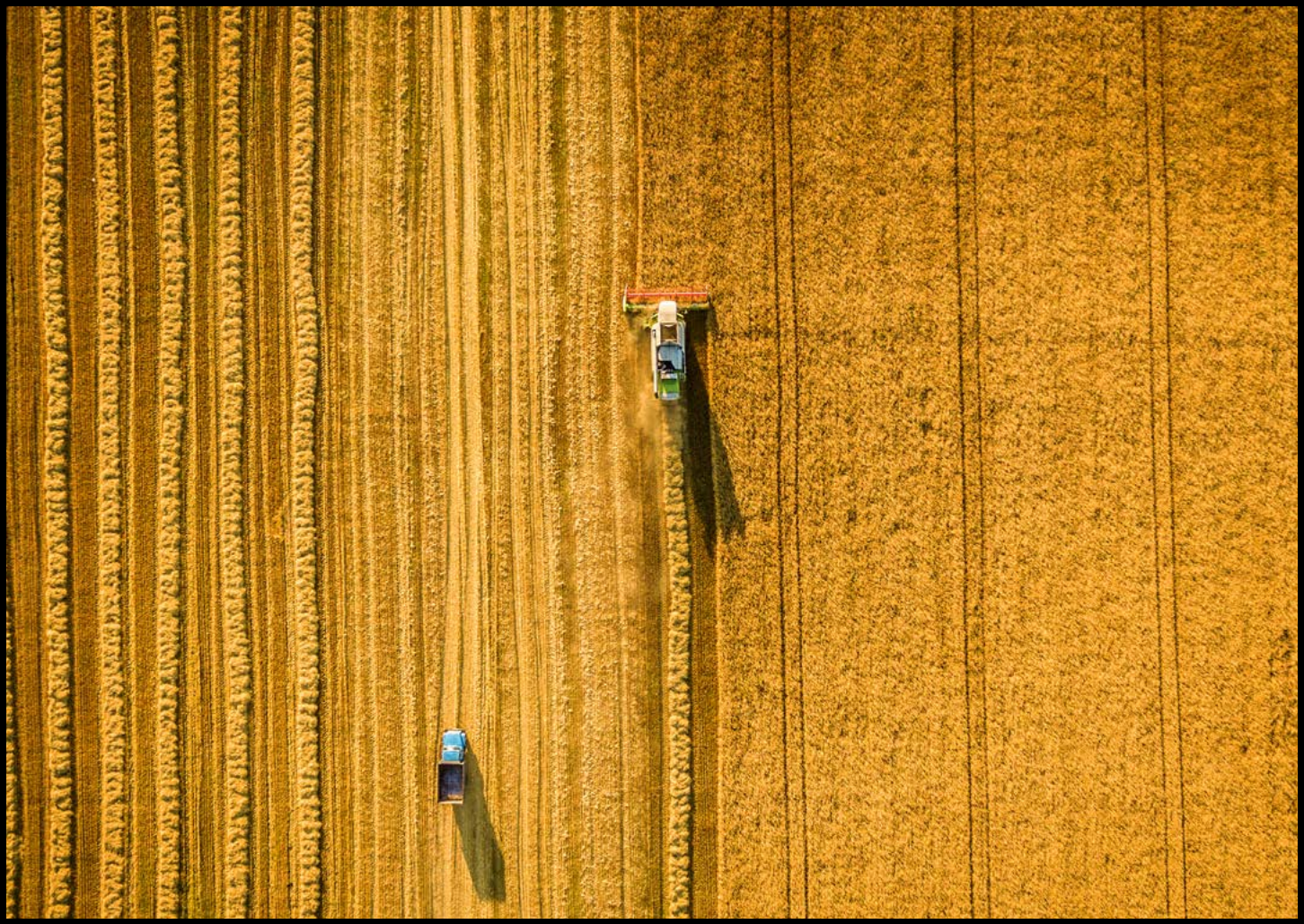
The Economist INTELLIGENCE UNIT

A report from The Economist Intelligence Unit

GLOBAL FOOD SECURITY INDEX 2018

BUILDING RESILIENCE IN THE FACE OF RISING FOOD-SECURITY RISKS



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Contents

Preface

The *Global Food Security Index 2018: Building resilience in the face of rising food-security risks* is the seventh edition of an Economist Intelligence Unit study, commissioned by Corteva Agriscience, the Agriculture Division of DowDuPont. This report discusses the key findings from the research and the benchmarking index. Robert Smith, Consulting Analyst, was the project manager. Katherine Stewart, Consulting Analyst, provided research, analytical and editorial support. Leo Abruzzese, Global Director of Public Policy, and Robert Powell, Senior Consultant, served as advisers. William Shallcross designed and constructed the benchmarking model and Mike Kenny was responsible for layout and design. We would like to extend our thanks to the many researchers who lent their expertise to this project. A full list of acknowledgements follows. ■

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Acknowledgements

The following economists, researchers, country analysts, and food, climate and natural resource specialists contributed to the report.

Economist Intelligence Unit specialists and contributors

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Peer panel members

The following experts on food security and agricultural policy contributed significantly to shaping the core index methodology and vetting the indicators. Their diverse backgrounds and extensive experience ensured that a wide variety of views were considered. The panel met as a group in February 2012 in Washington, DC to review an initial indicator list. The panel has also provided ongoing support, as needed, throughout all seven editions of the index, as well as advising on the selection of weightings. We thank them for their participation.

Ademola Braimoh (World Bank); Margaret Enis (US Agency for International Development); Craig Gundersen (National Soybean Research Laboratory, University of Illinois at Urbana-Champaign); Eileen Kennedy (Friedman School of Nutrition Science and Policy, Tufts University); Samarendu Mohanty (International Rice Research Institute); Prabhu Pingali (Gates Foundation); Pedro Sanchez (Earth Institute, Columbia University); David Spielman (International Food Policy Research Institute); Robert Thompson (Chicago Council on Global Affairs); Patrick Westhoff (Food and Agricultural Policy Research Institute, University of Missouri—Columbia).

For the sixth iteration, The Economist Intelligence Unit convened an additional expert panel in March 2017 to assist in the development of a fourth index category, Natural Resources & Resilience, which captures climate-related and natural resource risks to global food security. The following experts on climate change and natural resources participated in the meeting. We thank them for their participation.

Joe Glauber (IFPRI); Elise Golan (USDA); Susanna Hecht (UCLA); Karin Kemper (World Bank); Catie Lee (Land O'Lakes); Shaun Martin (World Wildlife Fund); Dawn Rittenhouse (DuPont Pioneer); Allison Thomson (Field to Market); Sonja Vermeulen (independent consultant); Sara Walker (World Resources Institute). ■

Executive summary

Following a slight decline in 2017, the trend in global food security has returned to positive territory, according to the 2018 Global Food Security Index (GFSI). Progress has been supported by improvements to infrastructure, in addition to increasing production capacity and relatively stable food prices. However, these positive developments are all under threat from a range of risks, both environmental and socioeconomic. Understanding these risks and how to address them are essential to building food systems resilience and thereby ensuring food security for future generations. The key findings below are derived from the 2018 iteration of the GFSI. For 2018 GFSI indicator scores and rankings, please refer to Appendix I.

- **Overall, the 2018 GFSI records a slight improvement in global food security**. Just over 70% of countries included in the index have seen their scores rise, with the most substantial gains achieved by lower-middle- and low-income countries. The improvement among lower-income countries signals a shift towards more resilient food-security measures such as strengthened agricultural infrastructure.
- **Higher-income countries are heavily exposed to the impact of climate and natural resource risks**. When applying the Natural Resources & Resilience category as an adjustment factor, average food-security scores for high-income countries fall further than for any other income group. Climate and natural resource risks pose a threat for which all countries must prepare.
- **Singapore claims the top spot in the 2018 GFSI ranking for the first time**. Singapore's strong food-security score is largely attributable to its status as a high-income economy. GDP per capita has risen by nearly 30% since 2012, and the percentage of household expenditure that is spent on food is the second-lowest in the index (after the US). The country also has the lowest agricultural import tariffs of any country in the index, which helps to reduce food import costs.
- **But Singapore's food-security score is the most susceptible to climate and natural resource risks**. Singapore is largely dependent on food imports, which make up over 90% of its food supply. This leaves it vulnerable to trade and supply chain disruptions, which can drive up food costs.

What is the Global Food Security Index (GFSI)?

The Economist Intelligence Unit's Global Food Security Index (GFSI), sponsored by Corteva Agriscience, the Agriculture Division of DowDuPont, provides a common framework for understanding the root causes of food insecurity by looking at the dynamics of food systems around the world. It seeks to answer the central question: How food-secure is a country? Food security is a complex, multifaceted issue influenced by culture, environment and geographic location. While the index does not capture intra-country nuances, by distilling major food security themes down to their core elements it provides a useful approach to understanding the risks to food security in countries, regions and around the world.

By creating a common framework against which to benchmark a country's food security, the GFSI has created a country-level food-security measurement tool that addresses the issues of affordability, availability, and quality and safety in 113 countries around the world. Since its inception, the GFSI has become a policy benchmark for governments and a country diagnostic tool for investment. Non-governmental organisations, multilaterals and academia have turned to the GFSI as a research tool to identify key countries in which to focus advocacy efforts for food-security policy changes and developments. The private sector uses the tool as a launch pad to make strategic decisions, explore food consumption trends and develop corporate social responsibility initiatives.

- **After maintaining the top spot between 2012 and 2016 and falling to second in 2017, the US has now dropped to third**. The fall in its ranking reflects a slower rate of improvement than that achieved by some of its peers, rather than any deterioration in its score. However, the (relatively modest) gains that the US has made are at risk due to a polarised political environment and rising protectionist sentiment.

- **As the economic crisis in Venezuela continues, the country's food-security situation has become critical**. Venezuela's food-security score has declined more than any other country's since 2012, demonstrating the significant impact that political and economic insecurity has on a country's food security: GDP per capita has fallen by nearly 30% during this period. The collapsing economy has had a significant impact on the health of Venezuela's population, with children especially affected.

- **Slovakia has overtaken Denmark as the top-ranking country in the Natural Resources & Resilience category**. Its innovations in resilience mechanisms are of particular interest, with an early-warning mechanism for climate risks and a water valuation programme to prevent and mitigate drought. New approaches will need to be developed and implemented around the globe to ensure food security amid the rising prevalence of climate risks, and smaller countries are already playing an important role in innovative approaches to climate risk mitigation.

The focus of this year's report is the role of resilience in food security, which is vital in enabling interconnected social, economic and biophysical systems to meet people's nutritional requirements. Understanding the interaction of risks and resilience—the ability to bounce back from a shock or crisis, ideally better off than before—in food systems can provide insights into how to alleviate those risks and build resilience in ways that reduce disruption and speed recovery. The key findings of the report are outlined below.

- **Fertile land, fresh water and the oceans are all essential resources that provide the foundation for food security.** Each of these resources is increasingly strained by population growth, urbanisation and changing tastes (on the back of rising incomes). Most of the world's current food supply is dependent on soil health, which ultimately supports crops grown for food, feed and fuel. Water is a limiting factor for agricultural production in many places, even more so as rainfall patterns shift and temperatures rise. The amount of fish and seafood being consumed is increasing, but only because of aquaculture—marine fisheries are in decline due to overfishing, ocean acidification and hypoxic "dead zones".

- **Climate change will affect food production for all physical systems—marine and terrestrial—as basic environmental conditions shift**. Rising temperatures and shifting precipitation patterns are making crop selection and seasons uncertain. Ocean acidification is slowing coral growth and disrupting food webs, with knock-on effects on important fisheries. While all countries are affected, the physical impacts of climate change are worst for the Gulf states and across the Middle East and North Africa more widely, followed by Central and South America. Flooding and sea level rise will cause the most harm to food security in countries with extensive coastal agriculture, such as India, Bangladesh, the Netherlands and Vietnam.

- **Financial risks threaten the affordability of food, especially for low-income households**. Food price shocks lead to food insecurity, causing hunger and triggering social unrest. Crop failures and conflict contribute to rising prices, as can currency depreciation (which pushes up the cost of imported food). Food safety nets make households more resilient through short-term relief or livelihood investments. Farmer access to credit and insurance helps to build more secure livelihoods.

- **Political stability is essential for agricultural production and relief efforts**. Conflict was a driver of food insecurity in 18 countries in 2017, causing damaged infrastructure and crops, blocked supply routes, displaced populations, and rising food prices. Although less dramatic, corruption undermines food security by siphoning money from farmers directly or by disrupting markets through insider arrangements.

- **Trade contributes to food security, but importing countries are vulnerable to rising protectionism**. Every country participates in the global food trade, and open trade provides a buffer to fluctuations in domestic food supply and helps to stabilise prices. Countries lacking self-sufficiency in production rely on trade, but this can make them vulnerable to policy shifts in food-exporting countries, such as export bans. Meanwhile, the expansion of global trade and supply chains adds potential vulnerabilities in cases where storage and transport infrastructure are unreliable.

Introduction

Food security relies on the capacity of interconnected social, economic and biophysical systems to meet people's nutritional requirements. Sometimes the causes of worsening food security can seem obvious—crop failures, armed conflict and hyperinflation are just a few of the culprits that can precipitate a crisis. However, it is essential to understand the myriad contributing factors that influence the severity and impact of a particular shock and recovery from it in order to build better food systems that can absorb and adapt to change—in short, to build resilience.

Resilience, put simply, is the ability to bounce back from a shock or disaster, ideally better off than before. Discussions of food security and development are increasingly incorporating the idea of resilience, defined by the UN Food and Agriculture Organisation (FAO) as "the ability to prevent disasters and crises as well as to anticipate, absorb, accommodate or recover from them in a timely, efficient and sustainable manner".[1] Understanding a country's exposure to specific risks and the resilience of its food systems provides insights into its level of food security.

The GFSI includes several indicators that measure risk and resilience, using a diverse set of economic, social, political and physical data. Some GFSI indicators are focused on risks to food security such as political stability and exposure to climate change. Resilience is measured through indicators such as proportion of household expenditure on food consumption, quality of agricultural infrastructure, investment in early-warning systems, and the health of freshwater resources, land and oceans. Each of the latter attributes enhances the ability of households and countries to anticipate, absorb and recover from a variety of shocks.

Food supplies face recurrent risks that are more or less known—farmers have always been subject to the vagaries of nature, and political conflicts have repeatedly thrown markets and economies into disarray. But even as the production capacity of the world's food systems increases, climate change is adding a more unpredictable and increasingly imminent set of adaptation challenges for farmers. Essential staple crops—such as maize, millet, sorghum and wheat are expected to witness some of the worst losses in yields as global warming proceeds.[2] Understanding how to shore up weak spots and enhance overall resilience is more important than ever in order to ensure that we can continue to feed the world.

Governments, the private sector and the non-governmental sector will all have vital roles to play in supplying short-term relief and long-term development funding and assistance. The GFSI provides an analytical tool that each of these groups can utilise to understand better the context

1 UN Food and Agriculture Organisation (FAO). "Resilience". Available at: http://www.fao.org/emergencies/how-we-work/resilience/en/

2 Zseleczky, L. and Yosef, S. "Are shocks becoming frequent or intense?" In *Resilience for food and nutrition security*, pp. 9-17. International Food Policy Research Institute. Available at: http://www.ifpri.org/publication/are-shocks-becoming-more-frequent-or-intense

of risks and resilience when making decisions about policies, investments and interventions. Recognising the unique characteristics of each country and the interrelated physical, social and economic dynamics that shape its vulnerability to diverse food-security risks is important for co-ordinated and collaborative efforts to build resilience.

- This report begins with the physical resources that support food systems—fertile land, fresh water and the oceans—and describes current challenges and concerns with regard to resource availability and quality.

- We then explore how a range of climate change, financial, political and social, and trade and supply chain risks (those captured within the GFSI) are affecting food security.

- The overall goal is to capture both the specific risks for food systems—fertile land, fresh water and the oceans—and the cross-cutting risks that underlie them. Many of these risks are highly interrelated. For example, conflict often causes food prices to rise, and rising food prices can cause social unrest and political instability. Climate change impacts contribute to financial and supply chain risks, as well as to physical and political conflicts.

- Throughout the report, we also include recommendations to strengthen resilience, identifying measures that can build resilience of land, water and ocean resources and mitigate the four categories of risk set out in the graphic below.

Fertile land, fresh water and the oceans are under threat from a range of cross-cutting and often interconnected risks, with a significant impact on global food security.

By understanding these risks (for example, their causes, effects and interconnections), insights can be developed into how to alleviate them and build resilience in ways that reduce disruption and speed recovery, thereby supporting global food security.

Resilience of food production systems

Food security is still tethered to the health of the world's fertile land, fresh water and the oceans, and this is the major constraint on increasing productivity to feed a global population forecast to reach 9.1bn by 2050. However, fertile land, fresh water and productive fisheries are all increasingly stretched due to population growth, urbanisation and rising incomes, which shift consumption patterns towards more meat and fresh produce, requiring more intensive resource use and generating more waste. Meanwhile, climate change is altering patterns of temperature, precipitation and seasonality and is increasing the severity and frequency of droughts, floods and storms.

Land

Most of the world's current food supply is dependent on the soil systems that support crops grown for food, feed and fuel: the FAO estimates that 80% of calories consumed are from crops grown in soil.[3] Agriculture covers around 38% of the global land surface and is still expanding, primarily in developing countries, even as existing farmland is degraded and abandoned, lost to salinisation or converted to urban use.[4]

As a result—and despite the attention given to the potential of innovations such as algae farms and laboratory-grown meat—quantity and quality of land are both essential determinants of global food production capacity. The amount of land suitable for farming is finite, and as arable land in use per capita steadily declines, soil depletion due to intensification is a concern. Healthy soils produce more food, and also contribute to food systems' resilience by retaining moisture and minimising erosion and nutrient loss.[5] Soil health is managed both at the household scale with decisions about farming practices, and at larger scales with decisions about diverse landscape use that can support ecosystem health and agricultural productivity.

Conversion of forests in the Amazon region illustrates the complex dynamics of soil quality. The rich plant diversity of the Amazon tropical rainforests is (perhaps surprisingly) supported by nutrient-poor soils, and widespread deforestation during the 1990s and 2000s for conversion to soy and cattle production resulted in rapid nutrient depletion, with the result that decent agricultural yields were short-lived. Reflecting this, Brazil ranks near the bottom of the GFSI on soil quality (GFSI 4.3.1), reflecting low nutrient availability. More positively, better land-registration systems and protection of indigenous land rights in Brazil have slowed deforestation and encouraged more sustainable management practices. In addition, large-scale reforestation efforts are under way, with conversion of abandoned farmland to forests that will store more carbon and reduce erosion, benefiting remaining farms.[6] Indonesia also scores poorly on the GFSI's land health assessment (GFSI 4.3), although in that country's case this is mainly

3 UN Framework Convention on Climate Change (UNFCCC). "Healthy soils are a key component of climate action". 2017. Available at: https://unfccc.int/news/healthy-soils-are-a-key-component-of-climate-action

4 UN Convention to Combat Desertification (UNCCD). "Global Land Outlook". 2017. Available at: https://knowledge.unccd.int/glo

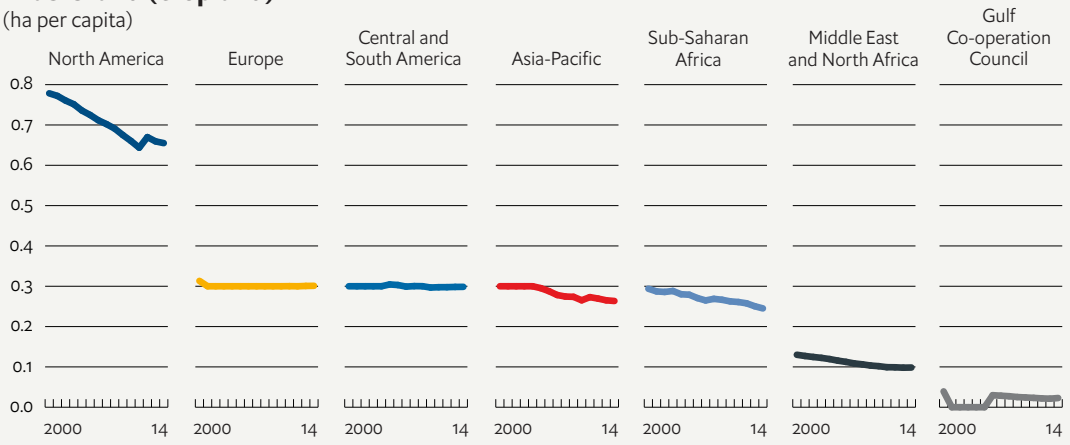
5 State of the Planet. "Can soil help combat climate change?" Earth Institute, Columbia University. Available at: https://blogs.ei.columbia.edu/2018/02/21/can-soil-help-combat-climate-change/

6 Smithsonian. "Brazil begins efforts to plant 73 million trees in the Amazon". 2017. Available at: https://www.smithsonianmag.com/smart-news/brazil-begins-effort-plant-73-million-trees-amazon-180967086/

due to its conversion of peatlands, driven by palm oil expansion.

In both instances, competition for land has played a direct role in harming soil quality and, ultimately, reducing food security. This competition between producers of food, feed and fuel will only intensify as populations and incomes grow.

Arable land (cropland)
(ha per capita)



Source: UN Food and Agriculture Organisation (FAO).

Land resilience mechanisms:

- Enhancing ecosystem services in agricultural landscapes increases food system resilience and productivity. Planting trees can support food production by increasing shade and improving soil fertility, and also by providing habitat for pollinators and a source of livestock fodder and fuelwood. In Malawi, farmers that planted leguminous trees and shrubs had higher maize yields and more food-secure months.[7] Expanding coastal mangrove forests in Vietnam increased collection of aquatic products by 122%.[8]
- Continued innovation in the development and diversification of crop species and varieties enhances resilience by increasing genetic and functional diversity. Crop diversification can help to suppress pest and disease outbreaks and improve the ability of food systems to respond to climate variability and extreme events.[9] Diversified farms in Honduras, Mexico and Cuba experienced less erosion and smaller economic losses from hurricanes and recovered faster than monoculture farms.[10]
- Agricultural research and extension services can support farmers with new cropping calendars and technical assistance to meet adaptive challenges, including coping with new pests and diseases (see In focus: Advance of the armyworm).

7 World Agroforestry Centre. "Agroforestry, food and nutritional security." 2013. Available at: http://www.fao.org/forestry/37082-04957fe26afbc90d1e9c0356c48185295.pdf

8 International Union for Conservation of Nature (IUCN). "Mangrove reforestation for food security." 2016. Available at: https://www.iucn.org/sites/dev/files/content/documents/20161021_viet-nam-flr-food-security-factsheet_web.pdf

9 Lin, B. "Resilience in agriculture through crop diversification: adaptive management for environmental change." March 2011. *BioScience* 61(3) Available at: https://academic.oup.com/bioscience/article/61/3/183/238071

10 Altieri, M. et al. "Agroecology and the design of climate change-resilient farming systems." May 2015. *Agronomy for Sustainable Development* 35(3). Available at: https://www.researchgate.net/publication/276291228_Agroecology_and_the_design_of_climate_change-resilient_farming_systems#pfa

In focus: Advance of the armyworm

The rapid spread of fall armyworm to at least 28 African countries in less than two years shows how quickly a new pest can cost millions of dollars in crop losses and interventions. The invasive species likely arrived in the form of eggs on a commercial flight from the Americas and was first reported in early 2016. With the adult moths' ability to spread more than 500 km on prevailing winds with each generation (new generations are produced as often as once a month), farmers across the African continent are now picking or spraying the larvae off their maize and sorghum plants. Estimated crop losses are extensive: in the case of Ghana, an average of 45% of its maize crop was lost in early 2017, costing the country US$284.4m in income for a single growing season.[11]

The threat of damage from pests is not new—locusts, red-billed quelea birds and rats all claim their share of African harvests. However, as global trade and climate change introduce new pests and diseases to the equation, more pressure is added to an already stressed system with limited resilience. Biosecurity measures to keep out potential migrant pests are important for prevention, but support is also needed to mount an effective response and communicate consistent messages to farmers on how to respond. International agencies can play an important role, and the UN Food and Agriculture Organisation (FAO) actively monitors and alerts national governments about potential outbreaks. In the case of locusts, satellite data on soil moisture predicts when rapid plant growth will trigger potential swarms up to three months in advance, giving local authorities a chance to prepare.[12] However, conflict zones make prevention more challenging. In 2012, for example, FAO researchers were tracking potential locust swarms in the Sahel but were unable to access parts of northern Mali and Niger owing to military restrictions.[13]

11 Centre for Agriculture and Biosciences International (CABI). "Fall Armyworm: Impacts and Implications for Africa". September 2017. Available at: https://www.invasive-species.org/Uploads/InvasiveSpecies/Fall%20Armyworm%20Evidence%20Note%20September%202017.pdf

12 European Space Agency (ESA). "Satellites forewarn of locust plagues". June 13th, 2017. Available at: https://m.esa.int/Our_Activities/Observing_the_Earth/Satellites_forewarn_of_locust_plagues

13 Devex. "Sahel faces new food security threat: Locust swarms". October 26th, 2012. Available at: https://www.devex.com/news/sahel-faces-new-food-security-threat-locust-swarms-79574

Water

Water is a limiting factor for agricultural production in many places, and is expected to become even more of a constraint as rainfall patterns shift and as temperatures rise, increasing the rate of water lost through evaporation. Areas that are using water faster than it can be recharged are depleting their groundwater reserves and are being forced to prioritise between industrial, residential and agricultural users, with the largest volume of groundwater depletion happening in India, Iran, Pakistan and China.[14]

Countries with less-intensive water use perform better on the GFSI water risk indicator (4.2); for example, Sub-Saharan African countries score highly, reflecting the relatively non-industrial nature of agriculture and limitations of infrastructure. The exception in the region is South Africa, which utilises its water resources much more intensively. The use of water-balance accounting to track inflows and outflows is helpful, but Cape Town still faced a water scarcity crisis in 2018 due to years of low rainfall during which water managers did not sufficiently limit supplies for either agricultural or urban use.[15] Middle Eastern

14 Dalin, C. et al. "Groundwater depletion embedded in international food trade". 2017. Nature. Available at: https://www.nature.com/articles/nature21403

15 University of Cape Town News. "What caused the recent water shortage?" 2018. Available at: https://www.news.uct.ac.za/article/-2018-07-19-what-caused-the-recent-water-shortage

countries such as Israel, Saudi Arabia and Yemen have even more limited agricultural water resources, but Israel in particular has introduced water conservation methods for agricultural production that are highly adapted to its arid context, demonstrating that investment in technical conservation solutions can build resilience through careful management of natural resources.

Water supplies are highly dependent on land use, and can require large-scale and transboundary co-ordination to maximize infiltration and groundwater recharge. For example, the water-intensive agricultural landscapes of South-east Asia's Mekong River Delta produce immense yields from paddy rice and floodplain agriculture, but are subject to competing uses for hydropower and upstream diversions that require intensive diplomatic efforts to negotiate.[16]

16 For more on the Mekong River Delta, see EIU, "Water security threats demand new collaborations: Lessons from the Mekong River Basin". 2017. Available at: https://foodsecurityindex.eiu.com/Resources

Water resilience mechanisms:

- Adoption of crops and techniques with lower water requirements, such as the System of Rice Intensification (SRI) method of rice production, contributes to resilience by enabling equal or better yields to be achieved with less water withdrawal.[17] With SRI principles, farmers plant single seedlings widely spaced, water intermittently instead of flooding, and improve soil health with compost and cultivation. The SRI method of rice production can also reduce greenhouse gas emissions compared with traditional methods.[18]
- Planting crops with lower water requirements and agricultural practices that maintain soil moisture, such as maintaining vegetative cover between crops, can also contribute to resilience. In Kenya, farmers are responding to changing climatic conditions by switching from maize to drought-tolerant crops like sorghum and millet as a coping strategy.[19] The use of continuous vegetative cover, including perennial grain crops, in the central US increases water resilience and reduces flood risks.[20]
- Use of more efficient irrigation technologies and soil moisture sensors enables farmers to conserve water with more targeted irrigation, which is beneficial for both large-scale industrial farms and small-scale food systems. In Zimbabwe, deploying soil moisture sensors decreased the amount of water used by smallholder farmers while yields increased.[21] Mobile phones are also being used to provide irrigation advice based on satellite imaging and water balance.
- Water markets have added flexibility and resilience to agriculture in Australia, allowing the transfer of water use rights between producers based on irrigation demand and providing economic incentives to reduce water use. Over several years of drought in the Murray-Darling Basin, farmers who typically plant rice and cotton sold their water use rights to horticulture growers, enabling both sides to maintain their assets and incomes.[22]

17 Cornell University. "About SRI." Available at: http://sri.ciifad.cornell.edu/aboutsri/FAQs.html#mainenvironmental

18 Oo, A. Z. "Methane and nitrous oxide emissions from conventional and modified rice cultivation systems in South India." 2018. *Agriculture, Ecosystems and Environment* 252. Available at: https://www.sciencedirect.com/science/article/pii/S0167880917304607#!

19 International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). "Drought-tolerant crops to the rescue in Kenya". 2017. Available at: http://www.icrisat.org/drought-tolerant-crops-to-the-rescue-in-kenya/

20 Basche, A. and Edelson, O. "Improving water resilience with more perennially based agriculture". 2017. Agroecology and Sustainable Food Systems 41(7). Available at: https://www.tandfonline.com/doi/full/10.1080/21683565.2017.1330795

21 International Water Management Institute (IWMI). "How smallholder farmers in Zimbabwe are succeeding with irrigation and fighting climate change impacts". 2018. Available at: https://wle.cgiar.org/thrive/2018/08/22/how-smallholder-farmers-zimbabwe-are-succeeding-irrigation-and-fighting-climate

22 National Climate Change Adaption Research Facility (NCCARF). "The role of water markets in climate change adaptation". 2013. Available at: https://search.ror.unisa.edu.au/record/UNISA_ALMA11143309950001831/media/digital/open/9915910004401831/12143309940001831/13143305660001831/pdf

Oceans

Fish are an essential source of protein and nutrients, and annual per-capita consumption globally has steadily increased over the past few decades to over 20 kg. The annual value of global trade in fish and fish products has soared to US$152bn, and for many coastal populations fish are essential for daily subsistence and provide up to 90% of their animal protein intake. Some of the most fish-dependent communities are the most at risk—Pacific Islanders, for example, consume 2-3 times more fish per capita than the global average and face some of the most severe environmental pressures on their coastal fisheries.[23]

Just over half of the 171m tonnes of fish produced globally in 2016 was caught in the ocean.[24] However, a combination of management challenges and climate change mean that marine stocks of fish are under threat. Overfishing occurs in part because marine fish stocks are inherently difficult to monitor and manage. Enforcing rules about an ever-shifting transboundary resource is difficult, even within a country's Exclusive Economic Zone. Outside such zones there is even more of a free-for-all, and the lack of regulation of the high seas contributes to an offshore "tragedy of the commons". Countries such as the US and Australia have made efforts to establish Marine Protected Areas in their own territorial waters (GFSI 4.4.3), which should help some of the more resilient fish stocks to recover, but such areas can also prove difficult to police.

Evidence suggests that current yields will not be maintained. The FAO reports that 60% of fisheries are already being harvested at the maximum sustainable levels and 33% at rates that are not biologically sustainable.[25] Some countries with large coastal communities that have fish-dependent diets, such as Bangladesh and Vietnam, are experiencing overfishing and a collapse of fish stocks (GFSI 4.4.2).

The health of marine ecosystems is also under threat from climate change, as ocean acidification and rising temperatures alter habitats (see In focus: Oceans taking the heat). Low-oxygen "dead zones" also continue to expand as a result of pollution by agricultural nutrients (fertilisers and manure) and sewage.[26] The Baltic Sea now has more than 60,000 sq km of hypoxic area, primarily caused by nutrient runoff but exacerbated by rising temperatures.[27]

23 FAO. "The State of World Fisheries and Aquaculture 2018". 2018. Available at: http://www.fao.org/documents/card/en/c/I9540EN/

24 Ibid.

25 Ibid.

26 *The Guardian*. "Oceans suffocating as huge dead zones quadruple since 1950, scientists warn". January 4th 2018. Available at: https://www.theguardian.com/environment/2018/jan/04/oceans-suffocating-dead-zones-oxygen-starved

27 European Environment Agency. "Ocean oxygen content". 2016. Available at: https://www.eea.europa.eu/data-and-maps/indicators/ocean-oxygen-content/assessment

In focus: Oceans taking the heat

Efforts to expand protection of crucial habitats and monitor fishing practices are important to protect fisheries, but even with improved governance, environmental changes that are under way will have major impacts on marine systems and their inhabitants. Notably, climate change is already having effects on ocean temperatures, chemistry and wider circulation patterns.

As the oceans heat up, a number of marine species are seeking cooler climes, moving from the tropics towards the poles and to deeper water.[28] In an example of the devastating impact this shift could have on fishing communities, warmer oceans are predicted to lead to production declines from 5-50% for regional fisheries along continental US coasts.[29]

The absorption of carbon dioxide (CO_2) from the atmosphere is slowly changing the ocean's pH as well, with acidification affecting organisms from tiny marine snails to shellfish and corals and on up the food chain. The concentration of key components needed to build calcium-based shells and skeletons is declining, affecting growth and survival and meaning that eventually coral reef-makers will be unable to keep up with erosion. By mid-century the entire tropical Pacific region, home to more than 25% of the world's coral reefs, could be too acidic to maintain coral growth.[30] When the tiny snails go, food webs unravel, affecting large-scale commercial fisheries such as salmon, mackerel, herring and cod. In the Northeastern US, ocean acidification is projected to reduce the fisheries catch by 20-30% by 2050.[31]

28 FAO. "The State of World Fisheries and Aquaculture 2018".

29 Oceana. "Ocean-Based Security Threatened in a High CO_2 World". 2012. Available at: https://oceana.org/sites/default/files/reports/Ocean-Based_Food_Security_Threatened_in_a_High_CO2_World.pdf

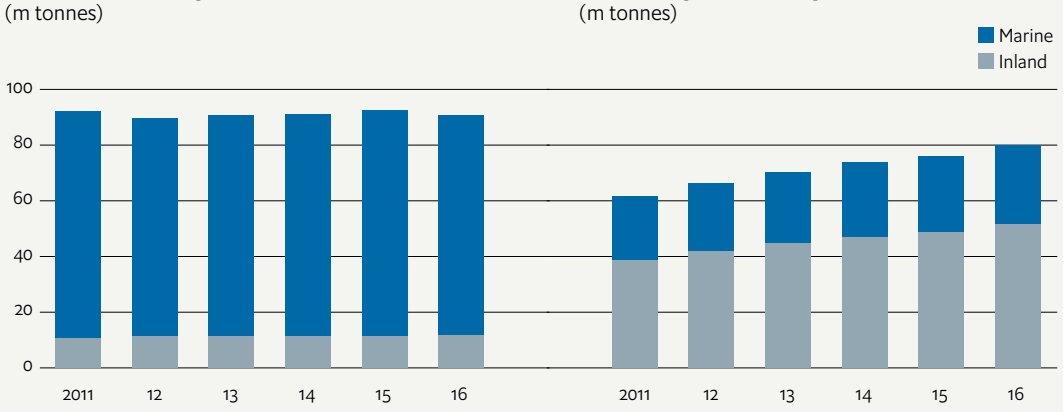
30 Johnson, J E et al. "Pacific Islands Ocean Acidification Vulnerability Assessment". 2016. Available at: https://www.researchgate.net/publication/305641374_Pacific_Islands_Ocean_Acidification_Vulnerability_Assessment

31 Oceana. "Ocean-Based Security Threatened in a High CO_2 World".

With the ocean catch at its limit, in recent years the increase in global fish consumption has come almost entirely from aquaculture production, which will also have to be the source of any future growth in fisheries production. Output from aquaculture has quadrupled over the past 30 years, led by China (which produces more fish than the rest of the world combined), mainly in freshwater inland systems. Globally, just 28% of fish are raised in marine environments, which are expected to suffer the same climate change effects from acidification and warming as wild fisheries. The rest are produced in inland fisheries, which should be more resilient except for some displacement by sea level rise and salinisation. While farmed fish are contributing an essential source of protein to the global food supply, continued growth of the aquaculture industry does have its risks. With marine fisheries in decline, fish farmers are shifting from fish oil and fishmeal to grains as a source of fish food, adding to the pressure on terrestrial farming systems.

World fisheries production
(m tonnes)

World aquaculture production
(m tonnes)



Source: FAO.

Ocean resilience mechanisms:

- Establishment and enforcement of Marine Protected Areas helps to rebuild fish and shellfish populations and enable species migration as oceans warm. Selecting the location of protected areas based in part on exposure to ocean acidification could help to encourage evolutionary adaptation by more resilient species.[32]
- Providing data on ocean temperature and chemistry can help shellfish growers adjust their plans and practices. In the Northwestern US, a regional association of the Integrated Ocean Observing System provides water chemistry measurements to shellfish growers via a mobile app.[33]
- Expansion of coastal wetlands such as mangroves and salt marshes creates refuges from ocean acidification due to plants that absorb CO_2 from the water, and contributes to coastal defences against sea level rise and intense storms.[34]
- Mandatory and voluntary efforts to reduce nutrient inputs to marine systems have had some effect—nitrogen inflows from the Rhine river to the North Sea have declined steadily since the 1980s due to Germany's pollution controls, for example.[35] In addition, water quality trading markets for nutrient emissions have been set up in Canada, New Zealand and the US as a way to limit total nutrient discharge.[36]

32 West Coast Ocean Acidification and Hypoxia Science Panel. "Supporting ecological resilience to address ocean acidification and hypoxia". 2016. Available at: http://westcoastoah.org/wp-content/uploads/2016/02/OAH-Panel-Ecosystems-3.30.16-FINAL.pdf

33 Northwest Association of Networked Ocean Observing Systems (NANOOS). "NANOOS Visualization System". Available at: http://nvs.nanoos.org/

34 Roberts, C. et al. "Marine reserves can mitigate and promote adaptation to climate change". June 13, 2017. *PNAS*. Available at: http://www.pnas.org/content/pnas/114/24/6167.full.pdf

35 German Environment Agency. "Indicator: Eutrophication of the North Sea/Baltic Sea by nitrogen". 2017. https://www.umweltbundesamt.de/en/indicator-eutrophication-of-the-north-seabaltic-sea#textpart-1

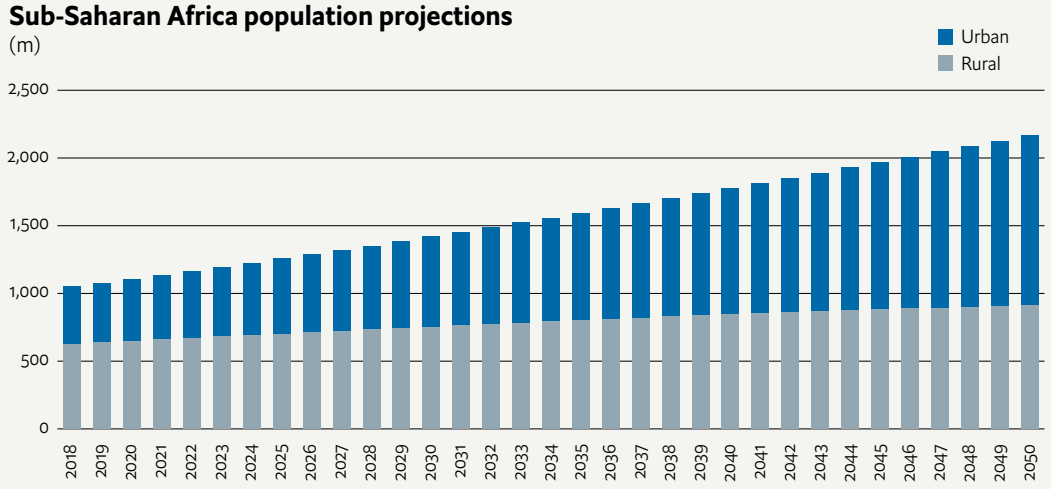
36 World Resources Institute. "Eutrophication: Politics, action and strategies to address nutrient pollution". 2009. Available at: http://wriorg.s3.amazonaws.com/s3fs-public/pdf/eutrophication_policies_actions_and_strategies.pdf

In focus: Resource pressures and demographic change

Physical systems (fertile land, fresh water and the oceans) shape and are shaped by the social, economic and cultural forces of human habitation. Questions of how and where food is produced are directly linked to the processes of demographics, livelihoods and migration. Thus, a country's rates of population growth and urbanisation have significant effects on food consumption patterns—in terms of both volume and type of food—and affect resilience.

Low-income countries, and in particular those in Sub-Saharan Africa, combine the challenges of rapid population growth with rapid urbanisation (GFSI 4.7). The region's population is expected to double by 2050, to 2.1bn,[37] and while many countries currently still have large proportions of rural residents—76% of East Africans live outside cities[38]—the rates of relocation to urban areas are at record highs.[39] Urbanisation is being accelerated by both conflict and climate change, with around 22m people in Sub-Saharan Africa displaced every year by climate events and natural disasters.[40] As populations grow and shift, the structures and services that support them must adapt. Newly urban residents, whether economic migrants or refugees, are vulnerable to higher food insecurity and malnutrition as they seek new livelihoods. Without urban planning, the expansion of high-density residential areas past the edges of urban zones also means that farmers are rapidly displaced, increasing the pressure on remaining agricultural land to supply the growing urban population. The growth of Africa's 300 coastal cities in particular is heightening vulnerability to coastal erosion, flooding and sea level rise by putting more people and buildings at risk—the World Bank has calculated that the Senegalese capital, Dakar, for example, has US$46bn of assets that are vulnerable to flooding, twice the value of Senegal's GDP.[41]

Sub-Saharan Africa population projections



Source: FAO.

37 UN Department of Economic and Social Affairs (UNDESA). "World Population 2012". Available at: http://www.un.org/en/development/desa/population/publications/pdf/trends/WPP2012_Wallchart.pdf

38 Ibid.

39 Devex. "Food security and nutrition in Africa's cities." 2014. Available at: https://www.devex.com/news/food-security-and-nutrition-in-africa-s-cities-83947

40 World Food Program USA. "Increasing urbanization threatens food security in Africa". 2016. Available at: https://wfpusa.org/articles/increasing-urbanization-threatens-food-security-africa/

41 Center for Strategic and International Studies. "Urbanization in Sub-Saharan Africa". 2018. Available at: https://www.csis.org/analysis/urbanization-sub-saharan-africa

In the following section, we will explore a range of cross-cutting risks captured within the GFSI that affect the affordability, availability, and quality and safety of food. Many of these risks are interlinked, and a change in one can alter the likelihood or severity of another. We also highlight examples of resilience mechanisms for each category of risk.

Climate change risks

Climate change will affect food production for all physical systems—marine and terrestrial—as basic environmental conditions change. Temperatures are rising and precipitation patterns are shifting, making crop selection and timing uncertain. The physiological responses of plants and soil systems to increased levels of CO_2 in the atmosphere remain unknown. Ocean acidification is slowing and reversing coral growth and is harming organisms at the bottom of the food chain, with knock-on effects for important fisheries [see In focus: Oceans taking the heat]. Increased frequency and intensity of storms adds to the toll of crop damage. The effects of these changes will be felt most by vulnerable households and communities that lack the physical and socioeconomic infrastructure to buttress their resilience.

Exposure

The physical effects of climate change, including increases in temperature, droughts, flooding, storms and rising sea levels, are likely to hit the Gulf states and the rest of the Middle East and North Africa hardest, followed by Central and South America. Worsening dust- and sandstorms cause significant agricultural losses in countries such as Saudi Arabia and Yemen,[42] which are near the bottom of the rankings in terms of historical susceptibility to storm damage (GFSI 4.1.4). Meanwhile, Central and South American countries are some of the most vulnerable to temperature rise (GFSI 4.1.1) and also experience severe losses from storms, especially in El Salvador, Guatemala and Venezuela.

Countries in Latin America and the Caribbean (LAC) have made substantial progress on global goals to eradicate hunger, with LAC being the only region to have halved both the proportion and the absolute number of residents with insufficient food since 1990.[43] However, agriculture sectors in Central America and the Andes are suffering some of the biggest consequences of climate change, as production of important crops such as coffee, sugarcane, potatoes and corn is having to shift to higher altitudes and latitudes as temperatures rise.[44] The Central American dry corridor, including El Salvador, Guatemala and Honduras, already has reduced precipitation and lower water availability in the dry seasons, alternating with heavy rainfall that causes erosion, runoff and crop damage. Changes in the annual distribution of rainfall mean that traditional subsistence production of corn, beans and squash (which is essential for rural food security) is under threat.[45]

Some of the worst effects of drought are being felt in dry Sub-Saharan African countries such as

42 Middle East Eye. "Rise in sandstorms threatens Middle East and North Africa". 2017. Available at: http://www.middleeasteye.net/columns/rise-sandstorms-threaten-middle-east-and-north-africa-1218388304

43 FAO. "Food and nutrition security and the eradication of hunger: CELAC 2025". 2016. Available at: http://www.fao.org/americas/noticias/ver/en/c/428177

44 Ibid.

45 Ibid.

Senegal, Niger and Sudan, as well as in Gulf states like Oman (GFSI 4.1.2). However, the Andean countries of Peru, Ecuador and Bolivia have also been experiencing severe droughts in recent years, due in part to glacial retreat, which threatens water availability for consumption, irrigation and livestock.[46] The GFSI reflects historical data on events such as floods and droughts, but as a result of global climate change unprecedented droughts are also occurring in places like Haiti, which is highly ranked on this subindicator but experienced a lengthy drought in 2015-16 that left 3.6m Haitians facing food insecurity.[47]

High temperatures contribute to and worsen the effects of drought, and also affect agriculture directly—altering crop physiology, reducing soil moisture and making outdoor work hazardous for farmers' health. As climate change effects worsen during the second half of this century, extreme heatwaves are expected to affect important agricultural areas like the North China Plain, which is currently home to 400m farmers but may become uninhabitable due to heat and humidity.[48]

Drought and flooding often work in tandem to damage food systems, as prolonged drought is often followed by heavy rainfall, causing serious erosion and damage. Countries with extensive low-elevation coastal agriculture face heightened risks from flooding in combination with sea level rise: India and Bangladesh have the highest flood risks (GFSI 4.1.3), and the Netherlands and Vietnam join Bangladesh in having the highest exposure to sea level rise (GFSI 4.1.5). Physical infrastructure plays an essential role in reducing vulnerability to coastal flooding—the Netherlands' extensive seawalls offer protection that is almost non-existent in Bangladesh, where migration is a more likely strategy.

Even countries that import most of their food should expect their food security to be affected by climate change. Singapore is the top-ranked country in the 2018 GFSI, but the city state's ranking drops markedly when climate and natural resource risks are taken into account—its dependence on imports for over 90% of its food supply makes it susceptible to trade and supply chain disruptions, as producing countries may decide to reduce exports to ensure their own food security.

46 *The Guardian*. "Brown and barren land: Bolivia's historic drought – in pictures". May 5th 2017. Available at: https://www.theguardian.com/global-development-professionals-network/gallery/2017/may/05/bolivia-historic-drought-water-in-pictures

47 UN World Food Programme (WFP). "El Nino, drought blamed as severe food insecurity doubles in 6 months in Haiti." February 9th 2016. Available at: http://www.wfp.org/news/news-release/el-nino-drought-blamed-severe-food-insecurity-doubles-6-months-haiti

48 *The Guardian*. "Unsurvivable heatwaves could strike heart of China by end of century". July 31st 2018. Available at: https://www.theguardian.com/environment/2018/jul/31/chinas-most-populous-area-could-be-uninhabitable-by-end-of-century

Climate resilience

- Participation in the Paris Agreement and related processes is helping countries to define their own contributions to mitigation and adaptation plans for agriculture and natural resources management.
- Agricultural planning and crop research based on climate change scenarios can help to identify future climatic zones and agricultural suitability and assist farmers in preparing with more resilient crops and seeds.
- Countries need an effective disaster risk reduction approach that accounts for the increased frequency and intensity of natural disasters such as drought, floods and storms. Slovakia's early-warning mechanism for the agricultural and forestry sectors, coupled with a national water programme that includes measures to prevent and mitigate drought, is one example.[49]

49 Inter Press Service, "Can drought be prevented? Slovakia aims to try?", 2018. http://www.ipsnews.net/2018/01/can-drought-prevented-slovakia-aims-try/

Financial risks

Food security at the household level requires access to affordable food. In the case of rising food prices, affordability means that consumers must be able to absorb higher costs, at least temporarily. Households for which food accounts for a lower proportion of their (total) expenditure are more likely to be able to absorb rises in food prices; for low-income households, safety nets are needed in the short term to ensure that food remains affordable. Over the longer term, livelihoods that provide higher incomes contribute to improvements in food security. Farmer access to financial services such as credit and insurance is another essential component of financial resilience.

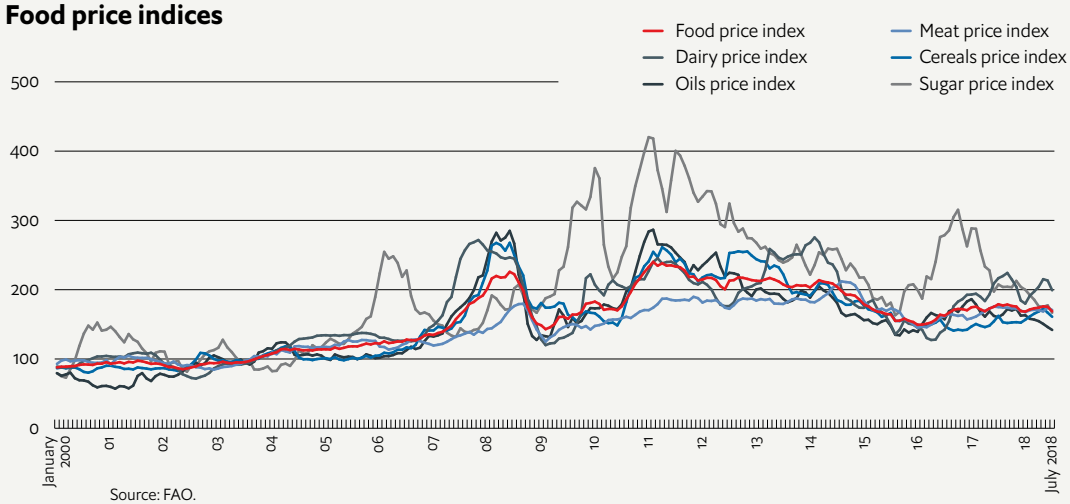
Food price shocks

When local or global food prices rise rapidly, households with low incomes and that allocate a sizeable proportion of their earnings to food can suddenly find themselves unable to purchase sufficient food. In 2007-08 and 2011, rapid rises in prices for key commodities such as rice had a direct impact on food security and global hunger levels, triggering unrest and violence in several countries.[50]

In terms of the drivers of higher food prices, weather disturbances and crop failures play a role—in the first half of 2017, floods in Bangladesh and drought in Sri Lanka contributed to record-

50 GiZ. "Trade rules and food security". 2015 Available at: https://www.giz.de/expertise/downloads/giz2015-en-Study__Trade_rules_and_food_security.pdf

Food price indices



Source: FAO.

high rice prices and low crop yields in East Africa caused cereal prices to rise sharply.[51] But the 2007-08 food price shocks were also linked to broader economic factors, notably: the steady ascent of oil prices, which increased the cost of farming inputs and food transport; stockpiling and export restrictions by major rice producers; and the expansion of biofuel demand, which diverted large portions of the US corn crop to ethanol production.[52] As oil prices fell during the 2008 financial crisis, food prices also returned to more affordable levels.

A country's dependence on imports for its food supplies can also heighten the potential impact of international food price shocks. The Gulf Co-operation Council (GCC) countries and Singapore are the most import-dependent for their food supplies (GFSI 4.5.1), but these countries also have smaller proportions of their populations below the poverty line (GFSI 1.2), which makes them more financially resilient when global prices skyrocket. In contrast, countries in Sub-Saharan African (which are on average the next most import-dependent nations) have the highest proportional household spending on food (GFSI 1.1) and the highest proportions of their populations below the global poverty line (GFSI 1.2), which translates into lower resilience and an inability to absorb the shock of price spikes. Most food-related riots between 2007 and 2015 took place in Sub-Saharan Africa, according to the World Bank's Food Riot Radar, which tracked 55 incidents during that period.[53]

Conflict is generally disruptive of economic and agricultural activities but can also contribute directly to food price shocks—the FAO reported price spikes owing to conflict in Nigeria, South Sudan, Yemen and Burundi during 2017.[54] In the worst cases, the combination of conflict with crop shortfalls and currency depreciation compounds the magnitude of price shocks, as in war-torn South Sudan, where the South Sudanese pound's 80% depreciation against the US dollar in 2017 contributed to an estimated 50% of the population being food-insecure.[55]

Food safety nets

All countries are subject to some seasonal or chronic food insecurity, but they vary greatly in the types of support that they provide, whether through established national welfare programmes or as one-time relief payments following a natural disaster. In the poorest countries, multilaterals and non-governmental organisations typically take the lead in providing safety nets, with food or cash to help households meet their nutritional needs and avoid negative coping strategies like the sale of productive assets or taking children out of school to work.

The countries with the best food safety nets (GFSI 1.5) tend to be those with the highest incomes and the most resources to support governmental programmes for their food-insecure citizens—nearly all countries in Europe and North America provide this type of support. A few middle-income countries, such as Argentina, Brazil and Mexico, also score well in this regard—in 2003 Brazil's president at the time, Luiz Inácio Lula da Silva, created the country's *Fome Zero* (Zero Hunger) programme, which evolved into *Bolsa Família*, a conditional cash transfer programme that provides payments via debit cards to nearly 14m households if children stay in school and receive medical checks.

Other programmes utilise cash or food payments as an investment in resilience—Ethiopia's Productive Safety Nets Programme (PSNP) pays cash or food for people to work on building infrastructure, such as irrigation or terracing systems, that will enhance productivity and agricultural resilience. PSNP has provided support for around 10m poor rural citizens and is

51 FAO. "Global report on food crises 2018". 2018. Available at: http://www.fao.org/emergencies/resources/documents/resources-detail/en/c/1107313/

52 Headey, D. and Fan, S. "Anatomy of a crisis: The causes and consequences of surging food prices". 2008. *Agricultural Economics*, 39:1, 375-391. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1574-0862.2008.00345.x

53 World Bank. "Food Riot Radar". Available at: http://www.worldbank.org/en/topic/poverty/food-price-crisis-observatory#4

54 FAO, "Global report on food crises 2018".

55 Ibid.

now expanding into urban areas.[56] Although Ethiopia continues to experience widespread food insecurity due to drought, conflict and regional migration, PSNP is thought to have had significant positive impacts on levels and duration of hunger.[57]

Transfers of cash or vouchers are a common mechanism for supporting low-income households through long-term support or as a shock-responsive safety net in case of crop shortfalls. Using cash or vouchers works well if local markets are functioning and inflation is not a major concern; if insufficient food supply is at the root of food insecurity, then physically providing food can be more appropriate. The FAO prefers cash and vouchers (ideally through electronic means) as a way to allow recipients to choose what they need most, and transferred US$53.1m to 2.9m people in 26 countries during 2017 using this approach.[58] In contrast, the UN World Food Programme (WFP) facilitates the donation of food between countries as a means of addressing food shortages, even though it is recognised that this type of safety net potentially limits investment and savings in recipient countries.[59] Both organisations are explicit in their delivery strategies and objectives about the importance of gender-sensitive principles that target women's needs and livelihoods.

Farmer financing: Credit and insurance

As with food safety nets, high-income countries have the best resources for farmers in terms of access to farmer financing (GFSI 1.6). The ability of the financial sector to support farmers with credit or insurance is linked to the sophistication of the financial sector, the size of farms and land tenure—in countries with insecure land rights or restrictions on land transfer, farmers face additional challenges in using their primary asset as collateral for loans. In Laos, which scores near the bottom on access to farmer financing, most farmers have been granted only "temporary land use rights", a legal status that explicitly prohibits the transfer of land or its use as security, and the process of creating permanent land titles has been much delayed.[60] A near-complete lack of access to finance is widespread in the poorest countries, which tend also to have the smallest farm sizes[61]—farmers in 22 of the 28 Sub-Saharan African countries included in the GFSI have limited or no access to finance.

Without finance, farmers are often limited in their ability to purchase inputs and equipment, which restricts the ability to invest in crop-enhancement measures such as fertiliser and irrigation. And without insurance, which is non-existent in many developing countries, crop failure often means debt or forced migration. However, insurance innovations are occurring in both the public and private sectors, such as weather-index insurance under which payouts are automatically triggered if certain weather conditions, such as rainfall amounts, are met. This enables farmers to hedge climate risks and receive faster payouts without having to account for crop losses. In Malawi, one of the only countries to improve since 2017 in farmer financing (GFSI 1.6), the WFP and Oxfam America offer weather-index insurance for drought, and coverage can be earned

56 *The Economist*. "Ethiopia's scheme to help the poor is setting an example". May 31st 2018. Available at: https://www.economist.com/middle-east-and-africa/2018/05/31/ethiopias-scheme-to-help-the-poor-is-setting-an-example

57 Berhane, G. et al. "Can social protection work in Africa? The impact of Ethiopia's Productive Safety Net Programme". 2014. *Economic Development and Cultural Change*. Available at: https://www.journals.uchicago.edu/doi/full/10.1086/677753

58 FAO. "Cash-based transfers". 2018. Available at: http://www.fao.org/3/I9684EN/i9684en.pdf

59 FAO. "Safety nets and the right to food". Ch. 7 in *The Right to Food Guidelines: Information Papers and Case Studies*. Available at: http://www.fao.org/tempref/docrep/fao/010/a0511e/a0511e04.pdf

60 Boutthavong, S. et al. "Historical changes of land tenure and land use rights in a local community: A case study in Lao PDR". 2016. *Land* 5:11. Available at: http://www.mdpi.com/2073-445X/5/2/11

61 FAO. "What do we really know about the number and distribution of farms and family farms in the world?" 2014. ESA Working Paper No. 14-02. Available at: http://www.fao.org/docrep/019/i3729e/i3729e.pdf

through completion of work on a farmer's own land to counter the risk of drought, such as the digging of swales to retain moisture.[62] Similar insurance is available for fish ponds in Taiwan that provides an automatic payout if extreme rainfall occurs for two consecutive days—a climatic event that has the potential to trigger flash floods and the loss of fish stocks.[63] In France, meanwhile, wheat farmers are able to customise various parameters of their weather-index insurance policies, such as crop and type of weather event.[64]

Financial resilience

- Governments have an important role to play in managing food price inflation and currency values, as macroeconomic forces can have rapid and devastating effects on food security.
- Provision of financial services, including reliable and affordable credit and low-cost insurance choices, can also help to build financial security for lean times.
- Programmes that couple short-term relief such as conditional cash transfers with longer-term investments in improved soil health or agricultural infrastructure can help to build underlying sources of resilience.

62 WFP. "Weather insurance boosts the resilience of Malawian farmers". Available at: https://insight.wfp.org/weather-insurance-boosts-the-resilience-of-malawian-farmers-485949556ef5

63 Swiss Re. "Swiss Re introduces first parametric aquaculture insurance solution in Taiwan to protect 120,000 hectares of grouper fish ponds from extreme rainfall in Ping Tung". May 15th 2017. Available at: http://www.swissre.com/reinsurance/first_parametric_aquaculture_insurance_solution_in_Taiwan.html

64 Weather and Economics. "Farmers seek parametric insurance after catastrophic losses across France linked to climate volatility". April 27th 2018. Available at: http://www.weatherandeconomics.com/2018/04/27/farmers-seek-parametric-insurance-after-catastrophic-losses-across-france-linked-to-climate-volatility/

Political and social risks

Political and social dynamics shape the economic context of food systems, and in particular whether and how farmers invest in agricultural production. An uncertain economic future makes it risky for farmers to plant crops in the expectation that their efforts and inputs will pay off at harvest time, and depresses longer-term investments. Corruption undermines economic incentives by imposing additional costs on producers and other stakeholders throughout the value chain. And when conflict breaks out, the negative impacts on food security include physical destruction, large-scale population displacement and an inability to continue productive employment, all of which reduce the resilience of conflict-affected households.

Political stability

Political stability is essential for both agricultural production and food relief efforts—farmers will only invest their labour and inputs if they can expect to reap benefits from a future harvest.[65] Delivering an effective response to a food crisis is also challenging in countries struggling with political instability and insecurity, especially where governance is ineffective. In a vicious cycle, food insecurity contributes to unrest and political instability, as seen with the public reaction to the 2007-08 food price shocks in many countries; this can then lead to increased food insecurity as support from public-sector agencies and non-profit organisations is disrupted.

In Venezuela, which ranks the lowest of all the countries in the GFSI for political stability (GFSI 2.5), government mismanagement has led to economic contraction, hyperinflation, a lack of access to food and basic goods and services, and large-scale emigration to Colombia and Brazil.[66] Food is available, but skyrocketing costs and low availability of currency mean that it is not affordable, which in turn is contributing to theft and violence.[67]

Political instability also threatens economic investment, which in turn translates into lower incomes. Even short-term uncertainty can take a toll, as when post-election unrest in Kenya in 2017 hurt the tourism and retail sectors and delayed infrastructure projects.[68]

65 Deaton, B. J. and Lipka, B. "Political instability and food security". 2015. *Journal of Food Security* 2015 3 (1), pp. 29-33. Available at: http://pubs.sciepub.com/jfs/3/1/5/

66 *Washington Post*. "The crisis next door". March 2, 2018. Available at: https://www.washingtonpost.com/news/world/wp/2018/03/02/feature/i-cant-go-back-venezuelans-are-fleeing-their-crisis-torn-country-en-masse/

67 PRI. "Delivering food is now a dangerous job in Venezuela". May 29, 2018. Available at: https://www.pri.org/stories/2018-05-29/delivering-food-now-dangerous-job-venezuela

68 Standard. "Kenya's economy feels pinch of prolonged political uncertainty". October 1st 2017. Available at: https://www.standardmedia.co.ke/business/article/2001256079/kenyans-feel-impact-of-prolonged-political-uncertainty

Conflict and social unrest

When conflict occurs, threats to food security can escalate quickly. The FAO reported that the number of people worldwide in urgent need of food aid increased by 11m in 2017, with conflict a major driver of food insecurity in 18 countries, mostly in Africa and the Middle East but also including Afghanistan and Myanmar.[69] Infrastructure and crops may be damaged, access to markets and supply routes blocked, populations displaced, livelihoods disrupted and aid organisations prevented from reaching affected populations.[70] In eastern Ukraine, years of conflict have caused displacement and runaway food price inflation, while restrictions on access imposed by both sides makes it difficult to provide assistance.[71] The combination of conflict and climate-related disasters in several African countries is considered responsible for significant population displacement, abandoned farms, negative coping strategies and a loss of resilience.[72] In Somalia, the International Committee of the Red Cross has called this combination a "double vulnerability" that has intensified the cycle of food insecurity.[73]

Population displacement and movement into camps or informal urban housing also increase the risk of food safety problems as the capacity of public infrastructure and services is stretched. High-density settlements with insufficient sanitation and hygiene facilities can cause problems with foodborne and waterborne disease, as shown by increases in hepatitis and diarrhoea in Syria[74] and cholera outbreaks in Yemen.[75]

Corruption

Corruption can undermine food security in several ways: by diverting funds intended for agricultural development, by siphoning off food supplies from incoming aid shipments, and by adding marginal expenses to poor farming households, whether through the need to pay bribes or the diversion of government subsidies for inputs. Bangladesh, for example, scores poorly on corruption (GFSI 2.6); research on Bangladeshi rice farmers found that the cost of corruption adversely affects caloric consumption and that low-budget households, which are the least flexible and resilient, are affected most.[76] In India, the public food-distribution system that is intended to provide poor people with subsidised grain is notoriously corrupt, with almost 60% of food meant for beneficiaries diverted for sale or export.[77] Corruption at the highest levels of politics can affect entire sectors—the Kenyan government, for example, has been plagued by corruption scandals related to national grain reserves and market prices.[78] Land grabs are another common mechanism of corruption that threatens food security, in which public or private entities push through favourable deals that secure valuable land resources for themselves and displace small farmers.

69 FAO. "Global Report on Food Crises".

70 Ibid.

71 United States Agency for International Development (USAID). "Ukraine: Food assistance fact sheet – December 11, 2017". Available at: https://reliefweb.int/report/ukraine/ukraine-food-assistance-fact-sheet-updated-december-11-2017

72 FAO. "Global Report on Food Crises".

73 Devereux, S. et al. "Famine: Lessons learned". August 2017. Humanitarian Learning Centre. Available at: https://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/13173/Lessons%20Learned%20FINAL%20online.pdf?sequence=1&isAllowed=y

74 UN Relief and Works Agency for Palestine Refugees in the Near East (UNRWA). "Conflicts and crises mean food safety vigilance is as important as ever in 2015". April 7th 2015. Available at: https://www.unrwa.org/newsroom/features/conflicts-and-crises-mean-food-safety-vigilance-important-ever-2015

75 Reuters. "WHO warns of new Yemen cholera surge, asks for ceasefire to vaccinate". August 2nd 2018. Available at: https://www.reuters.com/article/us-yemen-security-cholera/who-warns-of-new-yemen-cholera-surge-asks-for-ceasefire-to-vaccinate-idUSKBN1KO18R

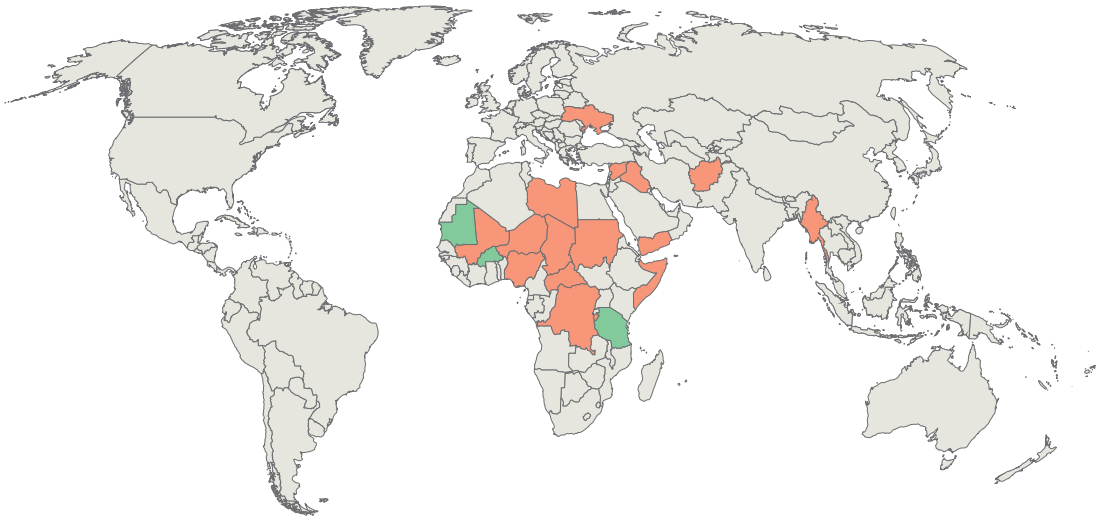
76 Anik, A. R. et al. "Impact of farm level corruption on the food security of households in Bangladesh". 2013. *Food Security* 5 (4), pp. 565-574. Available at: https://link.springer.com/article/10.1007/s12571-013-0282-8

77 Inter Press Service. "Poor bear the brunt of corruption in India's food distribution system". July 1st 2015. Available at: http://www.ipsnews.net/2015/07/poor-bear-the-brunt-of-corruption-in-indias-food-distribution-system/

78 Regarding Rights. "When corruption violates human rights: The right to food in Kenya". 2015. Available at: http://asiapacific.anu.edu.au/regarding-rights/2015/03/27/when-corruption-violates-human-rights-the-right-to-food-in-kenya/

Political and social risks as drivers of food insecurity

(2018 forecast)



■ Conflict and insecurity
■ Population displacement

Source: FAO.

Yemen	Iraq
Afghanistan	Ukraine
Syria	Chad
Democratic Republic of Congo	Niger
South Sudan	Mali
Nigeria	Libya
Sudan	Myanmar
Somalia	Burkina Faso
Burundi	Mauritania
Central African Republic	Tanzania

Political and social resilience

- Resolving conflict and ensuring access to food in the midst of conflict are essential, with the disruption created by conflict having been the main driver of food crises in 2017.[79]
- Ideally, political and social systems enhance resilience by providing responsive support that meets the needs of domestic producers and consumers in terms of stable and predictable market dynamics, investments in research and infrastructure, and facilitation of trade and transport.
- Policy and programme innovations are needed to reduce losses of money and food to corruption.

79 FAO. "Global Report on Food Crises".

Trade and supply chain risks

Trade is an essential element of food security: every country participates in the global food trade, with about a quarter of all the food produced for human consumption crossing international borders.[80] Trade supports food security by providing a buffer against fluctuations in domestic food supply and by stabilising prices.[81] Countries lacking self-sufficiency in food production must rely on trade to fill the gap, but this reliance means that trade-dependent countries are vulnerable to shifts in the trade policies of food-exporting nations, including export bans. Meanwhile, the expansion of global trade and supply chains creates the risk of breakdowns in the storage and transport infrastructure that physically enables the growing volume of trade.

Trade policy

The recent increase in global trade tensions has demonstrated how shifting trade policies—in this case, the use of tariffs (GFSI 1.4)—can affect food supplies. In the short term, the imposition of tariffs on agricultural imports can increase costs as buyers scramble to find substitutes, while lowering margins for producers. The tariffs that China imposed on US soybeans in July 2017, for example, caused Chinese buyers to cancel orders, and US soybean futures dropped to a five-year low.[82] As China pays more for soybeans, whether due to tariffs on US imports or comparatively higher prices on soybeans from Brazil or other sources, its consumers will pay more as well. For low-income households around the globe that already spend most of their income on food (GFSI 1.1), sudden cost increases caused by higher import duties are particularly painful.[83]

Over the longer term, tariffs can drive agricultural investment in alternative locations, both at home and abroad, with mixed effects on resilience. If Chinese farmers respond to government incentives to plant more soybeans,[84] the country's domestic supplies will increase, making it less dependent on imports. However, soybean cultivation is less productive in China than in Brazil or the US, and China is unable to replace a significant portion of the 100m tonnes of soybeans that it currently imports. Meanwhile, the tariffs are having at least one negative environmental impact: Brazil has increased its exports to China and is buying US soybeans to make up the difference, thereby increasing the crop's total carbon

80 D'Odorico, P. and Laio, F. "Feeding humanity through global food trade". September 2014. *Earth's Future* 2(9). Available at: https://www.researchgate.net/publication/264675389_Feeding_humanity_through_global_food_trade

81 World Bank. "Trade policy and food security". 2015. Available at: https://openknowledge.worldbank.org/handle/10986/20537

82 CNBC. "North Dakota soybean processors hit by tariffs as China cancels orders". July 11th 2018. Available at: https://www.cnbc.com/2018/07/11/north-dakota-soybean-processors-hit-by-tariffs-as-china-cancels-orders.html; CNBC. "Soybeans". Available at: https://www.cnbc.com/quotes/?symbol=%40S.1

83 GiZ. "Trade rules and food security."

84 *New York Times*. "China's taste for soybeans is a weak spot in the trade war with Trump". July 9th 2018. Available at: https://www.nytimes.com/2018/07/09/business/china-trade-war-soybeans.html

footprint.[85] If Brazil's soybean production expands further at the expense of Amazon forests, carbon emissions will also increase, as will soil degradation.[86]

Protectionist trade policies can contribute to world food price increases and limit agricultural competitiveness. When food-exporting countries respond to rising prices by restricting exports to protect their own food security, this exacerbates the initial price shock and often prompts other countries to put their own export restrictions in place, further raising global food prices.[87] In Sub-Saharan Africa, trade barriers such as cumbersome licensing and inspection requirements are also limiting the potential for countries' food surpluses to be traded internationally, undermining incentives for agricultural investment.[88]

Infrastructure constraints

As the global volume of long-distance food trade grows, constraints on transport and storage infrastructure pose a risk to food security, exacerbated by potential political and physical chokepoints where trade flows can be constricted.

Political conflict is one of the main drivers of food insecurity, disrupting not only food production and distribution but also transport. Certain routes are particularly at risk, such as the trade passage through the Bosphorus, which transits one-fifth of global wheat exports but has been affected by ongoing tensions between Ukraine and Russia. The Strait of Malacca, meanwhile, is an important waypoint for bulk shipments including grains travelling from the US and Brazil to Asia, giving it strategic geopolitical and commercial importance.[89]

Physical infrastructure can also cause delays, as when ageing highways and waterways slow the movement of grain from North and South America. Climate change, too, can be expected to add to the strain on infrastructure, for example through the effect of higher temperatures, sea level rise and storm surges on roadways. In 2017, heavy rains on Brazil's roads caused major delays for trucks carrying soybeans to the country's ports.[90]

Meanwhile, storage infrastructure—or the lack thereof (GFSI 2.3.1)—is a significant determinant of the proportion of the harvest that will be available to leave the farm gate. Although this is not a significant concern in high-income countries, in lower-income countries up to 40% of a crop can be lost during post-harvest storage, due to lack of climate control in traditional storage methods (often woven bags or baskets) or because of damage from insects and rodents (GFSI 2.8). Another 10% may be lost during transport because of spillage or contamination.[91] Quality of storage is important for household subsistence as well as income—in Ethiopia, the use of improved food storage technologies such as metal silos was shown to reduce food insecurity and child malnutrition.[92]

85 Bloomberg. "Brazil may buy 1 million metric tons of US soybeans". July 5th 2018. Available at: https://www.bloomberg.com/news/articles/2018-07-05/wait-what-brazil-may-buy-up-to-1-million-tons-of-u-s-soybeans

86 ResourceTrade.Earth. "Food security, trade and its impacts". Available at: https://resourcetrade.earth/stories/food-security-trade-and-its-impacts#section-110

87 World Bank. "Trade policy and food security". 2015.

88 Ibid.

89 Bloomberg. "Choking on our harvest: Threats loom over global food trade". Available at: https://www.bloomberg.com/graphics/2018-food-trade-chokepoints/

90 Reuters. "Thousands of soy trucks stranded on swamped Amazon highway in Brazil". March 1st, 2017. Available at: https://www.reuters.com/article/us-brazil-soybeans-road-idUSKBN1685AN

91 Kumar, D. and Kalita, P. "Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries". 2017. *Foods* 6(1). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5296677/

92 Tesfaye, W. and Tirivayi, N. "The impacts of postharvest storage innovations on food security and welfare in Ethiopia". 2018. *Food Policy* 75. Available at: https://www.sciencedirect.com/science/article/pii/S030691921630416X?via%3Dihub

Trade and supply chain resilience

- More open trade policies have been shown to benefit developing countries, resulting in higher production and exports and lower price volatility.[93]
- Regional trade agreements can also be a useful way to improve trade flows across borders, especially if supported by efficient transport and logistics.
- Investing in infrastructure that reduces losses and enables longer-term storage of reserves builds resilience as well, by giving farmers more flexibility when they sell their products and the ability to respond to price signals (that reflect abundance or scarcity).

93 World Bank. "Trade policy and food security". 2015.

Conclusion

Food security relies on the capacity of interconnected social, economic and biophysical systems to meet the nutritional requirements of a growing global population. Climate change will pose unprecedented risks to food supplies, in tandem with (and often exacerbating) ongoing financial, social and political, and trade and supply chain risks. The fact that so many of the risks discussed here are cross-cutting and interrelated illustrates the complexity of the interactions and dynamics of the food supply system, which can be positive as well as negative. For example, just as rising food prices and political instability can be mutually reinforcing in a negative spiral, addressing one of these risks can help to mitigate the other.

The GFSI is already in use as a policy benchmark for governments and a research tool for academics and investors. By highlighting the ways in which the GFSI captures elements of risk and resilience in measuring food security, we demonstrate another important way that the index's analytical findings can be used in discussions of how to enhance food security by building resilience.

From a perspective of risk and resilience, how can we enable food systems—including production, distribution and consumption—to anticipate, absorb and recover from the shocks and stresses that they face?

- **Change is certain**. Global climate change is already introducing added uncertainty into the conditions of food production and distribution, and will create unprecedented challenges as the world continues past an increase of 2 degrees Celsius in average temperatures. As uncharted territory makes anticipation more difficult, preparations must be made to build more resilience into food systems.
- **Information is essential**. Just as early-warning systems for natural disasters have proved essential for allowing those in their path more time to prepare, we also need systems that track and report on crop yields, pest outbreaks and price inflation. With additional historical and comparative analysis, there is more potential to identify trends and triggers of food insecurity.
- **Rapid responses are needed.** Time is of the essence in providing effective food aid in the case of crisis, but also in responding to agricultural threats of pests and disease and to the potential for political instability and conflict to impinge on the availability and affordability of food.
- **Knowledge creates options**. The ability of farmers, extension agents, agricultural researchers and those higher up the value chain to identify and implement coping strategies and adaptive options is dependent on technical knowledge and resources. Funding of high-technology research and innovation in practices and technology should happen in tandem with participatory experiential learning on the ground.

Appendix I: GFSI 2018 results

2018 GFSI overall rankings table

Weighted total of all category scores (0-100 where 100 = most favourable)

Rank	Country	Score / 100
1	Singapore	85.9
2	Ireland	85.5
=3	United Kingdom	85.0
=3	United States	85.0
5	Netherlands	84.7
6	Australia	83.7
7	Switzerland	83.5
8	Finland	83.3
9	Canada	83.2
10	France	82.9
11	Germany	82.7
=12	Norway	82.2
=12	Sweden	82.2
14	Austria	82.1
15	New Zealand	81.3
16	Denmark	80.9
17	Belgium	80.2
18	Japan	79.9
19	Portugal	79.3
20	Israel	78.6
21	Spain	78.0
22	Qatar	76.5
23	Italy	76.3
24	Czech Republic	76.1
25	South Korea	75.6
26	Poland	75.4
27	Chile	75.1
28	Kuwait	74.8
29	Oman	74.4
30	Hungary	72.8
31	United Arab Emirates	72.5
32	Saudi Arabia	72.4
33	Greece	71.6
34	Uruguay	71.3
35	Slovakia	70.3
36	Costa Rica	69.3
37	Argentina	69.2
38	Romania	68.9
39	Brazil	68.4
40	Malaysia	68.1
41	Bahrain	67.8
42	Russia	67.0
43	Mexico	66.4
44	Belarus	65.7
45	South Africa	65.5
46	China	65.1
47	Bulgaria	64.5
48	Turkey	64.1
49	Colombia	63.7
50	Panama	61.9
51	Tunisia	60.9
52	Botswana	60.8
53	Serbia	59.8
54	Thailand	58.9
55	Peru	58.7
56	Azerbaijan	58.2
57	Kazakhstan	57.7
=58	Dominican Republic	57.2
=58	Paraguay	57.2
60	Jordan	57.0
61	Egypt	56.3
62	Vietnam	56.0
63	Ukraine	55.7
64	Morocco	55.0
=65	Ecuador	54.8
=65	Indonesia	54.8
67	Sri Lanka	54.3
68	El Salvador	53.7
69	Algeria	52.1
70	Philippines	51.5
71	Guatemala	51.4
72	Nicaragua	51.1
73	Ghana	50.9
=74	Bolivia	50.7
=74	Honduras	50.7
76	India	50.1
77	Pakistan	49.1
78	Venezuela	47.4
79	Nepal	46.0
80	Uzbekistan	45.9
81	Cote d'Ivoire	45.8
82	Myanmar	45.7
83	Bangladesh	43.3
84	Cameroon	42.4
85	Cambodia	42.3
86	Mali	42.0
=87	Kenya	41.9
=87	Senegal	41.9
89	Uganda	41.4
90	Benin	41.0
91	Tajikistan	40.7
92	Angola	38.6
=93	Rwanda	38.4
=93	Togo	38.4
95	Laos	38.3
96	Nigeria	38.0
97	Burkina Faso	37.9
98	Tanzania	37.1
99	Sudan	36.4
100	Ethiopia	36.0
101	Mozambique	35.0
102	Guinea	34.9
103	Syria	34.1
=104	Niger	33.7
=104	Zambia	33.7
106	Haiti	33.0
107	Malawi	32.4
108	Chad	31.5
109	Sierra Leone	29.2
110	Yemen	28.5
111	Madagascar	27.0
112	Congo (Dem. Rep.)	26.1
113	Burundi	23.9

2018 GFSI overall score changes

Weighted total of all category scores (0-100 where 100 = most favourable)

Score improved Score delined

Country	Score change
Burkina Faso	3.7
Colombia	3.0
Belarus	2.9
Niger	2.8
Laos	2.7
Philippines	2.5
Chad	2.2
Finland	2.0
Tunisia	1.9
Kazakhstan	1.8
Ukraine	1.8
Argentina	1.8
Dominican Republic	1.7
Morocco	1.7
Mali	1.7
Turkey	1.7
Netherlands	1.6
Malawi	1.6
Uruguay	1.6
Indonesia	1.6
Cote d'Ivoire	1.6
Honduras	1.5
Yemen	1.4
Bangladesh	1.3
Poland	1.2
Guatemala	1.1
Congo (Dem. Rep.)	1.1
Romania	1.0
Tajikistan	1.0
Singapore	0.9
Syria	0.9
China	0.9
United Arab Emirates	0.8
Russia	0.8
Ghana	0.8
Canada	0.7
Bulgaria	0.7
Vietnam	0.7

Country	Score change
Rwanda	0.7
South Korea	0.7
Norway	0.6
Thailand	0.6
Benin	0.6
United Kingdom	0.6
Switzerland	0.6
Hungary	0.6
Malaysia	0.6
Brazil	0.5
Paraguay	0.5
Zambia	0.5
Haiti	0.5
France	0.4
Saudi Arabia	0.4
Azerbaijan	0.4
Cambodia	0.4
Chile	0.4
Denmark	0.3
El Salvador	0.3
Nicaragua	0.3
Angola	0.3
Tanzania	0.3
Portugal	0.3
Italy	0.3
Slovakia	0.3
South Africa	0.3
Sri Lanka	0.3
Mozambique	0.3
Australia	0.2
Sweden	0.2
Oman	0.2
Madagascar	0.2
Sudan	0.2
Austria	0.2
Czech Republic	0.2
Belgium	0.1
Japan	0.1

Country	Score change
Algeria	0.1
Myanmar	0.1
Cameroon	0.1
United States	0.1
New Zealand	0.1
Mexico	0.0
Sierra Leone	0.0
Germany	-0.1
Botswana	-0.1
Nepal	-0.1
Togo	-0.1
Greece	-0.1
Costa Rica	-0.1
Spain	-0.2
Kuwait	-0.2
Pakistan	-0.3
Bahrain	-0.5
Serbia	-0.6
Uzbekistan	-0.6
Kenya	-0.6
Israel	-0.7
Senegal	-0.7
Peru	-0.8
Bolivia	-0.8
India	-0.8
Guinea	-0.8
Ecuador	-0.9
Panama	-1.0
Nigeria	-1.1
Ethiopia	-1.1
Ireland	-1.2
Jordan	-1.2
Burundi	-1.4
Qatar	-1.6
Egypt	-1.6
Venezuela	-2.7
Uganda	-2.7

2018 GFSI Natural Resources & Resilience rankings table

Weighted total of all Natural Resources & Resilience indicator scores (0-100 where 100 = most favourable)

Rank	Country	Score / 100
1	Slovakia	81.7
2	Denmark	81.5
3	Czech Republic	80.9
4	Austria	80.2
5	Hungary	79.2
6	Switzerland	78.5
7	Poland	77.7
8	Sweden	77.3
9	France	76.0
=10	Germany	75.7
=10	Portugal	75.7
12	Uruguay	75.0
=13	Bulgaria	74.7
=13	Romania	74.7
15	Greece	74.6
16	Italy	74.3
17	Canada	73.5
18	Russia	73.4
19	Spain	71.9
=20	Finland	71.8
=20	New Zealand	71.8
22	Japan	71.7
23	Turkey	70.2
24	Uganda	70.0
25	Myanmar	69.6
=26	Ireland	69.2
=26	Malawi	69.2
=28	Laos	69.0
=28	Serbia	69.0
=30	Belgium	68.5
=30	Burkina Faso	68.5
32	Rwanda	68.4
33	Paraguay	68.1
34	Netherlands	67.9
35	Niger	67.8
36	Kazakhstan	67.7
37	Norway	67.6
38	Cote d'Ivoire	67.5
39	Burundi	67.2
40	Thailand	66.4
41	Zambia	66.2
42	Argentina	66.1
43	Tanzania	65.4
44	United States	64.9
45	United Kingdom	64.8
46	Mali	64.6
47	Madagascar	64.5
48	Botswana	64.4
49	Jordan	63.5
50	Pakistan	63.2
=51	Australia	63.1
=51	Brazil	63.1
53	Belarus	62.9
54	Chile	62.7
55	Uzbekistan	62.3
=56	Bolivia	62.1
=56	Venezuela	62.1
58	Kenya	61.7
=59	Cambodia	61.3
=59	Ethiopia	61.3
61	Senegal	60.9
62	Nicaragua	60.3
63	Honduras	59.5
64	Chad	59.3
65	China	59.2
66	Bangladesh	59.1
67	Guatemala	58.8
=68	Nigeria	58.7
=68	Togo	58.7
70	Haiti	58.4
=71	Algeria	57.8
=71	Costa Rica	57.8
=73	Nepal	57.7
=73	Sudan	57.7
75	Azerbaijan	57.6
76	Ukraine	57.5
77	South Africa	57.0
78	Ghana	56.7
79	El Salvador	56.6
80	Sierra Leone	56.5
81	Sri Lanka	56.3
82	Cameroon	55.6
=83	Benin	55.1
=83	Kuwait	55.1
85	Vietnam	55.0
86	Egypt	54.7
=87	Angola	54.5
=87	Mexico	54.5
89	Tunisia	54.4
90	Panama	54.0
91	Morocco	53.9
92	Guinea	53.1
93	Qatar	53.0
94	Dominican Republic	52.9
95	South Korea	52.4
96	Tajikistan	52.0
=97	Malaysia	51.9
=97	Mozambique	51.9
99	India	51.7
100	Syria	51.3
101	Philippines	51.0
102	Colombia	50.8
103	Singapore	50.3
104	Israel	49.9
105	Ecuador	49.5
106	Yemen	48.2
=107	Oman	46.9
=107	Saudi Arabia	46.9
109	Bahrain	46.6
110	Congo (Dem. Rep.)	45.0
111	Indonesia	43.9
112	Peru	42.6
113	United Arab Emirates	40.7

2018 adjusted overall GFSI score

Overall GFSI score adjusted by the Natural Resources & Resilience overall score (0-100 where 100 = most favourable)

Rise in ranking Decline in ranking

Rank	Country	Score / 100	Rank change
1	Switzerland	79.0	6
2	Ireland	78.9	0
3	Austria	78.0	11
=4	France	77.9	6
=4	Netherlands	77.9	1
=6	Canada	77.7	3
=6	Germany	77.7	5
=8	Sweden	77.5	4
=8	United Kingdom	77.5	-5
=8	United States	77.5	-5
11	Finland	77.4	-3
12	Denmark	77.2	4
13	Australia	76.0	-7
14	New Zealand	75.6	1
15	Norway	75.5	-3
16	Singapore	75.2	-15
17	Portugal	74.5	2
18	Japan	74.2	0
19	Belgium	73.9	-2
=20	Czech Republic	72.5	4
=20	Spain	72.5	1
22	Italy	71.4	1
23	Poland	71.2	3
24	Hungary	69.0	6
25	Israel	68.8	-5
26	Chile	68.1	1
27	Qatar	67.5	-5
=28	Greece	67.1	5
=28	Slovakia	67.1	7
30	Uruguay	66.8	4
31	South Korea	66.6	-6
32	Kuwait	66.4	-4
=33	Oman	64.5	-4
=33	Romania	64.5	5
35	Argentina	63.3	2
36	Saudi Arabia	62.8	-4
37	Russia	62.5	5
38	Brazil	62.1	1
39	Costa Rica	62.0	-3
40	United Arab Emirates	61.8	-9
41	Bulgaria	60.4	6
42	Malaysia	59.9	-2
43	Belarus	59.6	1
44	Turkey	59.3	4
45	Mexico	58.8	-2
46	Bahrain	58.7	-5
=47	China	58.5	-1
=47	South Africa	58.5	-2
49	Colombia	55.9	0
50	Botswana	55.4	2
51	Serbia	55.2	2
52	Panama	54.8	-2
=53	Thailand	54.0	1
=53	Tunisia	54.0	-2
55	Kazakhstan	53.0	2
56	Paraguay	52.6	2
57	Azerbaijan	52.0	-1
58	Jordan	51.8	2
59	Dominican Republic	50.5	-1
60	Peru	50.3	-5
61	Egypt	49.9	0
62	Ukraine	49.8	1
63	Vietnam	49.7	-1
64	Morocco	48.7	0
65	Sri Lanka	48.4	2
=66	Ecuador	47.9	-1
=66	El Salvador	47.9	2
68	Indonesia	47.1	-3
69	Algeria	46.6	0
70	Guatemala	46.1	1
71	Nicaragua	46.0	1
72	Bolivia	45.9	2
73	Honduras	45.6	1
74	Ghana	45.4	-1
75	Philippines	45.2	-5
76	Pakistan	44.6	1
77	India	44.1	-1
78	Venezuela	42.9	0
79	Myanmar	42.2	3
80	Cote d'Ivoire	42.1	1
81	Uzbekistan	41.6	-1
82	Nepal	41.1	-3
83	Bangladesh	38.9	0
=84	Mali	38.3	2
=84	Uganda	38.3	5
86	Cambodia	38.2	-1
87	Kenya	37.9	0
88	Senegal	37.8	-1
89	Cameroon	37.7	-5
90	Benin	36.4	0
91	Tajikistan	35.8	0
92	Rwanda	35.4	1
93	Laos	35.3	2
94	Burkina Faso	34.9	3
95	Togo	34.4	-2
96	Angola	34.2	-4
97	Nigeria	34.1	-1
98	Tanzania	33.9	0
99	Sudan	32.6	0
100	Ethiopia	32.5	0
101	Niger	31.0	3
102	Zambia	30.9	2
=103	Guinea	30.8	-1
=103	Mozambique	30.8	-2
=105	Malawi	29.9	2
=105	Syria	29.9	-2
107	Haiti	29.6	-1
108	Chad	28.3	0
109	Sierra Leone	26.0	0
110	Yemen	24.8	0
111	Madagascar	24.6	0
112	Congo (Dem. Rep.)	22.5	0
113	Burundi	21.9	0

Appendix II: Methodology

The objective of the Global Food Security Index (GFSI) is to determine which countries are most and least vulnerable to food insecurity. The GFSI is a dynamic quantitative and qualitative benchmarking model that measures drivers of food security across 113 countries. The methodology used by The Economist Intelligence Unit, including category and indicator definitions, scoring criteria, country selection, weightings, and sources, is provided below.

Scoring criteria and categories

Categories and indicators were selected on the basis of Economist Intelligence Unit expert analysis and consultation with a panel of food-security specialists. We convened the panel in February 2012 to help select and prioritise food-security indicators using a transparent and robust methodology. The goal of the meeting was to review the framework, selection of indicators, weighting and overall construction of the index.

A fourth category was added to the 2017 iteration of the index to capture the impact of climate-related and natural resource risks. We convened a new expert panel in March 2017 to assist in the development of this new category.

The four category scores are calculated from the weighted mean of underlying indicators and are scaled from 0 to 100, where 100 = most favourable. These categories are: Affordability, Availability, Quality & Safety, and Natural Resources & Resilience. The overall score for the GFSI (on a range of 0-100) is calculated from a simple weighted average of the first three category scores (Affordability, Availability and Quality & Safety). The Natural Resources & Resilience category is an adjustment factor that serves as a lens through which overall food security can be viewed to demonstrate changes to the overall score when climate-related and natural resource risks are taken into account (See *Natural Resources & Resilience: Adjustment factor* below for more detail).

The categories and indicators are:

1. Affordability

1.1 Food consumption as a share of household expenditure
1.2 Proportion of population under the global poverty line
1.3 Gross domestic product per capita (PPP)
1.4 Agricultural import tariffs
1.5 Presence of food safety-net programmes
1.6 Access to financing for farmers

2. Availability

2.1 Sufficiency of supply
2.1.1 Average food supply
2.1.2 Dependency on chronic food aid
2.2 Public expenditure on agricultural R&D
2.3 Agricultural infrastructure
2.3.1 Existence of adequate crop storage facilities
2.3.2 Road infrastructure
2.3.3 Port infrastructure

2.4 Volatility of agricultural production
2.5 Political stability risk
2.6 Corruption
2.7 Urban absorption capacity
2.8 Food loss

3. Quality & Safety

3.1 Diet diversification
3.2 Nutritional standards
3.2.1 National dietary guidelines
3.2.2 National nutrition plan or strategy
3.2.3 Nutrition monitoring and surveillance
3.3 Micronutrient availability
3.3.1 Dietary availability of vitamin A
3.3.2 Dietary availability of animal iron
3.3.3 Dietary availability of vegetal iron
3.4 Protein quality
3.5 Food safety
3.5.1 Agency to ensure the safety and health of food
3.5.2 Percentage of population with access to potable water
3.5.3 Presence of formal grocery sector

4. Natural Resources & Resilience

4.1 Exposure
4.1.1 Temperature rise
4.1.2 Drought
4.1.3 Flooding
4.1.4 Storm severity (annual average loss)
4.1.5 Sea level rise
4.1.6 Commitment to managing exposure
4.2 Water
4.2.1 Agricultural water risk - quantity
4.2.2 Agricultural water risk - quality
4.3 Land
4.3.1 Soil erosion / organic matter
4.3.2 Grassland
4.3.3 Forest change
4.4 Oceans
4.4.1 Eutrophication and hypoxia
4.4.2 Marine biodiversity
4.4.3 Marine protected areas
4.5 Sensitivity
4.5.1 Food import dependency
4.5.2 Dependence on natural capital
4.5.3 Disaster risk management
4.6 Adaptive capacity
4.6.1 Early-warning measures / climate-smart agriculture
4.6.2 National agricultural risk management system
4.7 Demographic stresses
4.7.1 Population growth (2016-21)
4.7.2 Urbanisation (2016-21)

Data for the quantitative indicators are drawn from national and international statistical sources. Where there were missing values in quantitative or survey data, the EIU has used estimates. Estimated figures have been noted in the model workbook. Of the qualitative indicators, some have been created by the EIU, based on information from development banks and government websites, while others have been drawn from a range of surveys and data sources and adjusted by the EIU.

The main sources used in the GFSI are the The Economist Intelligence Unit, the World Bank Group, the International Monetary Fund (IMF), the UN Food and Agriculture Organisation (FAO), the UN Development Programme (UNDP), the World Health Organisation (WHO), the World Trade Organisation (WTO), the Organisation for Economic Cooperation and Development (OECD), Agricultural Science and Technology Indicators (ASTI), the Notre Dame Global Adaptation Initiative (ND-GAIN), the World Resources Institute (WRI) and national statistical offices.

Country selection

The 113 countries in the index were selected by the EIU based on regional diversity, economic importance, population size (countries with larger populations were chosen so that a greater share of the global population is represented) and the goal of including regions around the globe. The countries included in the 2018 index are:

Asia & Pacific	Central & South America	Europe	Gulf Cooperation Council	Middle East & North Africa	North America	Sub-Saharan Africa
Australia	Argentina	Austria	Bahrain	Algeria	Canada	Angola
Azerbaijan	Bolivia	Belarus	Kuwait	Egypt	Mexico	Benin
Bangladesh	Brazil	Belgium	Oman	Israel	United States	Botswana
Cambodia	Chile	Bulgaria	Qatar	Jordan		Burkina Faso
China	Colombia	Czech Republic	Saudi Arabia	Morocco		Burundi
India	Costa Rica	Denmark	United Arab Emirates	Syria		Cameroon
Indonesia	Dominican Republic	Finland		Tunisia		Chad
Japan	Ecuador	France		Turkey		Congo (Dem. Rep.)
Kazakhstan	El Salvador	Germany		Yemen		Côte d'Ivoire
Laos	Guatemala	Greece				Ethiopia
Malaysia	Haiti	Hungary				Ghana
Myanmar	Honduras	Ireland				Guinea
Nepal	Nicaragua	Italy				Kenya
New Zealand	Panama	Netherlands				Madagascar
Pakistan	Paraguay	Norway				Malawi
Philippines	Peru	Poland				Mali
Singapore	Uruguay	Portugal				Mozambique
South Korea	Venezuela	Romania				Niger
Sri Lanka		Russia				Nigeria
Tajikistan		Serbia				Rwanda
Thailand		Slovakia				Senegal
Uzbekistan		Spain				Sierra Leone
Vietnam		Sweden				South Africa
		Switzerland				Sudan
		Ukraine				Tanzania
		United Kingdom				Togo
						Uganda
						Zambia

Weightings

The weighting assigned to each category and indicator can be changed by users to reflect different assumptions about their relative importance. Two sets of weightings are provided in the index. One possible option, known as neutral weights, assumes that all indicators are equally important and distributes weightings evenly. The second available option, known as peer panel recommendation, averages the weightings suggested by five members of the 2012 expert panel. The expert weightings are the default weightings in the model. The model workbook also enables users to create customised weightings to allow them to test their own assumptions about the relative importance of each indicator.

Data modelling

Indicator scores are normalised and then aggregated across categories to enable a comparison of broader concepts across countries. Normalisation rebases the raw indicator data to a common unit so that it can be aggregated. The indicators for which a higher value indicates a more favourable environment for food security—such as GDP per head or average food supply—have been normalised on the basis of:

x = (x - Min(x)) / (Max(x) - Min(x))

where Min(x) and Max(x) are, respectively, the lowest and highest values in the 113 economies for any given indicator. The normalised value is then transformed from a 0-1 value to a 0-100 score to make it directly comparable with other indicators. This in effect means that the country with the highest raw data value will score 100, while the lowest will score 0.

For the indicators for which a high value indicates an unfavourable environment for food security—such as volatility of agricultural production or political stability risk—the normalisation function takes the form of:

x = (x - Max(x)) / (Max(x) - Min(x))

where Min(x) and Max(x) are, respectively, the lowest and highest values in the 113 economies for any given indicator. The normalised value is then transformed into a positive number on a scale of 0-100 to make it directly comparable with other indicators.

Natural Resources & Resilience: adjustment factor

The Natural Resources & Resilience category is designed so that the user can opt to view the results with climate-related and natural resource risks taken into account or not taken into account. Indicator scores follow the same methodology as noted above (see Data modelling), while the formula for the adjusted overall score is as follows:

Adjusted overall score = X * (1 - Z) + (X * (Y / 100) * Z)

where X is the original overall score, Y is the Natural Resource & Resilience score, and Z is the adjustment factor weighting (where 0 = 0% adjustment, 0.5 = 50% adjustment and 1 = 100% adjustment). The default setting for the adjustment factor weighting is 0.25 = 25%.

Sources and definitions

In the 2017 version of the index, we replaced the UN World Food Programme data for indicator (2.1.2) with more up-to-date OECD sources. Across all indicators, where the quantitative or survey data have missing values, the EIU has estimated the scores.

Indicator	Primary source(s)	Year	Indicator definitions and construction
1) Affordability			
Food consumption as a share of household expenditure	National accounts; UN	Latest available year in 2009-18	A measure of the national average percentage of household expenditure that is spent on food.
Proportion of population under global poverty line	World Bank, *World Development Indicators*	Latest available year in 2005-16	A measure of the prevalence of poverty, calculated as the percentage of the population living on less than US$3.20/day at 2011 purchasing power parity (PPP) exchange rates.
GDP per capita at PPP	The Economist Intelligence Unit (EIU)	2017	A measure of individual income and, hence, the affordability of food, calculated in US dollars at PPP.
Agricultural import tariffs	World Trade Organisation (WTO)	Latest available year in 2012-16	Measured as the average applied most-favoured nation (MFN) tariff on all agricultural imports.
Presence of food safety-net programmes	Qualitative scoring by EIU analysts	Based on data availability, 2001-18	A measure of public initiatives to protect the poor from food-related shocks. This indicator considers food safety-net programmes, including in-kind food transfers, conditional cash transfers (e.g. food vouchers) and the existence of school feeding programmes provided by the government, non-governmental organisations (NGOs) or the multilateral sector. Measured on a 0-4 scale based on the prevalence and depth of food safety-net programmes: 0 = No evidence of food safety-net programmes or very minimal presence of ineffective programmes run by NGOs or multilaterals only. 1 = Minimal presence of food safety-net programmes run by NGOs and multilaterals only or very rudimentary, ineffective government-run programmes. 2 = Moderate prevalence and depth of food safety-net programmes run by government, multilaterals or NGOs. 3 = National coverage, with very broad, but not deep, coverage of food safety-net programmes. 4 = National government-run provision of food safety-net programmes. Depth indicates the quantity of funds available to recipients; breadth indicates the range of services available.

Indicator	Primary source(s)	Year	Indicator definitions and construction
Access to financing for farmers	Qualitative scoring by EIU analysts	Based on data availability, 2010-18	A measure of the availability of financing to farmers from the public sector. Measured on a 0-4 scale based on the depth and range of financing for farmers: 0 = Virtually no access to government or multilateral financing programmes (typically, but not necessarily, a developing economy). 1 = Limited multilateral or government financing programmes (typically, but not necessarily, a developing economy). 2 = Some multilateral or government financing (typically, but not necessarily, an emerging-market economy). 3 = Broad, but not deep, financing (typically, but not necessarily, a developed economy) OR well-developed multilateral financing programmes (typically, but not necessarily, an emerging-market economy). 4 = Access to deep financing (typically, but not necessarily, an advanced economy). Depth indicates the quantity of funds available; range covers credit and insurance.
2) Availability			
Sufficiency of supply	EIU scoring	–	A composite indicator that measures the availability of food. It comprises the following subindicators: • Average food supply in kcal/capita/day • Dependency on chronic food aid
Average food supply	UN Food and Agriculture Organisation (FAO)	2005-13	An estimate of the amount of food available for human consumption in kcal/capita/day.
Dependency on chronic food aid	OECD	2011-16	Measures whether a country is a recipient of chronic food aid. For the purpose of this index, chronic aid recipients are defined as those countries that have received non-emergency food aid over a five-year time span. Measured on a 0-2 scale: 0 = Received chronic food aid on an increasing basis over the past five years. 1 = Received chronic food aid on a decreasing basis over the past five years. 2 = Receives little or no food aid, or receives food aid only on an emergency basis.
Public expenditure on agricultural research and development (R&D)	EIU estimates based on OECD and Agricultural Science and Technology Indicators (ASTI)	Latest available year in 2004-15	A measure of government spending on agricultural R&D. Expenditure on agricultural R&D is a proxy for agricultural innovation and technology that increases market efficiency and access. Measured as a percentage of agricultural GDP and is scored on a nine-point scale: 1 = 0-0.5% 2 = 0.51-1.0% 3 = 1.01-1.5% 4 = 1.51-2.0% 5 = 2.01-2.5% 6 = 2.51-3.0% 7 = 3.01-3.5% 8 = 3.51-4.0% 9 = 4.01-4.5%

Indicator	Primary source(s)	Year	Indicator definitions and construction
Agricultural infrastructure	EIU scoring	-	A composite indicator that measures ability to store crops and transport them to market. Subindicators include: • Existence of adequate crop storage facilities • Road infrastructure • Port infrastructure
Existence of adequate crop storage facilities	Qualitative scoring by EIU analysts	Based on data availability, 2011-18	This binary indicator assesses the presence of sufficient crop storage facilities based on size of agricultural sector and population. Measured on a 0-1 scale: 0 = No 1 = Yes
Road infrastructure	EIU Risk Briefing	2018	This qualitative indicator measures the quality of road infrastructure and is measured on a 0-4 scale, where 4 = best.
Port infrastructure	EIU Risk Briefing	2018	This qualitative indicator measures the quality of port infrastructure and is measured on a 0-4 scale, where 4 = best.
Volatility of agricultural production	FAO	1996-2015	This indicator measures the standard deviation of the growth of agricultural production over the most recent 20-year period for which data are available.
Political stability risk	EIU Risk Briefing	2018	A measure of general political instability. Political instability has the potential to disrupt access to food, for example through transport blockages or reduced food aid commitments.
Corruption	EIU Risk Briefing	2018	This indicator measures the pervasiveness of corruption in a country by assessing the risk of corruption. Corruption can impact food availability through distortions and inefficiencies in the use of natural resources, as well as bottleneck inefficiencies in food distribution. Measured on a 0-4 scale, where 4 = highest risk.
Urban absorption capacity	World Bank, World Development Indicators; EIU	2014-18	This indicator measures the capacity of a country to absorb the stresses placed on it by urban growth and still ensure food security. It does so by evaluating a country's resources (real GDP) against the stress of urbanisation (urban population growth rate). It is calculated as the average (annual) real percentage change in GDP minus the urban population growth rate.
Food loss	FAO	2013	A measure of post-harvest and pre-consumer food loss as a ratio of the domestic supply (production, net imports and stock changes) of crops, livestock and fish commodities (in tonnes).
3) Quality & Safety			
Diet diversification	FAO	2011-13	A measure of the share of non-starchy foods (all foods other than cereals, roots and tubers) in total dietary energy consumption. A larger share of non-starchy foods signifies greater diversity of food groups in the diet.
Nutritional standards	EIU scoring	–	A composite indicator that measures government commitment to increasing nutritional standards. It comprises the following binary subindicators: • National dietary guidelines • National nutrition plan or strategy • Nutrition monitoring and surveillance
National dietary guidelines	Qualitative scoring by EIU analysts based on WHO, FAO and national health ministry documents	Based on data availability, 2001-18	A binary indicator that measures whether the government has published guidelines for a balanced and nutritious diet: 0 = No 1 = Yes

Indicator	Primary source(s)	Year	Indicator definitions and construction
National nutrition plan or strategy	Qualitative scoring by EIU analysts based on WHO, FAO and national health ministry documents	Based on data availability, 1995-2018	A binary indicator that measures whether the government has a current, published national strategy to improve nutrition: 0 = No 1 = Yes *A country receives credit if the national strategy was current as of July 2018. For example, a national strategy covering 2010 20 would receive credit; a strategy covering 2010-17would not receive credit. Credit may also be assigned if there is clear evidence that an expired strategy is currently being re implemented or updated.
Nutrition monitoring and surveillance	Qualitative scoring by EIU analysts based on WHO, FAO and national health ministry documents	Based on data availability, 2002-18	A binary indicator that measures whether the government monitors the nutritional status of the general population. Examples of monitoring and surveillance include the collection of data on undernourishment, nutrition-related deficiencies, etc. 0 = No 1 = Yes
Micronutrient availability	EIU	-	A composite indicator that measures the availability of micronutrients in the food supply. Subindicators include: • Dietary availability of vitamin A • Dietary availability of animal iron • Dietary availability of vegetal iron
Dietary availability of vitamin A	FAO	2005-07	The dietary availability of vitamin A is calculated by converting the amount of food available for human consumption (as estimated by the FAO Food Balance Sheets) into the equivalent of vitamin A. This indicator is expressed in micrograms of retinol activity equivalent (RAE)/capita/day on a 0-2 scale. 0 = less than 300 mcg RAE/capita/day; 1 = 300-600 mcg RAE/capita/day; 2 = more than 600 mcg RAE/capita/day
Dietary availability of animal iron	FAO	2005-07	The dietary availability of iron is calculated by converting the amount of food available for human consumption (as estimated by the FAO Food Balance Sheets) into the equivalent of iron. Animal iron is obtained from foods such as meat, milk, fish, animal fats and eggs. This indicator is expressed in mg/capita/day.
Dietary availability of vegetal iron	FAO	2005-07	The dietary availability of iron is calculated by converting the amount of food available for human consumption (as estimated by the FAO Food Balance Sheets) into the equivalent of iron. Vegetal iron is obtained from foods such as cereals, pulses, roots and tubers, vegetable oils, fruits and vegetables. This indicator is expressed in mg/capita/day.
Protein quality	EIU calculation based on data from FAO, WHO and US Department of Agriculture (USDA) Nutrient Database	2005-13	This indicator measures the amount of high-quality protein in the diet using the methodology of the Protein Digestibility Corrected Amino Acid Score (PDCAAS). The PDCAAS methodology assesses the presence of nine essential amino acids in the average national diet. The inputs for this calculation include: the amino acid profile, protein digestibility value and the average amount (in grams) consumed of each food item that contributes a minimum of 2% to total protein consumption.
Food safety	EIU scoring	-	A composite indicator that measures the enabling environment for food safety. The subindicators are: • Agency to ensure the safety and health of food • Percentage of population with access to potable water • Presence of a formal grocery sector

Indicator	Primary source(s)	Year	Indicator definitions and construction
Agency to ensure the safety and health of food	Qualitative scoring by EIU analysts	Based on data availability, 2009-18	Binary indicator that measures the existence of a regulatory or administrative agency to ensure the safety and health of food: 0 = No 1 = Yes
Percentage of population with access to potable water	World Bank	Latest available in 2012-15	The percentage of people using at least basic drinking water services, namely piped water, boreholes or tubewells, protected dug wells, protected springs, and packaged or delivered water.
Presence of formal grocery sector	Qualitative scoring by EIU analysts	Based on data availability, 2010-18	Qualitative indicator measuring the prevalence of a formal grocery sector, measured on a 0-2 scale: 0 = Minimal presence 1 = Moderate presence 2 = Widespread presence
4) Natural Resources & Resilience			
Exposure	EIU scoring	-	A composite indicator that measures exposure to and management of the impacts of climate change. Subindicators include: • Temperature rise • Drought • Flooding • Storm severity (annual average loss—AAL) • Sea level rise • Commitment to managing exposure
Temperature rise	Notre Dame Global Adaptation Initiative (ND-GAIN)	2016	Assessment of a country's projected temperature rise, and the potential impact on agricultural production. Measured on a linear transformation of data values (0 = least vulnerable) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Drought	World Resources Institute (WRI) Aqueduct	2014	Assessment of a country's historical susceptibility to drought, and the potential impact on agricultural production. Linear transformation of data values (0-5, where 5 = most risk) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Flooding	ND-GAIN	2016	Assessment of a country's projected susceptibility to flooding, and the potential impact on agricultural production and food distribution systems. Linear transformation of data values (0 = least vulnerable) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Storm severity (AAL)	Global Assessment Report on Disaster Risk Reduction	2015	Assessment of a country's historical susceptibility to damage from storms (aside from flooding), and the potential impact on agricultural production and food distribution systems. Measured as annual average loss (AAL) from earthquakes, wind, storm surge and tsunamis. Linear transformation of data values (US$ m) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Sea level rise	ND-GAIN	2016	Assessment of a country's projected sea level rise, and the potential impact on agricultural production and food distribution systems in coastal areas. For landlocked countries, an estimate is provided based on the country's major coastal trading partners. Linear transformation of data values (0 = least vulnerable) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.

Indicator	Primary source(s)	Year	Indicator definitions and construction
Commitment to managing exposure	CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)	2016	Assessment of whether countries are committed to addressing agriculture-related climate exposure and natural resource management under the Nationally Determined Contributions (NDC). NDC mitigation measures include croplands, grasslands, forest management, degraded lands, coasts and peatlands. NDC adaptation measures include water management, soil, fisheries and aquaculture, and agroforestry. The high-income countries that do not cover adaptation in their NDCs were given full credit for adaptation measures based on proxy scoring. Qualitative measurement from 0-13: 0 = No commitments 13 = Full commitment
Water	EIU scoring	-	A composite indicator that measures the health of fresh-water resources and how depletion might impact agriculture. Subindicators include: • Agricultural water risk—quantity • Agricultural water risk—quality
Agricultural water risk—quantity	WRI Aqueduct	2014	Assessment of the ratio of total annual water withdrawals to total available annual renewable supply, which may limit water available for agriculture. Data is based on the WRI's agriculture weighting scheme and is an average of baseline water stress, inter-annual variability, seasonal variability, upstream storage and groundwater stress. Linear transformation of data values (0-5, where 5 = highest risk) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value score 0.
Agricultural water risk—quality	WRI Aqueduct	2014	Assessment of the risk that water might be polluted, making it unsuitable for agriculture. Data is based on the WRI's agriculture weighting scheme for return flow ratio and upstream protected land. Linear transformation of data values (0-5, where 5 = highest risk) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value score 0.
Land	EIU scoring	-	A composite indicator that measures the health of land, and how land degradation might impact agriculture. Subindicators include: • Soil erosion / organic matter • Grassland • Forest change
Soil erosion / organic matter	Harmonized World Soil Database	n/a	Assessment of land degradation through soil quality constraints. Soil quality is the average of nutrient availability and toxicity, measured using geographic information system (GIS) data: 4 = Low soil quality 1 = High soil quality
Grassland	FAO	2015	Assessment of greenhouse gas emissions from the drainage of organic soils (e.g. peatlands) under grassland. Grasslands act as carbon sinks that help to maintain organic matter in the soil. Loss of this organic matter could impact agricultural production. Linear transformation of data values (Net emissions / removals of CO_2, gigagrams) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Forest change	World Bank	2000-15	Assessment of the health of forests, which help store groundwater and act as carbon sinks, preserving ecosystems. Ecosystem changes could impact agricultural productivity. Linear transformation of data values (change in forest areas as a percentage of total land area) to a fixed range of 0-100. The country with the highest data value scores 100 and the country with the lowest data value scores 0.

Indicator	Primary source(s)	Year	Indicator definitions and construction
Oceans	EIU scoring	-	A composite indicator that measures the health of oceans, a crucial source of protein for many populations. Subindicators include: • Eutrophication and hypoxia • Marine biodiversity • Marine protected areas
Ocean eutrophication and hypoxia	WRI	2000-10	Assessment of the health of oceans. Over-enrichment of oceans depletes oxygen, killing off aquatic life and disrupting ecosystems, which can ruin fisheries as well as agricultural production from saltwater areas. Landlocked countries receive the highest possible score. Qualitative measurement from 0-2: 0 = Saltwater bodies with both eutrophication and hypoxia 1 = Saltwater bodies with either eutrophication or hypoxia 2 = No saltwater bodies with eutrophication or hypoxia
Marine biodiversity	Yale Environmental Performance Index	2018	Assessment of the health of marine life through the overexploitation and collapse of fishing stocks. Falling fish stocks limit access to protein for populations whose diets are fish-dependent. Landlocked countries receive the highest possible scores. Linear transformation of data values (%) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Marine protected areas	World Bank	2016	Assessment of the percentage of territorial waters that are protected areas. Preservation of protected waters helps to maintain marine ecosystems, which preserves fish as a food source while also protecting against overfishing. Landlocked countries receive the highest possible score. Linear transformation of data values (%) to a fixed range of 0-100. The country with the highest data value scores 100 and the country with the lowest data value scores 0.
Sensitivity	EIU scoring	-	A composite indicator that measures how susceptible countries are to the depletion of natural resources and agricultural productivity. Subindicators include: • Food import dependency • Dependence on natural capital • Disaster risk management
Food import deficiency	FAO	2016	Assessment of how dependent a country is on cereal imports. If climate and natural resource risks negatively impact agricultural production, countries that are dependent on imports could become more vulnerable to food shortages as major agricultural producers limit food exports to feed their own populations. Linear transformation of data values (ratio) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Dependence on natural capital	World Bank	2013-16	Assessment of how dependent a country is on natural resources for economic output. In countries dependent on natural resources, natural resource shortages could impact the economy and affect incomes, making it harder to purchase food. Linear transformation of data value (sum of forest rents and mineral rents as a percentage of GDP) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.

Indicator	Primary source(s)	Year	Indicator definitions and construction
Disaster risk management	EIU Risk Briefing; World Bank Climate Smart Agriculture Indicators	2016-17	Assessment of whether countries are co-ordinating their disaster risk management and their adaptation and mitigation measures, particularly in the agricultural sector. Underlying metrics include: social capital; legislation and/or policy for disaster risk reduction (DRR) in the agricultural sector; specific action plan or strategy for addressing DRR in agriculture, and commitment to the Hyogo Framework for DRR. For countries not covered by the World Bank's Climate Smart Agriculture Indicators, the EIU has undertaken qualitative research. Where information is not publicly available, the EIU has not given credit. Measured on a scale of 0-7: 0 = Low co-ordination 7 = High co-ordination
Adaptive capacity	EIU scoring	-	A composite indicator that measures the degree to which countries are creating systems and adopting practices to manage the risk that exposure poses to the agricultural sector. Subindicators include: • Early-warning measures / climate-smart agriculture • National agricultural risk management system
Early-warning measures / climate-smart agriculture	CCAFS	2016-17	Assessment of commitment to developing early-warning measures for the agricultural sector and investing in climate-smart agriculture practices. The high-income countries that do not cover adaptation in their NDCs were given full credit based on proxy scoring. Qualitative measurement from 0-2: 0 = No commitment 2 = High commitment
National agricultural risk management system	World Bank Climate Smart Agriculture Indicators	2017	Assessment of a country's commitment to managing risk to the agricultural sector. Underlying metrics include grain stock management, agricultural insurance and agricultural information systems. For countries not covered by the World Bank's Climate Smart Agriculture Indicators, the EIU has undertaken qualitative research. Where information is not publicly available, the EIU has not given credit. Qualitative assessment from 0-6: 0 = No commitment 6 = High commitment
Demographic stresses	EIU scoring	-	A composite indicator that measures the degree to which demographic stresses might increase countries' sensitivity to agriculture-related climate exposure and natural resource risk. Subindicators include: • Population growth (2016-21) • Urbanisation (2016-21)
Population growth (2016-21)	UN	2017	Forecast population growth. Rapid population growth increases demand for food, straining food systems. Linear transformation of data values (population growth percentage, 2016-21) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.
Urbanisation (2016-21)	UN	2018	Forecast urban growth. Rapid urbanisation can disrupt food systems, putting strain on production and infrastructure. Linear transformation of data values (urbanisation rate, 2016-21) to a fixed range of 0-100. The country with the lowest data value scores 100 and the country with the highest data value scores 0.

Indicator	Primary source(s)	Year	Indicator definitions and construction

5) Output variables

Indicator	Source	Year	Indicator definitions and construction
Prevalence of undernourishment	FAO	2014-16	The percentage of the population that does not receive the minimum number of required calories for an average person as defined by the FAO/WHO/UN University Expert Consultation in 2001.
Percentage of children stunted	WHO	Latest available year in 1995-2016	The percentage of children aged less than five years who have a height-for-age below -2 standard deviation from the National Centre for Health Statistics (NCHS)/WHO reference median.
Percentage of children underweight	WHO	Latest available year in 1970-2016	The percentage of children under five years who have a weight-for-age below -2 standard deviation from the NCHS/ WHO reference median.
Intensity of food deprivation	FAO	2014-16	A measure of how far, on average, the population falls below the dietary energy requirement. It is measured as the difference between the minimum dietary energy intake and the average dietary energy intake of the undernourished population.
Human Development Index	UNDP	2015	A composite index that measures development by combining indicators on life expectancy, educational attainment and income.
Global Gender Gap Index	World Economic Forum	2017	The Global Gender Gap Index seeks to measure the gaps between women and men across a large set of countries and across the four key areas of health, education, economy and politics.
EIU Democracy Index	EIU	2017	The Democracy Index provides a snapshot of the state of democracy in 165 states and two territories. The index includes indicators in the following five categories: electoral process and pluralism, functioning of government, political participation, political culture, and civil liberties.
Prevalence of obesity	WHO	2016	Measures the percentage of the population over 18 years of age that is obese. Obesity is defined as having an age-standardised body mass index (BMI) greater than 30.

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