The Economist INTELLIGENCE UNIT

GLOBAL FOOD SECURITY INDEX 2019

Strengthening food systems and the environment through innovation and investment

Supported by

CORTEVA™ agriscience

Contents

About the Global Food Security Index

The Global Food Security Index 2019: Strengthening food systems and the environment through innovation and investment is the eighth edition of The Economist Intelligence Unit's study, commissioned by Corteva Agriscience. This report discusses the key findings from the research and the benchmarking index, the Global Food Security Index (GFSI). The 2019 edition of the GFSI includes updated indicators and source data. Research and analysis for this report was conducted between September 2019 and November 2019.

The GFSI is produced by The Economist Intelligence Unit and supported by Corteva Agriscience. The index 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 a central question: how food secure is a country? Food security is a complex, multifaceted issue influenced by culture, environment and geographical location. Although 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 of food 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.

The complete index can be accessed online via: https://foodsecurityindex.eiu.com/

About The Economist Intelligence Unit

The Economist Intelligence Unit (The EIU) is the research arm of The Economist Group, publisher of The Economist. As the world's leading provider of country intelligence, it helps governments, institutions and businesses by providing timely, reliable and impartial analysis of economic and development strategies. Through its public policy practice, The EIU provides evidence-based research for policymakers and stakeholders seeking measureable outcomes, in fields ranging from gender and finance to energy and security. Through a global network of more than 900 analysts and contributors, The EIU continuously assesses and forecasts political, economic and business conditions in more than 200 countries. For more information, visit www.eiu.com or follow us on Twitter at www.twitter.com/theeiu.

About Corteva

Corteva Agriscience is a publicly traded, global pure-play agriculture company that provides farmers with seed, crop protection and digital solutions to maximize yield and profitability. With some of the most recognized brands in agriculture and an industry-leading product and technology pipeline, the company is works with stakeholders in the food system to enrich the lives of those who produce and those who consume, ensuring progress for generations to come. Corteva Agriscience became an independent public company on June 1, 2019 (NYSE:CTVA), and was previously the Agriculture Division of DowDuPont. More information can be found at www.corteva.com.

Project team and acknowledgements

We would like to extend our thanks to the many researchers who lent their expertise to this project. The following economists, researchers, country analysts, and food, climate and natural resource specialists contributed to this research programme.

Project management team:
Priya Bapat, Shubha Bharadwaj, Samantha Grenville and Robert Smith

Research reviewers:
Bassam Aoun, Agathe Demarais, Emily Mansfield, Giancarlo Morelli, Benedict Craven, Meriem Menani, Sumana Rajarethnam and Katherine Stewart

Country research and analysis:
Diane Alarcon, James Drayton-Losotov, Lin Fu, Tom Felix Joehnk, Christian Johnson, Eamon Kircher-Allen, Lian Lin, Rachel Mazzarella and Abbie Watts

Model and report production:
Adam Green, Mike Kenny, William Shallcross and Paul Tucker

Marketing and website:
Sandra Balouzian, Dorene Cano Perales, Carlos Guaneme, William Howey, Kim Meijer, Vaibhav Morje, Alison Murphy, David Voight and Jennifer Wells

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 editions of the index, as well as advising on the selection of weightings.

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 – IFPRI); 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 and 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:

Joe Glauber (IFPRI), Elise Golan (US Department of Agriculture), Susanna Hecht (University of California, Los Angeles), Karin Kemper (World Bank), Catie Lee (Land O'Lakes), Shaun Martin (World Wildlife Foundation), Dawn Rittenhouse (DuPont Pioneer), Allison Thomson (Field to Market), Sonja Vermeulen (independent consultant), Sara Walker (World Resources Institute).

Executive summary

Food systems and the environment are deeply interconnected. While agriculture is noted as a contributing force to today's environmental crisis, it is also among the sectors most affected by rising temperatures and extreme weather. With the right choices, innovations and public commitments, agriculture could shift from being a major stress for environmental degradation to a leading force for improved climate change adaptation and mitigation.

The relationship between food security and the environment is often framed as a trade-off, as increasing agricultural production frequently leads to rising emissions, land stress and resource exhaustion. However, the two need not be opposing forces, and can instead benefit from a mutually supportive relationship. Increasingly, food security innovations, from earth monitoring and imaging to generate early warning systems through to new forms of food production, such as plant-based meat or algae, are supporting people's nutritional needs, and increasing agricultural resilience, with little to no impact on the environment relative to past alternatives.

The 2019 edition of The Economist Intelligence Unit's Global Food Security Index (GFSI), now in its eighth year, tracks the performance of 113 countries in providing for the dietary needs of their populations. As measured in this year's index, 88% of countries report that they have enough available food supply in their country, yet in over a third of all countries in the index, 10% or more of the population is undernourished. The GFSI is a holistic measure of a country's food system, taking into account not only its ability to supply enough calories to the population, but also how the food system is affected by factors ranging from political stability to climate threats. This year's index provides new data and insights for critical metrics including agriculture infrastructure and nutritional standards. The following report combines index trends and results with a deeper dive into the nexus of food security-climate innovation.

Key findings

Key findings

The 2019 GFSI introduces new metrics and additional indicators which have not been used in previous editions. Although the over-arching categories and most indicators remain the same, the scores and rankings for the 2019 edition are not directly comparable to previous years, although we have updated the 2018 scores and rankings to allow for year-on-year comparisons. Below is an overview of the major findings from the 2019 results:

- **Singapore and Ireland remain the two most food secure countries, with Kuwait, Qatar and Malawi making the most improvements since 2018.** According to the new GFSI framework, which includes updated metrics for factors such as changes in the cost of food, public R&D in agriculture, and nutritional standards, Singapore and Ireland rank at the top of the index for both 2018 and 2019, followed by the US and Switzerland. Venezuela, Burundi and Yemen rank at the bottom of the index, while Nicaragua, Argentina, Tunisia and Ecuador have declined the furthest in the rankings over the past year.

- **The percentage of cultivated land equipped for irrigation is inadequate to meet global needs.** For the first time, the 2019 Index measures global irrigation infrastructure. Data indicate that less than 10% of agricultural land is equipped for irrigation in 79 of the 113 countries included in the study (70%). Given decreased water security in the context of climate change and drought risks across the globe, this is an area for attention.

- **However, overall agricultural infrastructure has improved markedly in a number of countries, including Qatar, Belarus, Slovakia, Australia and Kuwait**. In the past year, Qatar has improved port and rail infrastructure, while the remaining countries have made recent investments in improving or expanding crop storage facilities. In Australia, for example, the government announced a new innovation fund to support innovation in the grain industry, including for grain storage logistics, while in Kuwait, the government has invested in new grain silos and expanded crop storage at a major port. Additionally, although Syrian infrastructure remains poor, the government has recently committed to rebuilding crop storage facilities which had been destroyed during the war. On the opposite side, the quality of road and air infrastructure has declined in Nicaragua, while port infrastructure quality has declined in Bangladesh and Madagascar.

- **Public expenditure on agriculture is stagnant.** Public expenditure on R&D is critical to develop the technological and innovations necessary to increase agricultural productivity and reduce environmental impact. The most recent figures for government spending, which are from 2016, show an overall decline in central government spending on agriculture relative to the sector's contribution to GDP, which has fallen worldwide from the previous year. Data from the UN indicate that relative spending on agriculture compared with the sector's contribution to GDP has declined globally since the early 2000s, particularly in East and

Southeast Asia. This is fuelled by an increase in the contribution of agriculture to overall GDP and a decline in government investment in agriculture. (see Figure 2 on page 10).

- **Global food prices are rising worldwide.** Over the past five years, the relative cost of food has increased worldwide. While food prices have risen most sharply in countries experiencing conflict, there have been steady increases in prices of the average basket of food goods worldwide. Over the past five years, the price for the average basket of food goods has nearly tripled in Angola and Egypt, and more than doubled in seven other countries in the index. Twenty-six countries in the index report food price inflation of 5% or higher in the past year. Argentina recorded the highest inflation rate for food prices in the past year (51%), followed by Turkey (25%) and Egypt (19%). Higher food prices in Argentina and Turkey are a reflection of currency collapses, while in Egypt, rising costs may be attributable to recent economic reforms and austerity measures.[1]

- **Access to financing for farmers tracks closely with overall performance in the index.** The GFSI metric for access to financing, assessing the depth and range of financing options available to farmers, is one of the indicators that most highly correlate with overall food security, with six countries scoring zero for financial access also in the bottom eight overall (Venezuela, Chad, Democratic Republic of the Congo, Haiti, Syria and Yemen). Nicaragua, the only country that sees its score decline in this metric, also has the biggest drop in overall GFSI score between the 2018 and 2019 editions of the index.

- **Food security is deteriorating in countries beset by turmoil.** Yemen, Syria and Venezuela are all in the red zone across multiple domains. Although average food supply is increasing in most regions, it has further fallen in countries already experiencing shortages, such as Venezuela and Yemen. Owing to their respective conflict and instability, Syria and Yemen have fallen further towards the bottom end of the overall rankings. Yemen sees declines in food availability and dietary diversity, and Venezuela continues to rank at the bottom of the index and near the bottom for crucial measures such as agricultural infrastructure. Nicaragua also stands out as a deteriorating state, with food costs increasing, access to finance falling, and airport and road quality worsening, alongside declining political stability.

- **Dependency on food aid is highest in Syria, Yemen, Benin and Haiti**. The index measures emergency food aid per capita over the most recent five year period (2013-2017 for the 2019 index). Despite improvements in countries including Jordan and Malawi, there was an overall worsening in score, driven by severely increased dependency in Yemen, where emergency food aid has nearly quadrupled from US$196m in 2013 to US$767m in 2017; Benin, where food assistance has risen to US$64m in 2017 from less than US$1m in 2013; and Haiti, where a combination of emergency food aid and food assistance has doubled from US$47m to US$88m. Although Syria has the highest levels of food aid dependency, dependency for the 2013-2017 period is two-thirds as high as it was between 2012-2016. Other countries, including Nigeria and Guatemala, have also registered increases.

1 AP. "Egypt's police step in to combat potato shortage". 30 October 2018. Available at: https://apnews.com/5b6ff1a53a9040dbbc32b8849df481e1.

- **Over the past 15 years, volatility in agricultural production has steadied in countries including Bulgaria, Malawi, Singapore, Morocco, Oman and Uganda**. Steady agricultural production allows for countries to better forecast food availability, while volatility can lead to periods of feasts or famine. Production volatility can be caused by numerous factors, but it is typically due to unpredictable shocks, such as bad weather, diseases and pests or price drops. This indicator has been updated for the 2019 GFSI and now assesses the volatility of agricultural total factor productivity over a five-year period. For the current data period (2012-16), Bangladesh and China have the least volatile production, while Paraguay, Burundi and Syria are the most volatile. Over the past eight years, Bulgaria is the most improved country in this metric: between 2005-09, the country had the most volatile agricultural productivity levels of any country in the index, but has stabilised each year (although still ranking in the bottom fifth of the index on this metric).

- **Nutrition plans and strategies do not always account for both children and adults.** The 2018 index found that nearly all countries (91%) had a valid nutrition plan or strategy. For the updated 2019 index framework, the analysis explored whether there was a valid nutrition plan or strategy within the past five years that accounted for both children and adults. Under this stricter standard, only 80% of countries achieved the target. Differential plans are important because of the distinct nutritional needs of young people versus adults. For instance, short-term nutrient deficiencies in the young can have life-long cognitive and physical effects.

- **Nutrition monitoring efforts, such as data collection on undernourishment and nutrient deficiencies, have fallen over the past year.** Only 70% of countries had completed a nutrition study in the past five years, compared with 73% of countries last year. Algeria, Azerbaijan, Ecuador, Nicaragua, Peru and Sierra Leone joined the group of countries lacking nutrition studies in the 2019 GFSI, having exceeded the five-year threshold in the past year. Honduras and Panama conducted new nutrition studies this year.

- **Ireland is the top ranking country when accounting for natural resources risks and resiliency.** As with previous years, this year's index includes an additional level of analysis, through a score adjustment for countries based on natural resources and resilience risks. This covers critical issues such as exposure to drought, flooding and sea level rise, levels of land degradation, ocean eutrophication and presence of early warning systems for natural disasters. All countries drop points as a result of this layer of analysis, although some see far greater overall score changes. Singapore, for instance, ranks at the top of the overall index, but drops 11 places when adding in the natural resources and resiliency metric, as a result of factors including vulnerability to sea level rises, ocean eutrophication and food import dependency. Ireland, Finland and Switzerland are the top-ranked countries when accounting for natural resource risks and resilience against future food security threats, particularly climate change. Burundi, Malawi and Myanmar are among the least impacted countries while Singapore, Israel and the UAE are the three most highly impacted countries.

Introduction: Reaping what we sow

The future of agriculture depends on the strength of our natural resources. However, agriculture can also place strains on the environment: figures show that food production causes up to 30% of global greenhouse gas emissions and accounts for 70% of freshwater use.2 Excessive use of chemicals like nitrogen and phosphorous, used in fertiliser, are blamed for a rise in eutrophication whereby estuaries and coastal waters are subject to harmful algal blooms and fish deaths owing to lower oxygen availability. Increased demand for land-intensive food sources like beef, palm oil and soy, has contributed to deforestation.

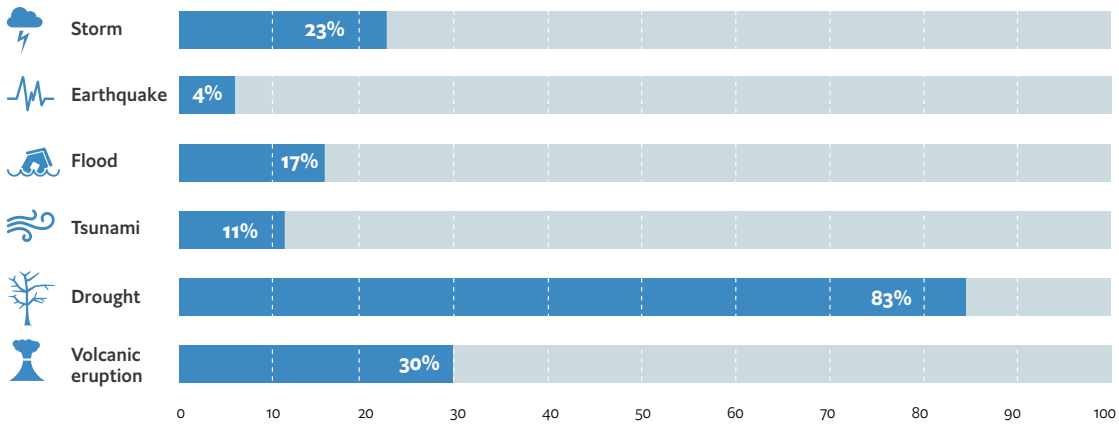
Yet the food system is also acutely vulnerable to the environmental volatility exacerbated by these actions. One review of 74 post-disaster needs assessment studies conducted in 53 developing countries between 2006 and 2016 found that agriculture (defined as crops, livestock, fisheries, aquaculture and forestry) absorbed 23% of all damage and loss caused by natural disasters, primarily droughts, followed by storms and floods (see Figure 1).[2] Individual countries suffer massive food losses from climate disaster. In 2013 Typhoon Haiyan devastated 600,000 ha of farmland in the Philippines, causing over US$700m in damage.[3]

Along with these sudden-onset crises, food producers are also affected by slow-onset disasters. Higher temperatures and drier weather reduce yields of crops like maize, wheat and barley. Hotter weather ruins perishable commodities, especially in countries with fragmented supply chains and inadequate cold-chain infrastructure (usually tropical

Figure 1

Damage and loss in agriculture as share of total damage and loss across all sectors

%, 2006–16, by type of hazard



Source: FAO, based on the Post-Disaster Needs Assessment. http://www.fao.org/3/I8656EN/i8656en.pdf

2 FAO. "2017 The impact of disasters and crises on agriculture and food security". 2018. Available at: http://www.fao.org/3/I8656EN/i8656en.pdf

3 FAO. "Typhoon Haiyan Emergency, Recovery and Rehabilitation Programme". 2017, Available at: http://www.fao.org/3/a-i6910e.pdf

countries in which heat stress, and food security, are already major factors).[4]

Climate change will further affect the quality and safety of food, leading to the production of toxins in crops, for instance, and a worsening of nutritional value of cultivate food. According to one forecast, climate change could reduce the concentrations of protein, zinc and iron in crops, causing an additional 175m people to be zinc-deficient and 122m to experience protein deficiency by 2050.[5] Current macro- and micro-nutrient deficiencies and quality deficits are highest in Africa and Asia, with countries such as Bangladesh and the DRC showing low availability of Vitamin A, zinc, iron and protein.

Food security innovation can lead the climate agenda

To date, efforts to improve the environmental impact of the food sector have primarily focused on two areas: reducing harmful products and methods, and adapting agricultural practices for a worsening climate. But this is an inadequate approach to achieve the huge emissions reductions that experts state are needed. Instead, all stakeholders in the food system—from growers to logistics companies to retailers and consumers—need to use innovation to identify entirely new ways of producing and consuming food that will support the radical transformation needed to achieve climate goals.

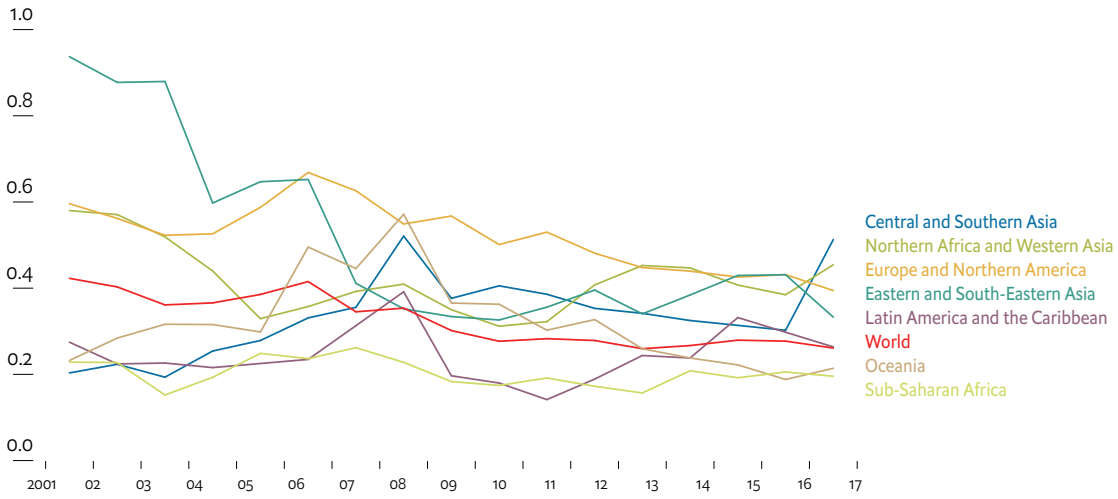
The last year has seen critical breakthroughs

Figure 2

Agricultural orientation index

The Agriculture Orientation Index (AOI) is the metric used by the United Nations Sustainable Development Goals to capture investment in the agricultural sector including for "rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity" under Target 2.a. It is defined as the agriculture share of government expenditures, divided by the agriculture share of GDP. An AOI >1 means the agriculture sector receives a higher share of government spending relative to its economic value. An AOI <1 reflects a lower orientation to agriculture.

Trend by regions, 2001-17



Source: FAO, http://www.fao.org/sustainable-development-goals/indicators/2a1/en/

4 IPCC. "Special Report on Climate Change and Land". Chapter 5: Food Security. 2019. Available at: https://www.ipcc.ch/site/assets/uploads/2019/08/2f.-Chapter-5_FINAL.pdf

5 Relief Web. "2019 Global Hunger Index: The challenge of hunger and climate change". 2019. Available at: https://reliefweb.int/report/world/2019-global-hunger-index-challenge-hunger-and-climate-change

across a broad range of areas, including low-cost satellite imaging and earth observation; distributed ledgers for supply chains; "brokering" digital apps to cut food loss; off-grid solar refrigeration; and far-reaching changes to what constitutes food itself, such as the rise of the edible insects industry, alternative protein and plant-based meats. Large-scale changes cannot be led by the private sector alone; government support is crucial for systemic shifts. However, according to the UN Food and Agriculture Organisation (FAO), central government spending on agriculture compared to sectoral GDP has fallen over the past two decades (see Figure 2).

This report situates these advances within the context of the GFSI, exploring how innovation trends can help to address key and ongoing food security challenges revealed by the index both over the past year and over the longer term.

Infrastructure and supply chains

Infrastructure is a critical factor in the GFSI. A key component of the Availability category, agricultural infrastructure is critical for a multitude of reasons, such as enabling the efficient movement of food from farmers to markets to consumers. This year's index expands the assessment of infrastructure beyond roads and ports to also assess airport and rail infrastructure, which many countries depend on for transporting agricultural goods and supplies. Furthermore, we have included a metric assessing on-farm infrastructure access, specifically irrigation infrastructure. As global temperatures increase and water becomes a more precious commodity, irrigation systems can help to ensure consistent and efficient use of water resources for agriculture. The new irrigation metric highlights the need for focus on irrigation systems; data from the FAO indicate that nearly 70% of countries report that less than 10% of agricultural land is equipped for irrigation.

In this year's index, we also introduce a new metric for crop storage facilities, which assesses if there has been investment in the past five years in improving, maintaining or expanding crop storage facilities. Nearly 90% of countries show signs of recent investment in crop storage facilities, either by the government, through donor assistance or from the private sector.

Overall, the index finds strong agricultural infrastructure improvements in Qatar, Belarus and Australia, and deteriorations in Nicaragua, Bangladesh and Madagascar. Asian countries are ranked above the global average in the current framework, reversing their below-average scores in the previous framework, probably owing to the importance that rail networks and airport infrastructure plays in food transport in several countries.

In addition to the infrastructure metric in the Availability category, the GFSI also assesses infrastructure through the ability to store food safely. Under the Food Safety metric, the GFSI assesses the ability of people to safely store food, using access to electricity as a proxy metric. African countries, which face high temperatures and humidity alongside constrained access to electricity, fare the most poorly in terms of access to the electricity needed for food refrigeration, with 27 of the bottom 30 countries located in the region. However, 17 of these countries have notched improvements this year, with the largest movers being Zambia, Rwanda and Sudan. The largest overall improvers in the index this year are Myanmar, Cambodia and Bangladesh, which have each recorded expansion in the proportion of the population with electricity access exceeding 10 percentage points in the past year.

Inadequate food storage will become more critical in the context of warming temperatures and the fight against emissions. One-third of the food produced for human consumption—approximately 1.3bn tonnes/year—is lost or wasted.[6] Yet the environmental impact of this food remains in the atmosphere, despite conferring no nutritional benefit. Between 2010 and 2016, global food loss and waste contributed to 8-10% of total greenhouse gas emissions caused by human activity.[7]

While food transport and storage assets are crucial, so, increasingly, is the cooling and

6 FAO. "Save Food: Global Initiative on Food Loss and Waste Reduction". Available at: http://www.fao.org/save-food/resources/keyfindings/en/

7 IPCC. "IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems". 2019. Available at: https://www.ipcc.ch/site/assets/uploads/2019/08/Edited-SPM_Approved_Microsite_FINAL.pdf

refrigeration needed to keep food better for longer. Building a seamless cold chain can reduce food waste and dramatically improve the efficiency of the food system by allowing storage of food in strategic locations and facilitating import and export logistics. At a local level, an efficient cold chain empowers farmers by giving them more control over the timing of sale of their perishable produce.

The past year has seen increased investment in cold chain infrastructure, with the total capacity of refrigerated warehouses reaching 616m cubic meters in 2019, a 2.6% increase from 2016. India is the largest market, with particularly rapid increases in cooled warehousing in Gujarat, Himachal Pradesh and Pondicherry. The US and China are respectively the second and third largest markets.8

At the local level, cold chains are advancing with the development of off-grid cooling technologies for farmers, such as solar-powered refrigeration. The Global LEAP award, funded by the UK Department for International Development and Power Africa, a US-government initiative, launched in 2013 and continues to catalyse innovation. In 2019 the initiative ran a competition for more energy-efficient, durable, off-grid and 'weak'-grid appropriate refrigerators.

8 GCCA. "2018 GCCA Global Cold Storage Capacity Report". 2018. Available at: https://www.gcca.org/sites/default/files/2018%20GCCA%20Cold%20Storage%20Capacity%20Report%20final.pdf

In focus: **Harnessing nature's defences**

Flooding and inundation from rising sea levels will both become more frequent occurrences in the future. Although lower income countries are more at risk, many wealthy nations are also vulnerable, as evidenced by floods this year in Venice, Italy. Sea level rise does not distinguish by income group: the ten countries identified in the GFSI as most susceptible to flooding range from Vietnam and Bangladesh to the Netherlands and Singapore. Looking more broadly at exposure factors such as flooding, temperature rise and drought, Bahrain, Ecuador, Singapore and Peru are the four countries most exposed.

The agriculture sector could make an active contribution to improving resilience. Current responses to floods and inundation focus on hard and grey infrastructures like seawalls and levees. These are expensive, take time to deliver and can disrupt ecosystems or push water away from urban areas into food-producing rural parts. Strong evidence is emerging in favour of ecosystem-based adaptation.

One example are mangroves; forests in intertidal zones of tropical and subtropical coastlines and warm waters. They are rich food systems as habitats and nurseries for over 3000 fish species, as well as crabs and shrimps, and they provide livelihoods for an estimated 120m people.[9] Mangroves have been significantly damaged by pollution, infrastructure development and runoff of harmful chemicals and pollutants including petroleum, herbicides and waste from mining. They are also the target of deforestation for firewood.

Nurturing mangroves by targeting the food sector—specifically commercial fishing and aquaculture—could encourage greater sustainability, potentially ensuring the maintenance of these vital natural buffers which act as a buffer to storm surges, waves and inundation, and sequester large quantities of carbon.[10] Current efforts to protect mangroves include education projects such as teaching ecologically sound shrimp production in Vietnam and Thailand.[11]

Mangrove conservation projects are also tapping into green finance instruments. One project, in Kenya, uses carbon credits linked to reductions in deforestation and degradation, achieved by raising aquaculture production standards and teaching communities about the value of mangroves (to reduce illegal logging). The introduction of fast-growing terrestrial casuarina tree plantations to provide an alternative source of wood fuel has also helped.[12] Some countries, including Kenya, Mexico and Madagascar, are also including quantifiable mangrove protection and restoration policies in their nationally determined contributions (NDCs—the steps that they are taking to achieve their emissions and adaptation goals).[13]

9 Global Mangrove Alliance. "Save our mangroves now". Available at: http://www.mangrovealliance.org/save-our-mangroves-now/

10 Friess, D. et al. "The State of the World's Mangrove Forests: Past, Present, and Future". 2019. Annual Reviews. Available at: https://www.annualreviews.org/doi/abs/10.1146/annurev-environ-101718-033302

11 International Union for Conservation of Nature (IUCN). "Mangroves and Markets". Available at: https://www.iucn.org/regions/asia/our-work/regional-projects/mangroves-and-markets-mam

12 Global Mangrove Alliance. "Mikoko Pamoja". Available at: http://www.mangrovealliance.org/mikoko-pamoja/

13 Global Mangrove Alliance. "Legal Frameworks for Mangrove Governance, Conservation and Use". November 2018. Available at: https://www.mangrovealliance.org/wp-content/uploads/2018/11/WWF-IUCN-Mangroves-Global-legal-Assessment-v10.pdf

Agroforestry is a second area of interest. Forests, which provide vital ecosystem services including storing ground water and acting as carbon sinks, are threatened by deforestation, often to make way for agriculture. The 2019 GFSI indicates that deforestation has increased the most in Central and South America and Sub-Saharan Africa. On the other hand, 36 countries in the index have made progress towards reforestation, including the Dominican Republic and Laos, which have increased forest area as a percentage of total land area by 10% since 2001.

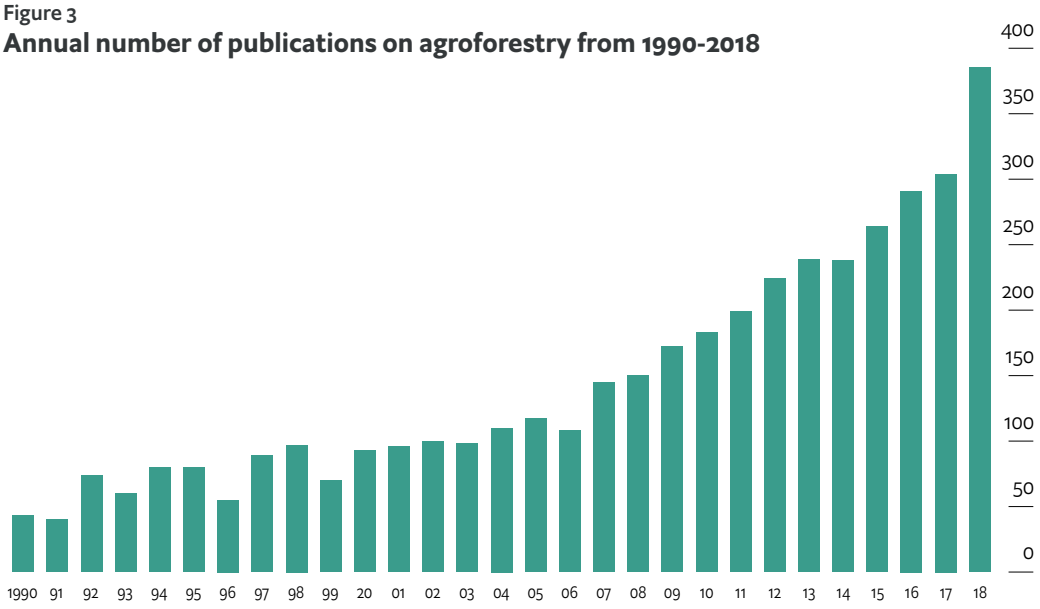
Although agriculture and forests are often posed as in direct conflict, the agroforestry movement is seeking to question this assumption. Agroforestry involves the simultaneous co-existence of crops and trees, usually woody perennials including shrubs, palms and bamboos, and can involve planting forestry products in agricultural areas or bringing crops or animals into forests or along forest margins.

Deliberately combining forestry in the same land management units as crops and animals brings many benefits that will be more important in a climate-constrained world, including controlling water runoff, maintaining soil organic matter and fertility, reducing soil toxicities, providing shade and temperature moderation effects and, through decomposition of trees, increasing nutrient recycling.[14]

Although agroforestry is an ancient practice, its utilisation fell out of favour during the era of mono-agriculture. However, there is evidence of a resurgence in interest in its logic and potential, with a marked increase in published research between 1990 and 2018 spanning a wide range of countries, from the US and Germany to India, Brazil and Kenya (see Figure 3).[15]

Figure 3

Annual number of publications on agroforestry from 1990-2018



Source: Trends and Features of Agroforestry Research Based on Bibliometric Analysis

14 RESET. "Agroforestry and its Benefits". Available at: https://en.reset.org/knowledge/agroforestry-and-its-benefits

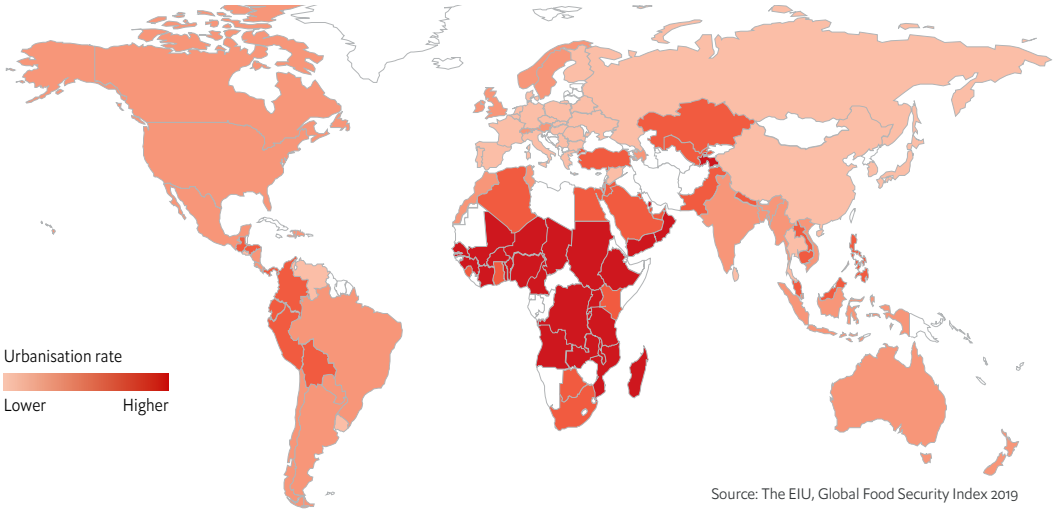
15 Liu, et al. "Trends and Features of Agroforestry Research Based on Bibliometric Analysis." June 25th 2019. Available at: https://www.researchgate.net/publication/334004672_Trends_and_Features_of_Agroforestry_Research_Based_on_Bibliometric_Analysis.

In focus: **Greening urban infrastructure**

Cities are key sites of climate risk not just because of their larger populations and density of economic assets but also because cities themselves contribute to climate disasters, such as the urban heat island effect, in which urban temperatures rise higher than in rural areas owing to the heat-trapping effects of buildings, urban materials like glass, and grey infrastructure. In addition, the prevalence of impermeable concrete surfaces can increase flooding. The higher impacts of storms and floods in cities can, in turn, lead aid budgets to be drawn away from rural regions, worsening the food security implications for such areas.[16]

Building green infrastructure in cities, such as more vegetation and green spaces like parks and urban farms, can reduce their aggravating effect on climate and, by reducing disaster impact, avoid trade-offs that lead to emergency spending being prioritised on cities at the expense of rural areas. One newly launched "anti-flood" park in the flood-prone Thai capital, Bangkok, can store over 4m litres of water during periods of heavy rain, while Hong Kong's 'Sponge City' strategy is tackling storm-water management.[17] At the farm level, decentralised energy supply, such as solar-powered irrigation technology, could help to improve agricultural resilience when power infrastructure is damaged during extreme weather.[18] Such measures will be critical as urbanisation intensifies.

Figure 4
Projected urban population growth (2015-2020)



Source: The EIU, Global Food Security Index 2019

16 The Guardian. "Severe floods 'threaten food security' say farmers and environmental groups". February 8th 2014. Available at: https://www.theguardian.com/environment/2014/feb/08/severe-floods-threaten-food-security-climate-change

17 South China Morning Post. "Sinking Bangkok fights to stay above water with anti-flood park". October 4 2018. Available at: https://www.scmp.com/magazines/post-magazine/long-reads/article/2166925/park-provides-anti-flooding-antidote-bangkoks

18 International Water Management Institute. "Mapping the suitability of solar energy-based irrigation pumps in Ethiopia". 2018. Available at: https://wle.cgiar.org/mapping-suitability-solar-energy-based-irrigation-pumps-ethiopia

Early warning and forecasting

The Natural Resources and Resilience section of the GFSI demonstrates how most countries are susceptible to climate impacts. In addition to needing to establish systems to mitigate the long-term effects, countries need to put in place effective early-warning mechanisms to ready themselves for volatile weather and climate events. Early response and action planning for extreme events can help to mitigate their effects, both on agricultural systems and populations as a whole. Positively, lower-income countries and Sub-Saharan African countries demonstrate high levels of commitment to early-warning measures, scoring near the average global score. Burundi, Côte d'Ivoire, Madagascar, Niger, Tanzania and Uganda all earn top marks in this metric, having incorporated both early-warning measures and climate-smart agriculture into their Nationally Determined Contributions (NDCs) under the Paris Agreement. Central and South America and the Middle East and North Africa scored the lowest; ten of the 15 countries in the Middle East and North Africa and 12 of the 18 countries in Central and South America have not included commitments to either early-warning measures or climate-smart agriculture in an NDC. Other top-scoring performers across the index include Japan and Turkey, who both have substantial histories with natural disasters, including earthquakes, tsunamis, flooding and landslides, which has led to a strong focus on improving preparedness.

Donors play an important role in shoring up preparedness globally. Myanmar, which ranks highly in the GFSI for early-warning measures, has been aided by a UN Office for Project Services (UNOPS) programme that, since 2017, has allowed forecasters, climatologists, hydrologists and other end users to have reliable access to weather data via PCs, smartphones and tablets. This has helped the country's Department of Meteorology and Hydrology to perform its communications role in informing the public of hazards. It has also given farmers a personalised dashboard through which they are directly informed of weather conditions and hazards.[19] Niger, which is vulnerable to the flooding of the Niger River as well as flash floods, also benefits from donor assistance through the Climate Risk and Early Warning System (CREWS) initiative, supported by Australia, France, Germany, Luxembourg and the Netherlands, facilitating the delivery of timely, impact-based warnings to at-risk populations.

Early warning alone is not enough, however. It is also critical to have a clear plan of action with interventions that can minimise loss and damage in agriculture. Such interventions include cash and vouchers, distribution of nutritional supplements, pre-emptive harvesting of crops, issuance of warnings to fisherpeople at sea, and distribution of storage containers for equipment. These can protect assets, reduce the cost of humanitarian response and keep livelihoods intact.[20]

19 Prevention Web. "Myanmar: Early warning system case study". 2019. Available at: https://www.preventionweb.net/news/view/63214

20 FAO. "Madagascar, Impact of Early Warning Early Action". 2019. Available at: http://www.fao.org/3/ca3933en/ca3933en.pdf

In focus: **Satellite and earth observation**

Countries can benefit significantly from advances in technology to improve the disaster-preparedness of their agricultural sector. The falling costs of sensors, growth of the nanosatellite sector, and ubiquitous connectivity and cloud computing are all helping to improve early-warning data through earth observation.

In 2016 the Philippines launched the Diwata-1 satellite to improve forecasting and weather monitoring and better predict extreme weather events like El Niño.[21] Diwata-1 was the first satellite carrying technology capable of detecting blight in banana groves, a major cause of economic damage in the country.[22] A second satellite, Diwata-2, launched in October 2018; its contributions will include monitoring changes in vegetation and assessing damage from disasters.

The program is a powerful example of how a lower-middle-income country can deploy satellite tools under its own programme, rather than purchasing such data from other providers, although close collaboration with Hokkaido and Tohoku University in Japan has been instrumental. On a larger scale, earth observation is benefiting from strong cross-border collaboration, such as the G20 Group of Earth Observations Global Agriculture Monitoring (GEOGLAM) programme, which provides monthly assessments of agro-climatic conditions likely to impact countries vulnerable to food insecurity.[23] Created in 2011, its Crop Monitor, to which over 40 countries and institutions contribute, encompasses over 80% of the global production and consumption of targeted crops (maize, rice, wheat and soybean).

21 Earth Observation Portal. "DIWATA-1". Available at: https://directory.eoportal.org/web/eoportal/satellite-missions/d/diwata-1

22 EurekAlert!. "DIWATA-2 successfully captures first images". January 23 2019. Available at: https://www.eurekalert.org/pub_releases/2019-01/hu-dsc012219.php

23 NASA. "The GEOGLAM Crop Monitor For Early Warning". Available at: https://nasaharvest.org/project/geoglam-crop-monitor-early-warning

In focus: **Artificial intelligence**

Artificial intelligence (AI) continues to improve food security and strengthen resilience to climate crisis. Refinements to machine-learning techniques are improving forecasting of weather and drought, with 2019 bringing positive modelling breakthroughs including in China.[24] AI is also helping address the "missing middle" of weather modelling; this refers to the fact that conventional weather models perform well to seven days in advance and climate forecasting models become more reliable as the time horizon stretches into the decades, but sub-seasonal forecasts have historically been of lower quality.

Applying a blend of machine-learning algorithms to historical weather and climate data allowed one research group to demonstrate promising forecasting data for temperature and precipitation from three to six weeks in advance.[25] Later development work led to sub-seasonal forecasting that improved the accuracy by 37-53% for temperature and 128-154% for precipitation.[26] The team are now in receipt of further development funding from Microsoft's AI for Earth Initiative, a US$50m scheme launched in 2017 that provides grants to programmes covering a range of food-security and climate topics, including neural networks for farm needs forecasting, hyperlocal climate risk modelling and ocean monitoring and surveillance tools to track illegal fishing activity.[27]

Such improvements in data analytics and early warning could significantly curb the loss and damage caused by weather disasters which otherwise can be catastrophic—not just for producers but also for consumers, owing to consequent price spikes or loss of availability. According to the FAO, for every dollar invested in early action, farmers and herders obtain between US$2.50 and US$7.10 in added benefits and avoided losses[28].

24 Zhang, R. et al. "Metereological drought forecasting based on a statistical model with machine learning techniques in Shaanxi province, China". 2019. NCBI. Available at: https://www.ncbi.nlm.nih.gov/pubmed/30772564

25 Bureau of Reclamation. "Teams complete Bureau of Reclamation's Sub-Seasonal Climate Forecast Rodeo — outperforming the baseline forecasts". March 7 2019. Available at: https://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=64969

26 Hwang, J. et al. "Improving Subseasonal Forecasting in the Western U.S. with Machine Learning". 22 May 2019. Available at: https://arxiv.org/pdf/1809.07394.pdf

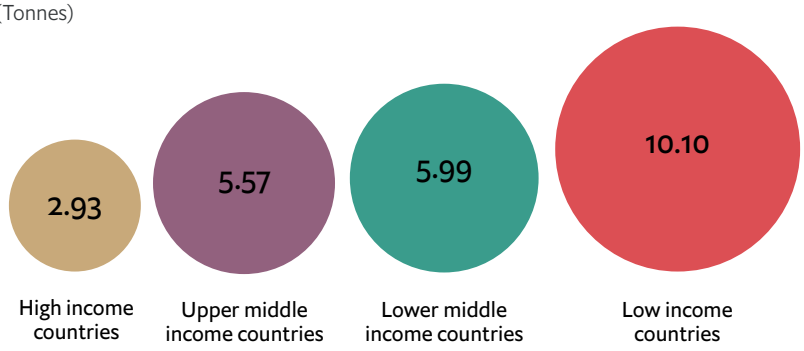
27 Microsoft. "AI for Earth partners". Available at: https://www.microsoft.com/en-us/ai/ai-for-earth-partners?activetab=pivot1:primaryr5

28 FAO. "Disaster risk reduction at farm level: Multiple benefits, no regrets". 2019. Available at: http://www.fao.org/3/ca4429en/ca4429en.pdf

Food waste and loss

Wastage and loss of food is a challenge globally, particularly for low-income countries. There are significant gaps in food loss data, covering post- and pre-consumer food loss, because of the difficulties of tracking such waste. The most recent data on food loss available from the FAO are from 2013. Although outdated, these data demonstrate that there is a significant disparity between the top-scoring and lowest-scoring countries, indicating that additional investment and support are needed for countries scoring at the lower end of the spectrum. Food loss not only hinders availability of food supply, but also reduces farmer incomes and necessitates overproduction in order to account for lost produce, thus putting additional strains on land, water and the environment. Therefore, closing the gap would have positive economic and environmental impacts. While developments in infrastructure and cold chains are helping, use of digital matchmaking technology is also improving supply-chain efficiency, yielding more easily adoptable, cost-effective solutions.

Figure 5
Food loss, total waste/total domestic supply quantity
(Tonnes)



Source: FAO (2013)

In focus: **Blockchain and distributed ledgers to optimise supply chains**

Blockchain, a distributed ledger technology, shows huge promise in the agriculture sector. The FAO has identified a series of use cases and pilots covering aspects including agricultural insurance in the Asia-Pacific region, land registration and food supply chains.[29] Global brands exploring blockchain now include Barilla (Italy) and Walmart (US), who are both working with IBM to improve supply chain traceability.[30] Separately, the FAO is working with the International Telecommunication Union on blockchain for livestock traceability in Papua New Guinea. Other pilots include blockchain usage to track fish and spot illegal fishing in New Zealand, wood supply traceability in China and Spain, and even monitoring of agriculture-relevant financial instruments like green bonds, which are created to find projects with positive environmental impact but require rigorous tracking and verification. These could further improve supply chain governance and food quality provenance.[31]

29 FAO. "E-agriculture in action: Blockchain for agriculture". 2019. Available at: http://www.fao.org/3/CA2906EN/ca2906en.pdf

30 TechCrunch. "Walmart is betting on the blockchain to improve food safety". September 25 2018. Available at: https://techcrunch.com/2018/09/24/walmart-is-betting-on-the-blockchain-to-improve-food-safety/

31 FAO. "E-agriculture in action: Blockchain for agriculture". 2019. Available at: http://www.fao.org/3/CA2906EN/ca2906en.pdf

In focus: **Food-broker apps cut waste in cities across the world**

The "on-demand" economy is most famously associated with ride-hailing apps like Uber, and the same innovations and platform tactics are now being deployed to tackle food loss. Food-brokering apps like Karma and Too Good to Go are connecting consumers to cut-price local meals and food products that are within shelf-life but will otherwise be tossed owing to supply and demand mismatches. Karma, founded in Sweden, raised £9.4m (US$12.2m) in 2018 to expand to the UK supermarket sector, and a number of similar such products are now being rolled out in cities in countries including Denmark, France, the UK and the US.[32] In India, a business-to-business food-broker model has emerged. Ninjacart, an online platform, connects farmers, manufacturers and brands, and processes over 500 tonnes of food a day. It has helped farmers to increase revenue by 20%, gives competitive prices to stores and provides fully traceability of produce for consumers.[33,34] Big tech companies are also deploying data science to tackle food loss. In June 2018 Chinese tech giant Alibaba launched *ET Agricultural Brain*, an AI tool that uses visual and voice recognition and parameter modelling to monitor the activity and health indicators of pigs, boosting productivity and reducing deaths.[35]

32 The Grocer. "Karma food waste app set to expand to UK supermarkets". 15 August 2018. Available at: https://www.thegrocer.co.uk/food-waste/karma-food-waste-app-set-to-expand-to-uk-supermarkets-/570571.article

33 Ninjacart. "Revolutionizing the Fresh Produce Supply Chain". Available at: http://ninjacart.in/

34 YourStory. "How Ninjacart built a tech-enabled supply chain for fresh farm produce, delivering 500 tonnes daily". March 21 2019. Available at: https://yourstory.com/2019/03/startup-ninjacart-tech-enabled-supply-chain-farmers-yrlcfr3a40

35 South China Morning Post. "Alibaba launches AI-backed agricultural tool to boost income for China's farmers". June 7 2018. Available at: https://www.scmp.com/tech/china-tech/article/2149674/alibaba-launches-ai-backed-agricultural-tool-boost-income-chinas

Diet and nutrition

The GFSI examines government commitment to increasing nutritional standards, measured through the presence of national dietary guidelines, a national nutrition plan or strategy, and nutrition monitoring and surveillance. For the 2019 Index, the questions looked beyond whether the country has such plans in place, examining more closely how relevant and recent they are. The weakest area globally, according to the latest ranking, is the presence of national dietary guidelines, which only 61 countries have in place. Whereas in previous years, the GFSI assessed if national dietary guidelines were in place, this year, countries only received a positive score if they also had published a visual guide that could be referenced by the general population to guide healthy decision making in relation to food (such as a food pyramid or plate visual).

For nutritional standards overall, Sub-Saharan Africa has the lowest regional scores, although there is significant variation, from lower-scoring countries such as Madagascar, Mozambique, Niger and Togo to countries such as Nigeria, South Africa and Benin, which all receive top scores in the index.

The drive to improve nutrition is where the climate and agriculture trade-off becomes the starkest, as many food products essential for a diversified, balanced diet have larger environmental cost, especially protein. In the GFSI, our metric focuses on quality of available protein, rather than overall quantity of protein. While overall supply and demand for animal protein has increased globally, the protein quality may not be keeping pace.[36] Although two low-income countries, Mali and Togo, top the list for most improvement, protein quality is closely tied to income levels, with high-income countries consistently scoring at the top of this metric while low-income countries score toward the bottom.

Rapid commercial innovation, and new approaches to food production and development, could help countries to increase their nutritional balance—including protein quality—without exerting harmful effects in terms of emissions, land use and chemicals.

Improvements in nutrition go beyond nutrition policy and also depend on protecting the quality of soils. As noted in the report introduction, worsening soil quality has the potential to reduce the micronutrient availability in crops. Land degradation is one consequence of unsustainable agricultural practices. With this in mind, the GFSI examines degraded land as a proportion of total land area. High performers that have agricultural industries of note include Chile, Romania and Slovakia. Data from the FAO indicate that 97% of land in Tajikistan is degraded, the highest figure in the index.

To increase food production without degrading land requires new approaches that combine the efficiency and yield-maximising benefits of synthetic fertilisers, pesticides, insecticides and herbicides without their environmental toll. Researchers are advancing this agenda through exploring new methods such as bioinoculants—eco-friendly microorganisms, usually bacteria or fungi that

36 McKinsey & Company. "How the global supply landscape for meat protein will evolve". October 2018. Available at: https://www.mckinsey.com/industries/agriculture/our-insights/how-the-global-supply-landscape-for-meat-protein-will-evolve

exist in the plant microbiome—that can be manipulated to positively influence nutrition, production, yield and disease susceptibility.[37,38] Bioinoculants of interest include rhizobacteria and arbuscular mycorrhizal fungi, as these could enhance plant growth in degraded or unfertile soil conditions, which will become increasingly normal given current land trends.[39] One study found significant benefits of two bioinoculants on the growth and yield of okra crops.[40]

37 Martinez-Hidalgo, P. eta. "Engineering root microbiomes for healthier crops and soils using beneficial, environmentally safe bacteria". February 2019. NCBI. Available at: https://www.ncbi.nlm.nih.gov/pubmed/30226998

38 Gu, Y et al. "Initial soil microbiome composition and functioning predetermine future plant health". September 25 2019. American Association for the Advancement of Science. Available at: https://advances.sciencemag.org/content/5/9/eaaw0759

39 Raju, K et al. "Consequences of Bioinoculants and Intercropping Approach to Alleviate Plant Drought and Salinity Stress for Sustainable Agriculture". October 22 2019. Available at: https://link.springer.com/chapter/10.1007/978-981-13-8805-7_8

40 Anjum, A. et al. "Role of Bioinoculants for Improving Growth and Yield of Okra (Abelmoshuses culentum)". 2018. Universal Journal of Agricultural Research. Available at: https://pdfs.semanticscholar.org/a87c/ce188af59154c84220ee34fbaff9d4f5f85f.pdf

In focus: **Alternative proteins**

Laboratory-based foods, alternative proteins, and vertical and hydroponic agriculture are all driving innovation and attracting increasing amounts of venture funding, which could help to meet the need for improved nutrition without compromising the environment.

Alternative protein is one innovation portfolio proving critical to improving food security. The edible insect sector, including crickets, grasshoppers and mealworms, has enjoyed a year of strong commercial funding, commercial breakthroughs and media interest as a "light footprint" protein source compared with meat, which is among the most environmentally destructive. Edible insects are also rich in vitamins and minerals.

One of the leading start-ups in the sector is France's Ynsect, which creates insect-based animal feed. Currently, crops used in animal feed are environmentally taxing, in terms of land usage and soil degradation, ultimately competing with human consumption. Fish feed, for instance, frequently contains soya and corn. Ynsect raised US$125m in early 2019, in the largest single round of fund-raising in agricultural technology outside of the US.[41] The overall market for insect protein is estimated at US$143.6m for 2019, and is set to reach US$1.3bn in 2025.[42]

Plant-based meat substitutes are a second source of alternative protein that could have a transformative effect in balancing food security with sustainability. To date, this innovation has taken place in more higher-income, technologically-advanced countries, including the US and Israel. The private sector is playing a lead role. Beyond Meat, a US-based producer of plant-based substitutes, launched an initial public offering (IPO) in early 2019 and is working with major food companies.[43] Consumer interest in alternative proteins is showing up in search activity online. Queries for alternative protein grew 30% per year in 2004-19, while queries for laboratory-grown meat, based on cultured meat cells, rose 16%.[44]

A third alternative food source of note is algae farms. These provide a win-win benefit for food security and environmental rescue, because algae both absorb CO_2 and provide a strong nutritional boost of amino acids, vitamins, minerals and essential fatty acids like omega-3. Although reforestation draws CO_2 from the atmosphere, there are food security implications, as it would also increase food prices by as much as 80% by 2050, owing to the necessary changes to land use.[45] Algae, combined with bioreactors, are up to 400 times more efficient than trees at CO_2 removal. Algae do not need soil or freshwater, meaning that they can grow in environments where ordinary crops would not survive. Several notable developments have taken place in the past year, including the inclusion of government support for the algae sector in the 2018 US farm bill.[46]

41 Financial Times. "Start-up that turns insects into animal feed raises $125m". Available at: https://www.ft.com/content/487f81a4-3510-11e9-bd3a-8b2a211d90d5

42 PR Newswire. "Global Insect Protein Market Forecast to 2025: Focus on Food & Beverages, Animal Nutrition, Pharmaceuticals & Cosmetics". August 6 2019. Available at: https://www.prnewswire.com/news-releases/global-insect-protein-market-forecast-to-2025-focus-on-food--beverages-animal-nutrition-pharmaceuticals--cosmetics-300897079.html

43 Financial Times. "Beyond Meat shares heat up as KFC tests plant-based 'chicken". Available at: https://www.ft.com/content/d92eddb2-c822-11e9-a1f4-3669401ba76f

44 Financial Times. "Mind your peas as queues grow for protein alternatives". Available at: https://www.ft.com/content/5460e02e-c4f0-11e9-a8e9-296ca66511c9

45 World Economic Forum. "The solution to fighting climate change could be lurking in our oceans". October 11 2019. Available at: https://www.weforum.org/agenda/2019/10/aquatic-plant-answer-solve-climate-crisis/

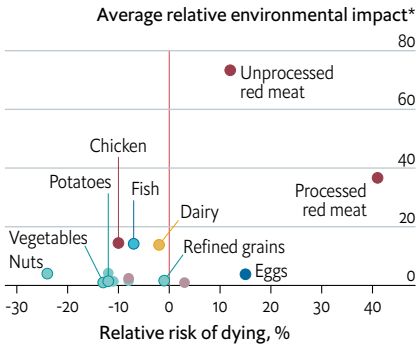
46 House of Representatives. "Agriculture Improvement Act of 2018". Available at: https://docs.house.gov/billsthisweek/20181210/CRPT-115hrpt1072.pdf

In focus: **Behaviour change and the "planetary health diet"**

Consumers are increasingly conscious of the impact that food choices have on the environment, and media coverage, public debate and growing evidence for environmentally-friendly food choices are beginning to affect the decisions of the industry.

Public interest in "flexitarian", vegetarian and vegan diets is rising, not only because of animal welfare concerns, but also as a result of environmental and health considerations. In the UK, major food brands including Marks and Spencers, Pret a Manger, Wagamama, Pizza Hut and Pizza Express have launched vegan ranges; supermarket giants Sainsbury's and Tesco have introduced new vegan ranges; and beverage-maker Guinness has stopped using fish bladders in its brewing process after over two centuries of doing so.[47] The number of Italians identifying as vegan nearly doubled in 2016-18 and the number of vegans in the UK quadrupled between 2014 and 2018.[48] Although brands in such countries are focused on serving food secure

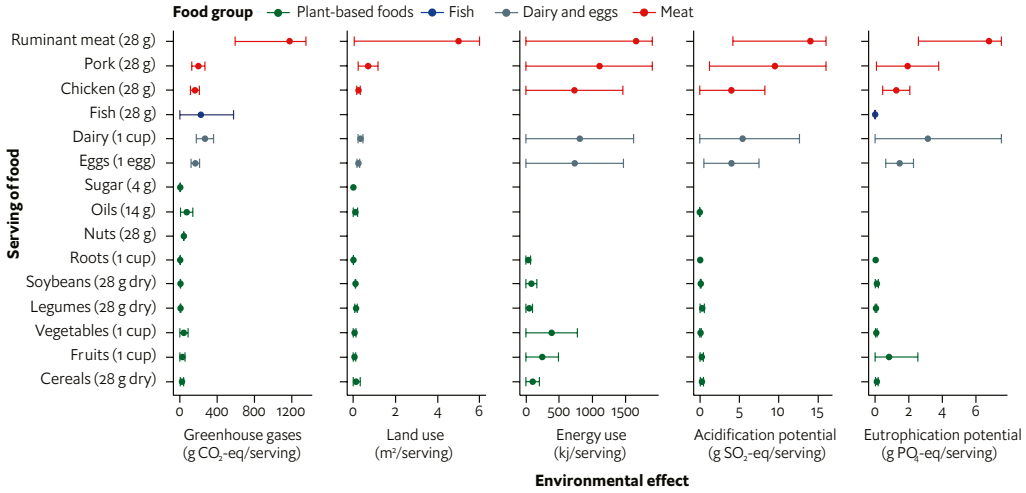
Figure 6
High-steak diets
Health and environmental impact of one extra serving per day



47 The Guardian. "The unstoppable rise of veganism: how a fringe movement went mainstream". April 1 2018. Available at: https://www.theguardian.com/lifeandstyle/2018/apr/01/vegans-are-coming-millennials-health-climate-change-animal-welfare

48 The Conversation. "The vegans are coming! What's fuelling the interest in plant-based eating?" October 3 2019. Available at: https://theconversation.com/the-vegans-are-coming-whats-fuelling-the-interest-in-plant-based-eating-123869

Figure 7
Environmental effects per serving of food produced



Bars are mean (SD).5,216 Some results are missing for fish due to lack of data for some impact categories (eg, land use stemming from plant-based feeds in aquaculture). This was, however, accounted for in the global food systems modeling framework used in Section 3. CO2=carbon dioxide. Eq=equivalent. PO4=phosphate. SO2=sulphur dioxide.
Source: "Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems", https://www.researchgate.net/publication/330443133_Food_in_the_Anthropocene_the_EAT-Lancet_Commission_on_healthy_diets_from_sustainable_food_systems

markets, the interconnectedness of global agricultural supply chains means trends such as increased veganism can, over time, reduce the stress levied by production of foods such as red meat.

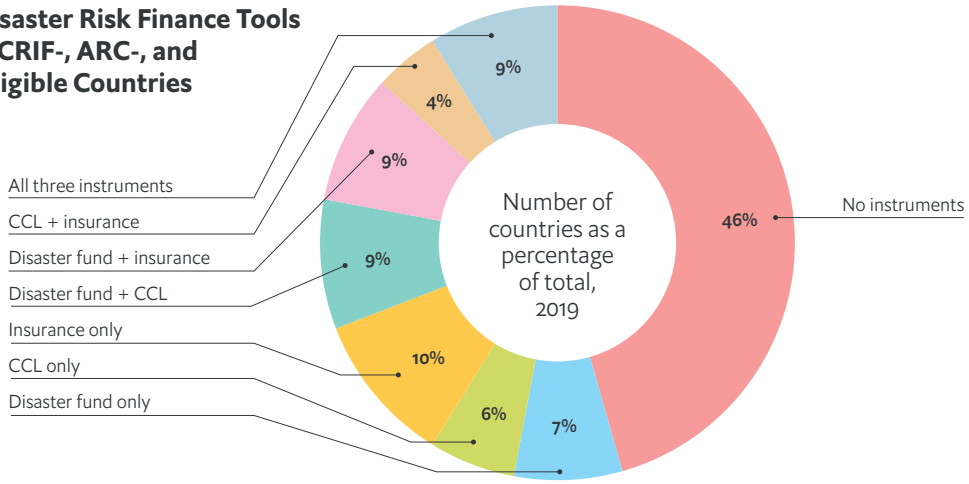
Consumers can also benefit from improvements in data on the ecological cost of food choice. In January 2019, *The Lancet*, as part of a landmark initiative with EAT, a global non-profit, published the first comprehensive scientific review of what constitutes a healthy diet from the perspective of food sustainability. Its quantitative reference study distinguishes between "lose-lose" diets that are harmful both for human health and the environment, such as those high in calories, added sugars, saturated fats, processed food and red meats, and "win-win" diets that deliver nutritional benefits for consumers with limited environmental costs. The review provides empirical data on the benefits of vegan and vegetarian diets on greenhouse gas emissions and land use, but also on the benefits of shifting meat consumption from ruminant meat that requires large grazing land to fish, poultry and pork.

Financing for farmers

Despite financial innovation being critical to food security in a climate-unstable world, there remains a gap in some areas, particularly in conflict-affected nations in Africa and the Middle East. Six countries score zero in the GFSI for access to finance for farmers, meaning that farmers have virtually no access to government or multilateral support. Half of these are African states (Guinea, the Democratic Republic of the Congo and Chad). Two others, Yemen and Syria, declined from minimal access to no access in 2016. A further 25 countries are highlighted as only having access to shallow financial markets.

More positively, the World Resources Institute (WRI) found that there have been recent improvements in the financial toolbox that can be deployed to support farmers, especially in the context of climate change. Available resources now include a wide range of options, including national disaster funds, contingent credit lines, parametric disaster risk insurance, catastrophe bonds and insurance-linked securities. However, the WRI notes that despite relatively few countries take advantage of such options, particularly in the context of disaster financing (see Figure 8).[49]

Figure 8
Use of Disaster Risk Finance Tools among CCRIF-, ARC-, and PCRIC-Eligible Countries



Source: World Resources Institute. "The Future of Disaster Risk Pooling for Developing Countries: Where Do We Go From Here?". August 2019. Available at: https://wriorg.s3.amazonaws.com/s3fs-public/future-disaster-risk-pooling-developing-countries.pdf

49 World Resources Institute. "The Future of Disaster Risk Pooling for Developing Countries: Where Do We Go From Here?". August 2019. Available at: https://wriorg.s3.amazonaws.com/s3fs-public/future-disaster-risk-pooling-developing-countries.pdf

In focus: **Parametric weather insurance**

Parametric disaster risk insurance is one approach that is receiving increasing interest as countries brace themselves for more regular climatic volatility. These schemes pay out to sovereigns when critical indicators such as cumulative rainfall, temperature or wind speed reach a predetermined threshold. Pay-outs from such schemes are far quicker and less costly in an administrative sense than conventional indemnity insurance, which requires visits to farms to verify losses. In addition, when sovereigns pool together regionally, they also provide risk diversification that allows a commercial reinsurance sector to emerge.

Three regional parametric systems exist at the time of writing: the Catastrophe Risk Insurance facility, formed in 2007 with a focus on hurricanes and earthquakes; the African Risk Capacity initiative, formed in 2012 to provide drought coverage; and the Pacific Catastrophe Risk Insurance, launched in 2016 to provide cyclone and earthquake coverage in the Pacific Islands. A new network, the Southeast Asia Disaster Risk Insurance Facility, is under development to provide flood insurance for Laos, Cambodia and Myanmar.[50] Such approaches could over time provide co-benefits such as generating data repositories and risk models that enable governments to better understand the risks that they face).[51]

Along with regional initiatives there are a growing number of national and subnational approaches. In October 2019, AXA Cameroon and AXA Climate, two arms of a France-based multinational insurer, launched the first parametric agricultural insurance programme in Cameroon, partnering with the World Bank's Global Index Insurance Facility, bringing insurance to thousands of farmers. Pay-outs are based on satellite data measuring evapotranspiration (the loss of water from soil and plants), which quantifies drought-related crop yield loss.[52] Subnational, index-based flood insurance projects exist in Bihar, India, and the International Finance Corporation is supporting MAIPARK, a special-risk reinsurance company that works with local insurance companies to develop, sell and bundle products with agricultural loans or inputs to mitigate weather-related risks[53,54]

50 Green Biz. "How developing countries are insuring against climate disasters". September 9 2019. Available at: https://www.greenbiz.com/article/how-developing-countries-are-insuring-against-climate-disasters

51 World Resources Institute. "The Future of Disaster Risk Pooling for Developing Countries: Where Do We Go From Here?". August 2019. Available at:https://wriorg.s3.amazonaws.com/s3fs-public/future-disaster-risk-pooling-developing-countries.pdf

52 AXA. "Protecting Cameroon's Farmers from Climate Risk: 3 questions for Antoine Denoix, CEO AXA Climate". October 28 2019. Available at: https://www.axa.com/en/newsroom/news/protecting-cameroon-s-farmers-from-climate-risk

53 Relief Web. "Fine-tuning flood risk management". February 20 2019. Available at: https://reliefweb.int/report/india/fine-tuning-flood-risk-management

54 IFC. "IFC Partners With PT Reasuransi MAIPARK to Insure Farmers Against Climate Risks". April 2017. Available at: https://ifcextapps.ifc.org/IFCExt/pressroom/IFCPressRoom.nsf/0/E5896666C23987DD8525810F002DB3B0

Conclusion: Breaking the food-climate trade-off

The past year has seen the climate agenda move further into the policy mainstream, from street protests to election campaigns that put decarbonisation at the heart of government rather than on the sidelines. Public awareness and activism is growing, and evidence is increasing of consumers reducing their consumption of environmentally harmful foods.

The energy sector attracts the most attention in relation to environmental issues, but global emissions and environmental degradation comes from many sources, of which the food system has been a prominent example. It is also on the front lines of climate risk, with huge economic damage caused to agriculture by both sudden and slow-onset disasters. Historically, food security has posed a trade-off with climate change mitigation, as increasing production risks worsening the ecological impact of the sector. Today, that dynamic is breaking down as a raft of innovations unlock ways to produce, transport and consume food with eve -lighter environmental impact. In some applications, such as agroforestry, mangrove restoration and urban greening, the food system can even buffer and protect us from climate risk.

The 2019 Global Food Security Index reveals slow overall improvements in food security and several areas of backsliding, showing the need to move quickly. Food prices have increased globally. Countries beset by turmoil, notably Yemen, Venezuela and Syria, are experiencing declining food security, with rising food aid dependency in Yemen, Benin and Haiti. New focal areas of this year's rankings show deficiencies hidden previously, such as in irrigation infrastructure. On nutrition, one-fifth of countries lack national plans covering both adults and children. Nutritional monitoring efforts, which are crucial to ensure a tailored, targeted response to under-nutrition and obesity, have reduced.

The innovation needed to tackle these issues and reframe the food-climate nexus is emerging globally, and this report identifies the most promising research and development trends. The ecosystem of actors is broad, encompassing start-ups, large food retailers, universities and tech giants. Artificial intelligence continues to advance in its performance capacity and range, as seen by its ability to provide the "missing middle" of sub-seasonal weather forecasting. Apps and consumer innovations such as "just in time" food-brokerage apps are helping to cut food loss. Off-grid cooling technology is improving in efficiency and cost, helping to protect supply chains in heat-stressed countries.

Governments are also stepping up to the challenge. The falling costs of satellites have seen resource-constrained countries able to monitor weather systems and agriculture from space for the first time. Sovereign parametric risk instruments are helping countries to issue rapid pay-outs to farmers during drought or extreme weather. Governments are also core to enabling "urban greening", issuing legislation to protect ecosystem services such as mangroves, and providing the overarching strategy for a coherent alignment of nutrition, economic security for agricultural producers, and the climate goals of the country.

Appendix I: GFSI 2019 results

2019 GFSI overall rankings table

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

Rank	Country	Score / 100
1	Singapore	87.4
2	Ireland	84.0
3	United States	83.7
4	Switzerland	83.1
=5	Finland	82.9
=5	Norway	82.9
7	Sweden	82.7
8	Canada	82.4
9	Netherlands	82.0
10	Austria	81.7
11	Germany	81.5
12	Australia	81.4
13	Qatar	81.2
14	Denmark	81.0
15	Belgium	80.7
16	France	80.4
17	United Kingdom	79.1
18	Israel	79.0
19	New Zealand	78.8
20	Portugal	77.8
=21	Japan	76.5
=21	United Arab Emirates	76.5
23	Italy	75.8
24	Poland	75.6
=25	Chile	75.5
=25	Spain	75.5
27	Kuwait	74.8
28	Malaysia	73.8
29	South Korea	73.6
30	Saudi Arabia	73.5
31	Greece	73.4
32	Czech Republic	73.1
33	Uruguay	72.8
34	Hungary	72.7
35	China	71.0
36	Belarus	70.9
37	Argentina	70.8
38	Romania	70.2
=39	Brazil	70.1
=39	Costa Rica	70.1
41	Turkey	69.8
42	Russia	69.7
=43	Colombia	69.4
=43	Mexico	69.4
45	Panama	68.8
46	Oman	68.4
47	Slovakia	68.3
=48	Kazakhstan	67.3
=48	South Africa	67.3
50	Bahrain	66.6
51	Bulgaria	66.2
52	Thailand	65.1
53	Azerbaijan	64.8
54	Vietnam	64.6
55	Egypt	64.5
56	Dominican Republic	64.2
57	Botswana	63.8
58	Peru	63.3
=59	Ghana	62.8
=59	Morocco	62.8
=59	Serbia	62.8
62	Indonesia	62.6
63	Ecuador	61.8
=64	Jordan	61.0
=64	Philippines	61.0
66	Sri Lanka	60.8
67	El Salvador	60.7
68	Guatemala	60.6
69	Tunisia	60.1
70	Algeria	59.8
71	Uzbekistan	59.0
72	India	58.9
73	Honduras	58.0
74	Paraguay	57.9
75	Bolivia	57.7
76	Ukraine	57.1
77	Myanmar	57.0
78	Pakistan	56.8
79	Nepal	56.4
80	Mali	54.4
81	Senegal	54.3
82	Nicaragua	54.2
83	Bangladesh	53.2
84	Cote d'Ivoire	52.3
85	Benin	51.0
86	Kenya	50.7
87	Burkina Faso	50.1
88	Cameroon	49.9
89	Niger	49.6
90	Cambodia	49.4
91	Ethiopia	49.2
92	Laos	49.1
93	Tajikistan	49.0
94	Nigeria	48.4
95	Rwanda	48.2
96	Tanzania	47.6
97	Guinea	46.7
98	Uganda	46.2
99	Sudan	45.7
100	Angola	45.5
101	Zambia	44.4
102	Togo	44.0
103	Haiti	43.3
104	Malawi	42.5
105	Mozambique	41.4
106	Sierra Leone	39.0
107	Syria	38.4
108	Madagascar	37.9
109	Chad	36.9
110	Congo (Dem. Rep.)	35.7
111	Yemen	35.6
112	Burundi	34.3
113	Venezuela	31.2

Score changes

(Net change in overall score, 2019 v 2018)
Weighted total of all category scores (0-100 where 100 = most favourable) ■ Score improved ■ Score declined

Rank	Country	Score change
27	Kuwait	+3.2
13	Qatar	+2.9
104	Malawi	+2.7
110	Congo (Dem. Rep.)	+2.4
102	Togo	+2.2
95	Rwanda	+2.0
109	Chad	+2.0
97	Guinea	+1.9
52	Thailand	+1.9
36	Belarus	+1.8
28	Malaysia	+1.7
=64	Philippines	+1.7
79	Nepal	+1.7
81	Senegal	+1.7
92	Laos	+1.6
47	Slovakia	+1.6
50	Bahrain	+1.5
86	Kenya	+1.5
89	Niger	+1.4
107	Syria	+1.3
=48	Kazakhstan	+1.2
66	Sri Lanka	+1.2
101	Zambia	+1.1
11	Germany	+1.1
=21	United Arab Emirates	+1.0
=43	Colombia	+1.0
77	Myanmar	+1.0
84	Cote d'Ivoire	+1.0
93	Tajikistan	+1.0
112	Burundi	+1.0
12	Australia	+0.9
=25	Chile	+0.9
67	El Salvador	+0.9
73	Honduras	+0.9
31	Greece	+0.8
=59	Morocco	+0.8
=64	Jordan	+0.8
90	Cambodia	+0.8
8	Canada	+0.7
42	Russia	+0.7
87	Burkina Faso	+0.7
100	Angola	+0.7
58	Peru	+0.7
94	Nigeria	+0.7
24	Poland	+0.7
3	United States	+0.6
62	Indonesia	+0.6
108	Madagascar	+0.6
2	Ireland	+0.6
14	Denmark	+0.6
23	Italy	+0.6
=25	Spain	+0.6
=48	South Africa	+0.6
57	Botswana	+0.6
78	Pakistan	+0.6
=5	Norway	+0.5
9	Netherlands	+0.5
18	Israel	+0.5
29	South Korea	+0.5
46	Oman	+0.5
51	Bulgaria	+0.5
54	Vietnam	+0.5
75	Bolivia	+0.5
105	Mozambique	+0.5
35	China	+0.4
56	Dominican Republic	+0.4
68	Guatemala	+0.4
85	Benin	+0.4
32	Czech Republic	+0.4
45	Panama	+0.4
83	Bangladesh	+0.3
10	Austria	+0.3
=21	Japan	+0.3
=39	Brazil	+0.3
53	Azerbaijan	+0.3
=59	Ghana	+0.3
71	Uzbekistan	+0.3
7	Sweden	+0.2
33	Uruguay	+0.2
76	Ukraine	+0.2
113	Venezuela	+0.2
74	Paraguay	+0.2
88	Cameroon	+0.2
34	Hungary	+0.1
=43	Mexico	+0.1
19	New Zealand	+0.1
20	Portugal	+0.1
1	Singapore	0.0
4	Switzerland	0.0
=5	Finland	0.0
15	Belgium	0.0
16	France	0.0
=39	Costa Rica	0.0
55	Egypt	0.0
72	India	0.0
96	Tanzania	-0.1
17	United Kingdom	-0.1
30	Saudi Arabia	-0.2
38	Romania	-0.2
91	Ethiopia	-0.3
=59	Serbia	-0.4
103	Haiti	-0.4
106	Sierra Leone	-0.6
41	Turkey	-0.6
99	Sudan	-0.7
111	Yemen	-0.7
98	Uganda	-0.8
70	Algeria	-0.8
80	Mali	-1.0
63	Ecuador	-1.1
69	Tunisia	-1.3
37	Argentina	-1.6
82	Nicaragua	-4.1

2019 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	Czech Republic	75.5
2	Finland	74.0
=3	Denmark	73.9
=3	New Zealand	73.9
5	Slovakia	73.1
=6	Sweden	72.1
=6	Switzerland	72.1
8	Uruguay	71.6
9	Ireland	71.0
=10	Austria	69.6
=10	Poland	69.6
12	Hungary	69.5
13	Norway	69.0
14	Malawi	68.7
=15	Japan	68.5
=15	Myanmar	68.5
=15	Niger	68.5
18	Germany	68.4
19	France	68.3
20	Netherlands	67.4
21	Cote d'Ivoire	67.1
22	Spain	66.3
23	Romania	66.2
=24	Bulgaria	65.3
=24	Canada	65.3
26	Russia	65.1
27	Uganda	65.0
=28	Greece	64.8
=28	Portugal	64.8
30	Italy	64.5
31	Burundi	64.2
32	United Kingdom	63.8
=33	Belgium	62.9
=33	Kazakhstan	62.9
=35	Burkina Faso	62.6
=35	Rwanda	62.6
37	Serbia	62.2
38	Laos	62.1
39	Honduras	61.5
40	United States	61.4
41	Venezuela	61.2
=42	Mali	61.0
=42	Zambia	61.0
44	Chile	60.1
45	Turkey	60.0
46	Thailand	59.0
47	Egypt	58.9
48	Costa Rica	58.5
=49	Botswana	58.3
=49	Paraguay	58.3
51	Tanzania	57.7
52	Nicaragua	57.5
=53	Pakistan	57.0
=53	Ukraine	57.0
=53	Uzbekistan	57.0
56	El Salvador	56.9
57	Colombia	56.4
58	Madagascar	56.3
=59	Belarus	56.0
=59	Togo	56.0
61	South Korea	55.8
=62	Bolivia	55.6
=62	Brazil	55.6
=64	Argentina	55.5
=64	Australia	55.5
66	Nigeria	55.2
67	Senegal	55.0
68	Jordan	54.9
69	China	54.5
70	Cambodia	53.3
71	Haiti	53.2
72	Ghana	53.0
73	Chad	52.9
74	Malaysia	52.8
=75	Angola	52.1
=75	Sudan	52.1
77	Cameroon	52.0
78	Kuwait	51.5
79	Ethiopia	51.2
80	Mexico	50.8
81	Kenya	50.6
82	South Africa	50.4
=83	Bangladesh	50.2
=83	Sierra Leone	50.2
85	Azerbaijan	49.9
86	Guatemala	49.7
87	Tunisia	49.5
=88	Mozambique	49.0
=88	Panama	49.0
90	Qatar	48.7
91	Ecuador	48.4
=92	Algeria	48.3
=92	Guinea	48.3
94	Vietnam	48.2
95	Morocco	47.9
96	Sri Lanka	47.7
97	Nepal	47.5
98	India	46.7
99	Congo (Dem. Rep.)	45.4
100	Syria	45.2
101	Israel	44.8
=102	Peru	44.4
=102	Saudi Arabia	44.4
104	Dominican Republic	44.2
105	Benin	44.1
106	United Arab Emirates	43.9
107	Oman	43.8
108	Philippines	42.5
109	Singapore	42.4
110	Indonesia	40.7
111	Tajikistan	40.5
112	Yemen	40.4
113	Bahrain	39.0

2019 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	Ireland	77.9	+1
2	Finland	77.5	+3
3	Switzerland	77.3	+1
4	Sweden	76.9	+3
5	Norway	76.5	0
6	Denmark	75.7	+8
7	United States	75.6	-4
8	Austria	75.5	+2
=9	Canada	75.3	-1
=9	Netherlands	75.3	0
11	Germany	75.1	0
12	Singapore	74.8	-11
13	France	74.0	+3
14	New Zealand	73.7	+5
15	Belgium	73.2	0
16	Australia	72.3	-4
17	United Kingdom	71.9	0
18	Portugal	71.0	+2
19	Qatar	70.8	-6
20	Japan	70.5	+1
21	Poland	69.9	+3
=22	Italy	69.1	+1
=22	Spain	69.1	+3
24	Czech Republic	68.6	+8
25	Israel	68.1	-7
26	Chile	68.0	-1
27	Uruguay	67.6	+6
28	Hungary	67.2	+6
29	Greece	66.9	+2
30	United Arab Emirates	65.8	-9
31	Kuwait	65.7	-4
32	South Korea	65.5	-3
33	Malaysia	65.1	-5
34	Romania	64.3	+4
35	Slovakia	63.7	+12
36	Russia	63.6	+6
37	Saudi Arabia	63.3	-7
38	Belarus	63.1	-2
=39	Argentina	62.9	-2
=39	China	62.9	-4
=41	Costa Rica	62.8	-2
=41	Turkey	62.8	0
43	Brazil	62.3	-4
44	Colombia	61.8	-1
45	Kazakhstan	61.1	+3
46	Mexico	60.9	-3
47	Bulgaria	60.5	+4
48	Panama	60.0	-3
49	South Africa	59.0	-1
50	Oman	58.8	-4
51	Thailand	58.4	+1
52	Egypt	57.9	+3
53	Botswana	57.1	+4
54	Serbia	56.9	+5
55	Azerbaijan	56.7	-2
56	Bahrain	56.4	-6
57	Vietnam	56.2	-3
58	Ghana	55.4	+1
59	Dominican Republic	55.2	-3
60	Morocco	54.6	-1
61	Peru	54.5	-3
62	El Salvador	54.2	+5
63	Jordan	54.1	+1
64	Ecuador	53.8	-1
65	Indonesia	53.3	-3
66	Guatemala	53.0	+2
67	Sri Lanka	52.9	-1
68	Uzbekistan	52.7	+3
=69	Myanmar	52.5	+8
=69	Tunisia	52.5	0
71	Honduras	52.4	+2
72	Philippines	52.2	-8
73	Algeria	52.1	-3
74	Paraguay	51.9	0
75	Bolivia	51.3	0
76	India	51.1	-4
77	Ukraine	51.0	-1
78	Pakistan	50.7	0
79	Mali	49.1	+1
80	Nepal	49.0	-1
81	Nicaragua	48.4	+1
82	Senegal	48.2	-1
83	Cote d'Ivoire	48.0	+1
84	Bangladesh	46.6	-1
85	Niger	45.7	+4
86	Burkina Faso	45.4	+1
=87	Kenya	44.4	-1
=87	Laos	44.4	+5
=89	Benin	43.9	-4
=89	Cameroon	43.9	-1
91	Rwanda	43.7	+4
92	Cambodia	43.6	-2
93	Ethiopia	43.2	-2
94	Nigeria	43.0	0
95	Tanzania	42.6	+1
96	Uganda	42.2	+2
97	Tajikistan	41.7	-4
98	Guinea	40.7	-1
99	Sudan	40.2	0
=100	Angola	40.1	0
=100	Zambia	40.1	+1
=102	Malawi	39.2	+2
=102	Togo	39.2	0
104	Haiti	38.2	-1
105	Mozambique	36.1	0
106	Sierra Leone	34.1	0
107	Madagascar	33.8	+1
108	Syria	33.1	-1
109	Chad	32.6	0
110	Burundi	31.2	+2
111	Congo (Dem. Rep.)	30.8	-1
112	Yemen	30.3	-1
113	Venezuela	28.2	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 The Economist Intelligence Unit (EIU) used, including category and indicator definitions, scoring criteria, country selection, weightings, and sources, is provided below.

Scoring criteria and categories

Categories and indicators were selected based on EIU expert analysis and consultation with a panel of food security specialists. We convened the panel in February 2012 to help to 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 zero to 100, where 100 is the most favourable score. 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).

For the 2019 GFSI, The EIU team reviewed the framework to identify indicators recommended for changes. Changes for the 2019 framework include updating indicators to rely on more recently updated sources and creating more challenging standards for existing qualitative metrics.

The categories and indicators are:

1. Affordability

1.1 Change in average food costs

1.2 Proportion of population under global poverty line

1.3 Gross domestic product per capita (US$PPP)

1.4 Agricultural import tariffs

1.5 Presence of food safety-net programmes

- 1.5.1 Presence of food safety-net programmes
- 1.5.2 Funding for food safety-net programmes
- 1.5.3 Coverage of food safety-net programmes
- 1.5.4 Operation 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 Change in dependency on chronic food aid

2.2 Public expenditure on agricultural research and development

2.3 Agricultural infrastructure

2.3.1 Existence of adequate crop storage facilities
2.3.2 Road infrastructure
2.3.3 Port infrastructure
2.3.4 Air transport infrastructure
2.3.5 Rail infrastructure
2.3.6 Irrigation 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 Dietary diversity
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 iron
3.3.3 Dietary availability of zinc
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 Ability to store food safely

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 Land degradation
4.3.2 Grassland
4.3.3 Forest change
4.4 Oceans
4.4.1 Ocean eutrophication
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 stress
4.7.1 Population growth (2015-20)
4.7.2 Urbanisation (2015-20)

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 Economist Intelligence Unit, the World Bank Group, the UN Food and Agriculture Organisation (FAO), the World Health Organisation (WHO), the World Trade Organisation (WTO), Organisation for Economic Cooperation and Development (OECD), Notre Dame Global Adaptation Initiative (ND-GAIN), the World Resources Institute (WRI), US Department of Agriculture (USDA) and health ministries.

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 2019 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	Saudi Arabia	Jordan		Burkina Faso
China	Colombia	Czech Republic	United Arab Emirates	Morocco		Burundi
India	Costa Rica	Denmark		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:

$$x = (x - \text{Min}(x)) / (\text{Max}(x) - \text{Min}(x))$$

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:

$$x = (x - \text{Max}(x)) / (\text{Max}(x) - \text{Min}(x))$$

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 or without taking into account climate-related and natural resource risks. Indicator scores follow the same methodology as noted above (see: Data modelling), while the formula for the adjusted overall score is as follows:

$$\text{Adjusted overall score} = X * (1 - Z) + (X * (Y / 100) * Z)$$

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

The 2019 version of the index introduces new data sources and datasets. New sources were introduced to 1) replace datasets which are no longer being updated on a regular basis; 2) align with metrics for the Sustainable Development Goals where data is relevant and available; 3) shifting from a multi-point scale (eg 0-4) to a series of binary questions (0-1) to ensure precision of answers; and 4) to introduce more challenging or higher-level questions for indicators where most countries were receiving positive scores.

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
1) Affordability					
1.1	Change in average food costs	FAO	2014-18	A measure of the change in the average food costs, as captured through the Food CPI which tracks the change in cost of the average basket of food goods since 2010.	Sharp increases in the cost of the average basket of food goods can indicate a decline in affordability.
1.2	Proportion of population under global poverty line	World Bank, World Development Indicators	Latest available year in 2008-17	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.	Poverty can lead to difficulty in being able to purchase food or inputs to produce food.
1.3	GDP per capita at PPP	The Economist Intelligence Unit (EIU)	2018	A measure of individual income calculated in US dollars at PPP.	Average income levels can determine the affordability of food.
1.4	Agricultural import tariffs	World Trade Organisation (WTO)	Latest available year in 2012-18	Measured as the average applied most-favoured nation (MFN) tariff on all agricultural imports.	Agricultural tariffs can increase the cost of food imports, and therefore food costs for consumers.
1.5	Presence of food safety-net programmes	EIU scoring	2019	A composite indicator assessing the presence and nature of food safety-net programmes. Subindicators include: • Presence of food safety-net programmes • Funding for food safety-net programmes • Coverage of food safety net programmes • Operation of food safety-net program	
1.5.1	Presence of food safety-net programmes	Qualitative scoring by EIU analysts	2019	A measure assessing if food safety-net programmes are present in the country.	Food safety net programmes help to provide consistent food access for food insecure populations.
1.5.2	Funding for food safety-net programmes	Qualitative scoring by EIU analysts	2019	A measure assessing if food safety-net programmes have funding.	Food safety net programmes with dedicated funding are better able to serve their target populations.
1.5.3	Coverage of food safety net programmes	Qualitative scoring by EIU analysts	2019	A measure assessing if food safety-net programmes have national coverage and provide a range of services.	A broad range of services with nationwide coverage ensures coverage of all food insecure people in the country.
1.5.4	Operation of food safety-net program	Qualitative scoring by EIU analysts	2019	A measure assessing if food safety-net programmes are operated by the national government (versus NGOs/multilaterals).	Food safety net programmes operated by the national government are more sustainable.

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
1.6	Access to financing for farmers	Qualitative scoring by EIU analysts	2019	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.	Access to finance improves farmer productivity and the ability of farmers to provide for their own families.
2) Availability					
2.1	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	
2.1.1	Average food supply	FAO	2016-18	An estimate of the sufficiency of the food supply to meet average dietary needs, assessed as a percentage averaged over a three year period.	A sufficient supply of available food is essential for ensuring food security.
2.1.2	Dependency on chronic food aid	OECD	2013-17	Measures whether a country is a recipient of chronic food aid by assessing the change in emergency food aid per capita over the past 5 years.	Food aid increases when the available food supply is insufficient to meet the population needs.
2.2	Public expenditure on agricultural research and development	United Nations	Latest available year in 2010-17	A measure of government spending on agricultural R&D, as captured through the Agricultural Orientation Index, a proxy indicator assessing public investment in agriculture. The Agriculture Orientation Index (AOI) is the metric used by the United Nations Sustainable Development Goals to capture investment in the agricultural sector including for "rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity" under Target 2.a.	Investment in agricultural research and development supports improvements in quality and availability of agricultural technology.
2.3	Agricultural infrastructure	EIU scoring	Latest available year in 2004-15	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 • Air transport infrastructure • Rail infrastructure • Irrigation infrastructure	
2.3.1	Existence of adequate crop storage facilities	Qualitative scoring by EIU analysts	2019	This binary indicator assesses if there is evidence that the government has made investments through national funds or multilateral/donor funding to improve crop storage within the past five years.	Investments to improve or expand crop storage facilities are critical for ensuring there is a sufficient food supply.

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
2.3.2	Road infrastructure	EIU Risk Briefing	2019	This qualitative indicator measures the quality of road infrastructure and is measured on a 0-4 scale, where 4 = best.	Depending on the country's geography and infrastructure, road, port, air and rail infrastructure play a crucial role in food transport.
2.3.3	Port infrastructure	EIU Risk Briefing	2019	This qualitative indicator measures the quality of port infrastructure and is measured on a 0-4 scale, where 4=best.	Depending on the country's geography and infrastructure, road, port, air and rail infrastructure play a crucial role in food transport.
2.3.4	Air transport infrastructure	EIU Risk Briefing	2019	This qualitative indicator measures the quality of air transport infrastructure and is measured on a 0-4 scale, where 4 = best.	Depending on the country's geography and infrastructure, road, port, air and rail infrastructure play a crucial role in food transport.
2.3.5	Rail infrastructure	EIU Risk Briefing	2019	This qualitative indicator measures the quality of rail infrastructure and is measured on a 0-4 scale, where 4 = best.	Depending on the country's geography and infrastructure, road, port, air and rail infrastructure play a crucial role in food transport.
2.3.6	Irrigation infrastructure	FAO	2016	This indicator assesses the percentage of cultivated agricultural area which is equipped for irrigation.	Irrigation infrastructure can support the ability of farmers to provide a consistent water supply for crops.
2.4	Volatility of agricultural production	USDA	2012-2016	This indicator measures the standard deviation of total factor productivity over the most recent 5-year period for which data are available.	Fluctuations in agricultural productivity can create difficulty in predicting and planning for a consistent food supply.
2.5	Political stability risk	EIU Risk Briefing	2019	This indicator measures general political instability. Measured on a 0-4 scale, where 4 = highest risk	Political instability has the potential to disrupt access to food, for example through transport blockages or reduced food aid commitments.
2.6	Corruption	EIU Risk Briefing	2019	This indicator measures the pervasiveness of corruption in a country by assessing the risk of corruption. Measured on a 0-4 scale, where 4=highest risk.	Corruption can impact food availability through distortions and inefficiencies in the use of natural resources, as well as bottleneck inefficiencies in food distribution.
2.7	Urban absorption capacity	World Bank, World Development Indicators; EIU	2015-19	This indicator evaluates 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.	The capacity of a country to absorb the stresses placed on it by urban growth influences its ability to ensure food security.
2.8	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).	Higher levels of food loss reduce the overall food availability.
3) Quality & Safety					
3.1	Dietary diversity	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.
3.2	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	
3.2.1	National dietary guidelines	Qualitative scoring by EIU analysts based on WHO, FAO and national health ministry documents	2019	A binary indicator that measures whether the government has published guidelines and created a country-specific visual food guide to disseminate messages on a balanced and nutritious diet: 0 = No 1 = Yes	Dietary guidelines help to share messaging on balanced and nutritious diets.

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
3.2.2	National nutrition plan or strategy	Qualitative scoring by EIU analysts based on WHO, FAO and national health ministry documents	2019	A binary indicator that measures whether the government has a current, published national strategy to improve nutrition for children and adults: 0 = No 1 = Yes *A country receives credit if the national strategy was current within five years of October 2019. For example, a national strategy covering 2010-16 would receive credit; a strategy covering 2010-12 would not receive credit. Credit may also be assigned if there is clear evidence that an expired strategy is currently being re-implemented or updated.	Children and adults have different nutritional needs.
3.2.3	Nutrition monitoring and surveillance	Qualitative scoring by EIU analysts based on WHO, FAO and national health ministry documents	2019	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 A country receives credit if there is evidence from the past five years.	Monitoring the nutritional status enables the government to identify current nutritional deficiencies and deploy resources where needed.
3.3	Micronutrient availability	EIU scoring	-	A composite indicator that measures the availability of micronutrients in the food supply. Subindicators include: • Dietary availability of vitamin A • Dietary availability of iron • Dietary availability of zinc	
3.3.1	Dietary availability of vitamin A	Global Nutrient Database	2013	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	Vitamin A is a critical micronutrient for health; deficiencies can cause blindness, among other health issues.
3.3.2	Dietary availability of iron	Global Nutrient Database	2013	This indicator is expressed in mg/capita/day.	Iron is a critical micronutrient for health; deficiencies can cause anaemia, among other health issues.
3.3.3	Dietary availability of zinc	Global Nutrient Database	2013	This indicator is expressed in mg/capita/day.	Zinc is a critical micronutrient for health; deficiencies can compromise immune function and lead to infections.
3.4	Protein quality	EIU calculation based on data from FAO, WHO and US Department of Agriculture (USDA) Nutrient Database	2011-13	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.	Protein supply alone is an insufficient assessment of nutrition; there are nine essential amino acids which humans cannot synthesize and must consume through dietary sources.
3.5	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 Ability to store food safely	
3.5.1	Agency to ensure the safety and health of food	Qualitative scoring by EIU analysts	2019	Binary indicator that measures the existence of a regulatory or administrative agency to ensure the safety and health of food: 0 = No 1 = Yes	Oversight of sanitary operations helps to ensure safety of the food supply.

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
3.5.2	Percentage of population with access to potable water	World Bank	2017	The percentage of people at least using basic drinking water services.	A clean and consistent water supply is essential for food safety, for everything from washing produce to maintaining appropriate hygiene for food workers.
3.5.3	Ability to store food safely	United Nations	2017	Assesses access to refrigeration through a proxy indicator of the proportion of the population with access to electricity.	Food-borne illnesses are caused by a range of factors including appropriate food storage.
4) Natural Resources & Resilience					
4.1	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 (AAL) • Sea level rise • Commitment to managing exposure	
4.1.1	Temperature rise	ND-GAIN	2017	A measure of projected temperature rise based 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.	Temperature rise affects agricultural production, both in terms of types of crops able to be grown in the area and the quantity produced.
4.1.2	Drought	World Resources Institute (WRI) Aqueduct	2014	A measure of historic susceptibility of drought based on a 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	Susceptibility to drought can lead to unpredictable crop loss and declines in food supply in certain years.
4.1.3	Flooding	ND-GAIN	2017	A measure of projected susceptibility to flooding based 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.	Susceptibility to flooding can lead to unpredictable crop loss and declines in food supply in certain years.
4.1.4	Storm severity (AAL)	Global Assessment Report on Disaster Risk Reduction	2015	A measure of historical susceptibility to damage from storms (aside from flooding). 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.	Susceptibility to severe storms can lead to unpredictable crop loss and declines in food supply in certain years.
4.1.5	Sea level rise	ND-GAIN	2017	A measure of projected sea level rise. 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.	Sea level rise can lead to increased unpredictable crop loss and soil salinity, as well as declines in food supply in certain years.

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
4.1.6	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	National commitments to addressing exposure-related factors are a sign of political will and investments to mitigate these risks to agriculture.
4.2	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	
4.2.1	Agricultural water risk – quantity	WRI Aqueduct	2014	Assessment of the ratio of total annual water withdrawals to total available annual renewable supply. 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.	Overall water availability may influence agricultural water supply.
4.2.2	Agricultural water risk – quality	WRI Aqueduct	2014	Assessment of the risk that water might be polluted. 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.	Water pollution may impact the quality and availability of water for agricultural purposes.
4.3	Land	EIU scoring	-	A composite indicator that measures the health of land, and how land degradation might impact agriculture. Subindicators include: • Land degradation • Grassland • Forest change	
4.3.1	Land degradation	United Nations	2015	Proportion of land that is degraded over total land area.	Land degradation may impact the quality and availability of soil and arable land.
4.3.2	Grassland	FAO	2016	Assessment of greenhouse gas emissions from the drainage of organic soils (e.g. peatlands) under grassland based on a 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.	Grasslands act as carbon sinks that help to maintain organic matter in the soil. Loss of grasslands may impact the quality and availability of soil and arable land.
4.3.3	Forest change	World Bank	2001-16	Assessment of the health of forests based on a 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.	Forests help store groundwater and act as carbon sinks, preserving ecosystems. Loss of forests and ecosystems changes may impact agricultural productivity.
4.4	Oceans	EIU scoring	-	A composite indicator that measures the health of oceans, a crucial source of protein for many populations. Subindicators include: • Ocean eutrophication • Marine biodiversity • Marine protected areas	

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
4.4.1	Ocean eutrophication	WRI	2000-10	Assessment of the health of oceans. Landlocked countries receive the highest possible score. Qualitative measurement from 0-2: 0 = Coastal areas with high or extremely high coastal eutrophication potential 1 = Coastal areas with low-medium or medium-high coastal eutrophication potential 2 = Coastal areas with low coastal eutrophication potential	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.
4.4.2	Marine biodiversity	Yale Environmental Performance Index	2018	Assessment of the health of marine life through the overexploitation and collapse of fishing stocks. 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.	Falling fish stocks limit access to protein for populations whose diets are fish-dependent.
4.4.3	Marine protected areas	United Nations	2014	Assessment of the percentage of territorial waters that are protected areas. Measures the average proportion of Marine Key Biodiversity Areas (KBAs) covered by protected areas.	Preservation of protected waters helps to maintain marine ecosystems, which preserves fish as a food source while also protecting against overfishing.
4.5	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	
4.5.1	Food import dependency	FAO	2017	Assessment of how dependent a country is on cereal imports based on 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.	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.
4.5.2	Dependence on natural capital	World Bank	2017	Assessment of how dependent a country is on natural resources for economic output based on 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.	In countries dependent on natural resources, natural resource shortages could impact the economy and affect incomes, making it harder to purchase food.
4.5.3	Disaster risk management	United Nations	2017-18	Assessment of whether countries are co-ordinating their disaster risk management and their adaptation and mitigation measures. For countries not covered by the dataset, the EIU has undertaken qualitative research. Where information is not publicly available, the EIU has not given credit.	Adaptation and mitigation measures help to reduce the impact of natural disasters, which can impact both agricultural productivity and supply through storage, imports and exports.
4.6	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	
4.6.1	Early warning measures / climate smart agriculture	CCAFS	2017	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	Commitments to early-warning measures for agriculture can improve country resilience for climate and natural resource risks.

Indicator		Primary source(s)	Year	Indicator definitions and construction	Indicator rationale
4.6.2	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	Commitments to risk management practices for agriculture can improve country resilience for climate and natural resource risks.
4.7	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)	
4.7.1	Population growth (2016-21)	United Nations	2019	Forecast population growth based on linear transformation of data values (population growth percentage, 2016-21) to a fixed range of 0-100. The country with the lowest data value scores100 and the country with the highest data value scores 0.	Rapid population growth increases demand for food, straining food systems.
4.7.2	Urbanisation (2016-21)	United Nations	2019	Forecast urban growth based on 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.	Rapid urbanisation can disrupt food systems, putting strain on production and infrastructure.

5) Output variables

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 2008-2018	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 2008-2018	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.

Cover: Shutterstock

LONDON

20 Cabot Square
London, E14 4QW
United Kingdom
Tel: (44.20) 7576 8000
Fax: (44.20) 7576 8500
Email: london@eiu.com

GENEVA

Rue de l'Athénée 32
1206 Geneva
Switzerland
Tel: (41) 22 566 2470
Fax: (41) 22 346 93 47
Email: geneva@eiu.com

NEW YORK

750 Third Avenue
5th Floor
New York, NY 10017
United States
Tel: (1.212) 554 0600
Fax: (1.212) 586 1181/2
Email: americas@eiu.com

DUBAI

Office 1301a
Aurora Tower
Dubai Media City
Dubai
Tel: (971) 4 433 4202
Fax: (971) 4 438 0224
Email: dubai@eiu.com

HONG KONG

1301 Cityplaza Four
12 Taikoo Wan Road
Taikoo Shing
Hong Kong
Tel: (852) 2585 3888
Fax: (852) 2802 7638
Email: asia@eiu.com

SINGAPORE

8 Cross Street
#23-01 Manulife Tower
Singapore
048424
Tel: (65) 6534 5177
Fax: (65) 6534 5077
Email: asia@eiu.com