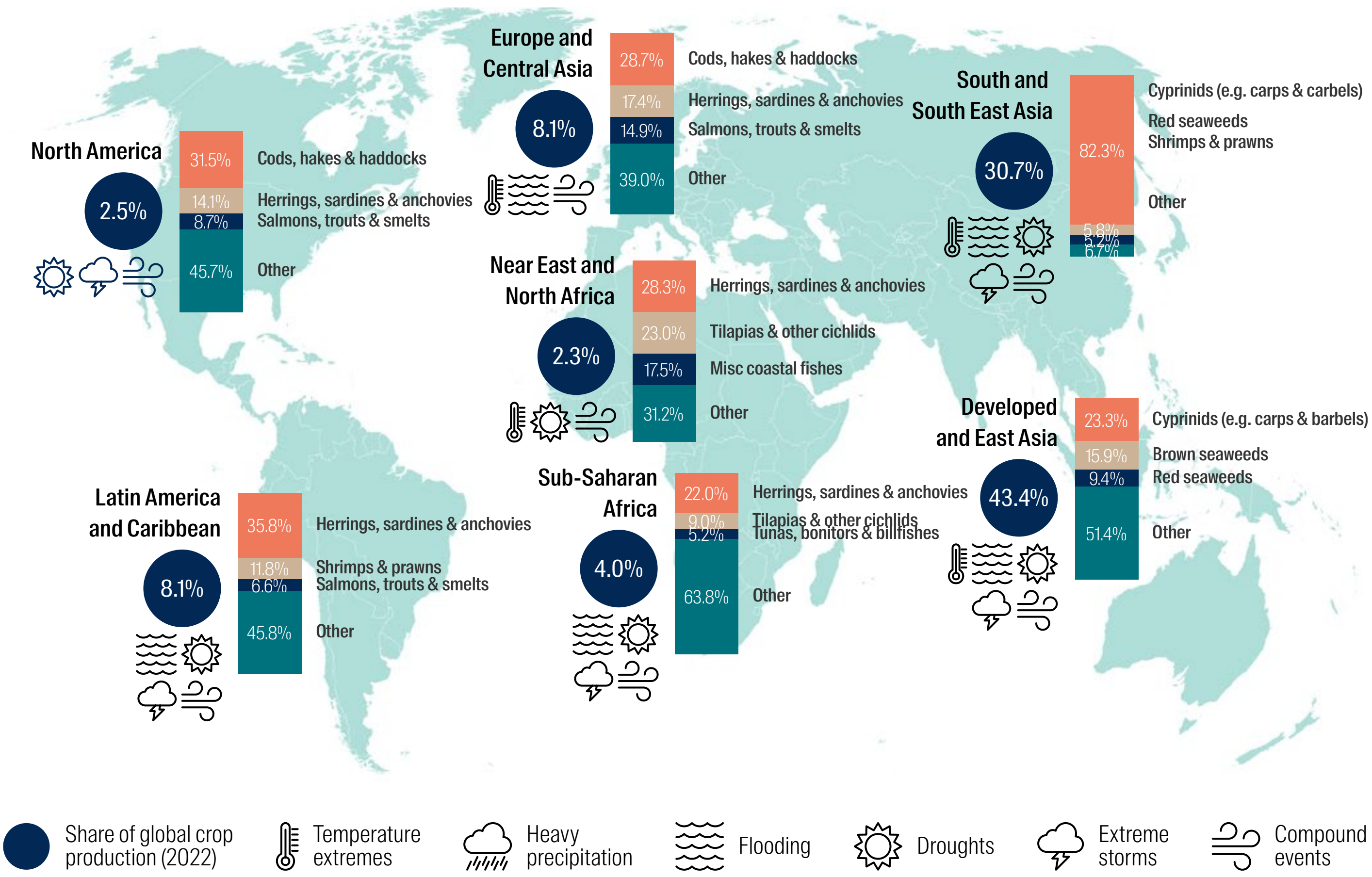
Figure 27. Example extreme weather hazards and asset and investor impacts across fisheries[8]

Value chain segment	Example extreme weather impacts	Asset and investor impact	Example occurrence
Inputs	• Heatwaves causing damage to fish broodstock in hatcheries and feed production systems • Storms damaging fishing vessels and port infrastructure	• Higher CapEx costs to protect against extreme weather • Higher OpEx costs (e.g. replacement broodstock)	• Extreme weather in Bangladesh in 2020 impacted fish hatcheries and farms leading to $56.2 million in losses and damage.[9]
Production	• Heavy precipitation causing stormwater runoff upsets water chemistry for inland or coastal systems • Droughts reduce river flows disrupting breeding cycles	• Reduced fishing yields • Higher OpEx costs (e.g. flooding defences)	• Heavy rains in Australia in 2022 were found to have reduced estuarine species diversity by 17–45%.[10]
Processing	• Heatwaves necessitating increased refrigeration costs • Typhoons causing significant damage to infrastructure and facilities	• Higher OpEx costs (e.g. cold chain storage, energy) • Lower processing productivity	• Typhoons in Tonga in 2022 from the Hunga Tonga-Hunga Ha'apai eruption led to fishery losses and damages of $7.3 million.[11]
Distribution	• Port closures and roadblocks / flooding from storms affecting supply chains • Heightened temperatures stressing cold-chain infrastructure	• Higher prevalence for food spoilage in transport • Higher OpEx costs (e.g. transport)	• Storms in the UK in 2024 led to freight trailer damage on freight boats with fresh salmon cargo being lost overboard.[12]

8 Baringa analysis
9 "Economic valuation of climate induced losses to aquaculture for evaluating climate information services in Bangladesh", Climate Risk Management (2024).
10 "Flood effects on estuarine fish are mediated by seascape composition and context", Marine Biology (2024).
11 "The Impact of Disasters on Agriculture and Food Security", FAO (2023).
12 "Fresh salmon lost overboard from NorthLink freight boat in severe weather", The Shetland Times (2024).

Fish farms in the sea

Figure 28. Global fishery production and most common extreme weather hazards by region (2022)[13]



13 "FishStat", FAO (2024).

4.3 | Mitigation & adaptation measures

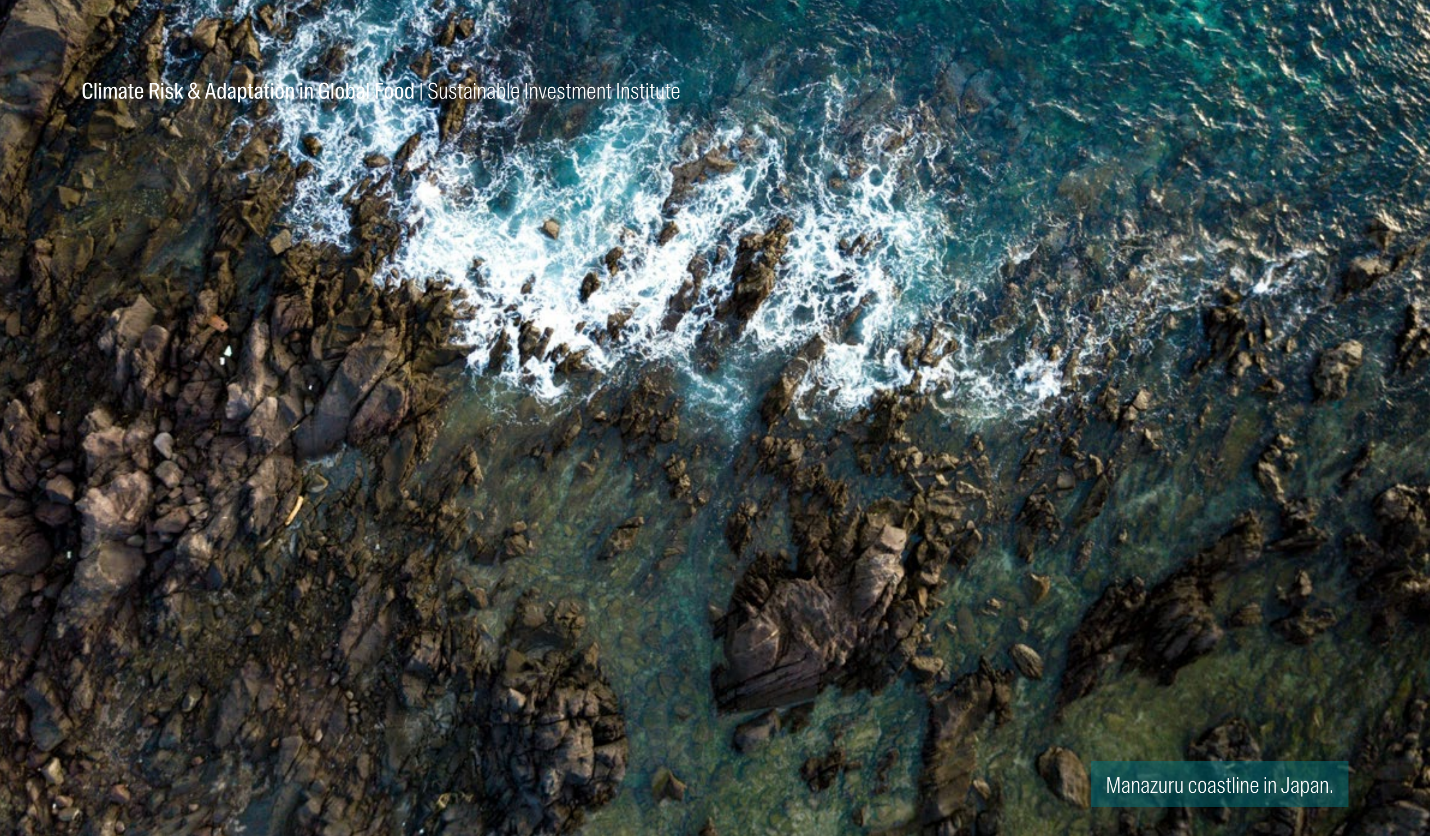
Considering the unique risks of fishery system, corporates and their investors should ask themselves 5 key questions as they plan mitigation and adaptation actions to protect investments and wider aquatic system resilience.

Operators throughout the fisheries value chain have multiple opportunities to both lessen their impact on climate change and adapt to the effects of increasingly extreme weather. They should begin by evaluating their entire value chains and resource usage to enhance efficiency and reduce resource demands. These initiatives would boost resilience against extreme weather while maintaining animal welfare and operational sustainability, thereby supporting commercial stability and growth.

Figure 29. Example mitigation and adaptation levers for fishery[14]

	Example lever	Potential impacts
Mitigation	**Increase feed efficiency** focusing on reducing nutrient waste and improving growth rates to lower the environmental footprint of aquaculture (e.g. precision aqua feeding systems minimizing waste and reducing uneaten feed in the water or enzyme-enhanced feeds to increase nutrient absorption)	• Reduced OpEx on inputs (e.g. lower quantities of feed required) • Improved yields • Alignment to ESG expectations for emissions reduction
	Integrated Multi-Trophic Aquaculture (IMTA) is a method aiming to leverage natural systems to recycle nutrients and reduce pollution and emissions (e.g. grow fish alongside shellfish and seaweed to utilise nutrient outputs efficiently and reduce waste)	• Reduced OpEx on inputs (e.g. lower quantities of feed, improved circularity, lower spend on waste management) • Alignment to ESG expectations for emissions and pollution reduction
	Blue carbon sequestration (as an example of a nature-based solution) through incorporating seaweed farming as part of the operation to absorb CO2 from the water and atmosphere (e.g. cultivating kelp which alongside absorbing CO2 also absorbs excess nutrients reducing eutrophication)	• Improved fishery yields • New revenue streams from blue carbon credits or seaweed biomass (e.g. sold to produce biofuels or feed)
	Renewables and clean energy to reduce emissions and energy costs (e.g. solar powered aerators or pumps)	• Lowered OpEx for fuel and reduced dependence on fossils • Alignment to ESG expectations for emissions reduction
Adaptation	**Fish breeding** aimed at supporting broodstock that can better withstand climate change and extreme weather (e.g. more tolerant to higher water temperatures or lower oxygen levels)	• Improved fishery yields • Lowered risk profiles with greater resilience to extreme weather
	Diversified feed sources to enhance resilience to climate-induced feed shortages and supply chain risks (e.g. using alternative insect-based proteins such as black soldier fly larvae)	• Improved fishery output • Reduced OpEx on inputs (e.g. price spikes on feed to be used in addition to futures contracts)
	Enhanced infrastructure to better protect fish farms from the impacts of climate change effects and extreme weather such as flooding or storms (e.g. elevating fish farms and reinforcing nets)	• Maintain fishery yields • Lowered risk profiles with greater resilience to extreme weather
	Improved water management including through 'Recirculating Aquaculture Systems' (RAS) to improve water quality whilst reducing water consumption	• Lowered OpEx for water management • Strengthened fishery yields

14 Baringa analysis.



Manazuru coastline in Japan.

Ultimately, corporates and investors can plan and prepare for increased climate risk to protect their fishery assets or downstream processing units. This should include asking 5 key questions:

1. What is my upstream supply chain for all key inputs including feed and energy, and what options do I have to hedge concentrated risk (including through feed diversification, renewables and water management)?
2. What are the broader climate risks and extreme weather hazards occurring in my [upstream] fishing pools over the term of the business or investment, and what opportunities exist to hedge this risk (e.g. through planting seagrass meadows)?
3. What opportunities exist to diversify fishing models to reduce over dependence on singular species and breeding techniques?
4. What refrigeration and logistics systems are required to support transport of my fishery goods especially considering extreme weather trends in my core supply and demand geographies?
5. What innovations does the company use to improve fisheries resilience to climate change and achieve better efficiency and circularity?

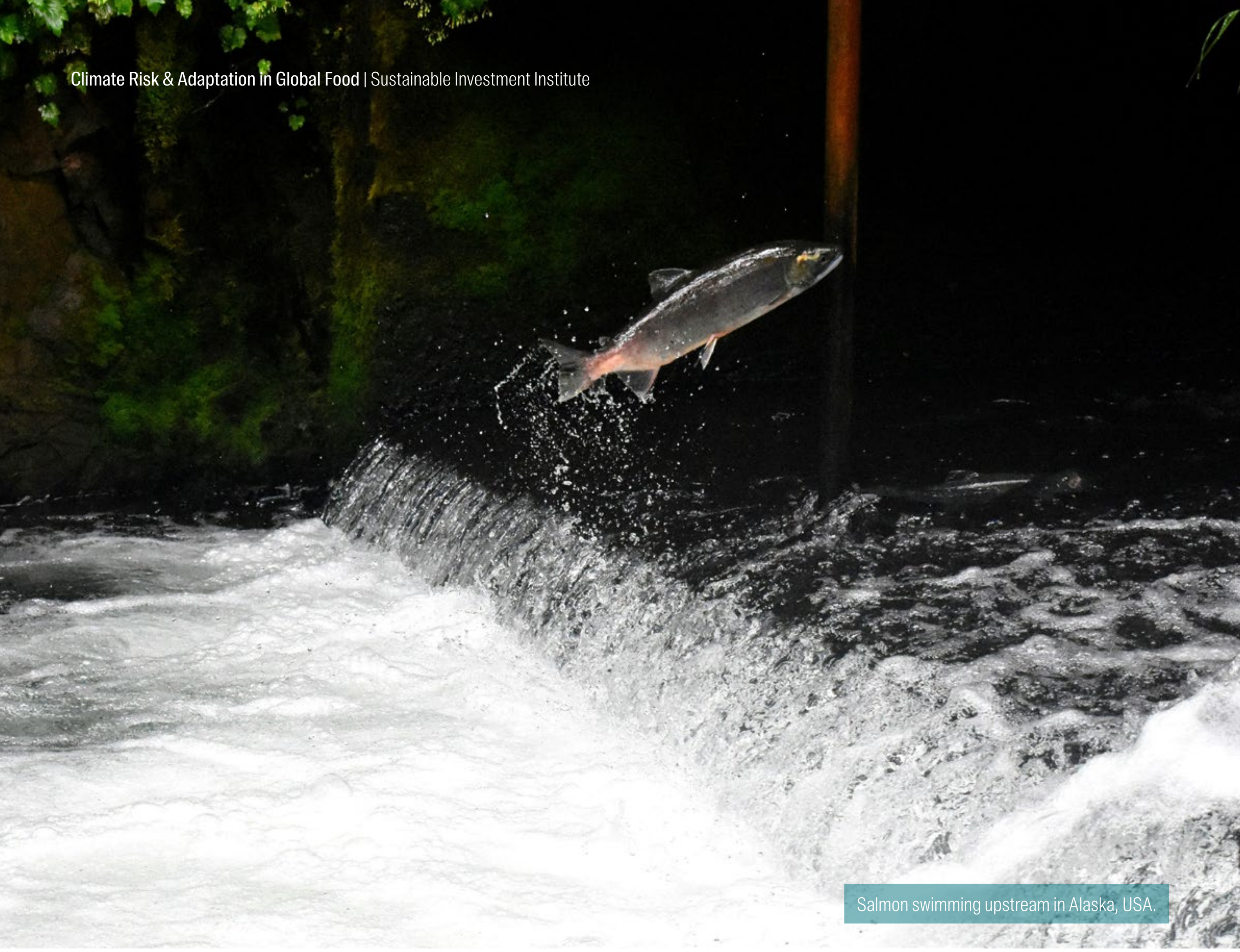
These questions will support actors across the fisheries value-chain to understand their risk profiles better, mitigate these risks and support a more resilient system.

Case Study 10. Blue carbon credits in Japan

Blue carbon credits refer to carbon captured and stored in marine ecosystems through initiatives such as planting or reseeding mangroves, salt marshes, and seagrass beds. These function in the voluntary carbon market and are typically more complicated due to higher implementation and monitoring costs. However, they are also generally seen as higher quality carbon credits due to the co-benefits achieved in addition to carbon sequestration (such as supporting biodiversity, reducing ocean acidification, and protecting from coastal erosion). Whilst blue carbon credits only account for a 0.2% issuance as of January 2024, their co-benefits tend to support stronger premiums of up to 4x terrestrial carbon credits.[15]

Japan has been at the forefront of blue carbon credit development with more than 45 initiatives underway including creating seagrass meadows in Yokohama City and Fukuoka City.[16] Together, these have covered more than 161 ha of annual emissions reductions, producing 'J Blue Credits' which are certified by the Japan Blue Economy Association (JBE). These projects have not only generated direct commercial returns through selling carbon credits, but they have also improved fishing environments (such as for sea urchins where catches increased 80% following seaweed planning in 3.4 ha in Mashike Town).[17]

15 "How the VCM can turn the tide for blue carbon", BeZero (2024).
16 "Case Study on Blue Carbon Initiatives in Japan", Blue Carbon Liaison Council (2023).
17 "Case Study on Blue Carbon Initiatives in Japan", Blue Carbon Liaison Council (2023).



Salmon swimming upstream in Alaska, USA.

Case Study 11. Recirculating aquaculture systems in Australia
Recirculating Aquaculture Systems (RAS) are advanced systems that recycle water to breed fish in controlled environment such as tanks. Unlike other aquaculture methods that rely on large bodies of water or open environments, RAS minimises water demand by up to 99% through filtering wastewater through mechanical and biofilters before adding additional components such as oxygenation, ozone disinfection, or heat exchanging depending on the fish breeding requirements. Leaving aside the higher breeding costs and energy intensive nature of the system, this optimises for economic and resource efficiency whilst also supporting fish growth year-round.

RAS solutions are common across multiple geographies especially for in-land fish farming. A large agricultural multinational operating in Australia announced plans in 2024 to invest over $100 million to build a new RAS facility in Tasmania focused on 99% water recycling. This will speed up the time for its in-land salmon farming operations, enabling young salmon to reach their ideal size faster and reducing sea time by up to 30% against industry averages.[18] Importantly, this will not only support aquaculture operations but also wider agriculture through supplying the remaining 1% of water to local farmers for horticulture farming (such as for cherries).[19]

Ultimately, solutions such as RAS enable both adaptation and mitigation measures for climate change within aquaculture farming. This is by protecting fish growth from the impacts of extreme weather on open environments (e.g. from temperature extremes, storms, or ocean acidification), reducing water dependencies including from groundwater sources, and improving stranded asset risks through strengthening fishery businesses through greater controls on fish development.

18 "Whale Point Nursery Expansion", Huon (2024).
19 "Huon Aquaculture to invest $110 million to boost land-based production at Port Huon, Tasmania", JBS (2024).

5.0 | Opportunities arising

5.1 | The investment environment

Whilst the food value chain provides ample opportunity for investors, it also can be a challenging sector to access with some segments harder to reach than others. This is especially true for production.

Investment opportunities vary across the agricultural value chain and investors tend to be drawn to certain segments more than others. This is due to common factors such as profitability, scalability, market dynamics, investor awareness, and technological innovation. Commonly, production sees lower rates of investment than processing due to lower growth prospects and lower proximity to consumers (and thus greater investor awareness). Each segment of the value chain faces its own relative investment risks. A broad overview of investment opportunities and risks across the value chain is provided in *Figure 30*.

Figure 30. Investment across the food value chain[1]

Value chain segment	Example extreme weather impacts	Asset and investor impact	Example occurrence
Inputs	• Wide access to investors especially as many providers of inputs into the food system also supply other industries to benefit from diversification (e.g. agricultural machinery often comes from automotive companies, or fertiliser companies that sit within larger energy groups)	• Listed equites • Private equity • Listed bonds of larger entities	• Slowdown in capital spending (e.g. due to demand or financing costs) • Raw materials supply availability and cost • Supply-demand mismatches of perishable inputs
Production	• Lower access to investors especially as most production comes from smallholder farmers on less than 2ha (32% of food supply) or medium-sized family businesses on less than 20ha (27% of food supply)[2]	• Limited corporate investment opportunities • Private equity • Government subsidies	• Climate risks • Input costs (e.g. seed, fertiliser, energy, labour) • Government policy and support
Processing	• Wide access to investors as global food producers are typically larger and more diversified groups spanning multiple food lines whilst smaller businesses have a more local or narrower focus with private equity playing a key role	• Global listed equities • Smaller listed equities • Private equity • Listed bonds of larger entities	• Agricultural commodity price fluctuations • Shifting consumer trends (e.g. local, organic) • Food regulations and taxes or tariffs • Supply-demand mismatches
Distribution	• Wide access to investors as food distribution specialists often couple food logistics with other non-food lines	• Global listed equities • Smaller listed equities • Private equity • Listed bonds of larger entities	• Inputs costs (e.g. energy, labour) • Supply-demand mismatches • Channel shifts

1 Baringa analysis.
2 "How much of the world's food to smallholders producer", Ricciardi et al., Global Food Security (2018).

Looking at downstream segments, the food industry is ultimately constrained by population growth and per capita consumption. Further, EBIT margins are typically low across the food industry (see *Figure 31*), hovering around 5% for food retail and food distributors. Whilst speciality foods, including confectionery, have higher margins and the bigger diversified groups have consistently achieving double-digit margins, they still appear below the wider consumer durables sector. This has meant that, more generally, the food sector has struggled to create strong shareholder value.

Figure 31. EBIT margin of food companies[3]

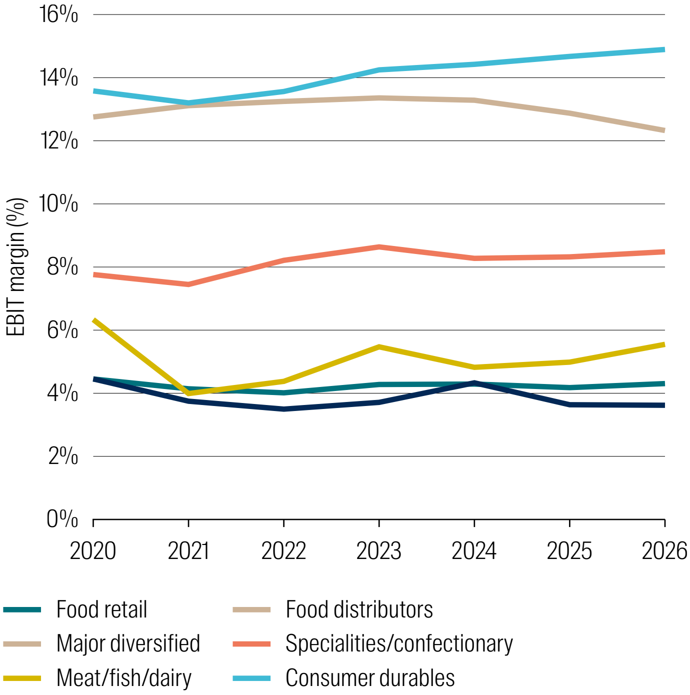
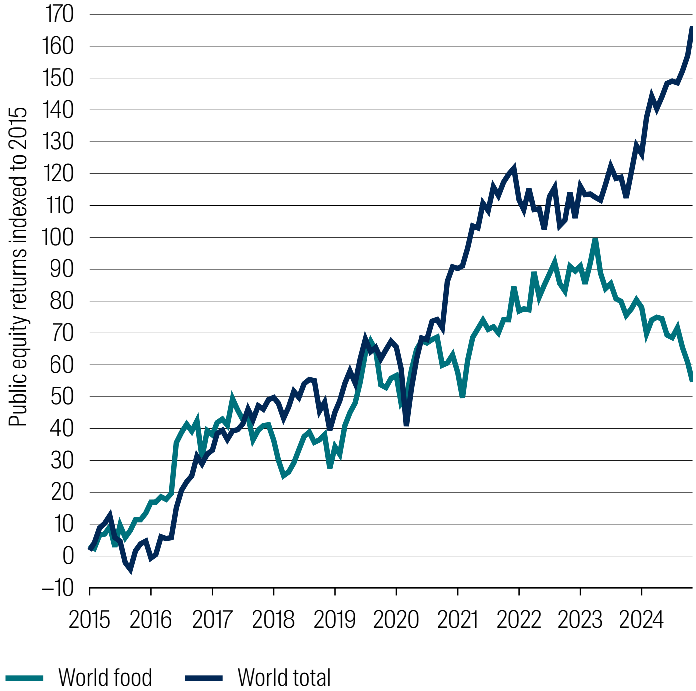


Figure 32 presents the indexed view of global food sector equity value compared to global portfolio.[4] While the industry just about matched returns in the wider equity market over the period 2015 to 2020, it has underperformed since. In addition to post-Covid lockdown challenges, one key driver for this has been the tech-boom that has driven equity markets higher through 2023–24 distorting comparisons for non-tech sectors. Ultimately, this challenging investment environment underlines the importance of investors seeking investments with stronger potential to out-perform the whole sector through market share gains, capturing growth in growing segments, deploying innovative methods and being on the right side of consumer, technology and environmental shifts. This requires a detailed understanding of the investment prospects as well as the role of climate risks on returns.

Figure 32. Performance of global food equities compared to the whole equity market[5]



3 "Total Return for Indexes: World Food: Major Diversified – Industry and World – All Listed Equities", FactSet (2024).
4 "Total Return for Indexes: World Food: Major Diversified – Industry and World – All Listed Equities", FactSet (2024).
5 "Total Return for Indexes: World Food: Major Diversified – Industry and World – All Listed Equities", FactSet (2024).

5.2 | Market shifts and the new winners

As a result of increasing climate risk as outlined in the preceding sections, global agricultural value chains are going through significant changes.

This is upending some established players and creating new rules for those who will capture the most value from growing food demand. This can be synthesised as 5 key market shifts:

1. **Shift in geographic viability:** Climate change is impacting established weather patterns improving the viability of certain regions such as Northern Europe and Canada as new agricultural hubs due to warmer climates. At the same time, improvements in genetic engineering for crops or livestock, alongside innovations such as RAS, are making it more feasible to shorten value chains to reduce global climate risk and support increasing consumer demand for locally sourced produce. The new winners are those that will be able to take advantage of shifting climate patterns, infrastructure enhancements, and the opportunities to shorten supply chains especially towards servicing large populations in ready demand markets especially to drive a premium for 'locally sourced' products.
2. **Shift to climate resilient species:** Regions experiencing increasing droughts and temperature spikes are likely to shift their livestock practices to desert practices who have historically faced the same climate these regions are facing now. Practically, this could resemble a shift away from cattle farming to goat and camel farming which some parts of the world are already adopting such as Ethiopia[6] and Kenya.[7] The new winners in these regions are those that can make the switch faster. They are benefited by supporting agricultural environments (e.g. through camel distribution programmes and training schemes), as well as where consumer markets are already being repositioned for the switch (e.g. towards camel milk).
3. **Shift in technology innovation:** The marriage of agriculture and technology is growing stronger and leading to significant changes in how we can efficiently and effectively manage agricultural operations. Example developments include precision agriculture informed by IoT sensors and improved data analytics, AI driven soil monitoring systems to optimise farming schedules, drones and satellite usage to better forecast extreme weather patterns, and biotechnologies and gene editing solutions to produce GM crops protected against pests or droughts. Ultimately, leveraging these solutions can improve agricultural yields driving improved outcomes across the rest of the food value chain. The new winners will be those who best understand the opportunities, and risks, brought by these new technologies whilst also preparing consumer markets to understand the same within the new contexts of higher climate risks and improved welfare expectations on plant, livestock, and fishery products.
4. **Shifts in consumer preferences:** All countries will see demand growth across agricultural products. However, changes to dietary choices will also be happening marking distinct contours of this growth unique to developed and emerging markets. High-income countries will continue to see shifts over the links between health and sustainability, for example leading to declining sweetener demand and stagnating meat growth. In contrast, other countries will see their per capita calorie intakes rise with a focus on more meat and dairy consumption, with middle-income countries representing up to 79% of global meat demand growth over the coming decade. India and Pakistan alone will account for 74% of total dairy production growth through to 2033.[8] The new winners will be those that are able to best understand different shifting consumer preferences to pre-empt demand impacts and meet demand where it will be.
5. **Shifts in agricultural trade:** Whilst global agricultural trade will continue to expand over the coming decade, expectations are for this to be more muted than previous years especially as liberalisation efforts have either slowed or reversed in some countries. For example, where the EU has concluded its Trade Agreement with Mercosur aiming to eliminate up to 90% of tariffs between both blocs, the US has introduced tariffs of up to 25% on all products traded from Canada and Mexico. Other countries may also look to restrict exports especially when domestic food security becomes a risk due to lower agricultural yields from climate change. As such, many producers and processors will look to influence trade policy whilst also diversifying import markets for inputs or core agricultural products, and diversifying export markets through catalysing new consumption centres. The new winners will be those able to do these to lower trade risks associated with their businesses.

6 "Effects of climate variability on livestock productivity and pastoralists perception: The case of drought resilience in Southeastern Ethiopia", Habte et al., Veterinary & Animal Science (2022).

7 "Camels replace cows in Kenya due to climate change", Le Monde (2024).

8 "Agricultural Outlook", OECD-FAO (2024).

5.3 | The Opportunity for Decarbonisation

Aside from these shifting market trends, the need and opportunity for decarbonisation within agricultural value chains will continue to remain strong too. This is especially in upstream inputs and production segments.

Agriculture and Land Use Change & Forestry (LUCF) account for 15–30% of global greenhouse gas emissions. The majority of this comes from enteric fermentation in livestock, land use change, manure, rice cultivation, and synthetic fertilisers primarily releasing of methane and nitrous oxide (see *Figure 34*).

Methane (CH4) and nitrous oxide (N2O) are especially potent greenhouse gases. Methane can remain in the atmosphere for 12 years but has up to 30 times the global warming potential of CO_2. This is primarily due to its much higher energy absorption rates meaning it causes more harm within its shorter lifetime. In contrast, nitrous oxide can remain in the atmosphere for over 100 years and has a global warming potential of over 270 times that of CO_2. Together, these two gases, especially from crop and livestock commodities, are the key drivers for agricultural emissions.

Growth in agricultural demand and shifting dietary trends means the impact of food system emissions will continue to get worse if left unabated. Several studies have demonstrated that reducing GHG impact from agricultural input and production systems will be critical to limit global warming to either a 1.5° or even 2° target.[9] This will be key to lower escalating climate risks brought on by more severe and compounded extreme weather events.

This paper has highlighted many opportunities, including with nature-based solutions, to mitigate climate change through reducing agricultural emissions. These include conservation tillage and other regenerative agricultural practices to increase soil carbon sequestration, incorporating livestock feed additives such as seaweed to reduce methane from livestock, and precision farming techniques to optimise fertiliser use and reduce N2O emissions. Whilst the business case for some of these are still being tested, others have already proven strong returns in either stronger yields or the ability to align to regulatory standards and catalyse sustainability premiums.

Figure 33. Global emissions by sector (2021)[10]

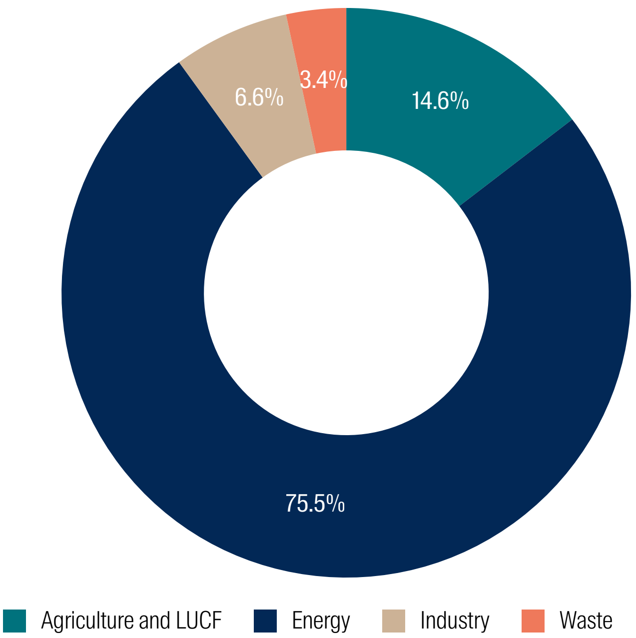
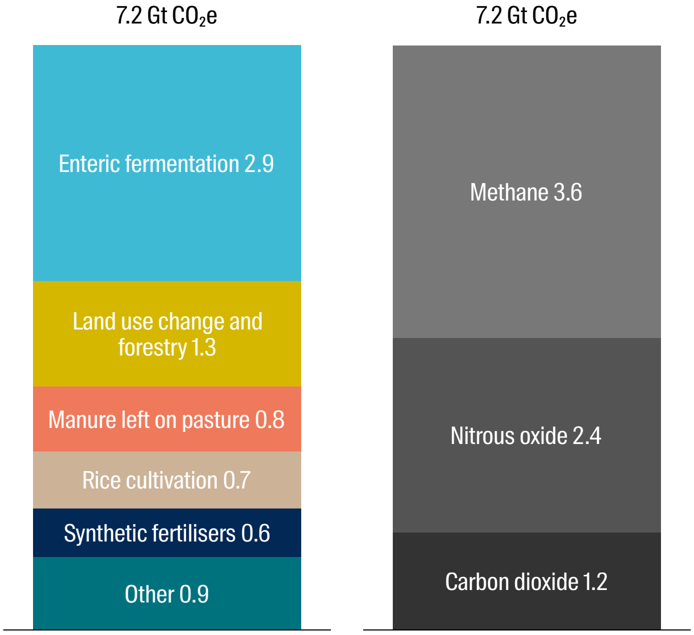


Figure 34. Agricultural emissions by source (2021)[11]



9 "Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets", Clark et al., Science (2020).
10 "Climate watch platform and data", Climate Watch (2024).
11 "Climate watch platform and data", Climate Watch (2024).

6.0 | Actions for investors

6.1 | Prerequisites for investors

Investors play a critical role in derisking their agricultural businesses from escalating climate impacts, and this matters regardless of where investors operate along the agricultural value chain. This happens across the investment lifecycle.

Most agricultural and food investors are involved in the processing, distribution, and marketing segments. In contrast, production, as one of the most impacted segments by extreme weather hazards in the value chain, has limited investor input. This is especially with one of the most important producer groups; small-holder farmers (SHFs)[1]. SHFs operate on less than 2 hectares and represent c.80% of farmers producing c.30% of global food supply.[2] It is important that investors understand the integrated supply chains of their investments, tracing back to SHFs if required, to identify and plan for climate risk.

There are 7 key subjects that investors should explore more to better understand the key risks within their agricultural or food portfolio companies:

1. **Value chain structures:** Identifying their upstream supply chains and partners;
2. **Economic structure:** Defining economic structures and flows of core businesses;
3. **Market dynamics:** Understanding forward demand and price trends;
4. **Physical climate risk:** Modelling extreme weather hazards and identifying measures required to adapt or mitigate impacts;
5. **Regulatory landscape:** Understanding trade policy, subsidy schemes, and ESG regulation;
6. **Diversification strategy:** Identifying options to reduce supply or demand dependencies; and
7. **Agricultural innovations:** Understanding new agricultural practices and solutions.

1 For further background see Stewart Investors work on "Investment and sourcing through smallholder supply chains".
2 "How much of the world's food do smallholders produce?", Ricciardi et al., Global Food Security (2018).

6.2 | Disclosure requirements

Investors have an opportunity to help their companies expand and deepen their strategic decision-making including through collecting and analysing the right data to assess their climate risk. Below are list 10 key disclosure categories (to Boards and/or publicly as appropriate) that can help investors to assess climate risks and opportunities.

Many of these disclosures align to recommendations and requirements under the Taskforce on Nature-related Financial Disclosures (TNFD), Taskforce on Climate-related Financial Disclosures (TCFD), International Sustainability Standards Board (ISSB), and EU's Corporate Sustainability Reporting Directive (CSRD). As such, they support best practice across a holistic reporting framework.

Figure 35. Disclosures to support investor decision making[3]

Disclosure	Objective	Information supporting						
		Value chain structures	Economic structures	Market dynamics	Physical climate risk	Regulatory landscape	Diversification strategy	Agricultural innovation
1. Value chain maps outlining core partners and regions that account for over 20% of either supply or offtake	Identify critical path dependencies in business operations especially where climate risk can accrue	✓	✓	✓	✓	✓	✓	
2. Climate risk scenarios over at least 10 years across all key extreme weather hazards for themselves and core supply chains	Define and quantify climate risk across extreme weather hazards impacting direct and dependent operations				✓	✓	✓	
3. Input price scenarios over 5 years across all key inputs including identifying key drivers for volatility	Define and quantify price volatility across key inputs (e.g. energy, feed, fertiliser, or agricultural yields)		✓	✓		✓	✓	
4. Nutrient density trends across key products linked to key drivers (e.g. reduction in wheat protein density due to drought)	Identify quality changes across product set linked back to key nature-based causal drivers				✓			
5. Emissions across scope 1–3 for their operations (including breakdowns between different emission types if possible)	Understand GHG footprint by source and type including as are subject to regulatory reductions or taxes		✓			✓		✓
6. Natural resource consumption across direct and indirect operations (e.g. spatial footprint of land controlled, land use change, water consumption) and opportunities to minimise usage	Identify resource usage across key nature related factors, and opportunities to lower resource consumption	✓			✓			✓

3 Baringa analysis.

Disclosure	Objective	Information supporting						
		Value chain structures	Economic structures	Market dynamics	Physical climate risk	Regulatory landscape	Diversification strategy	Agricultural innovation
7. Priority and material ESG factors impacting direct and dependent operations (e.g. biodiversity loss, soil health, worker welfare)	Define material impacts, risks, and opportunities relevant to the business[4]	✓	✓	✓	✓			✓
8. Impacts of current and projected carbon taxes on their operations impacting both economics as well as product mix	Project the future impact of carbon taxes on the business including informing required shadow carbon prices to future-proof investment planning		✓	✓		✓		
9. Market demand trends at the end of their agricultural value chains that could change demand growth	Understand consumer sensitivity, elasticity, and preference shifts (e.g. sugar reductions or alternative proteins)		✓	✓			✓	✓
10. Operational, product, and investment plans to decarbonise operations, improve material impacts, and hedge towards future consumer demand	Plan towards lowering climate risk and building business resilience including through setting interim targets to 2050 and alignment to specific standards (e.g. SBTI)		✓	✓	✓	✓	✓	✓

4 This is akin to Corporate Sustainability Reporting Directive (CSRD) requirements to conduct a double materiality assessment for firms operating or listed within the European Union; this would identify relevant impacts, risk, and opportunities from and to firm operations on the environment and wider society.

6.3 | Investor engagement plan

Ultimately, the world remains on track towards a 2.5° scenario by 2050 unless we can course correct and fast. This will require greater involvement from investors especially working with their companies, value chains, and policy makers to shape and direct agricultural value chains to mitigate the harmful impacts of current practices and adapt to changing weather patterns and consumer demands.

Investors can have a crucial role to drive sustainable business practices beyond their primary function around capital allocation. Investors have an opportunity to accelerate sustainable business models and mitigate climate risk through active engagement with key stakeholder groups.

In this section, we outline the direction investors and asset owners can take when engaging with five key stakeholder groups in an effort to build climate resilience and mitigate negative impacts within global food value chains. They demonstrate the opportunities investors have to leverage their influence, convening power, and financial resources to steward their portfolios away from significant climate risk and towards a more resilient 1.5° future.

Figure 36. Key stakeholder groups and objectives for investor engagement

Stakeholder	Example objectives
Corporate	• Encourage disclosures on the full extent of climate risk impacting the business either directly or indirectly across its value chain • Support portfolio companies to engage with agricultural innovations and climate-smart technologies through investing in R&D and implementation • Facilitate resilience planning through driving integration of climate risk assessments into investment decisions at Board Level
Investors and asset owners	• Align frameworks on climate risk and sustainability into due diligence and portfolio management • Collaborate on impact initiatives to fund scalable projects in agricultural innovation and biodiversity preservation • Develop innovative financial instruments and structures to mobilise capital to support large scale agricultural transformation
Wider industry	• Promote climate resilience practices through encouraging portfolio companies to adopt sustainable sourcing policies • Foster collaboration and innovation through connecting value chain companies to co-pilot new agricultural innovations • Convene companies and stakeholders to define suitable and aligned net-zero pathways benchmarks, and climate resilience plans
Policy makers	• Engage with governments to understand and influence policy to align to climate goals, including carbon pricing, subsidies, and biodiversity conservation incentives • Collaborate on developing public-private financing schemes to support farmer transitions towards climate resilient and regenerative agricultural practices • Collaborate with policymakers to support trade agreements that advance low-carbon sustainable agricultural value chains
Civil society	• Partner with NGOs to run campaigns on sustainable consumption and the importance of climate-friendly agricultural products • Convene transparent discussions between corporates, policymakers, and civil society on sustainability challenges • Fund local projects focused on reforestation, water conservation, and biodiversity, empowering civil society to lead climate action

7.0 | Appendix

Term	Definition
Adaptation	Adjusting to actual or expected climate change impacts to minimize harm or exploit beneficial opportunities.
Agroforestry	A land-use system combining trees, crops, and livestock to improve sustainability and biodiversity.
Aquaculture	The controlled cultivation of aquatic species like fish, shellfish, and seaweed.
Asset stranding	The risk of investments becoming obsolete due to climate policy changes or environmental shifts.
Biochar	A type of charcoal produced from plant biomass and used to improve soil fertility and carbon sequestration.
Blue sarbon sredits	Carbon credits generated from marine ecosystems such as mangroves and seagrass meadows.
Biodiversity loss	The decline of species variety in an ecosystem due to environmental changes and human activities.
Broodstock	Animals retained for breeding purposes.
Carbon sequestration	The process of capturing and storing atmospheric CO_2 to mitigate climate change.
Climate risk	Financial and operational risks arising from climate change and extreme weather.
Compound events	Multiple extreme weather events occurring simultaneously or sequentially, amplifying impact.
Corporate Sustainability Reporting Directive (CSRD)	An EU regulation requiring in-scope companies operating within the EU to increase and standardise their non-financial reporting on ESG performance.
Crop rotations	Alternating different types of crops in the same field to maintain soil fertility and reduce pests.
Decarbonization	Reducing carbon dioxide emissions from industrial and energy sectors.
Deforestation	The clearing of forests for agriculture or other uses, often leading to loss of biodiversity.
Diversification strategy	A risk management approach that spreads investments across different markets or assets.
Emission scope	Categories of greenhouse gas (GHG) emissions: Scope 1 – Direct emissions from company-owned sources. Scope 2 – Indirect emissions from purchased energy. Scope 3 – Indirect emissions from the full value chain.
Extreme weather	Severe and unusual weather events such as hurricanes, droughts, and heatwaves.
Food system resilience	The ability of food supply chains to withstand and recover from climate shocks.
Genetically modified (GM)	Organisms where the genetic material has been artificially altered towards desired characteristics.
Greenhouse gas (GHG) emissions	Gases such as CO_2, methane (CH_4), and nitrous oxide (N_2O) that contribute to climate change.
Global value chain (GVC)	The interconnected system of production, processing, and distribution across multiple regions.
Integrated multi-trophic aquaculture (IMTA)	A method that combines different aquatic species to optimize resource use and reduce waste.
International sustainability standards board (ISSB)	An organization setting global sustainability disclosure standards.
Land use change & forestry (LUCF)	Changes in land use affecting carbon storage and emissions.
Livestock emissions	Methane and other gases released by livestock farming.
Methane reduction strategies	Techniques such as modifying livestock feed or biogas capture to reduce methane emissions.
Microclimate regulation	Using environmental features like tree lines to moderate local temperatures and weather conditions.
Nature-based solutions (NBS)	Strategies leveraging natural ecosystems to address environmental challenges.

Ocean acidification	The decrease in ocean pH due to CO_2 absorption, negatively affecting marine life.
Physical climate risk	Risks from climate change, such as rising sea levels and temperature fluctuations.
Precision farming	The use of technology to optimize agricultural inputs and improve yields.
Recirculating aquaculture systems (RAS)	A closed-loop fish farming system that filters and reuses water.
Regenerative agriculture	Farming practices that restore soil health and biodiversity.
Sustainable Development Goals (SDGS)	17 global objectives set by the United Nations to promote sustainability.
Shadow carbon price	A hypothetical cost assigned to carbon emissions to assess regulatory or financial risk.
Smallholder farmers (SHFS)	Farmers with small-scale operations, often under 2 hectares, significant in global food production.
Soil mulch	A protective layer of organic material applied to soil to retain moisture and improve fertility.
Taskforce on climate-related financial disclosures (TCFD)	A framework for companies to disclose climate-related financial risks.
Taskforce on nature-related financial disclosures (TNFD)	A framework for assessing financial risks linked to biodiversity.
Value chain mapping	Analysing key players, inputs, and processes in a supply chain to identify risks and opportunities.

8.0 | Bibliography

1 Atmosphere (2021). "Agricultural Disaster Prevention System: Insights from Taiwan's Adaptation Strategies".

2 Baringa (2024). "Baringa Base Case".

3 BeZero (2024). "How the VCM can turn the tide for blue carbon".

4 Blue Carbon Liaison Council (2023). "Case Study on Blue Carbon Initiatives in Japan".

5 Canadian Climate Institute (2023). "The Case for Adapting to Extreme Heat".

6 Clark et al., Science (2020). "Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets".

7 Climate Council (2022). "The Great Deluge: Australia's New Era of Unnatural Disasters".

8 Climate Risk Management (2024). "Economic valuation of climate induced losses to aquaculture for evaluating climate information services in Bangladesh".

9 Climate Watch (2024). "Climate watch platform and data".

10 CZ (2023). "Soybean in Brazil".

11 EC (2023). "Field to fork: global food miles generate nearly 20% of all CO2 emissions from food".

12 ESM (2024). "Tasmanian 'Eco-Milk' Tests Shoppers' Thirst for Climate-Friendly Dairy".

13 euronews (2022). "'Absolute emergency': 'Billions' needed to compensate drought losses in France".

14 FactSet (2024). "Total Return for Indexes: World Food: Major Diversified – Industry and World – All Listed Equities".

15 FAO (2023). "Pathways towards lower emissions: A global assessment of the GHG emissions and mitigation options from livestock agrifood systems".

16 FAO (2023). "Statistical Yearbook".

17 FAO (2023). "The Impact of Disasters on Agriculture and Food Security".

18 FAO (2024). "FAO Stat".

19 FAO (2024). "FishStat".

20 FAO (2024). "The State of World Fisheries and Aquaculture".

21 Farm Bureau (2024). "Major Disasters and Severe Weather Caused Over $21 Billion in Crop Losses in 2023".

22 Farm Progress (2023). "Fertilizer Outlook: Global dynamics to influence 2024 fertilizer prices".

23 Farmland LP (2024). "Impact".

24 Farmlytics (2024). "Extreme weather and its impact on farming viability in Wales".

25 Fertiliser Daily (2023). "Brazilian drought slows fertilizer purchases affecting global suppliers".

26 Geophysical Research Letters (2024). "Warming Leads to Lower Rice Quality in East Asia".

27 Habte et al., Veterinary & Animal Science (2022). "Effects of climate variability on livestock productivity and pastoralists perception: The case of drought resilience in Southeastern Ethiopia".

28 House of Commons Canada (2022). "Confronting Urgent Challenges and Building the Resilience of the Canadian Food Supply Chain".

29 Houston Chronicle (2023). "Amid heat waves and drought crop insurance costs skyrocket".

30 Huon (2024). "Whale Point Nursery Expansion".

31 IOFAM (2024). "The World of Organic Agriculture".

32 IPCC (2021). "Weather and Climate Extreme Events in a Changing Climate".

33 IPCC (2023). "Climate Change 2023 Synthesis Report".

34 Iroquois Valley Farmland REIT (2023). "Public Benefit Report".

35 JBS (2024). "Huon Aquaculture to invest $110 million to boost land-based production at Port Huon, Tasmania".

36 Journal of Food Quality (2023). "Aflatoxin Contamination of Maize from Small-Scale Farms Practicing Different Artisanal Control Methods in Kitui, Kenya".

37 Kotz et al., Nature (2024). "The economic commitment of climate change".

38 Le Monde (2024). "Camels replace cows in Kenya due to climate change".

39 Marine Biology (2024). "Flood effects on estuarine fish are mediated by seascape composition and context".

40 Meiji Group (2023). "Making Japan's Dairy Industry More Sustainable. Meiji Group Calculates Greenhouse Gas Emissions from Milk Production".

41 Mongabay (2024). "Experimenting with shed design to reduce heat stress in livestock, poultry".

42 Natural Hazards and Earth System Sciences (2022). "A Case Study on Flooding in the Southern Taiwan during Typhoon Morakot and Typhoon Fanapi".

43 Nature (2015). "Productivity limits and potentials of the principles of conservation agriculture".

44 Nature (2022). "Multi-week prediction of livestock chill conditions associated with the northwest Queensland floods of February 2019".

45 Nature Sustainability (2020). "Conservation agriculture for sustainable intensification in South Asia".

46 Niti Aayog (2023). “India’s White Revolution”.

47 OCHA (2009). “Typhoon Morakot Situation Report No. 1”.

48 OCHA (2022). “Flash Update No3: Philippines: Super Typhoon Noru/Karding”.

49 OECD (2022). “Climate Tipping Points”.

50 OECD (2023). “World Projections”.

51 OECD-FAO (2024). “Agricultural Outlook”.

52 PR Newswire (2023). “Farmland LP Launches $250M Third Fund Focused on Organic and Regenerative Agriculture”.

53 Queensland Farmers’ Federation (2023). “North Queensland flooding has significantly impacted farming communities and supply chains”.

54 Real Leaders (2022). “Farm Grows ‘Organic’ Returns for Impact Investors”.

55 Reuters (2023). “Massive Brazilian soybean exports too heavily leaning on China?”.

56 Ricciardi et al., Global Food Security (2018). “How much of the world’s food do smallholders produce?”.

57 S&P Global (2022). “Agriculture Industry Is Still Sweating This Year’s Droughts”.

58 Science (2018). “Reducing food’s environmental impacts through producers and consumers”.

59 Science Advances (2018). “Carbon dioxide (CO2) levels this century will alter the protein micronutrients and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries”.

60 Stewart Investors (2021). “Investment and sourcing through smallholder supply chains”.

61 Sustainability (2021). “Agriculture Adaptation Options for Flood Impacts under Climate Change”.

62 The Guardian (2020). “Cargo ship with 43 crew and nearly 6000 cattle sank off Japan survivor says”.

63 The Shetland Times (2024). “Fresh salmon lost overboard from NorthLink freight boat in severe weather”.

64 The Texas Tribune (2023). “Texas drought has deepened amid this year’s brutal heat”.

65 UN (2024). “UN Comtrade Database”.

66 UNDP (2023). “UNDP India partners with Absolute Foods to further sustainable agriculture practices in the country”.

67 UNEP (2024). “Emissions Gap Report”.

68 UNEP FI (2023). “Climate Risk in the Agriculture Sector”.

69 United Nations (2024). “World Population Prospects”.

70 USDA (2019). “Interdependence of China, United States, and Brazil in Soybean Trade”.

71 USDA (2022). “Impacts and Repercussions of Price Increases on the Global Fertilizer Market”.

72 USDA (2023). “Feed Grains Sector”.

73 USDA (2023). “Prices for genetically modified seeds have risen much faster than non-GM seeds”.

74 WEF (2022). “The Horn of Africa is facing an unprecedented drought. What is the world doing to help solve it?”.

75 World Bank (2022). “World Integrated Trade Solution”.

76 World Bank Group (2022). “Pakistan: Flood Damages and Economic Losses Over 30 billion and Reconstruction Needs Over 16 billion”.

Agricultural fields in Piedmont, Italy

Important Information

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