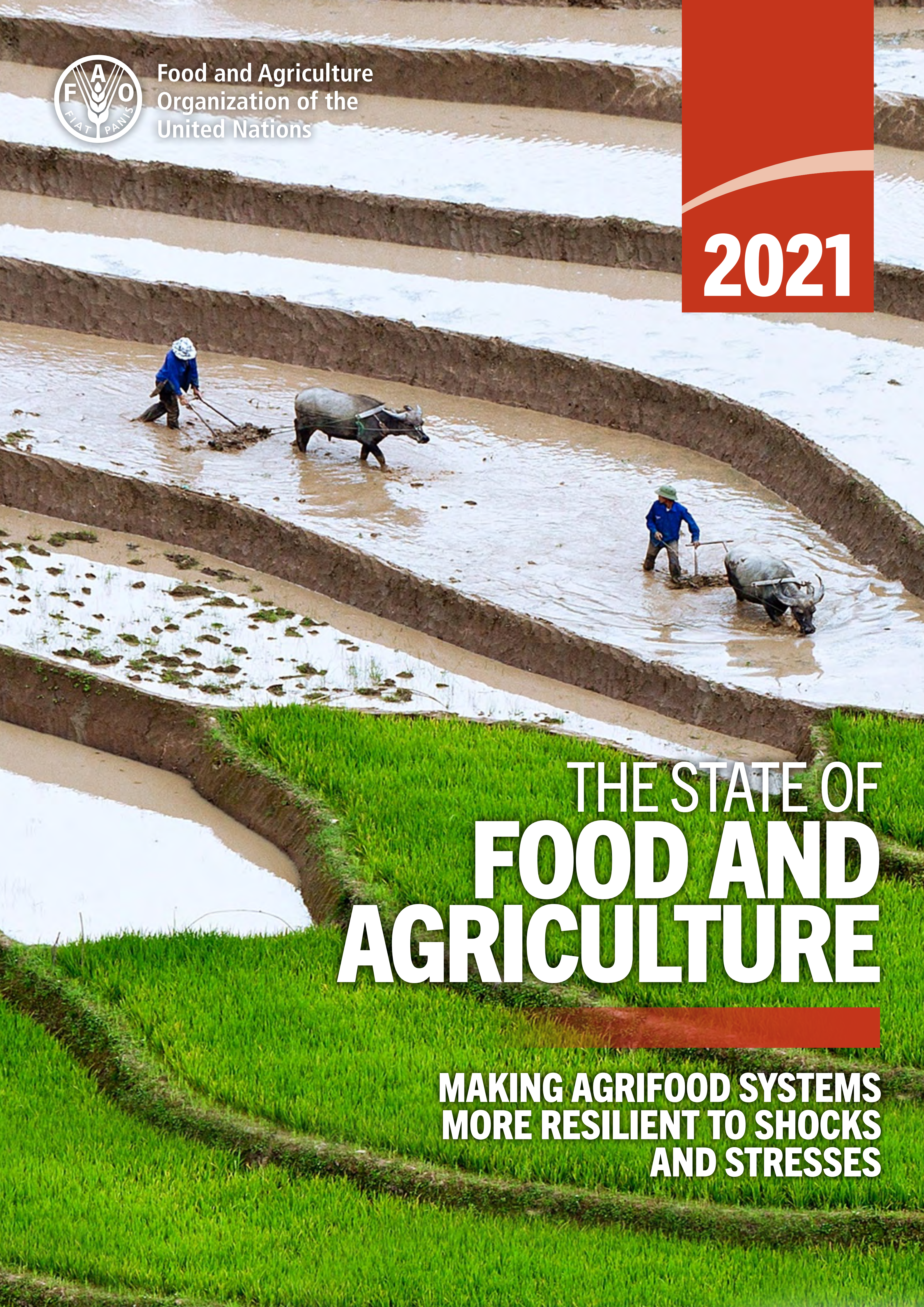

Food and Agriculture Organization of the United Nations

2021

THE STATE OF FOOD AND AGRICULTURE

MAKING AGRIFOOD SYSTEMS MORE RESILIENT TO SHOCKS AND STRESSES

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VIET NAM. Farmers working in terraced rice fields in Mu Cang Chai, Yen Bai.

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2021 THE STATE OF FOOD AND AGRICULTURE

MAKING AGRIFOOD SYSTEMS MORE RESILIENT TO SHOCKS AND STRESSES

Food and Agriculture Organization of the United Nations
Rome, 2021

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FOREWORD

The novel coronavirus disease (COVID-19) pandemic has had profound impacts on all our lives and we continue to struggle with it. Border closures and curfews to contain the spread of the SARS-CoV-2 virus stopped international travel, shut down countless businesses and left millions of people unemployed. Restrictions on the movement of people and goods, particularly in the initial stages of the pandemic, impeded the flow of inputs to farmers and of their produce to markets. Where harvesting and transport were blocked, huge quantities of fresh fruits and vegetables were left to decay in farmers' fields.

Restrictions have harmed not only agrifood trade, agrifood supply chains and agrifood markets, but also people's lives, livelihoods and nutrition. After initial disruptions and uncertainty, many supply chains showed a remarkable degree of resilience in absorbing and adapting to the shock caused by the pandemic; however, lack of access to adequate food for millions of people emerged as a huge and persistent problem. Many rural people were unable to travel for seasonal work – an important source of income in poor communities. Immobilized by lockdowns, low-income urban households saw their incomes and spending on food fall sharply.

Even before the COVID-19 pandemic, the world was not on track to meet the shared commitment to end global hunger and malnutrition in all its forms by 2030, but the pandemic has sent us even further off track. This year's *State of Food Security and Nutrition in the World* estimates that between 720 and 811 million people were affected by hunger in 2020, up to 161 million more than in 2019, with the increase largely propelled by the COVID-19 crisis. Tragically, women and children have often borne the brunt of the crisis. According to the *Sustainable Development Goals Report 2020*, the disruption of health services and access to adequate food has added to the toll of under-five and maternal deaths. The United Nations' *Policy Brief: The Impact of COVID-19 on Food Security and Nutrition* suggests that 370 million children have been denied school meals owing to school closures. There is no doubt that the impact of the pandemic on food security and nutrition will be felt for many years.

Agrifood production and supply chains have historically been vulnerable to shocks – from droughts and floods to armed conflict and food price hikes – and are under growing pressure from longer-term stresses, including the climate crisis and environmental degradation. But the COVID-19 pandemic is exceptional in that it has shown how a shock of global proportions can occur suddenly, spread rapidly and compromise the food security, nutrition status and livelihoods of billions of people to an unprecedented degree and over a long period.

The COVID-19 pandemic has left the fragilities of national agrifood systems widely exposed. An obvious reason to address these fragilities is, of course, the unwelcome increase in food insecurity and malnutrition. However, agrifood systems are too large for us to believe that their fragilities, if left unaddressed, will impede only the goal of achieving Zero Hunger by 2030, however crucial this objective may be. The implications go further. Agrifood systems produce 11 billion tonnes of food a year, employing 4 billion people directly or indirectly. The agrifood sector, including forestry and fisheries, also accounts for one-third of the anthropogenic greenhouse gas emissions driving climate change and occupies 37 percent of the Earth's land area. Agrifood systems have, therefore, an essential role to play in realizing other Sustainable Development Goals (SDGs) related to poverty, resource and energy efficiency, cleaner economies, and healthy aquatic and terrestrial ecosystems, among others.

International consensus has grown around the idea that transforming agrifood systems – towards greater efficiency, resilience, inclusiveness and sustainability – is an essential condition for realizing the 2030 Agenda for

Sustainable Development. Momentum for change led to the first ever United Nations Food Systems Summit in September 2021, which agreed on innovative solutions and strategies to transform agrifood systems and leverage those changes to deliver progress across all the SDGs. The Summit's call to action focused on five objectives, one of which is building resilience to vulnerabilities, shocks and stresses to ensure the continued functioning of healthy, sustainable agrifood systems.

The theme of this year's report responds to the United Nations Food Systems Summit's call to bring forward a series of concrete actions that people from all over the world can take to support transformation of the world's agrifood systems. More specifically, the report provides evidence and guidance on actions that can help actors in agrifood systems manage their vulnerability to shocks and stresses, and strengthen the capacity of these systems to support livelihoods and sustainably provide continuous access to sufficient, safe and nutritious food to all in the face of disruptions.

To this end, the Food and Agriculture Organization of the United Nations (FAO) has developed a suite of resilience indicators designed to measure the robustness of primary production, the extent of food availability, and the degree of people's physical and economic access to adequate food in countries worldwide. These indicators can help assess the capacity of national agrifood systems to absorb the impact of any shock, which is a key aspect of resilience. Analysis shows that a country's primary production sector is more resilient when it produces a diverse mix of food and non-food products and sells them to a wide range of markets, both domestic and international, a configuration mainly seen in higher-income countries or those with a large agrifood base. In terms of food availability, however, analysis of multiple sourcing pathways for crop, fish and livestock commodities shows that lower-income countries have a diversity that is comparable to that of larger, higher-income countries.

Another important aspect underscored by this report is that low-income countries face much bigger challenges in ensuring physical access to food through transport networks, key to keeping agrifood supply chains active. Analysis of data from 90 countries shows that if main transport routes were disrupted, many low-income countries in particular would have limited capacity to decentralize food distribution or use alternative delivery routes. For nearly half the countries analysed, the closure of critical network links would increase local transport time by 20 percent or more, thereby increasing costs and food prices for consumers.

Taking an agrifood systems approach, the report also notes that risks associated with economic access to food are even more worrisome. Globally, we already know that around 3 billion people cannot afford a healthy diet to protect against malnutrition. Since low-income households spend most of their income on food, any significant loss of purchasing power – from food price hikes, crop failures or loss of income – poses a threat to their food security and nutrition. In fact, this report finds that an additional 1 billion people are at risk as they would not be able to afford a healthy diet if a shock were to reduce their incomes by one-third. The burden of this shock would fall mostly on middle-income countries, but the report also notes that, in the event of such an income shock, proportionately many more people in low-income countries would be unable to afford even an energy-sufficient diet. These risks are unacceptable in a world that produces enough food to feed its entire population.

The report finds that diverse, redundant and well-connected agrifood supply chains are needed to increase resilience, as they provide multiple pathways for producing, sourcing and distributing food. However, some actors in these agrifood supply chains are more vulnerable than others. The vulnerability of small and medium agrifood enterprises (SMAEs) is critical, as well as the fact that the resilience capacity of rural households – especially those involved in small-scale agricultural production – is increasingly put to the test in the face of adverse climatic events and depletion of natural resources.

Based on the evidence of this report, FAO is in a strong position to recommend that governments make resilience in agrifood systems a strategic part of national and global responses to ongoing and future challenges. A guiding principle is diversity – input sources, production mixes, output markets and supply chains – because diversity creates multiple pathways for absorbing shocks. Connectivity multiplies benefits: well-connected agrifood networks overcome disruptions faster by shifting sources of supply and channels for transport, marketing, inputs and labour.

Governments should encourage better coordination and organization of SMAEs within agrifood supply chains through, for example, forming consortia, which increase their scale, visibility and influence. Similarly, small-scale food producers can stay competitive and resilient by integrating into supply chains through producer associations and cooperatives, and by adopting resource-conserving practices. Social protection programmes may be needed to improve rural households' resilience in the event of shocks. Policies should also address issues beyond agrifood systems, including the need for better health and education services, gender equality and women's participation, and must recognize agrifood's role as a steward of the natural environment.

FAO stands firmly committed to taking advantage of the opportunity offered by events such as the United Nations Food Systems Summit and others to move from commitments to action in order to transform agrifood systems to make them more efficient, more inclusive, more resilient and more sustainable for better production, better nutrition, a better environment and a better life for all, leaving no one behind. This report offers evidence and guidance to take concrete steps in this important direction.

Qu Dongyu
FAO Director-General

METHODOLOGY

The preparation of *The State of Food and Agriculture 2021* began with a workshop that was held virtually on 26–30 October 2020 and attended by FAO specialists and external experts to discuss the outline of the report. Following the workshop, an advisory group representing all relevant FAO technical units was formed and, together with a panel of external experts, it assisted the research and writing team. The preparation of the report was informed by four background papers and original empirical analysis prepared by FAO and external experts. The advisory group met virtually to discuss the research on 26 January 2021 and commented on the first draft of Chapter 1 in February 2021. Drafts of the chapters were presented to the advisory group and panel of external experts in advance of a workshop held virtually on 10–16 March 2021 and chaired by the Deputy Director of FAO's Agrifood Economics Division. With guidance from that workshop and a follow-on advisory group meeting, the report was revised and presented to the management team of FAO's Economic and Social Development stream. The revised draft was sent for comments to other FAO streams and to the FAO regional offices for Africa, Asia and the Pacific, Europe and Central Asia, Latin America and the Caribbean, and the Near East and North Africa. Comments were incorporated in the final draft, which was reviewed by the Deputy Director of FAO's Agrifood Economics Division, the FAO Chief Economist and the Office of the Director-General.

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RESEARCH AND WRITING TEAM

Theresa McMenomy, Fergus Mulligan (consulting editor), Ahmad Sadiddin, Jakob Skøt, Graeme Thomas (consulting editor) and Sara Vaz.

BACKGROUND PAPERS AND DATA ANALYSIS

Imran Ali (CQUniversity), Mark Brussel (University of Twente), Mark Constas (Cornell University), Ellestina Jumbe (FAO), Rolf de By (University of Twente), Marco d'Errico (FAO), Serkan Girgin (University of Twente), Vu Minh Hien (FAO), John Hoddinott (Cornell University), Hong Anh Luu (FAO), Andy Nelson (University of Twente), Robert Ohuru (University of Twente), Rebecca Pietrelli (FAO), Jeanne Pinay (FAO), Thomas Reardon (Michigan State University), Alessandro Tavoni (University of Bologna), Tom Thomas (University of Twente), Valentijn Venus (University of Twente) and David Zilberman (University of California, Berkeley).

ADDITIONAL FAO INPUTS

Abram Bicksler, Adriana Ignaciuk, Giorgo Grussu, Yuka Makino, Dario Lucantoni, Anne Mottet, Beate Scherf and Antonio Scognamillo.

FAO ADVISORY GROUP

Fenton Beed, Dubravka Bojic, Ben Davis, Marco d'Errico, Ana Paula de la O Campos, Kim Friedman, Stepanka Gallatova, Giorgo Grussu, Panagiotis Karfakis, Michelle Kendrick, Preetmoninder Lidder, Yuka Makino, Roman Malec, Erdgin Mane, Zitouni Oulddada, Rebecca Pietrelli, Pilar Santacoloma, Guido Santini, Nick Sitko, Beate Scherf, Josef Schmidhuber, Kostas Stamoulis, Salar Tayyib, Jim Tefft, José Valls Bedeau and Sylvie Wabbes Candotti.

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Imran Ali (Central Queensland University Melbourne), Mark Constas (Cornell University), Ika Darnhofer (University of Natural Resources and Life Sciences, Vienna), Rolf de By (University of Twente), Paolo D'Odorico (University of California, Berkeley), John Hoddinott (Cornell University), Helena Kahiluoto (LUT University), Matti Kummu (Aalto University), Andy Nelson (University of Twente), Mohan Rao (University of Massachusetts Amherst), Thomas Reardon (Michigan State University), Donato Romano (University of Florence), David Seekell (Umeå University), Jamie Stone (Biotechnology and Biological Sciences Research Council), Alessandro Tavoni (University of Bologna), Paul Winters (University of Notre Dame) and David Zilberman (University of California, Berkeley).

ANNEXES

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ACRONYMS AND ABBREVIATIONS

AA	Anticipatory Action
BFA	biodiversity for food and agriculture
CSA	climate-smart agriculture
COVID-19	novel coronavirus disease
DSFI	dietary sourcing flexibility index
FAO	Food and Agriculture Organization of the United Nations
GHG	greenhouse gas
HLPE	High Level Panel of Experts
ICT	information and communications technology
LLDC	landlocked developing country
MFI	midstream flexibility index
MICS	multiple indicator cluster surveys
MPP	Mountain Partnership Products
NGO	non-governmental organization
PPFI	primary production flexibility index
R&D	research and development
RCI	resilience capacity index
RIMA	resilience index measurement and analysis
SDGs	Sustainable Development Goals
SIDS	small island developing States
SMAE	small and medium agrifood enterprise
TAPE	tool for agroecology performance evaluation
UN	United Nations
WASH	water, sanitation and hygiene
WHO	World Health Organization

GLOSSARY

Agricultural household. A household that derives any income, however minimal, from agriculture or contributes some labour input to agricultural production.[1]

Agricultural innovation. The process whereby individuals or organizations bring new or existing products, processes or ways of organization into use for the first time in a specific context in order to increase effectiveness, competitiveness, resilience to shocks or environmental sustainability and thereby contribute to food security and nutrition, economic development or sustainable natural resource management.[2]

Agrifood systems. Encompass the entire range of actors, and their interlinked value-adding activities, engaged in the primary production of food and non-food agricultural products, as well as in storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, disposal and consumption of all food products including those of non-agricultural origin.

- **Food systems.** Comprise all food products that originate from crop and livestock production, forestry, fisheries and aquaculture, and from other sources such as synthetic biology that are meant for human consumption.

Agrifood systems' resilience. The capacity over time of agrifood systems, in the face of any disruption, to sustainably ensure availability of and access to sufficient, safe, and nutritious food for all, and sustain the livelihoods of agrifood systems' actors.[a]

Agroecology. An integrated approach that simultaneously applies ecological and social concepts and principles to optimize interactions between plants, animals, humans and the environment while addressing social aspects to achieve sustainable and fair agrifood systems.[4]

Biodiversity for food and agriculture (BFA). The variety and variability of animals, plants and micro-organisms at the genetic, species and ecosystem levels that sustain ecosystem structures, functions and processes in and around production systems and provide food and non-food agricultural products.[5]

Climate-smart agriculture (CSA). An approach to guide actions to transform and reorient agricultural systems to effectively support development and ensure food security under a changing climate through: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and mitigating greenhouse gas emissions.[6]

Covariate shock. An event that directly affects groups of households, communities, regions or even entire countries.[7]

Event. The manifestation of threats and hazards or disturbances, or a combination thereof, in a particular place and in a specific period of time.[8, 9]

Exposure. The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.[8]

Food safety. The assurance that food will not cause adverse health effects to the consumer when prepared or eaten according to its intended use.[10]

Food security. The situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Four traditional dimensions can be identified (food availability, economic and physical access to food, and food utilization), as well as the two additional dimensions of agency and sustainability that are proposed by the High Level Panel of Experts (HLPE) of the Committee on World Food Security (CFS) but are not formally agreed upon by FAO or other bodies, nor is there an agreed language on the definition.[11, 12]

Food supply chain. Consists of a connected series of activities encompassing the primary production of food from crops, livestock, forestry, fisheries and aquaculture; and the value-adding activities of storage, transportation, processing; wholesale

a This definition is adapted from Tendall *et al.* (2015).[3]

and retail distribution. This definition differs from that of "food value chains" as proposed by FAO (2014) by excluding food consumption and disposal.[13]

- **Traditional food supply chains.** Spatially short involving a small number of small-scale producers, intermediaries and micro to small enterprises using labour-intensive technology and relying on spot markets. They handle locally produced food with basic processing, storage, logistics and other post-farm activities.
- **Transitional food supply chains.** Spatially long, with many small-scale producers and small to medium enterprises and intermediaries, such as processors, wholesalers and retailers who are fragmented; product diversification and value-addition are relatively high; contracts are used although spot market relations still prevail.
- **Modern food supply chains.** Serve large urban populations; spatially short, long or very long (including transnational); dominated by supermarkets and large processors; technology is largely capital-intensive where cold storage, packaging and private quality standards are very common; contracts dominate but spot markets are used for perishables.

Hazard. A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental degradation.[9]

Household. A group of people, related or not, living together in the same dwelling, amenable to the same household head, and sharing food, food expenses, income and other household assets.

Idiosyncratic shock. An event that affects individuals or households.[7]

Net food consumer. Individual whose total sales of food to the market are less than purchases of food from the market.[14]

Net food producer. Individual whose total sales of food to the market exceed total purchases of food from the market.[14]

Redundancy. The duplication of critical components or functions of a system that increase its reliability. Often refers to backup systems or processes such that, if one part fails, the system as a whole will still be able to function. Examples of relevance for agrifood systems include spare inventory capacity at the firm level, alternative transport routes between stages or backup infrastructure at supply chain level and strategic food stocks at national level. Incorporating redundancy within a system typically entails a cost that needs to be weighed against how much it improves system performance.[15–17]

Resilience. The ability of individuals, households, communities, cities, institutions, systems and societies to prevent, anticipate, absorb, adapt and transform positively, efficiently and effectively when faced with a wide range of risks, while maintaining an acceptable level of functioning, without compromising long-term prospects for sustainable development, peace and security, human rights and well-being for all.[18]

Resilience capacities. Systems, institutions and people are considered resilient when they have at their disposal the following distinct capacities, many of which overlap. They are crucial to manage multiple risks and to withstand, cope with and recover from adverse events.[8]

- **Preventive capacity.** The ability to take measures to reduce exposure and vulnerability to shocks and stresses, i.e. to reduce existing risks and avoid creating new ones.[9]
- **Anticipative capacity.** The ability to take early action in anticipation of a threat to reduce its potential negative impacts, through early warning, early action or forecast-based financing.[19]
- **Absorptive capacity.** The ability to withstand shocks and stresses and bounce back afterwards using predetermined responses to preserve and restore essential basic structures and functions.[20–22]
- **Adaptive capacity.** The ability to make incremental adjustments and changes to the structure and actions of a system, to preserve its core functions without major changes in functional or structural identity.[21–24]

- **Transformative capacity.** The ability to create fundamentally new systems when ecological, economic or social structures make the existing ones untenable.[23, 25] Transformative capacity is required when the change needed goes beyond systems' anticipatory, preventive, absorptive and adaptive capacities and when there is recognition that ecological, economic or social structures trap people in a vicious circle of poverty, disasters and conflict, making current systems unsustainable.[26]

Risk. The potential of shocks and stresses to negatively affect systems, communities, households, or individuals. Risk is a function of hazard, exposure, vulnerability and capacity and accounts for the probability of direct and indirect social, economic and environmental costs of shocks and stresses.[9, 27]

Rural livelihood. The capabilities, assets and activities that rural people need to make a living.[28]

Shocks. Short-term deviations from long-term trends that have substantial negative effects on a system, people's state of well-being, assets, livelihoods, safety and ability to withstand future shocks.[8, 29] Shocks impacting on food systems include disasters, extreme climate events, biological and technological events, surges in plant and animal diseases and pests, socio-economic crises and conflicts. Shocks may be covariate or idiosyncratic.

Small and medium agrifood enterprises (SMAEs). These are independent post-harvest agrifood businesses (e.g. food processing, storage, transport or distribution) whose revenues, assets and number of employees are below a certain threshold. They are seen as more vulnerable and require special attention from both policy and research perspectives.[30, 31]

Small-scale producers. They comprise households running small-scale agricultural businesses of crops, livestock, fisheries, aquaculture, pastoralism or forestry, operating under greater constraints due to limited access to markets and resources such as land and water, information, technology, capital, assets and institutions.[32]

Stresses. Long-term trends or pressures that undermine the stability of a system and increase vulnerability within it. Stresses can result from natural resource degradation, urbanization, demographic pressure, climate variability, political instability or economic decline.[33]

Sustainable agrifood systems. Systems that deliver food security and nutrition for all, while sustaining the livelihoods of agrifood systems' actors, without compromising the economic, social, and environmental bases for the food security and nutrition of future generations. Systems must be sustainable economically (i.e. profitable and equitable), socially (having broad-based benefits for society) and environmentally (with positive or neutral impact on the natural environment).[34]

Sustainable development. The management of economic, social and environmental resources and technological and institutional change, to attain and continue to meet the human needs of present and future generations.[35]

Uncertainty. Refers to a situation where no probability can be assigned to outcomes of shocks and stresses, either because relevant information and data are missing (i.e. the outcomes cannot be measured or inferred based on past information and modelling), or the outcome is completely unforeseeable because it results from an unpredictable shock.

Vulnerability. The conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an individual, a community, assets or systems to the adverse impacts of shocks and stresses.[9]

CORE MESSAGES

1 To preserve their functionality and ensure the food security, nutrition and livelihoods of millions of people, agrifood systems must become more resilient to increasing shocks and stresses of diverse origins, both biophysical and socio-economic.

2 Because agrifood systems are complex – including primary production, food supply chains, domestic transport networks and households – and involve many interlinked actors, a shock in any component can spread rapidly throughout systems.

3 The fragility of agrifood systems can affect large numbers of people: already 3 billion people cannot afford a healthy diet and an additional 1 billion would join their ranks if a shock reduced their income by one-third. Food costs could increase for up to 845 million people if a disruption to critical transport links were to occur.

4 Of the five distinct resilience capacities agrifood systems must have – to prevent, anticipate, absorb, adapt and transform – absorptive capacity is critical in confronting unforeseen shocks and is complementary to risk management of shocks that can be anticipated.

5 Key to building the absorptive capacity of agrifood systems is diversity in food sources (domestic production, imports or existing stocks), diversity of actors in food supply chains, redundant and robust transport networks, and affordability of a healthy diet for all households, particularly the poorest and most vulnerable.

6 Risk management strategies for shocks such as droughts, floods and pests – including multi-risk assessments, timely forecasts, early warning systems and early action plans – are key to help all agrifood systems' actors prevent and anticipate major disruptions to systems and avoid human suffering and costly recovery interventions.

7 Enhancing the resilience of food supply chains requires government support to develop small and medium agrifood enterprises, cooperatives, consortia and clusters, as well as social protection programmes.

8 Resilience capacities of rural low-income households, in particular small-scale producers whose livelihoods are increasingly vulnerable to climate shocks and depletion of natural resources, can be significantly strengthened through education, non-farm employment and cash transfers.

9 Ensuring economic access to sufficient food for a healthy diet at all times is a key dimension of agrifood systems' resilience. Policies and investments that reduce poverty, generate decent employment and expand access to education and basic services, as well as social protection programmes when needed, are essential building blocks of resilience.

10 Building resilient agrifood systems should be a key policy objective and must ensure that all agrifood systems' components function well over time. This requires mainstreaming resilience in agrifood policies and greater coordination across all relevant sectors and layers of government institutions to ensure policy coherence.

EXECUTIVE SUMMARY

RESILIENT AGRIFOOD SYSTEMS ARE A STRATEGIC PART OF THE WORLD'S RESPONSE TO ONGOING AND FUTURE CHALLENGES

Agrifood systems encompass primary agricultural production of food and non-food products (from crops, livestock, fisheries, forestry and aquaculture), the production of food of non-agricultural origin (e.g. synthetic meat), the food supply chain from producer to consumer and the final consumer of food. Globally, these systems produce some 11 billion tonnes of food each year and form the backbone of many economies. In an ideal world, agrifood systems would be resilient, inclusive and sustainable, producing sufficient, safe and nutritious food for all, and generating livelihoods that guarantee people's economic access to that food. Today, however, agrifood systems fail to keep about 10 percent of the world's population free from hunger.

Increasingly, food supply chains and the livelihoods of agrifood systems' actors are disrupted by shocks – from droughts and floods to armed conflict and food price hikes – and long-term stresses, including climate change and environmental degradation. Risk and uncertainty are inherent in agrifood systems, affecting both primary production and their middle and downstream food supply components, as well as all actors at all stages. The vulnerability of agrifood systems became starkly clear in 2020, when measures to contain the novel coronavirus disease (COVID-19) pandemic disrupted global and national supply chains and caused economic downturns in many countries. Loss of purchasing power harmed the food security and nutrition of billions of people, particularly in low-income countries and among the poorest.

Truly resilient agrifood systems address all dimensions of food security

This report examines the challenge of building more resilient agrifood systems. Drawing on the *UN Common Guidance on Helping Build Resilient Societies*, it defines agrifood systems' resilience as "the capacity over time of agrifood systems, in the face of any disruption, to sustainably ensure availability of and access to sufficient, safe and nutritious food for all, and sustain the livelihoods of agrifood systems' actors".

Whether traditional, modern or transitioning between the two, agrifood systems have three main components: (i) primary production; (ii) food distribution, linking production to consumption through food supply chains and transport networks; and (iii) household consumption, including intra-household food distribution. Key actors are: primary producers; those providing input supply, post-harvest, storage, transport and food processing services; food distributors, wholesalers and retailers; and households and individuals as final consumers.

Truly resilient agrifood systems must have a robust capacity to prevent, anticipate, absorb, adapt and transform in the face of any disruption, with the functional goal of ensuring food security and nutrition for all and decent livelihoods and incomes for agrifood systems' actors. Such resilience addresses all dimensions of food security, but focuses specifically on stability of access and sustainability, which ensure food security in both the short and the long term. Another dimension of food security – agency – is deeply connected to human rights, including the right to food, and underscores the need for inclusiveness in systems.

Shocks have immediate impact, while stresses gradually undermine systems' coping capacity

Compared to other economic sectors, agriculture is disproportionately exposed and vulnerable to adverse natural hazards, especially those climate related. Climate change drives short-term shocks, such as extreme weather events, and generates slow-onset stresses, such as higher temperatures and loss of biodiversity. Shocks have immediate impact, while stresses are slow processes that gradually undermine the capacity of systems to cope with change and which render them more vulnerable. Agrifood systems' components and actors are exposed to shocks and stresses of various types and intensity and, because components are interlinked, disruption in any of them can spread quickly throughout systems. The same shock or stress may have different impacts on different systems' components and actors. Among producers, shocks are most likely to affect the livelihoods of low-income, small-scale operators; among food consumers, the poorest will be the most affected by rising food prices.

Risk management strategies that reduce exposure and vulnerability to a known, specific shock – such as drought preparedness – help build agrifood systems' resilience. However, the COVID-19 crisis has shown that some shocks are unpredictable in terms of timing and extent. Agrifood systems must have the capacity to continue functioning in the presence of shocks that are not foreseeable. Building resilience is, therefore, more than risk management: resilient agrifood systems are a strategic component of the world's response to ongoing and future challenges.

The ability to withstand shocks and stresses and bounce back is key in an uncertain environment

A key focus of the report is building the capacity of agrifood systems to absorb the impacts of shocks and stresses. Absorptive capacity refers to the ability to withstand shocks and stresses and bounce back in the aftermath, using predetermined responses to preserve and restore essential basic structures and functions. It is particularly important to address unforeseeable shocks.

Shocks and stresses can be very different in nature and origin. The magnitude of their impact is shaped by the specific vulnerabilities and resilience capacity of agrifood systems' components and actors, as well as the surrounding context (including climatic, environmental, socio-economic and political dimensions) and external sectors, such as energy and health. Complex, bidirectional linkages between the different systems' components mean that disruptions to food production eventually impact on household food security, while shocks affecting food consumption can ripple back to affect producers; this in turn will affect the environment.

In low-income countries, agricultural households with limited access to farm insurance and credit often rely on crop diversification and crop–livestock integration to mitigate the risks associated with climate variability and market volatility. However, diversification foregoes specialization, a strategy that allows households to accumulate experience. This raises the issue of the potential trade-off between building resilience through diversification, on the one hand, and efficiency, on the other. Another effective resilience strategy is redundancy, which reinforces the capacity of agrifood systems to absorb shocks by duplicating critical components and functions. However, this same redundancy can be costly to society and is particularly challenging when resources are limited.

UNDERSTANDING SYSTEMS' FUNCTIONS AND VULNERABILITIES

The report analyses the absorptive capacity of agrifood systems at the national level using a series of indicators linked to four key systems' functions, that is, to ensure: (i) robust primary production; (ii) availability of food; (iii) physical access to food; and (iv) economic access to food. Each national system is unique, comprising numerous components and actors, operating on several interlinked levels, and often including international trade. Some components may be more resilient than others and the impacts of shocks may be component or actor specific. Policymakers need to understand systems' functioning and be aware of potential vulnerabilities. A participatory, inclusive and collaborative process may then help engage systems' participants in a more coordinated response to challenges.

Diversity in production and trade partners can help minimize risk

To measure the capacity of primary producers to absorb shocks, FAO developed a primary production flexibility index (PPFI) for this report, covering 181 countries, to measure the extent of diversity in production across crop and livestock commodities and the potential to produce for domestic and export markets. A high PPFI value indicates multiple potential pathways for generating agricultural value and for finding final outlets for primary food production. For more than 80 percent of countries, the PPFI is driven by domestic market diversity, and countries with the lowest diversity values are strongly skewed towards the domestic market. Most are low-income countries, with little external trade, where primary production is vulnerable to shocks that affect key commodities or reduce consumers' incomes. Greater diversification in primary production is found in high-income countries or in those with a large agricultural base. These countries rely on a mix of comparative advantage in producing and exporting agricultural products, openness to international trade, and a sizeable domestic demand for marketing their products.

Not all agricultural powerhouses are exempt from vulnerabilities: even countries with a sizeable agricultural base and export demand may reveal a low capacity to absorb shocks if the number of trading partners is limited. If those partners suffer a shock, the country is left with limited options. It can also be indicative of specialization in very few export commodities, which increases vulnerability to commodity-specific domestic shocks, such as pests, and to international shocks, such as sharp price declines due to oversupply.

An important function of agrifood systems is to make available a diverse range of foods that provide the nutrients essential for human health. To measure their capacity to absorb shocks and ensure the availability of food necessary for a nutritious diet, FAO also developed the dietary sourcing flexibility index (DSFI) for this report, computed with data for 153 countries. The indicator captures the multiple sourcing pathways of crop, fish and livestock commodities available from domestic production, food imports and available stocks. What emerges is that countries diversify their sources of food in different ways and effectiveness in diversifying does not depend on country size or income level. Where income does matter is in diversifying sources of fruits and vegetables, which is limited in low-income countries due to logistical constraints associated with transporting and storing perishables.

Countries with a sizeable agricultural base that rely more on domestic production may have the same absorptive capacity as countries that diversify more through imports. Those importing from multiple trade partners and across multiple commodities attain among the highest DSFI scores by buffering any supply shocks over many partners and commodities. Conversely, countries dependent on food imports from only a few major sources are vulnerable to shocks that hit their trading partners. In this case, diversifying import baskets and international trade partners, and possibly investing in domestic stocks, would be prudent.

Ensuring physical and economic access to food is a key aspect of agrifood systems' resilience

An efficient, flexible transport network with optimal redundancy guarantees physical access to food at subnational level. To capture the structural vulnerabilities of food transport networks around the world, FAO analysed their resilience in 90 countries, by examining how transport networks connect food demand nodes to where food is produced. The analysis measured food systems' capacity to respond locally to disruptions, the availability of alternative routes, and systems' sensitivity to the closure of critical links owing to shocks or stresses. While several very large countries had long distribution networks, food production and distribution in others could be adjusted to more locally based systems, if needed.

Low-income countries face the biggest challenges in applying system-wide resilience measures to their food transport networks. They have limited capacity to adjust to local systems and lack reliable alternative routes during disruptions. Since proximity-based resilience depends on how production is distributed relative to demand, some large, high-income countries are also vulnerable. For nearly half the countries analysed, the closure of critical network links would increase local travel time by 20 percent or more, increasing food costs.

Providing physical access to food is not enough to ensure food security. Well-functioning agrifood systems must also ensure people's economic access to food. Globally, some 3 billion people cannot afford a healthy diet, one that protects against malnutrition in all its forms. Since the share of household expenditure on food is highest in low-income households, any significant loss of purchasing power – caused by disruptions such as food price spikes, crop failures and loss of assets – poses a threat to their food security and nutrition. Based on data for 143 countries, FAO also developed an indicator for this report revealing that, if a shock reduced their income by one-third, a healthy diet would be beyond the financial reach of an additional 1 billion people. The burden of this additional challenge would fall mostly on middle-income countries: out of the 1 billion people at risk of not being able to afford a healthy diet, 95 percent live in lower- and upper-middle-income countries. In low-income countries – where already a large majority cannot afford a healthy diet – the challenge is that, in the face of the same one-third cut in income, many more people risk not being able to afford even an energy-sufficient diet, consisting mainly of starchy staples that provide the energy needed for a day's work.

When incomes are affected by a shock, truly resilient, inclusive and sustainable agrifood systems must aim at ensuring the affordability of a healthy diet. To achieve that, either the cost of food must come down, or the incomes of the vulnerable population must increase or be supported through, for example, social protection programmes – or, ideally, both.

DIVERSE, REDUNDANT, WELL-CONNECTED FOOD SUPPLY CHAINS UNDERPIN RESILIENCE

Labour shortages during COVID-19 lockdowns exposed the vulnerability of small and medium agrifood enterprises

The smooth functioning of food supply chains underpins the resilience of national agrifood systems. A food supply chain is composed of interconnected activities performed by various actors – farmers, processors, wholesalers and retailers – who, in turn, draw on lateral chains that supply inputs and logistic services. The capacity of a food supply chain to absorb shocks depends on the resilience of each of its segments. Diverse, redundant and well-connected food supply chains enhance agrifood systems' resilience by providing multiple pathways for producing, sourcing and distributing food. This resilience is necessary not only for safeguarding and enhancing the livelihoods of farmers and businesses, but also for ensuring the physical availability of food to all.

The vulnerabilities and resilience capacities of food supply chains are shaped largely by their structural characteristics and product attributes. Traditional chains are spatially short, involve a small number of local intermediaries, but lack product diversification, quality and safety standards, and economies of scale. Transitional supply chains are spatially longer, with many small and medium agrifood enterprises (SMAEs) handling midstream processing and distribution. Modern chains, which supply large urban populations mainly with horticultural and animal products, are dominated by multinationals in their midstream and downstream segments.

Understanding how shocks and stresses are likely to affect a given food supply chain is the key to developing resilience capacities that mitigate damage and provide recovery options. Large-scale modern food supply chains proved resilient to COVID-19 lockdowns because they operate on a global scale, with the capacity to adjust to disruptions geographically and temporally. Transitional supply chains, with their multitude of SMAEs and heavy reliance on labour, were more vulnerable to labour and transport disruptions. There is also evidence that some traditional supply chains filled gaps left by modern and transitional chains disrupted by lockdowns. Many proved to be nimble in their responses, especially in high-income countries. However, traditional supply chains are usually more vulnerable because, as they are often highly informal, they are invisible in national statistics, and government support and social protection programmes do not reach them.

Resilience-building strategies may involve trade-offs with efficiency and inclusiveness

Agrifood businesses are heterogeneous in terms of economic scale, input composition, technology use and outputs, which range from bulk food commodities to niche items and differentiated products. They have different capacities to bear risk and make resilience-building investments. Businesses may adopt diversification or redundancy strategies, or both. For example, the world's biggest rice milling firm has built two ports upriver from its primary port in Thailand to guarantee shipping movements in the event of a typhoon; this is a representative case of the trade-off between efficiency and resilience. To reduce such trade-offs, businesses may seek partnerships with other, complementary companies. But this may not be feasible for SMAEs, which face the double challenge of being resilient to shocks while also remaining competitive with larger enterprises. What they gain in resilience and agility, they may lose in access to lucrative markets.

Essential to all these strategies is public infrastructure – roads, culverts, power lines, running water, irrigation schemes and ports – that helps to avert or buffer shocks. Producers and food chain actors located in agricultural territories with well-developed infrastructure will have greater absorptive capacity. Increasingly, public infrastructure is complemented by private infrastructure, such as collection stations, road hauliers and temperature-controlled warehouses. Businesses with the capacity to make the necessary investments and bear the risks will survive and outcompete those with less capacity, adding momentum to the competitive forces that are concentrating the off-farm segments of food supply chains in fewer hands. Agrifood businesses, farmers and agricultural territories that are excluded in this way lose their crucial link to urban and export markets and find themselves in a poverty trap, where the confluence of market and climate changes makes them especially vulnerable. The social cost of unemployment and lost livelihoods incurred as SMAEs are driven out of business may outweigh gains from the increased resilience of large-scale firms.

The limited resources available to small-scale producers and SMAEs in food supply chains often make recovery following a disruption more difficult. Improving public infrastructure, along with easier access to credit and information, can create synergies between efficiency and resilience that accelerate recovery. Governments can also support better coordination and organization of SMAEs within food supply chains. One approach is to form consortia, which increase the scale, visibility and influence of small businesses and facilitate access to private and government funding. Nurturing inter-organizational relationships in networks or strategic alliances can generate relational, structural and cognitive capital, promote more robust and effective risk management through resource pooling, and improve access to modern technologies and know-how. Another way of encouraging coordination and enhancing relational capital among SMAEs is through territorial development tools such as clusters. In countries where credit markets are imperfect or underdeveloped, enhancing industrial clusters can contribute to easing credit constraints. Consortia and clusters are also excellent facilitators of human development programmes and the diffusion of digital technologies.

ROBUST RURAL LIVELIHOODS STRENGTHEN ENTIRE SYSTEMS

The resilience capacities of all households are important for the functioning of agrifood systems. All households have a role to play in agrifood systems, whether as food producers and suppliers or as consumers. The resilience capacities of rural households – especially low-income small-scale farm families – are particularly and increasingly put to the test in the new normal of climate change and depletion of natural resources. While they often engage in non-farm activities, many rural people depend mainly on agriculture for their livelihoods. The impacts of shocks and stresses on those livelihoods, and consequently on people's food security and nutrition, play out essentially within households. Hundreds of millions of farming households contribute to agrifood systems, through primary food production and small-scale agrifood businesses. Rural households that engage in diverse and multiple activities are generally better able to cope with, and recover from, stresses and shocks.

Households that are net food producers are more vulnerable to shocks and stresses that affect agricultural and food production, such as pests and diseases, drought, and disruptions to input and food marketing chains. On the other hand, households that are net food consumers – practising farming as a part-time activity and relying on employment mainly in the non-farm economy – are more prone to shocks such as price spikes that affect their purchasing power. Households running small-scale agrifood businesses operate under greater constraints than their larger competitors due to more limited access to information, technology, capital, assets and institutions. They bear a double burden of vulnerability to risks and shocks: while facing those intrinsic to agriculture, they also risk being excluded from productive assets and lucrative markets in the accelerating modernization of food supply chains in developing countries.

Education, non-farm work and cash transfers help rural households cope better with shocks and stresses

Rural households have developed a variety of strategies to help navigate foreseen and unforeseen disruptions and strengthen their capacity to prevent, anticipate, absorb, adapt and transform. At farm level, households respond to the unpredictable interplay between natural, technological and social factors by reconfiguring and using available resources in novel ways. To reduce risks and mitigate the impacts of shocks before they occur, they diversify production mixes, adjust planting dates to cope with rainfall variability, and invest in risk reduction by improving irrigation, drainage and pest control and adapting land use practices to reduce soil erosion. They diversify their sources of income through part-time employment in the rural non-farm economy. Households also have coping mechanisms for the aftermath of shocks: they cover their losses and smooth out their consumption by liquidating assets, taking out loans or drawing on savings and informal insurance based on community networks. However, coping strategies that reduce household assets run the risk of aggravating vulnerability by undermining future income-generating capacity.

FAO's resilience index measurement and analysis (RIMA) model was used to identify the main factors underpinning resilience in rural households in 35 countries. Findings from 23 countries indicate that education, income diversification and cash transfers mainly drove gradual improvements in resilience capacity. Analysis of another 12 countries showed that in more than half of cases, the most important pillar of resilience was access to productive and non-productive assets. Also important to household resilience was adaptive capacity, which depended critically on education and human capacity development within the household. Access to basic services, such as improved sanitation and safe drinking water, and primary services, especially schools, hospitals and agricultural markets, provided important support to household resilience, particularly in very arid zones and in pastoralist households.

The RIMA analysis also showed that rural households comprising mainly women pay the heaviest toll during and after shocks. Women tend to have much less access than men to land and other assets that are crucial for resilience. Children are particularly vulnerable to shocks and stresses. Studies show that widespread shocks increase the rates of stunting and underweight among children under two years of age. Since child nutrition status is associated with performance in cognitive tests, school attainment and labour market outcomes later in life, shocks may generate substantial, long-term economic costs to both individuals and society.

Small-scale producers need organization, sustainable practices and social protection

To stay competitive and protect their livelihoods, small-scale agricultural producers need to be well integrated in supply chains for food, inputs and services. One means of achieving this integration is producer associations and cooperatives, which reinforce livelihoods by allowing the pooling of resources to achieve scale, facilitating access to productive resources such as machinery, equipment and credit, and enhancing marketing power. Coordination with other actors in the food supply chain is also key to managing market risks. Mutual benefits can be achieved, for example, through forward contracts: farmers receive guaranteed prices for their outputs regardless of market conditions, while processors and distributors receive products of a desired quality.

Another resilience-enhancing strategy that small-scale farming households use increasingly is the adoption of more sustainable production practices. One option is agroecology, an approach that applies ecological and social principles to the design and management of agrifood systems. An important element of agroecology is food and agricultural biodiversity, which boosts resilience to shocks and stresses, facilitates adaptation, maintains stability and supports recovery from disturbances. Another option is climate-smart agriculture, which enhances food security and healthy livelihoods while promoting climate change adaptation and mitigation. These concepts recognize that conventional mainstream agriculture cannot feed the growing world population sustainably because it degrades the natural resource base.

Social protection programmes, which emerged in developing countries in the 1980s and early 1990s, now extend beyond welfare concerns, with increasing emphasis on reducing risks and the harmful effects of shocks on vulnerable livelihoods. Social protection supports low-income farming households in adopting more profitable, but also riskier, economic activities and provides an alternative to negative coping strategies. Programmes that provide social protection and productive support are highly complementary and their implementation is increasing in rural areas.

GUIDING PRINCIPLE FOR POLICYMAKERS: PREPARE FOR DISRUPTION

Diversity in food sources and output markets creates multiple pathways for absorbing shocks

In a multi-risk environment, some disruptions are predictable and some not. Preparing for the unknown requires careful assessment of the structural characteristics of systems, including the absorptive capacity provided by their diversity of pathways and connectivity. Policies and investments need to recognize the distinction between risk and uncertainty. Managing risk typically involves reducing exposure and vulnerability to a specific adverse event. Managing uncertainty, on the other hand, requires that systems have sufficient diversity of actors and responses to maintain their core functions should an unforeseen shock materialize. Both approaches are needed and are complementary.

Key to building the absorptive capacity of agrifood systems is diversity in all its forms. Agrifood systems – and related food supply chains – with access to more diversified sources of food and output markets are less vulnerable. Knowing the multiple pathways through which a shock can be absorbed is crucial for policymakers to devise strategies to deal with a crisis. While sourcing through international trade makes agrifood systems less vulnerable to domestic shocks and stresses, a high dependency on imports from only a few partners may make them vulnerable to external shocks. Importing diversified foods from different countries with heterogeneous socio-economic and climatic profiles helps diversify the risks and reduce vulnerability to external shocks. International efforts to overcome trade barriers between countries may be needed for such flexible sourcing of food. In countries where the capacity to absorb shocks mostly stems from what is produced and traded domestically, diversifying domestic production and imports, as well as stocks, will be an essential part of food security and nutrition strategies, especially where many cannot afford or are at risk of not being able to afford a healthy diet.

Well-connected agrifood systems overcome disturbances faster by shifting sources of supply and channels for transporting and marketing of food products, inputs and labour, as well as transmission channels for knowledge and financial resources. Connectivity and diversification contribute to absorptive capacity and being prepared for disruption: they do not target a specific event but provide options once a disruptive event occurs. However, connectivity and diversification should be complemented with risk management. For example, disasters and crises can significantly impact on infrastructure and services, such as roads, transport or food storage. It is very important, therefore, to assess, protect and risk-proof infrastructure and to develop new risk-sensitive and climate-resilient infrastructure.

To ensure climate resilience, it is essential to assess and address the infrastructure's physical vulnerabilities.

The heterogeneity of farms and businesses must be recognized

Policies and interventions should facilitate a mix of traditional, transitional and modern food supply chains, which can buffer shocks and stresses of different types. Policymakers should acknowledge the heterogeneity of farms and businesses along the urban–rural continuum and address vulnerabilities at different scales. Improvements in risk management and early warning capacity may be needed to help predict shocks and their impacts. To enhance decision-making, government at various levels should work with academia, research centres, civil society and the private sector and make data available and accessible for analysis throughout systems. Inclusive governance and institutions will promote better risk management capable of rapid responses during crises. Subnational and local multi-risk management strategies may be needed to address underlying vulnerabilities and risk drivers.

Existing disaster and risk management tools in national laws, policies and regulations could be tailored to food supply chains to help stakeholders function more effectively and collaboratively within and across sectors. Policies also need to help producers and agribusinesses adopt resilience-enhancing business tools, including business literacy, expanded access to the Internet, credit and insurance, and funding for research and agricultural extension services. An environment that supports individual agrifood systems' actors will include leveraging information and communications technologies for logistics. Central and local governments, along with the private sector, non-governmental organizations and international development agencies, have an important role to play in supporting their adoption.

Risk management, crop insurance and social protection enhance household resilience

Resilient livelihoods are the basis of resilient agrifood systems because they ensure access to food even in the face of shocks. Among vulnerable rural households, those involved in small-scale agriculture and other primary agrifood production will benefit most from the logistical support, production innovations and inclusive governance of food supply chains. In framing policies to build the resilience capacities of small-scale producers and vulnerable households, policymakers should seek to facilitate risk management and enable household resilience capacities. As extreme climatic events become more frequent and more pronounced, producers will need access to agroclimatic disaster risk and early warning systems. Increasing their access to crop and weather insurance will enhance their ability to take out production loans and participate in more risky, higher-return farming activities.

Social protection programmes may be needed to improve household resilience in the event of a shock. Risk-informed and shock-responsive social protection systems are designed to provide support not only to routine beneficiaries, such as pensioners, but also at-risk and crisis-prone populations before, during and after disruptions. They can expand the provision of benefits according to the emerging needs of potential beneficiaries and enable them to invest and engage in productive activities. If well designed, social protection enables synergies with productive support programmes and investments, which strengthen both the resilience and the sustainability of small-scale producers' livelihoods.

Policies will need to address issues beyond agrifood systems. Key policy areas that have a clear impact on household resilience include strong, inclusive health insurance and medical services. Education and training are also important for strengthening long-term household resilience. Broader policies aimed at promoting gender equality will significantly improve resilience thanks to the increased participation of women in all components. Policies aimed at boosting employment can also strengthen livelihoods and incomes, with positive impacts on agrifood systems.

Ensuring the sustainability of agrifood systems is an integral part of building resilience. Policies can promote systems' sustainability by recognizing its role in stewardship of the natural environment. Rather than aggravating climate change and natural resource degradation, agrifood systems need to adopt agroecological farming and other resource-conserving practices.

It is important to recognize that policymaking can have unintended consequences. To avoid implementing restrictions that hurt agrifood systems' actors, policymakers must understand how systems function and interact. Policy coherence is essential. A significant issue requiring policy coherence is that of subsidies, such as agricultural price support. Subsidies can provide immediate and short-term relief to agricultural producers, but may also reduce their capacity to adapt to shocks when they occur. At the same time, subsidies, as well as any other policies supporting agrifood systems' resilience, will need to be fiscally sustainable. To meet the challenge of policy coherence, government institutions across all relevant sectors and different layers must be involved. ■

KENYA
A refugee grows vegetables as a source of food and income by using collected water near Kakuma refugee camp in Kalobeyei.
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CHAPTER 1
AGRIFOOD SYSTEMS' RESILIENCE: WHAT IT IS

KEY MESSAGES

➔ The COVID-19 pandemic's unprecedented impact on livelihoods and food security is a wake-up call to address the weaknesses, vulnerabilities and multiple risks in agrifood systems and safeguard their functions in the face of disruptions.

➔ Enhancing the resilience of agrifood systems means strengthening their capacities and those of their actors to prevent, anticipate, absorb, adapt and transform when struck by shocks and stresses.

➔ Agrifood systems are increasingly threatened by long-term stresses, such as climate change, deforestation, natural resource degradation and other protracted crises.

➔ Stresses aggravate vulnerabilities to multiple shocks, such as extreme weather events, conflicts, pandemics and socio-economic crises, which can strike anywhere in agrifood systems and spread through them and beyond.

➔ Building resilience in agrifood systems contributes in a fundamental way to their sustainability by enhancing their capacities to manage the risks posed by multiple shocks and stresses.

➔ Building agrifood systems' resilience begins by identifying systems' characteristics, their components and actors, understanding the linkages and interactions between them and broader economic, social and environmental contexts, to assess specific risks, vulnerabilities and responsive capacities.

➔ Key elements of building resilience are diversification (e.g. in production and sources of supply) and redundancy (i.e. duplication of agrifood systems' components). These may require managing trade-offs with efficiency and sometimes with equity.

The world's agrifood systems comprise a gargantuan global enterprise that each year produces approximately 11 billion tonnes of food[1] and a multitude of non-food products, including 32 million tonnes of natural fibres[2] and 4 billion m^3 of wood.[3] The estimated gross value of agricultural output in 2018 was USD 3.5 trillion.[4] Primary production alone provides about one-quarter of all employment globally, more than half in sub-Saharan Africa and almost 60 percent in low-income countries.[5] Including middle and downstream segments – from food storage and processing to transportation, retailing and consumption – agrifood systems are the backbone of many economies. Even in the European Union, the food and beverage industry employs more people than any other manufacturing sector.[6]

In an ideal world, all agrifood systems would be resilient, inclusive and sustainable, producing sufficient safe and nutritious food to meet the needs of all for an active and healthy life – without compromising the food security, health and nutrition of future generations. They would be underpinned by biological systems allowing them to be abundant providers of food and to sustain livelihoods. By generating livelihoods and prosperity, agrifood systems would guarantee billions of people economic access to food, a key pillar of food security.

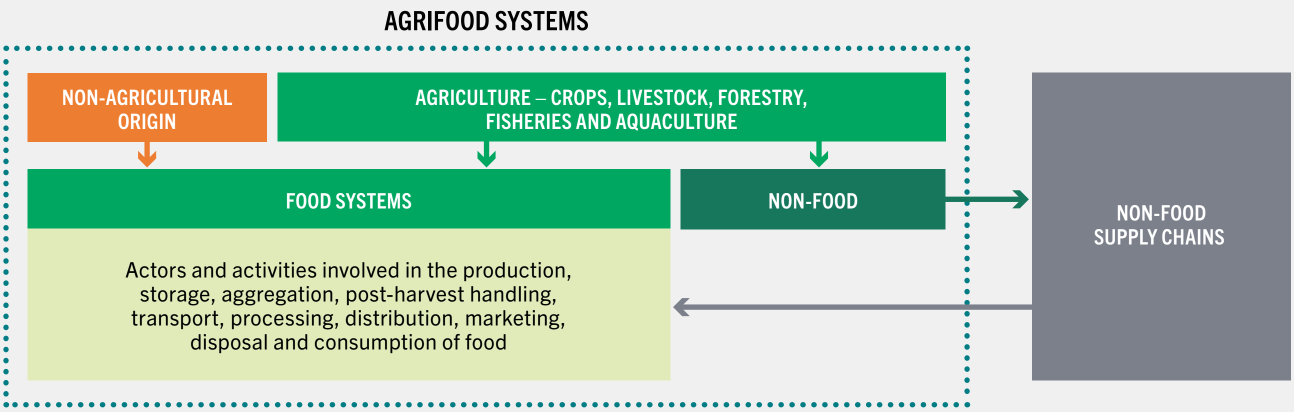
Then there is reality. In 2020, an estimated 768 million people, or 9.9 percent of the global population, suffered from hunger, an increase of nearly 118 million compared to 2019 and 153 million compared to 2015.[7] Even as the world faces extreme pressure to produce more food, shocks ranging from droughts and floods to armed conflict and price instability, aggravated by longer-term stresses such as economic inequalities

BOX 1 DEFINING AGRIFOOD SYSTEMS IN RELATION TO FOOD SYSTEMS

As illustrated in the figure in this box, **agrifood systems** encompass the entire range of actors and their interlinked value-adding activities in the primary production of food and non-food agricultural products, as well as in food storage, aggregation, post-harvest handling, transportation, processing, distribution, marketing, disposal and consumption. Within agrifood systems, **food systems** comprise all food products that originate from crop and livestock production, forestry, fisheries and aquaculture, and from other sources such as synthetic biology, and that are intended for human consumption. While non-agricultural food products, such as synthetic meat, are currently negligible, they are likely to grow and could have a major impact on the resilience of agrifood systems. They may limit risks linked to climatic events and pests, but could have potentially negative impacts as well, especially in terms of loss of jobs and livelihoods for people working in agricultural food production.

Agrifood systems interact with non-food supply chains through the purchase of inputs such as fertilizer, pesticide, and farm and fishing equipment, and the provision of intermediate inputs for the production of non-food commodities (e.g. maize for biofuel production or cotton for textiles). Broader economic, social and natural environments shape and influence agrifood systems and their diverse production systems.

FIGURE A CONCEPTUAL FRAMEWORK FOR AGRIFOOD SYSTEMS



NOTE: Food of non-agricultural origin includes meat analogues produced through synthetic biology.
SOURCE: FAO elaboration for this report.

and climate variability, threaten both agricultural production and other vital segments of agrifood systems. Multiple risks and uncertainties have a disproportionate effect on the world's most vulnerable and food-insecure populations, who are on the front line facing multiple shocks and stresses. Even before the novel coronavirus disease (COVID-19) pandemic, nearly 3 billion people could not afford a healthy diet, one that protects against malnutrition in all its forms.

Shocks and stresses impair agrifood systems by disrupting the operations of related institutions, supply chains and actors.[8] Box 1 shows how agrifood systems encompass food systems, including the entire range of actors and their interlinked value-adding activities, and the primary production of non-food products in the crop, livestock, forestry, fisheries and aquaculture sectors. Shocks and stresses can emerge from the surrounding socio-economic and environmental context and spread both within and outside systems: the most recent major example is the COVID-19 pandemic. Physical, social, economic and environmental conditions determine the level of *vulnerability* of individuals, communities, institutions, assets, infrastructures or systems to the negative impacts of shocks and stresses.[9] Understanding differences in vulnerability to various shocks and stresses and the resilience capacities of agrifood systems is necessary to identify specific measures that build resilience in the face of disturbances.[10]

Being heavily dependent on climatic, biological, physical and chemical processes, agrifood systems face multiple potential shocks and stresses, including climate change, extreme weather events, pest and disease upsurges, water scarcities and deteriorating natural resources. FAO estimates that between 2008 and 2018, the agriculture sector in low-income and lower-middle-income countries – without considering their broader agrifood systems – absorbed 26 percent of all economic damage and losses caused by medium- to large-scale disasters.[11] For small-scale producers and other agrifood systems' actors in those countries, stresses can be particularly pervasive and chronic. They amplify the effects of existing structural deficiencies, such as inadequate road, power, irrigation, clean water, processing, storage and marketing infrastructures. Those deficiencies condemn millions of farmers and other rural people to geographic and economic isolation, limited opportunities to develop businesses, poor access to services and high dependence on local weather conditions.

The consequences can be highly adverse: factors of production are underused, productivity is low, food and non-food agricultural output is lost, and access to lucrative markets is blocked. Amplifying agrifood systems' vulnerability to multiple shocks and stresses undermines the capacities of actors to prevent, anticipate, absorb, adapt and transform. Once resilience capacities are compromised, the likelihood of acute and chronic food insecurity and malnutrition increases.

The international community has recognized the urgent need for action to strengthen food systems, the part of agrifood systems that encompass producing, processing, transporting and consuming food (Box 1). The United Nations (UN) Food Systems Summit, held in September 2021, launched bold new actions to accelerate progress towards all the Sustainable Development Goals (SDGs), each of which relies to some degree on healthier, more sustainable and equitable food systems. Building *resilience* is essential to implement the SDGs and the overall 2030 Agenda for Sustainable Development. Agrifood systems' resilience is directly aligned with achieving SDG 2, Zero Hunger, and key to progress towards several other SDGs with a socio-economic focus (SDG 1, No poverty; SDG 5, Gender equality; SDG 8, Decent work and economic growth; SDG 10, Reduced inequalities; SDG 11, Sustainable cities and communities) and those relating to environmental sustainability (SDG 6, Clean water; SDG 12, Responsible consumption and production; SDG 13, Climate action; SDGs 14 and 15, Life below water and on land). By creating peace and prosperity for all people on the planet by 2030 (in line with SDG 16, Peace, justice and strong institutions), achievement of the SDGs will prevent many disturbances, or at least strongly mitigate their impact.

This report addresses the following questions: What characterizes resilient agrifood systems? How can agrifood systems' actors manage their vulnerability to shocks and stresses? How can households – especially the poor and most vulnerable – meet their food needs when disruptions to agrifood systems reduce production and incomes, force price increases or create food shortages? How can we ensure that agrifood systems support livelihoods and sustainably provide continuous access to sufficient, safe and nutritious food to all in the face of disruptions? In short, how do we improve the resilience of our agrifood systems? ■

THE NEED FOR MORE RESILIENT AGRIFOOD SYSTEMS

Building agrifood systems' resilience becomes all the more urgent given the persistence of hunger and malnutrition. Hunger is increasing, and more so in countries affected by conflict, climate extremes and economic downturns, and with high income inequality.[12] The magnitude and severity of food crises also worsened in 2020 as protracted conflict, the economic fallout of the COVID-19 pandemic and weather extremes exacerbated pre-existing fragilities.[13] Economic downturns in 2020, including those resulting from COVID-19 restrictions, delivered the hardest blow in decades to those suffering from hunger, increasing the number of undernourished people by 118 million in 2020 alone[12] and illustrating the devastating impact of a shock that occurs alongside existing vulnerabilities. There is little evidence of reduced food supply (beyond initial disruptions due to panic buying),[8] which may be attributable to government exemptions for the agrifood sector. However, lockdowns and other mobility restrictions drastically reduced the movement of people and goods, impacting on livelihoods. Loss of income and purchasing power sharply reduced the food security and nutrition of billions of people, particularly in low-income and middle-income countries. Families were forced to shift consumption to cheaper, less nutritious foods[8] at a time when they needed to protect and strengthen their immune system.[14] Reduced access to nutritious food and a shift to low-quality and energy-dense diets triggered by the economic impacts of the COVID-19 pandemic, also risk increasing the levels of overweight and obesity in almost all regions of the world. Adult obesity is on the rise with no reversal in the trend at global or regional level for more than 15 years, increasing the non-communicable diseases associated with those forms of malnutrition.[12]

The ability of agrifood systems to ensure food security and nutrition for all will depend not only on their own capacities, but also on the functioning of other interconnected socio-economic and environmental systems such as transport, education, health, water, soil and energy, as well as social protection mechanisms. The negative impact of the shock triggered by the pandemic on infant and young child morbidity could be exacerbated by reduced healthcare to prevent and treat malaria, diarrhoea and other infectious diseases. School closures may lead to missed meals and nutrition education provided through school food and nutrition programmes.[8] A compelling body of evidence shows that the adverse impacts of such shocks and related stresses on preschool children's nutritional status are not only immediate but persist into adulthood.[15]

Demographic and environmental pressures make agrifood systems' resilience ever more imperative as a rapidly growing global population drives increased demand for food. At the same time, shocks and stresses, including more frequent and intense extreme and slow-onset events due to climate change, threaten both agricultural production – crops, livestock, aquaculture, fisheries and forestry – and the middle and downstream stages of agrifood systems. But as agrifood systems are affected by climate shocks and stresses, they are themselves a major driver of climate change. To feed a world population forecast to reach 9.7 billion in 2050,[16] agriculture may need to produce 40–54 percent more food, feed and biofuel feedstock than in 2012,[17] depending on the scenario. This is a daunting task that could place unsustainable pressures on the Earth's natural resources. Moving towards more sustainable agriculture and food production is needed. Central to this are the three priorities of: protecting nature; restoring and rehabilitating natural environments; and sustainably managing food production systems.[18] Significant reductions in food loss and waste,[19] better resource-use efficiency and trade have an important role, as imports may be needed to fill domestic deficits where there are natural resource constraints.

Another approach is agroecology, which encompasses three dimensions: science, a set of practices, and a social movement. There is increasing evidence to show how agroecology benefits the environment, biodiversity and farmers' incomes, as well as helping farmers adapt to and mitigate climate change and build resilience to multiple shocks and stresses. Climate-smart agriculture (CSA), another resilience-enhancing approach, emerged in response to climate change[20] and other stresses, including environmental degradation and demographic pressures, as further shown in this report.

Also required is far-reaching adjustment to current dietary trends. Urbanization and greater affluence are shifting diets in many low-income and middle-income countries towards increased consumption of more resource-intensive animal source and processed food.[17] If those trends continue, by 2030, diet-related health costs linked to non-communicable diseases will exceed USD 1.3 trillion a year, while the annual cost of associated greenhouse gas (GHG) emissions will exceed USD 1.7 trillion.[7]

Given these and future challenges, agrifood systems must not only find ways to cope with adverse changes but strive towards achieving the SDGs by transforming current business-as-usual approaches. Agrifood systems need to focus on providing nutritious food for all and using resources efficiently, while becoming more inclusive, sustainable and resilient. Producing more with less, and at the same time protecting and enhancing the livelihoods of small-scale agricultural producers and other agrifood actors, are global challenges. The COVID-19 pandemic, along with lessons from other shocks in recent decades, shows clearly that some degree of risk and uncertainty is inherent in agrifood systems. Therefore, risk management strategies that reduce exposure and vulnerability to a specific shock – such as drought preparedness in drought-prone areas – will be a key measure to build resilience. The sudden appearance of the COVID-19 pandemic, however, shows that some shocks may be unknown in terms of timing and extent of their impacts until they actually happen. Resilience building is, therefore, broader than risk management. Risk management is key to help agrifood systems' actors anticipate and prevent major disruptions; however, to be resilient, agrifood systems must have all of the five resilience capacities – prevent, anticipate, absorb, adapt and transform – in order to continue functioning in the presence of shocks that are not completely predictable.

Investments in risk-informed and shock-responsive social protection and insurance programmes, diversified supply chains and farming systems, and flexible logistics are examples of essential interventions to build or enhance these capacities. ■

UNDERSTANDING RESILIENCE IN AGRIFOOD SYSTEMS

The concept of resilience originated in the study of ecosystems[21] and has evolved over 50 years into an object of study across an array of disciplines, including engineering, agriculture, economics and psychology. Although there is little agreement today as to a precise definition across disciplines, broadly speaking, *resilience* can be defined as the dynamic capacity to continue to achieve goals despite disturbances.[22]

In a call for cross-sectoral collaboration to prevent, anticipate, absorb, adapt and transform in the face of shocks and stresses across all sectors of society, the UN has developed and adopted the *UN Common Guidance on Helping Build Resilient Societies*.[9] Since there is a wide variety of risks relating to understanding *resilience*, the UN offers the following definition:

> the ability of individuals, households, communities, cities, institutions, systems and societies to prevent, anticipate, absorb, adapt, and transform positively, efficiently and effectively when faced with a wide range of risks, while maintaining an acceptable level of functioning and without compromising long-term prospects for sustainable development, peace and security, human rights and well-being for all.

This definition underscores the fact that shocks and stresses can have detrimental effects in the short and the long term. Resilience entails recognizing their dynamic and intertemporal nature. For agrifood systems to overcome shocks and stresses,[9, 23] they require five distinct resilience capacities – to prevent, anticipate, absorb, adapt and transform in the face of multiple evolving, overlapping and even colliding events.

This report focuses mainly on the absorptive capacity of resilience and how it should be combined with risk management, such as preventive and anticipatory actions, to enable positive adaptation and inclusive and sustainable agrifood systems' transformation. Absorptive capacity refers to the ability to withstand shocks and stresses and bounce back after a shock, using predetermined responses to preserve and restore essential basic structures and functions. Building absorptive capacity requires designing and investing in diversified responses to preserve and restore essential structures and functions. Absorptive capacity is in part also determined by systems' structural characteristics, such as the number and diversity of stakeholders involved, the institutions that coordinate them and the robustness of the infrastructure on which they rely. The structural nature of absorptive capacity is central in this report, guiding the development of indicators and shaping new insights on how to improve the resilience of agrifood systems.

The report applies the UN definition of resilience specifically to food and agriculture, defining agrifood systems' resilience as the objectives of ensuring food security and nutrition for all and decent livelihoods and incomes for agrifood systems' actors. Building resilient agrifood systems calls for linking the concept of resilience to all dimensions of food security, not only food availability, economic and physical access to food, food utilization and stability over time, but also the dimensions of agency and sustainability, recently proposed by the High Level Panel of Experts (HLPE) of the Committee on World Food Security. These two dimensions are not formally agreed upon by FAO or other bodies, nor is there an agreed language on the definition. However, due to their relevance in the context of this report, they are included here. The HLPE defines *agency* as the capacity of individuals or groups to make their own informed decisions about which foods they eat and produce, how food is produced, processed and distributed within food systems, and their ability to engage in shaping food systems' policies and governance. *Sustainability* refers to the long-term ability of food systems to provide food security and nutrition in a way that does not compromise the economic, social and environmental bases that can generate food security for future generations.[24]

Agrifood systems' resilience focuses on all six dimensions of food security and nutrition, but more specifically on stability of access and sustainability, to ensure short- and long-term food security and nutrition. Agrifood systems' resilience is a dynamic process defined as:

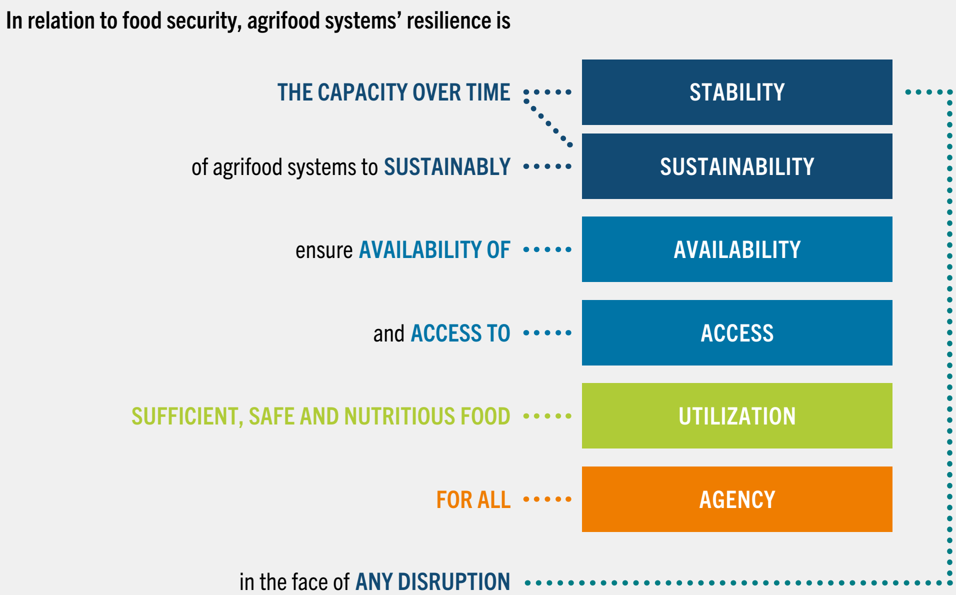
> the capacity over time of agrifood systems, in the face of any disruption, to sustainably ensure availability of and access to sufficient, safe and nutritious food for all, and sustain the livelihoods of agrifood systems' actors.[b]

Figure 1 illustrates how the definition of agrifood systems' resilience supports each of the six dimensions of food security.

Agency, a key dimension of food security, is deeply connected to human rights, including the right to food, and emphasizes the need for inclusiveness in agrifood systems. As indicated in the HLPE's 2020 report, historically disadvantaged individuals and communities, such as women and small-scale agricultural producers, often lack agency with respect to food security and food systems, and frequently experience high levels of food insecurity.[24] Their disempowerment manifests itself in, for example: income and gender inequalities affecting choices; uneven local and global power dynamics regarding individual and community decisions on agrifood systems; weak and fragmented governance of agrifood systems; and the failure of States to uphold the right to food. When agency is upheld, all people and groups can make choices and use their voice to shape agrifood systems and the livelihood opportunities they provide. ■

b This definition is based on Tendall *et al.* (2015).[22]

FIGURE 1 AGRIFOOD SYSTEMS' RESILIENCE AND THE SIX DIMENSIONS OF FOOD SECURITY



SOURCE: FAO elaboration based on HLPE. 2020, Figure 1.[24]

HOW SHOCKS AND STRESSES DISRUPT AGRIFOOD SYSTEMS

As societies develop and transform, they also transform the surrounding environment, the vulnerabilities, embedded risks, and the set of stresses and shocks with which they must deal. While some shocks and stresses depend on factors at supranational or global level, many are the result of specific geographical or local conditions. In either case, the risk of negative impacts will depend on how shocks and stresses manifest themselves, interact with and affect the vulnerabilities and capacities of each component of agrifood systems and their actors. Understanding these processes is essential to design effective interventions to manage multiple risks and build the resilience of agrifood systems by strengthening their capacities to prevent, anticipate, absorb, adapt and transform.

Agrifood systems are very diverse. They depend on agricultural and natural ecosystems and encompass numerous actors along several interlinked components, from production to consumption. For this reason, a shock or stress, impacting on any component, will not only affect the actors in it but will spread throughout systems upstream or downstream, eventually impacting on many if not all other actors and components. The magnitude of the impacts of a shock or stress will depend on the type of event, the vulnerabilities of the components and systems as a whole, and the resilience of each component, including individuals and groups of actors. It will also depend on the degree and direction of interdependence between them. For example, the current global spread of fusarium wilt on bananas is a threat to production and to the livelihoods of those depending on the value chain,[25] with potential impacts on household nutrition should scarcities lead to higher prices. A comprehensive approach that accounts for multiple risks to agrifood systems and their internal interactions – and potential interactions with other systems – is key to understanding and analysing systems' resilience and addressing its associated challenges.[22]

Characteristics of agrifood systems shape the impact of disturbances

Broadly speaking, agrifood systems can be classified into three types: traditional, mostly located in rural and coastal areas and serving local populations; modern, focused on serving urban populations from diversified sources, including global markets; and transitional, in a phase of transition from the former towards the latter, possibly co-existing with them.[26] Classifying agrifood systems into discrete types should not, however, hide the huge diversity within each type. Multiple agrifood systems co-exist simultaneously in any given country but may differ substantially in terms of their structure or access to markets and services, or interactions with other systems. The key actors in agrifood systems are producers, input providers, those providing post-harvest services, such as storage, transportation, food processing, food distribution and marketing (wholesaling and retailing), and the final consumers.

The characteristics of agrifood systems will determine their ability to prevent, anticipate, absorb, adapt and transform rapidly in the face of shocks and stresses. Traditional agrifood systems are usually found in specific regions and are vulnerable to delimited shocks, while local agrifood systems may be transitional or modern. Traditional systems typically have inadequate infrastructure and lack access to inputs, markets and services such as credit, with higher vulnerability to weather conditions. When a shock such as a flood occurs, whole systems, including the actors, may be severely affected, with negative short- to long-term implications for food security and livelihoods.

Modern and transitional agrifood systems, on the other hand, may be affected by the same event in different ways, depending on their scale of operations, the structure and contracting process between actors, the level of risk proofing of infrastructure and capacities, and their access to inputs and services such as climate risk insurance. Becoming increasingly interconnected and interdependent with other agrifood systems, they may be more vulnerable to shocks transmitted from elsewhere. Modernization has contributed to agricultural specialization and intensification, leading to declining crop diversity and deforestation in many parts of the world with a loss of diverse agricultural landscapes and ecosystems, undermining the biological base of agrifood systems.

In building agrifood systems' resilience, the first tasks are to identify the type of system and its components and actors, understand the linkages and interactions between them, and assess the specific vulnerabilities, threats and capacities that shape the multiple risks facing each one.

In this report, agrifood systems' components refer to three main types of agrifood systems' functions. Their nature and characteristics, and how they affect livelihoods, may vary widely across and within countries.

i. **Primary production** includes food from agricultural and non-agricultural origins, as well as non-food agricultural products that serve as inputs to other industries. Agriculture here means all subsectors: crops, livestock, pastoralism, fisheries, aquaculture and forestry. Food may be produced by a mix of large-scale producers and business enterprises – typical in modern agrifood systems – and small-scale producers and small and medium agrifood enterprises (SMAEs), operating in a range of traditional, transitional and modern systems. Small-scale producers account for around one-third of the world's food and contribute significantly to food security and nutrition.[27]
ii. **Food distribution** links production to consumption through food supply chains and domestic food transport networks. **Food supply chains** include all actors and activities involved in post-harvest

handling, storage, aggregation, transport, processing, distribution and marketing of food. They range from modern, highly integrated and very long chains with plenty of sourcing options, including international trade, to very short chains, mainly serving local urban, peri-urban or rural populations. Similarly, **domestic food transport networks** range from those with well-developed infrastructure linking producers to consumers efficiently (including through trade), to those relying on fragile infrastructure and services that are easily exposed to disruptions resulting in bottlenecks and inefficiencies.

iii. **Consumption** is the downstream outcome of functioning agrifood systems, subject to varying degrees of demand shocks, such as loss of income, depending on the proportion of vulnerable groups in the population. The higher this proportion, the more difficult it is to protect food security and nutrition from shocks. Examples of vulnerable households include small-scale farmers, fishers and pastoralists, landless agricultural workers, poorer population groups, and those that suffer greater inequality and marginalization, such as Indigenous Peoples. The level of agrifood systems' resilience is a crucial determinant of adequate and stable access to food.

The different characteristics, risk environments, and inherent vulnerabilities and capacities of these components determine their susceptibility to various adverse shocks and stresses. The same shock or stress may have different impacts across different components. For example, given its reliance on natural processes, the agriculture sector is disproportionately exposed and vulnerable to adverse climate-related events, especially droughts, floods and storms. Over half of all shocks to crop production are the result of extreme weather events, reinforcing concern about the vulnerability of arable systems to climatic and meteorological volatility.[28] Drought is the single greatest cause of agricultural production losses, with 82 percent of its impact on agriculture.[11] In aquatic systems, there are well-established linkages between harvesting of fish, ocean productivity and global meteorology. Global climate plays a major role in fluctuating fishery productivity.[29, 30]

Actors within the same agrifood systems' component may be affected differently. The livelihoods of small-scale agricultural producers are more likely to be adversely affected by a shock owing to their limited access to resources compared to large-scale producers. Likewise, actors in formal markets will be less affected than those in informal markets, thanks to regulation, government programmes, access to safety nets, finance, insurance, and other risk and impact mitigation mechanisms.

Components of agrifood systems are interlinked, and their characteristics will determine how each is affected as the impact of a shock or stress propagates through systems. Shocks affecting **household consumption** are a case in point. Households who rely on agrifood systems – as agricultural producers or supply chain actors – will be negatively affected by any shock to their business or their employer. The poorest will be the most affected by rising food prices because food represents a larger share of their household budget and they have limited capacity to access credit and savings or to liquidate assets to cover deficits.[31] When faced with a shock, they are more likely to reduce their spending on food by shifting towards cheaper, less nutritious items and in a downward spiral become more vulnerable to food insecurity and malnutrition.

The higher the proportion of vulnerable households, the greater the likelihood that demand responses to shocks (such as reduced demand for certain foods) will disturb or disrupt other agrifood systems' components, ultimately affecting the flow of produce and, in the medium and longer term, even the structure of entire systems. Just as vulnerable households are the most affected by income shocks, small-scale producers and SMAEs in **agricultural production** are possibly more exposed to this ripple effect as well as to longer-term stresses, including climate change. Their vulnerability is often accentuated by their limited assets and access to credit and insurance, which may constrain their ability to adapt and transform.

The degree of diversity and connectivity of **food distribution networks** also shapes the impacts of shock events. Producers and SMAEs who are well connected to supply chains, have various sources and deal in diverse food products, are likely to overcome supply shortages and recover from disturbances more quickly. Connecting to international trade is one of several strategies that distribution networks use to buffer against agrifood systems' disruptions caused by domestic production failure or domestic variability in food supply. However, there is a flip side: the same links can become a channel for transmission of policy-induced shocks, as evidenced by the impact of COVID-19 lockdowns, closure of ports and export restrictions that disrupted food supply chains and international trade. The development level of domestic logistics and infrastructure matters; they can be either an additional bottleneck or a facilitator of fast recovery.

Various shocks and stresses affect agrifood systems differently

Agrifood systems are exposed to shocks and stresses of various types that differ in nature and intensity. Some, such as technological innovation and social pressure for more inclusiveness and equality, can have a positive impact. However, given the theme of building agrifood systems' resilience, this report focuses on negative shocks and stresses that can disrupt systems' functions. Such a focus is crucial to inform the range of strategies and investments required to prevent, anticipate, absorb, adapt and transform.

While shocks have an immediate impact, stresses are slow processes that gradually alter the internal nature of agrifood systems, undermining their capacities to cope with change and rendering them more vulnerable. Shocks and stresses are also different in terms of their predictability. A stress represents a continuous pressure, often observable and predictable – at least in theory – though with various degrees of precision. For example, agricultural intensification, a characteristic of modern high-productivity food systems, may threaten environmental sustainability and, eventually, production outcomes.[32] Since this process can be observed and measured and its consequences projected over time, action is possible to prevent, adapt and even transform, so as to reduce risks and negative impacts. Shocks, on the other hand, are sudden disruptions, which are at best predictable based on levels of probability and previous experience. Identifying and investing in risk assessment and appropriate measures will be needed to reduce vulnerability and risk.

Shocks and stresses can have many sources originating from various domains, for example: biophysical and environmental; demographic and socio-economic; biological; and socio-political and legal. Examples of biophysical and environmental shocks include adverse weather and geophysical phenomena such as earthquakes and tsunamis, while significant stresses are associated with climate change and its effects, loss of biodiversity, and natural resource degradation. Demographic and socio-economic shocks may include economic crises, while examples of stresses are socio-economic inequality or high levels of population growth. Pandemics like COVID-19 and food safety breaches represent typical examples of biological shocks, while stresses may be the emergence of antimicrobial resistance or the persistence of food safety issues. In the socio-political domain, examples of shocks include crises involving civil unrest and population displacement or the erection of trade barriers by individual countries. Examples of socio-political stresses are distress migration or endemic corruption.

Shocks and stresses can directly affect either agrifood supply or demand, or both. However, as sustainable agrifood livelihoods are fundamental to food security, the impacts of shocks or stresses on agrifood supply and food demand are closely connected. Where agrifood suppliers are negatively affected, the incomes and purchasing power of the actors will decline, which can then affect demand for food and non-food products.

Developing options to deal with threats to agrifood systems requires an understanding of the types of shocks and stresses that strike systems, the mechanisms that affect »

BOX 2 FAO'S ANTICIPATORY ACTION APPROACH

Working with national governments and humanitarian, development and scientific partners, FAO's Anticipatory Action (AA) approach monitors risk information systems and translates warnings into anticipatory actions to reduce the impact of disasters. A key enabling factor for anticipatory action is the development of pre-agreed plans – ideally developed jointly by multiple actors – which provide details on early warning information, the risk monitoring process, triggers, predefined funding sources, and a decision-making protocol. Multilevel early warning information is analysed to identify and prioritize the greatest risks to agricultural livelihoods and food security. Then, where needed, FAO's Special Fund for Emergency and Rehabilitation Activities can rapidly release funds from its anticipatory action window (SFERA-AA).

Anticipatory actions are varied and flexible; they include cash transfers for fishing communities to safely store their nets ahead of an impending cyclone, livestock feed and treatments for herders before the peak of a drought, and waterproof storage equipment for farmers before a forecast flood. They may also include agricultural inputs and technical skills to boost food production ahead of potential food crises.

Since 2016, FAO has implemented AA projects across high-risk countries in Africa, Asia and Latin America to protect the livelihoods of vulnerable farming and herding households. These communities were at the forefront of droughts, floods, socio-economic crises (e.g. due to the COVID-19 pandemic), transboundary animal diseases, and crop pests, often combined with conflict, displacement and forced migration.

The table in this box summarizes the results of impact assessments of FAO anticipatory action interventions in various countries. Depending on the context, the shocks addressed and the socio-economic characteristics of targeted vulnerable households, AA interventions have resulted in relatively high to very high returns on investments in terms of avoided disaster impacts and additional benefits. The table, and the results of impact assessments conducted in the targeted countries, show that even with small funds, well-designed and timely interventions can lead to very positive results in terms of protecting vulnerable livelihoods and empowering households to cope with shocks.

However, these assessments shed light on the enormous challenges that governments and international agencies face to scale up these interventions to the level of national agrifood systems. The growing intensity and increasing frequency of climate-driven disasters and conflicts mean that different priorities will compete for limited resources. When resources are limited, anticipatory action should target the most vulnerable – typically those living in extreme poverty and facing multiple risks – combined with efforts to strengthen the absorptive capacity of agrifood systems. Additional efforts are needed to fully mainstream this approach into disaster risk management frameworks, leading to a decisive shift from a reactive to a preventive approach to food crises.

TABLE SUMMARY OF SELECTED FAO ANTICIPATORY ACTION INTERVENTIONS – FUNDS SPENT, NUMBER OF BENEFICIARIES AND RETURN ON INVESTMENTS

Country	Type of action	Amount of dedicated funds (USD)	Beneficiary households	Return on investment (per USD spent)
Bangladesh	Protect farming families from impending floods	500 000	18 700	0.8
Colombia	Curb the impact of drought and migration crisis	955 000	1 003	2.6
Kenya	Protect pastoralist livelihoods ahead of drought	400 000	1 493	3.5
Madagascar	Protect farming livelihoods ahead of drought	400 000	8 400	2.5
Mongolia	Protect livelihoods of herders from a very harsh winter	290 000	1 008	7.1
Philippines	Protect farming communities from El Niño-induced drought	400 000	1 500	4.4
Sudan	Protect pastoralist livelihoods ahead of drought	400 000	5 000	6.7

SOURCES: FAO. 2018,[33,34] FAO. 2019,[35–37] FAO. 2020,[38] and FAO. 2021.[39]

» them, and their specific vulnerabilities. For example, drought, export restrictions, transport bottlenecks and climate variations can all reduce food supply but do so in very different ways and through different channels, impacting on countries and people differently. The impact of the same shock or stress can vary widely, depending on the vulnerabilities of agrifood systems, the components impacted and their capacities to prevent, anticipate, absorb, adapt and transform. The impact of a shock such as severe drought may be mitigated by preventative and anticipative investments in irrigation; however, the drought may still have devastating effects if the surface water or groundwater is already overexploited.

Building absorptive capacities within agrifood systems – the focus of this report – is complementary to and should go hand in hand with risk management, especially actions focused on anticipation and prevention. The importance of building absorptive capacity is linked to the cost and often limited potential of early action initiatives despite their high returns, given the resources required to scale up anticipatory actions geared to identifiable risks (Box 2). In addition, absorptive capacity is critical to confront shocks that are unknown in terms of their timing and extent until they actually happen and cannot therefore be addressed through risk management strategies that reduce exposure and vulnerability to anticipated shocks. ■

AGRIFOOD SYSTEMS' RESILIENCE IN CHANGING CONTEXTS

Growing concern over the resilience of agrifood systems is driven by increases in the frequency and intensity of adverse shocks, from climate-related disasters, and animal and crop diseases, to sudden price hikes. Cottrell *et al.* (2019) associate this with a rising number of conflicts exacerbated by climate change and depleted natural resources.[40] Conflicts appear to be a key driver of higher levels of hunger in recent years.[41] In particular, the incidence of hunger has grown in the Near East and North Africa since 2012, mainly because of increasing conflict and instability.[42]

Climate change also impacts on agrifood systems, food supply chains and food security through short-term shocks, such as extreme weather events, and slow-onset stresses, such as increasing temperatures, desertification, salinization and loss of biodiversity.[43] Climate change is also associated with shifts in the geographic occurrence, prevalence and intensity of transboundary animal and plant pests and diseases, and changes in patterns of pathogens, mycotoxins, marine biotoxins and heavy metal contamination, all of which threaten food safety.[31, 44, 45] Yet agrifood systems themselves are a major driver of climate change. Innovative mechanisms to reduce climate-related risks, widespread adoption of climate-smart production techniques, and the conservation and rehabilitation of natural environments can strengthen the sustainability and resilience of agrifood systems against increased climate variability and extremes.[12]

Globalization has altered the set of risks agrifood systems face. On the one hand, it smooths disruptions in supply due to domestic shocks thanks to international trade, but on the other, it facilitates transmission of unpredictable shocks originating far away. For example, after the 2008–2009 global financial crisis, Mexico's economy shrank by almost 7 percent in 2009, poorer households reduced their spending on food and the number of severely food-insecure individuals grew from 9.8 million in 2008 to 12.2 million in 2010.[46]

More recently – a prime example of how crises from other systems can affect agrifood systems – the COVID-19 health crisis disrupted global and national food supply chains as governments sought to contain the spread of the virus by imposing lockdowns. The resulting bottlenecks in labour availability, import and distribution of farm inputs, and transport and logistics networks disrupted food supply chains, especially those of perishable high-value products such as fruits and vegetables, raising concerns over food security and nutrition.[47, 48]

Many food supply chains demonstrated remarkable resilience, supported by government declarations that food was an essential sector. It also helped that when the pandemic began, global food markets were well supplied and stable and most supermarket shelves remained stocked. Countries learned from the 2008–2009 crisis and adopted measures to reduce vulnerability to future food shortages. Most countries in the Near East and North Africa, highly dependent on food imports, used a mix of policies to encourage domestic food production, diversify import sources and build national food stocks. The pandemic also sparked changes in many countries' output markets, such as a switch from reliance on exports to serving domestic markets, as was the case with Kenya's coffee industry.[49]

A study by Béné *et al.* (2021) finds that despite disruptions caused by initial panic buying, there is no clear evidence that food availability was universally affected during the pandemic.[50] In fact, the biggest threat to food security and nutrition during the COVID-19 pandemic has come not from disruptions to food availability but from the often severe limitations on households' physical and economic access to food, particularly in urban areas and in low-income and middle-income countries.[50] The pandemic caused dramatic reductions in the purchasing power of many households, as lockdowns and other restrictions led to shrinking incomes and job losses. The services sector, which employs the largest share of the population in most countries, has been hard hit, pushing many vulnerable households into poverty and food insecurity. Millions of households have been forced to reduce spending on food, with high risk of lowering overall calorie intake and dietary quality.

The adverse impacts of these past and ongoing crises reveal that current agrifood systems are fragile and not taking due consideration of issues like equity, access, resilience and sustainability. They fail to provide sufficient and nutritious food for all and are the principal driver of biodiversity loss, land degradation and freshwater depletion. They interfere heavily with global nitrogen and phosphorus cycles and are a major source of the GHG emissions driving climate change.[51] The COVID-19 pandemic has also heightened concern over the threat of zoonotic diseases in agrifood systems.[52]

By becoming more inclusive, resilient and sustainable, agrifood systems can ensure access to food – not only physical, but also economic access. One way to achieve this is through the agricultural production of food and non-food products to generate income and livelihoods for the estimated 3.4 billion people worldwide who live in rural areas.[53] Resilience is one means of achieving sustainability, especially during times of disruption[54, 55] and is thus essential to enable sustainability.[56, 57] Part of the challenge of making agrifood systems more sustainable is to reduce their inherent vulnerabilities and enhance their capacities to manage risks posed by multiple shocks and stresses. ■

BUILDING AGRIFOOD SYSTEMS' RESILIENCE – A FRAMEWORK

The global crisis triggered by the COVID-19 pandemic and its impacts on food security and livelihoods adds a new sense of purpose to investigating the weaknesses of agrifood systems, the risks they face and why they fail to deliver desired outcomes. Exploring these issues will help to strengthen agrifood systems' resilience as an essential element in efforts to build back better and achieve the SDGs. Rendering agrifood systems resilient means enhancing their capacity to prevent, anticipate, absorb, adapt and transform in the face of risks to particular shocks and stresses and to safeguard their specific functional goal: sustaining the livelihoods of agrifood systems' actors and ensuring food security and nutrition for all.

A tangible framework for agrifood systems' resilience analysis

Building on the discussion so far, Figure 2 presents a conceptual framework for analysing agrifood systems' resilience. It frames the analysis around three fundamental questions: *Resilience to* what? *Resilience of* what? and *Resilience for* what? Broadly speaking, the overall objective »

ITALY
Syrian farmers learning how Robiola cheese is made during a visit to Amaltea farm in the village of Roccaverano.
©FAO/Alessandra Benedetti

» is to build the resilience of agrifood systems to shocks and stresses so that all actors and stakeholders – producers, intermediaries and consumers – can prosper while sustainably contributing to, and benefiting from, food and nutrition security.

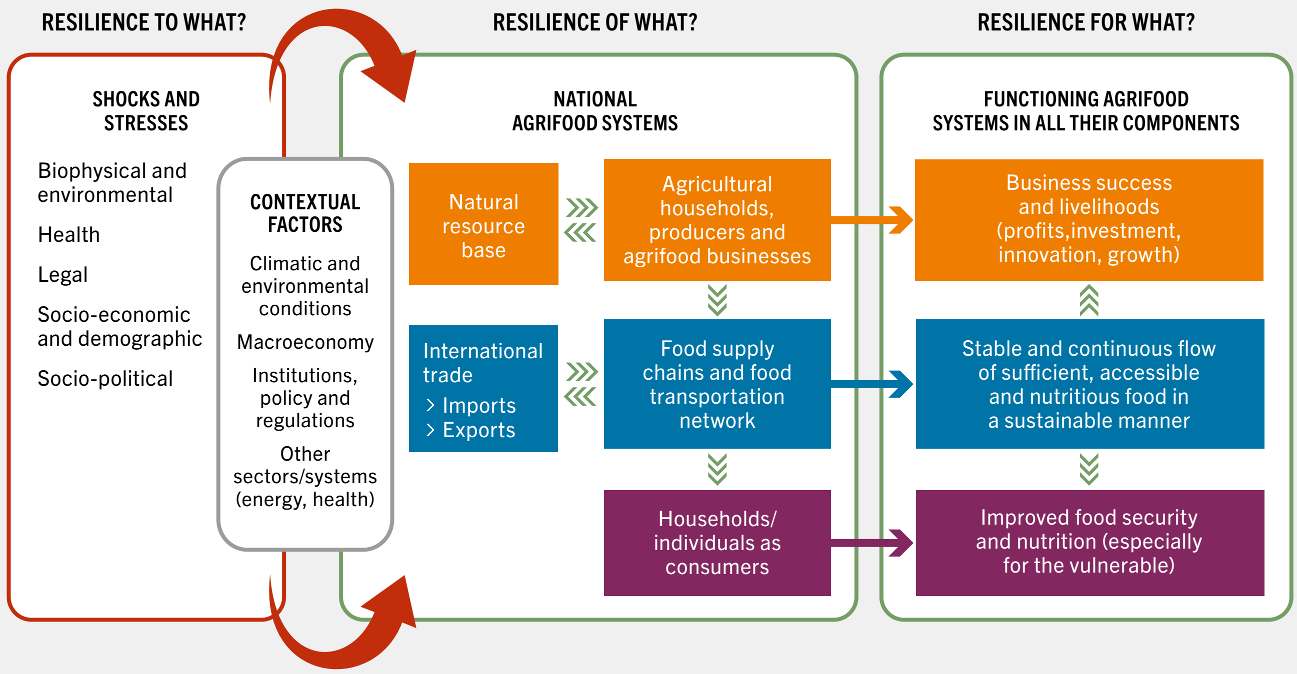
As illustrated in column 1 of Figure 2 (Resilience to what?), shocks and stresses can vary greatly and have different origins. The nature and magnitude of their impacts will depend not only on the shocks and stresses themselves but also on the specific vulnerabilities and resilience capacity of each of the components and actors in agrifood systems and the overall context (column 2, Contextual factors). These factors include the climatic, environmental, social, economic and political dimensions that influence and shape agrifood systems' activities. Other contextual factors are systems and sectors (such as energy and health) that are external but linked to agrifood systems. The COVID-19 pandemic is a prime example of the interaction between the food and health systems. The energy sector is another: energy is required to grow, process and distribute food, while crops are grown to produce biofuel energy. In addition, non-food agricultural crops – essential to the livelihoods of many agricultural producers – compete with food production for limited resources. Resilient and sustainable agrifood systems need to balance their dual objectives of providing food for all and generating income through non-food production, while preserving the natural resource base. The framework highlights these interactions as they contribute to agrifood systems' functioning and to their final outcomes.

How shocks and stresses impact on agrifood systems depends also on the characteristics of their components. Column 3 (Resilience of what?) presents national agrifood systems, in which food and non-food agricultural products are produced by agricultural households (see Glossary), producers and businesses reliant on the natural resource base and services provided by ecosystems. Food is then processed, stored, transported and distributed by agrifood businesses through food supply chains and domestic transport networks to households and individual consumers. It is worth noting the crucial role of food supply chains and domestic food transport networks to connect production and consumption. Whether domestically produced or imported, food must go through these channels to reach households and individual consumers. Agricultural households living in rural areas – namely as small-scale producers – are both consumers and producers of food. The impact of shocks on the food security and nutrition of agricultural households depends also on the extent of their engagement in agriculture and food production (Chapter 4).

Building agrifood systems' resilience requires action that addresses all the components that constitute national agrifood systems, from producers to consumers, including international trade. It also requires maintaining or restoring ecosystem services and biodiversity to preserve the natural resource base on which agriculture depends.

Column 4 (Resilience for what?) illustrates the outcomes or desired objectives of agrifood systems' resilience. Agricultural households, producers and other food supply chain actors produce, process and supply food using resources, innovations and technology to their own advantage. Their private objective is to maximize profits, improve livelihoods and reduce risks. They need to be resilient to remain economically viable in the face of shocks and stresses. Actors need to be aware they are part of a broader socio-environmental system and must ensure the sustainable management and use of natural resources for the benefit of present and future generations. Resilient food supply chains and domestic food transport networks essentially provide the public goods and coordination necessary to ensure a continuous, sustainable and stable flow of goods through systems. This is essential for the success of both farmers and agrifood enterprises so that safe and nutritious food is physically and economically available to all to ensure food security of households and individual members as final consumers. In this report, the focus is on households; indeed, if a household is food insecure no one in the household is food secure. However, due to intra-household distributional issues, even within food-secure households, individuals, particularly women of reproductive

FIGURE 2 CONCEPTUAL FRAMEWORK FOR AGRIFOOD SYSTEMS' RESILIENCE ANALYSIS



SOURCE: FAO elaboration for this report.

age, adolescent girls and young children, may be food insecure. Attention to intra-household variability is needed to effectively target the most vulnerable.

It is important to emphasize the complexity of the linkages between different parts of the analytical framework in Figure 2, as well as their bidirectional nature. Shocks directly affecting food production or food imports are transmitted through forward market linkages and eventually affect households and consumers, worsening their food security. At the same time, external shocks that affect food consumption or other systems' parts can also ripple back and affect primary producers. For example, policy changes that adversely affect productive activities and incomes in other economic sectors can impact on agrifood systems by reducing demand for both food and non-food products. Lifting subsidies on fuel directly affects the energy-intensive stages of the food supply chain, such as processing and transport, triggering a series of further impacts affecting both primary producers and consumers.

The proposed conceptual framework suggests five vantage points for analysis of agrifood systems' resilience that shape this report:

i. **Agricultural households and producers and agrifood businesses**, including small-scale producers and SMAEs, aiming to maximize their livelihoods and business success. Agriculture (crop and livestock production, aquaculture, fisheries and forestry) transforms land and other natural resources, capital and labour into food and non-food products. Agrifood enterprises are involved in food processing, manufacturing, packaging and distribution.
ii. **Food supply chains**, whose effectiveness, resilience and capacity – ranging from local to global level – depend on the agrifood market

structure and are influenced by network infrastructure and logistics.

iii. **Domestic food networks** that span the rural–urban continuum. Connectivity within agrifood systems is highly influenced by transport infrastructure and logistics, critical for how systems deal with shocks to the network.

iv. **Households**, including individuals within households, representing the level of final demand for food. Analysis here focuses on the food security and nutrition of vulnerable rural households, and the role played by various factors in achieving it, including access to basic services such as education and sanitation.

v. **National agrifood systems**, aggregating all subsystems – economic, social and environmental – including the full range of actors, networks and food supply chains that contribute to food security and nutrition and impact on the environment. Agrifood systems encompass climatic and environmental conditions, along with macroeconomic factors, institutions, policies and regulations and the role of international trade in balancing supply and demand.

Managing trade-offs when building resilience

In the framework proposed in Figure 2, a shock occurring at one point in agrifood systems can propagate through systems and affect all the other components. In response to that shock, all agrifood systems' actors will want options to absorb the impact and adapt. One possibility for food supply chains is to diversify sourcing of food products through expanded international trade. A country whose agrifood systems are highly connected into global and regional markets can more easily respond to domestic shocks by sourcing what it needs through international trade. However, the country may become more exposed to outside shocks, in particular policy-induced shocks such as trade restrictions, and face a trade-off: greater exposure to internal or to external shocks. This trade-off raises the important question of how to manage multiple risks originating from various sources. In the case of high reliance on food imports, managing international trade connectivity is critical to reduce exposure to external shocks. A country can balance domestic sourcing of food with diversified imports and international trade partners with different socio-economic and climatic profiles to manage multiple risks from various sources.

Diversification is a common resilience strategy among agricultural households in low-income countries. In the absence of well-functioning crop and livestock insurance and credit markets, crop diversification and integration with livestock production help to mitigate risks associated with climate variability and market volatility. Agricultural households also diversify into the non-farm economy to counter the seasonality of agricultural income and cope with shocks that affect farm output. Beyond the farm, households engaged in the informal economy diversify livelihoods and income sources to cope with the uncertainties of informal employment. Diversification can thus be a strong resilience tool providing sizeable benefits when a shock occurs.

However, diversification is not without costs: it foregoes the specialization that allows households to accumulate experience. This raises the question of a potential trade-off between building resilience through diversification on the one hand and efficiency on the other. Until recently, the balance has been in favour of the greater efficiency provided by specialization, to the detriment of diversification.[58, 59] However, it has become increasingly evident that improved efficiency through specialization requires stable conditions. In a world increasingly facing unexpected shocks, on top of long-term stresses, specialization might actually reduce efficiency when shocks occur. The trade-off between efficiency and resilience is a short-term concern, where building resilience may weaken efficiency in the short term but improve it in the long term.

The question then becomes: what kind of diversification is needed and at what level should it be applied to maximize the benefits of increased diversity? Developing a diverse set of responses to specific challenges, rather than diversity for its own sake, can be the guiding principle of a strategy in which diversification facilitates synergies between efficiency and resilience.[59] Countries with limited agricultural resources, such as most of the Near East and North Africa, may have little scope to meet their food needs by expanding and diversifying agricultural production. Given limited land and water resources, they may need to maximize efficiency by specializing in products for which they have comparative advantages, while engaging in international trade to source other products. This would mean greater reliance on imports for essential food items they cannot produce locally in sufficient quantities. The risks of high import dependency can be mitigated by diversifying import sources from countries and regions with different climatic profiles, combined with building food stocks to deal with supply uncertainties in times of crisis.

Redundancy – the duplication of critical systems' components or functions to increase their reliability – is another effective resilience strategy. It reinforces the capacity of agrifood systems to absorb shocks by assigning the same function to multiple actors. However, incorporating redundancy into agrifood systems can be costly to society and is particularly challenging when resources are limited. More redundancy in one systems' component may weaken resilience in another. For example, the option of importing food or increasing commercial food production in a new region may expose small-scale agricultural producers to unsustainable competition if there is a new shock.

While it is widely acknowledged that redundancy and diversification improve resilience, there can be trade-offs with efficiency and even equity. Decisions on optimal levels of redundancy and diversification, and the parts of systems where they should be applied, remain very much context-specific and depend on understanding multiple risks and their potential impacts as well as available alternatives. Diversification through integrating crop and livestock production may create synergies between resilience and efficiency by using crop residues as cattle feed, and livestock manure to maintain soil health. At the same time, the existence of an efficient crop and livestock insurance system may encourage producers to limit crop/livestock diversification and integration to the level necessary for productivity growth (e.g. crop rotation) rather than risk reduction. The final choice will depend on the balance between costs, in terms of efficiency losses, and the benefits of increased resilience. Minimizing costs, maximizing benefits, and reducing damage and losses requires identification of optimal combinations that create synergies and balance trade-offs, so that redundancy and diversification increase long-term efficiency without eroding specialization gains. Although sustainability considerations can provide guidance, the exercise can be very challenging owing to huge uncertainties surrounding future shocks, stresses and cascading crises. ■

LAYING OUT THE SCOPE OF THIS REPORT

This chapter has argued for the urgency of building more resilient agrifood systems to ensure food security and nutrition for all, now and in the future. It stresses the close relationship between resilience and sustainability, with its social, economic and environmental dimensions. Within the economic and social dimensions, special attention needs to be given to decent livelihoods and incomes for small-scale producers and other vulnerable people with agrifood livelihoods. It highlights the complexity and diversity of agrifood systems, as well as the wide spectrum of stresses and shocks they endure. Owing to these multiple factors, building more resilient agrifood systems is no simple task; it requires urgent and converging collective and individual actions on the part of a multitude of public, private and community actors. To this end, the chapter presents a conceptual framework to understand risks, vulnerabilities and capacities of agrifood systems, focusing on the capacity to absorb, as well as five vantage points for analysing their resilience: agricultural households and producers and agrifood businesses, food supply chains, domestic food networks, households, and national agrifood systems.

These vantage points will shape the discussion in the following four chapters. Chapter 2 examines the absorptive capacity of agrifood systems through four indicators that measure the robustness of primary production, the availability of food, physical access to food and economic access to food. Chapter 3 focuses on the resilience of individual food supply chains and agrifood businesses. Chapter 4 addresses the resilience of rural livelihoods, especially the most vulnerable. Based on that analysis, the concluding Chapter 5 discusses policy and investment priorities for building resilient agrifood systems at multiple levels.

This report follows the UN Food Systems Summit's call to bring forward a series of concrete actions that support a transformation of agrifood systems for realizing the 2030 Agenda for Sustainable Development. The Summit's call to action focused on five objectives, one of which is building resilience to vulnerabilities, shocks and stresses to ensure the continued functionality of healthy and sustainable food systems. This report provides evidence and guidance for actions that can help agrifood systems' actors manage vulnerability to shocks and stresses, and strengthen the capacity of agrifood systems to support livelihoods and sustainably provide continuous access to sufficient, safe and nutritious food to all in the face of disruptions. ■

PERU
Workers from the port of Pucusana loading boxes of pota (giant squid) onto a refrigerated truck.
©FAO/Jordi Vaque

CHAPTER 2
AGRIFOOD SYSTEMS' RESILIENCE AT NATIONAL AND SUBNATIONAL LEVELS

KEY MESSAGES

➔ The agriculture sector can better absorb disturbances when it has access to diversified domestic and international markets and produces a diversified mix of food and non-food products. This occurs mostly in high-income countries or those with a large agricultural base.

➔ Combined with stocks and imports, diversified domestic production ensures food is available even during disruptions. Yet, due to logistical constraints, stocks and imports on their own may not guarantee the diversity of fruits, vegetables and other perishables needed for a healthy diet.

➔ A robust transport network supports agrifood systems' resilience to shocks and stresses and guarantees physical access to food at local level. Yet, for half of the 90 countries analysed, the closure of a critical transport route could increase travel time by 20 percent or more for food diverted from the disrupted route, potentially affecting food costs for 845 million people.

➔ A key characteristic of agrifood systems' resilience is its capacity to ensure access to sufficient nutritious food. Around 3 billion people cannot afford a diet that will protect against malnutrition and an additional 1 billion would join their ranks if a shock reduced their income by one-third in the 143 analysed countries.

➔ Low-income countries are the ones unlikely to be able to afford a healthy diet. However, the threat from shocks and stresses for those who normally can afford such a diet, in 95 percent of cases, affects people in lower- and upper-middle-income countries. In low-income countries many more people may be unable to even afford an energy-sufficient diet if incomes are reduced by one-third.

Building on the conceptual framework in Chapter 1, this chapter uses national indicators as proxies to assess the vulnerability of agrifood systems to shocks and stresses. It analyses one of the five main resilience capacities: that of agrifood systems to absorb any disturbance that affects them, from natural hazards to pests to financial shocks, using the multiple pathways that protect food security and sustain the livelihoods of agrifood systems' actors. Exploring these pathways is important to understand how to improve agrifood systems' resilience. Absorptive capacity is essential to maintain agrifood systems' functions, ensuring food is available and accessible and generating incomes.

The analysis considers four key agrifood systems' dimensions: (i) the robustness of primary production; (ii) food availability; (iii) physical access to food; and (iv) economic access to food. These are relevant to food security, nutrition and sustainable livelihoods. The resilience of agrifood systems depends on many factors and some – for example, social and environmental dimensions – do not appear among these indicators. Because the chapter considers resilience at the system level, the absorptive capacity of individuals is also not discussed. ■

RESILIENCE OF AGRIFOOD SYSTEMS' FUNCTIONS

Assessing the resilience of national agrifood systems is challenging because each one has many components and actors, at several interlinked levels from production to consumption, including international trade. Some components and actors may be more resilient than others, and some shocks and stresses may be specific to one or more component or actor. Assessing resilience should consider the full range of actors and levels involved. The first step is to understand how those levels function and identify vulnerabilities. A participatory and inclusive process may help engage systems' actors in a more coordinated response to shocks and stresses.[1]

While agrifood systems differ substantially in their structure and access to markets and services, key actors are invariably agricultural producers, processors, distributors and consumers. Building on the conceptual framework in Figure 2, the resilience of national agrifood systems is a function of:

i. the existing domestic agricultural production system;
ii. the availability of food for consumers through domestic production, stocks and imports;
iii. the efficiency and flexibility of food transport systems to facilitate domestic trade and provide physical access to food; and
iv. people's economic access to food.

Any shock or stress affecting one dimension is likely to impact on others, with consequences for food security as well as the livelihoods of actors, particularly those most vulnerable. Shocks can also spread through trade channels, financial markets, remittances, etc. During large-scale disruptions, such as the 2008–2009 financial crisis and early in the COVID-19 pandemic, export restrictions affected food supply.[2–4] Diversifying international trade partners is crucial to buffer against external shocks. This requires considering a number of factors that influence choice of trading partners, from price and proximity, to the degree of integration in the global economy. Diversifying trade partners depends on a balance between costs and the benefits of increased resilience.

Managing the diversity of food production for the domestic market, and of stocks and exports is also essential for food security, nutrition and health. It allows agrifood systems to maintain food availability despite shocks, such as pests or sudden demand shifts as occurred during the COVID-19 pandemic. Exports are important to generate livelihoods. They are also a resource that can be leveraged to absorb supply and demand shocks as they express the breadth of the agricultural base of a country. ■

ABSORBING SHOCKS IN THE PRIMARY PRODUCTION SECTOR

In the course of a farming season, agricultural producers need to make decisions in the face of uncertainties about weather, prices, logistics, pests, diseases and other factors. Their resilience depends on the right decisions regarding, for example, farm or income diversification strategies, and on contextual factors such as the natural resource base, access to credit, markets and infrastructure, and the viability of production practices.

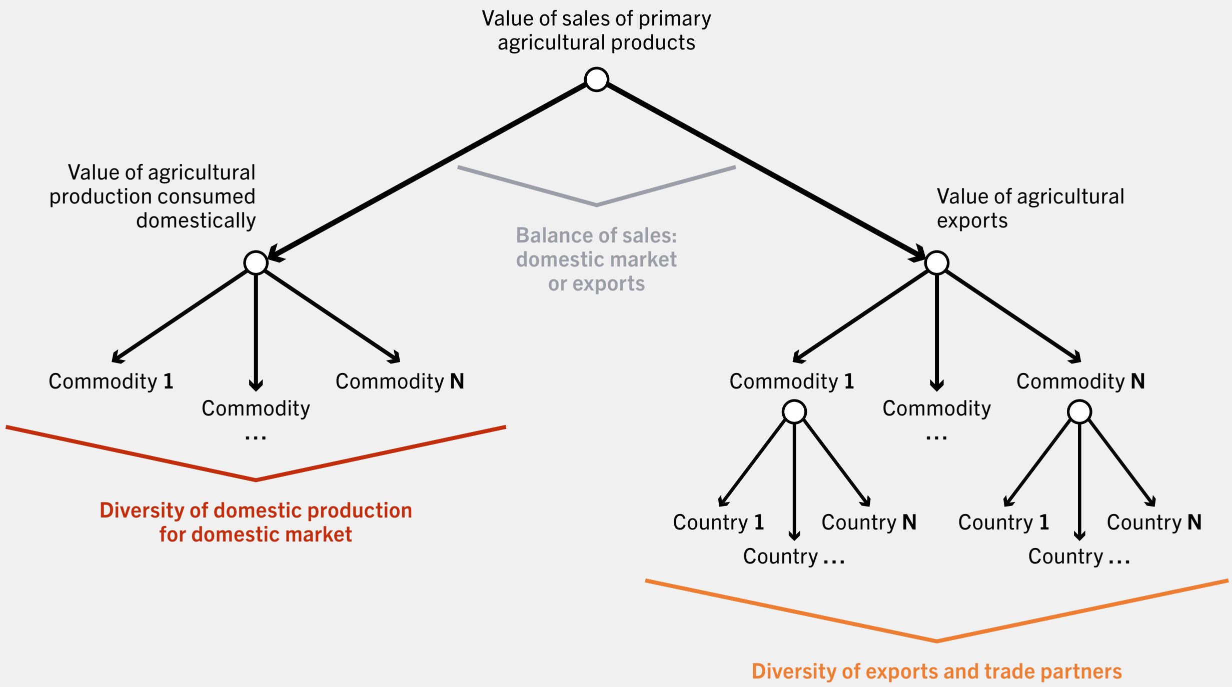
Aggregating those characteristics into a national indicator is challenging. Put simply, the capacity of a country's primary production sector to absorb a shock depends to a large extent on two factors: (i) the diversity of commodities produced; and (ii) the diversity of output markets as regards trading partners and the domestic demand for those commodities. These underpin the primary production flexibility index (PPFI), developed for this report to measure the extent of diversity across commodities and the potential to produce for domestic or export markets. A high value of this index indicates multiple potential paths for generating agricultural value and finding final outlets for primary production (i.e. redundancy of demand channels) and thus a higher capacity to absorb shocks. Box 3 describes the methodology underpinning the PPFI. »

BOX 3 THE PPFI IN A NUTSHELL

The PPFI uses FAO's extensive production and trade data to examine the pathways to generate agricultural value and find outlets for primary production. A production sector with wider options to produce and market agricultural products is better able to absorb covariate risks that affect groups, regions or entire countries. Covariate risks include pest attacks, floods and droughts that reduce supply, as well as demand shocks to domestic and export markets. The primary production sector can increase its absorptive capacity through, *inter alia*, product and income diversification and, in the case of demand shocks, by being able to switch from export to domestic markets and vice versa. An example of the latter is coffee, typically exported with limited domestic demand in many producing countries, except Brazil and Ethiopia. Higher domestic consumption in countries such as Kenya helped producers weather the storm during the COVID-19 pandemic, as logjams at ports and a sharp drop in global demand devastated exports.[5] National agrifood systems that provide some latitude to producers in terms of production options (agroecological zones and climate) and markets (logistics, certification and institutions) will be more resilient and maintain production.

The figure in this box illustrates potential pathways as a tree. A unit of agricultural product value is marketed through either domestic or export channels (top branches) and then distributed across a range of commodities and importing countries if exported. Domestic sales may be as finished products or intermediate inputs into processing. The indicator does not track whether the processed product is consumed domestically or exported. The more channels, the easier it is to absorb a demand shock, unless all domestic and export channels are affected simultaneously, or a shock occurs to a specific commodity. See Annex 1 for a more comprehensive description of the PPFI.

FIGURE PATHWAYS TO PRODUCE AGRICULTURAL OUTPUT AND SELL IT IN DOMESTIC OR EXPORT MARKETS, FOR VALUE



SOURCE: FAO elaboration for this report.

BOX 3 (CONTINUED)

Limited producer commodity price data impeded calculation of the indicator for value terms. It is calculated for protein terms instead, as the two were found to be closely correlated in countries for which price data were available. This implies excluding non-food primary commodities (e.g. wood), which cannot be converted into nutrients, despite their importance in generating income and livelihoods.

Interpreting the PPFI – The PPFI shows how the structure of production can facilitate or hamper absorption of a production shock to a specific commodity or a demand shock. Low values reflect low absorptive capacity, high values indicate high capacity. The total value of the PPFI can be further divided into three parts: (i) the balance between exports and domestic sales (grey branches in the figure); (ii) diversity of domestic production for domestic market (red); and (iii) diversity of exports and trade partners (orange).

For producers, if all agricultural production goes to the domestic market without the option to export, the value of the PPFI is equal to the contribution of domestic demand (red in the figure). Exports add two types of producer flexibility: the relative balance between exports and domestic sales (grey in the figure); and the diversity of exports and trade partners (orange in the figure).

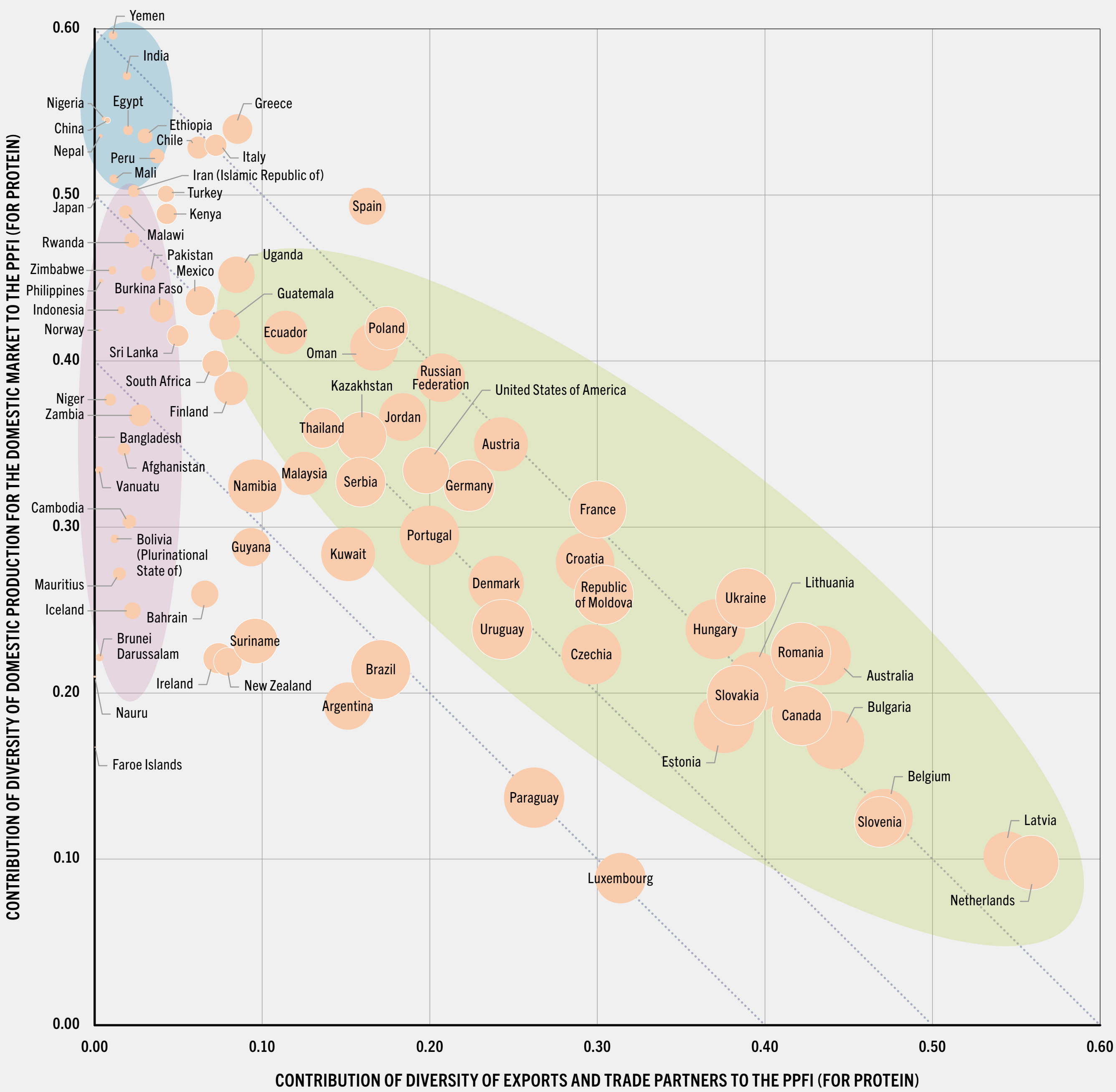
Higher values across all three types of diversity indicate a greater capacity to absorb a shock to the primary production sector. If a reduction in global commodity prices affects exporters, a high PPFI value indicates there is a broad domestic market and they may be able to redirect their products to it. For instance, due to the COVID-19 pandemic, some Chinese exporters turned to the domestic market to sell their outputs.[6] Similarly, producers may reabsorb a shock in domestic demand if there are export channels open to them. Looking at these diversities – or PPFI contributors – can also help identify specific weaknesses in systems' absorptive capacity. By way of illustration, if export sales are significant but the diversity of exports and international trade partners is limited and the primary sector diversifies very little between domestic sales and exports, this could make it vulnerable if, for example, a shock hits the main export commodity on the production or demand side.

Caveats – The PPFI is a systemic measure of how agricultural producers may be susceptible to shocks. However, it does not mean that individual producers can switch from one form of production to another or one market to another. The PPFI does not differentiate between sales to processors (intermediate demand) and consumers (final demand). Without this, it cannot capture the diversity of exports of processed goods because producers' primary commodity sales to processors are registered as domestic sales. Similarly, it does not differentiate between primary commodities sold as food, feed or biofuel, despite potentially significant competition between the three. The PPFI will therefore need additional information on the resilience of the midstream (see Annex 1). Information on unequal access to resources (credit, information, technology, land and water, etc.) across primary producers would be useful, because they shape capacities to shift between different production mixes and markets.

» Diversifying trade partners and commodities may come at a cost. Producers make decisions based on input and output prices and resource constraints, affecting a country's comparative advantage in agricultural exports. A country may need to overcome trade barriers, such as limited infrastructure or meeting phytosanitary measures, and make decisions based on historical relationships with other countries or political orientation. Trade openness, avoiding export restrictions, which exacerbates market volatility, and limiting commodity subsidies are examples of best practices to increase production flexibility.

Figure 3 presents the three dimensions of the PPFI for protein – valid proxy for value given scarce producer price data – as a 2016–2018 average for all crop and livestock products. The contribution of the diversity of exports and trade partners is in the horizontal axis, while that of the diversity »

FIGURE 3 PPFI FOR PROTEIN, 2016–2018



NOTES: The graph plots the contribution of diversity of exports and trade partners against the contribution of diversity of domestic production for the domestic market, both to the total value of the PPFI, for protein terms. The size of the orange bubbles represents the balance between the two (i.e. the balance between what is exported and what goes to the domestic market). Countries placed in the same diagonal line report the same value for export and domestic diversity – 0.4, 0.5 and 0.6, respectively. Results include all crop and livestock commodities for which FAOSTAT production and trade data were available. Fisheries and aquaculture are excluded due to the lack of trade partner data and protein conversion factors for fish species. Due to limited producer price data, non-food agricultural commodities are also excluded and the protein content of food commodities is a proxy for agricultural value. Protein conversion factors are calculated based on FAOSTAT data and then used to convert tonnes of food into tonnes of protein. To simplify graphic presentation, 90 countries that overlapped in the graph were dropped. Results are the three-year average of 2016, 2017 and 2018. Results for the full set of countries are in **Annex 3**. See **Annex 1** for methodology and data sources.
SOURCE: FAO elaboration for this report.

» of production for the domestic market is in the vertical axis. The size of the bubble indicates the contribution of the balance between the two (domestic sales or exports). Diagonal lines are the sum of export and domestic market diversity where countries along the same line report the same diversity level.

The results indicate that countries have several possible options to diversify production and to market agricultural products domestically and abroad. These are driven by a combination of country-specific factors. First, a country's comparative advantage, or lack thereof, in producing and exporting agricultural products, depends on the resource base, infrastructure, input cost and a business-enabling environment. Second, where there is openness to international trade, producers can export easily without restrictions or trade barriers by importers. And third, the size of domestic demand relative to domestic markets may partly determine the importance of exports. In China, India and Nigeria, for example, the low contribution of exports to diversification (blue oval in Figure 3) can be partly explained by their large agricultural base and diverse domestic demand. This, however, increases vulnerability to domestic economic downturns, indicated by the small orange bubbles which pinpoint domestic market orientation.

High-income countries with open trade policies, such as Australia, or part of large trading blocs like the European Union, have some of the highest PPFI values (see green oval in Figure 3), combining diversity of domestic and export markets. However, openness to trade and comparative advantage do not necessarily increase production flexibility. In Argentina and Brazil, more than 70 percent of protein value is from two commodities: soybean and maize. Specializing in a few export commodities with limited domestic demand increases vulnerability to international shocks, such as sharp price declines due to excess supply from other exporting countries.

For more than 80 percent of countries, the PPFI is driven by domestic market diversity. This is especially true for those with low PPFI values, mostly in the low-income group with little external trade and most production consumed locally (purple oval in Figure 3).[7] Consequently, the primary production sector is particularly vulnerable to domestic income shocks,[c] even for populous countries like Bangladesh and Indonesia where domestic demand is strong but commodity diversity is lower than in countries like China and India. High-income countries with a protected agriculture sector and limited comparative advantage in agriculture, such as Japan and Norway, also exhibit low diversity in exports and domestic markets, indicating low production flexibility. A low PPFI can also be due to having few trading partners, even if exports are significant. Brazil is again a case in point, having 60 percent of export value coming from one trading partner. Relying on a limited number of significant trading partners leaves a country with fewer options if a shock hits a partner country.

Small countries, such as Latvia or Slovenia, despite having a small agriculture sector, report a PPFI value almost as high as those with a much broader agricultural base, such as Canada or France, even in export diversity. This highlights the fact that the indicator does not measure magnitude but the primary sector's absorptive capacity through diversity of domestic production and marketing.

These findings can help policymakers determine which elements of production and trade add to the absorptive capacity of their country's primary sector and which contribute to its vulnerability. The analysis, however, excludes non-food primary commodities (e.g. tobacco and wool) due to lack of producer price information for all commodities and because these cannot be converted into nutrients. Their contribution to a primary sector's absorptive capacity is therefore not captured, although they generate important potential economic value for primary producer livelihoods. Box 4 discusses this issue, comparing the PPFI for value and protein terms for selected countries with sufficient information on prices of food and non-food primary commodities. As seen in Box 4, the PPFI is generally higher when measured in value terms, due to the addition of non-food

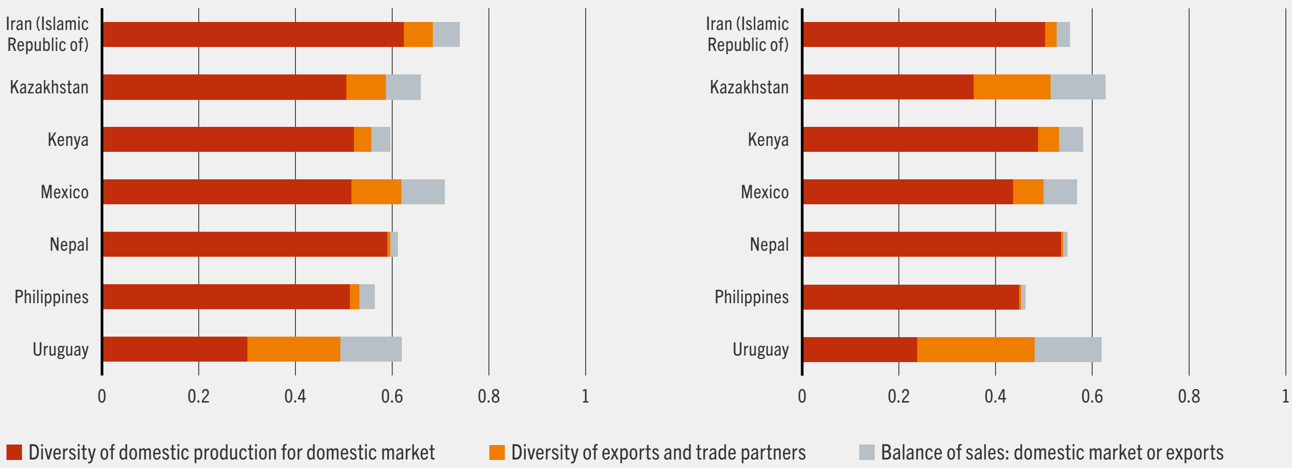
c These shocks are of particular concern in low-income countries where the share of household expenditure on food is higher and therefore an income shock may lead to a sharper reduction in food purchases.

BOX 4 THE PPFI IN VALUE TERMS, INCLUDING NON-FOOD PRODUCTS

During the COVID-19 pandemic and other major crises affecting agrifood systems in the past, timely and reliable food price information has been important to monitor food security and inform policies to build agrifood systems' resilience. Food price information also supports humanitarian aid decisions, especially in low-income countries and regions susceptible to food insecurity and malnutrition. Unfortunately, it is precisely in these areas that timely and accurate data are most often unavailable. For this reason, the PPFI is measured for protein terms, given the high correlation between protein and value. Using protein instead of value conceals a vital part of agrifood systems: non-food primary commodities, such as some types of feed and biofuel, fuelwood, fibre, skins, hides and construction materials.

The non-food agriculture sector is an important source of livelihoods for primary producers. For this reason, the figure in this box compares the PPFI for value terms (left) with that for protein terms (right) for countries where food and non-food prices were available for items representing more than 70 percent of food production. The flexibility of primary production is always higher when measured in value terms, except for Uruguay where the values are practically identical. This is explained by the inclusion of non-food items, such as tobacco and wool, and the fact some food items may be high in value but low in protein content. The contribution of domestic demand has also increased for virtually every country.

FIGURE PPFI FOR VALUE (LEFT) AND PROTEIN (RIGHT) FOR SELECTED COUNTRIES, 2016–2018



NOTES: The two bar graphs represent the total value of the PPFI, for value (left) and protein terms (right) for selected countries as a 2016–2018 average. The different stacked bars represent the relative contribution of export and domestic diversity, and the balance between the two, to the total value of the PPFI. Price data were taken from FAOSTAT. Due to the lack of protein content, non-food agricultural commodities are excluded from the PPFI for protein terms (right) but included when measured for value (left). See **Annex 1** for methodology and data sources.
SOURCE: FAO elaboration for this report.

items representing new pathways to generate value for primary producers. The analysis does not distinguish between commodities sold as food, feed or biofuel. Future analysis should take this into consideration, as growing crops for feed or biofuel may reduce food production.[8] These results highlight the need for a more thorough understanding of the issues, through more and better data and improved, expanded analysis.

In summary, results from the PPFI have shown that the primary sector can better absorb disturbances when it produces a diversified mix of products, and when it has access to diversified domestic and international markets. This occurs mostly in high-income countries or in those with a large agricultural base. ■

GUARANTEEING AVAILABILITY OF NUTRITIOUS FOOD

Species diversity in crop and livestock production, forestry, fisheries and aquaculture stimulates productivity, stability and ecosystem services.[9–11] Aquaculture, in particular, has shown to be one of the world's most diverse farming practices in terms of species, farming methods and environments used. Findings indicate that, in the future, the number of farmed species in the world will oscillate around 428, of which 29 dominant and 116 relevant, that is, responsible for 99 percent of annual production.[12] Diversifying aquatic farmed species can be of importance for long-term performance and viability of the sector with respect to sustaining food production under changing conditions. Indeed, countries with high species diversity are usually associated with higher production, with Asian countries – particularly China – producing the most diverse collection of species.[13]

Just as diversity helps ensure the capacity of agricultural production to absorb disturbances, diversity in food availability strengthens consumer resilience, providing the nutrients essential for health. Beyond producing more food to meet a growing demand from a growing and increasingly affluent population, agrifood systems must provide diverse foods of high nutritional quality.[7, 14] There is evidence pointing to declining diversity of national food supplies[15] and this trend is likely to continue as farm sizes increase,[14] raising concerns about global nutritional diversity. Maintaining diversity of food supplies needs to happen in a context where specialization and intensification of agrifood systems lead to loss of resilience in agricultural landscapes, evidenced by a decline in crop diversity, landscape multifunctionality and regulating ecosystem services.[16]

In most low-income countries where international trade is generally limited, consumption diversity requires a wide range of agricultural goods produced domestically, as seen in the PPFI results. Diversifying production is thus essential to ensure food security and nutrition. Conversely, countries with specialized production of a small basket of commodities can enhance food supply by importing a range of food products from a similarly broad range of trading partners. This is particularly important for countries with a narrow agricultural base, where climate or lack of land or water limits diversification, as in small island developing States (SIDS) and landlocked developing countries (LLDCs). Countries with broad-based agriculture can achieve food diversity more easily by combining diversified national production and international trade; production and supply diversity are not strongly interdependent.

International trade is one of the many strategies for buffering against shocks and stresses and increasing food supply diversity. It allows countries and regions to maintain food security and overcome growth limitations.[17, 18] Trade can reduce pressures on natural resources such as water,[17, 18] help keep prices down[3] and provide seasonal goods throughout the year.[4] Through trade, agrifood systems are becoming increasingly interconnected and interdependent. Data for 1992–2009 show global wheat and rice trade connections doubled while trade flows increased by 42 percent for wheat and 90 percent for rice.[19] Fish and fishery products are some of the most traded food commodities. In 2018, 67 million tonnes, or 38 percent of total fisheries and aquaculture production, were traded internationally.[20] However, although it buffers against domestic shocks, international trade increases exposure to external shocks and can itself become a channel of shock transmission.[19, 21, 22]

Studies of resilience often focus on the response to a shock, such as a trade shock, without looking at resilience capacities ranging from prevention, anticipation and absorption of

BOX 5 THE DSFI IN A NUTSHELL

The DSFI uses FAO's food balance sheets and trade data to plot the pathways through which a unit of food is available to consumers with external stock data complementing FAO data. It is assumed food availability can be linked to the share of food produced domestically, stocked from previous years or imported, and to the food's diversity. Agrifood systems that draw on food from many different sources have greater capacity to absorb supply shocks.

The three possible pathways a unit of food, measured for kilocalories, can reach a consumer are represented as a tree in the figure as follows: (i) food produced domestically; (ii) imported food; and (iii) stocks carried over from the previous year (imports or domestic production, public and private).

Since stocks and production are within a country, policymakers can exercise through them more direct control over food self-sufficiency, represented in the figure by the Stocks in kilocalories and Kilocalories domestically available branches. The latter is further disaggregated by destination (local market or export) and subsequently by commodity produced. If a supply shock occurs, exports may be redirected by producers to the domestic market through price signals or policy interventions – of last resort – to ensure food availability. Imports are represented on the right side of the figure as Imports in kilocalories, also further disaggregated into trading partners and import diversity. The balance between imports and what is produced or stocked domestically measures the role of trade in supplying food and sourcing diversity. A country with balanced production relative to imports may still be vulnerable if it imports from only a few trading partners and holds limited food stocks, restricting the possibility to redirect surplus food to the domestic market. Increasing buffer stocks or diversifying international trade partners before the shock hits can enhance absorptive capacity. This will help policymakers identify the weaknesses in their food systems' absorptive capacity for different supply shocks.

shocks to adapting and transforming systems. Policymakers make decisions in a multi-risk environment, where the next disruption may be domestic. Building on Kummu *et al.* (2020),[17] FAO developed a dietary sourcing flexibility index (DSFI) for this report to assess the role of diversification in domestic production, stocks and imports, so as to ensure the food that makes up a healthy diet is available to a country's population. The index captures multiple sourcing pathways of a unit of food (for nutritional outcomes, such as kilocalories) based on a country's domestic production, food imports, and public and private stocks. A high value indicates multiple possible sourcing pathways for a unit of food (i.e. redundancy of sources). The DSFI thus measures flexibility in sourcing a specific food unit. National agrifood systems supplying food from different sources are more flexible and capable of absorbing supply shocks. See Box 5 for a more detailed description of the indicator, and Annex 1 for the full methodology. This index complements the PPFI by extending the focus beyond domestic agriculture to imports and food stocks in order to capture the multiple pathways through which a unit of food can reach the consumer. In short, the DSFI measures the capacity of agrifood systems to absorb shocks and ensure food availability to consumers, while the PPFI focuses on ensuring livelihoods for primary producers.

Figure 4 illustrates the DSFI for kilocalories for all crop, fish and livestock commodities for available FAOSTAT new food balance sheets and trade data, as a 2016–2018 average. To provide for healthy diets, countries also need to source a variety of other nutrients.[23] The report expands the analysis to cover another three nutritional components: fruits and vegetables, fat, and protein, included in Annex 2. Other nutrients, such as vitamins and iron, are also required for a healthy diet, yet data are lacking in FAO's food balance sheets.

Aside from nutritional components, the DSFI can also be divided into different elements that »

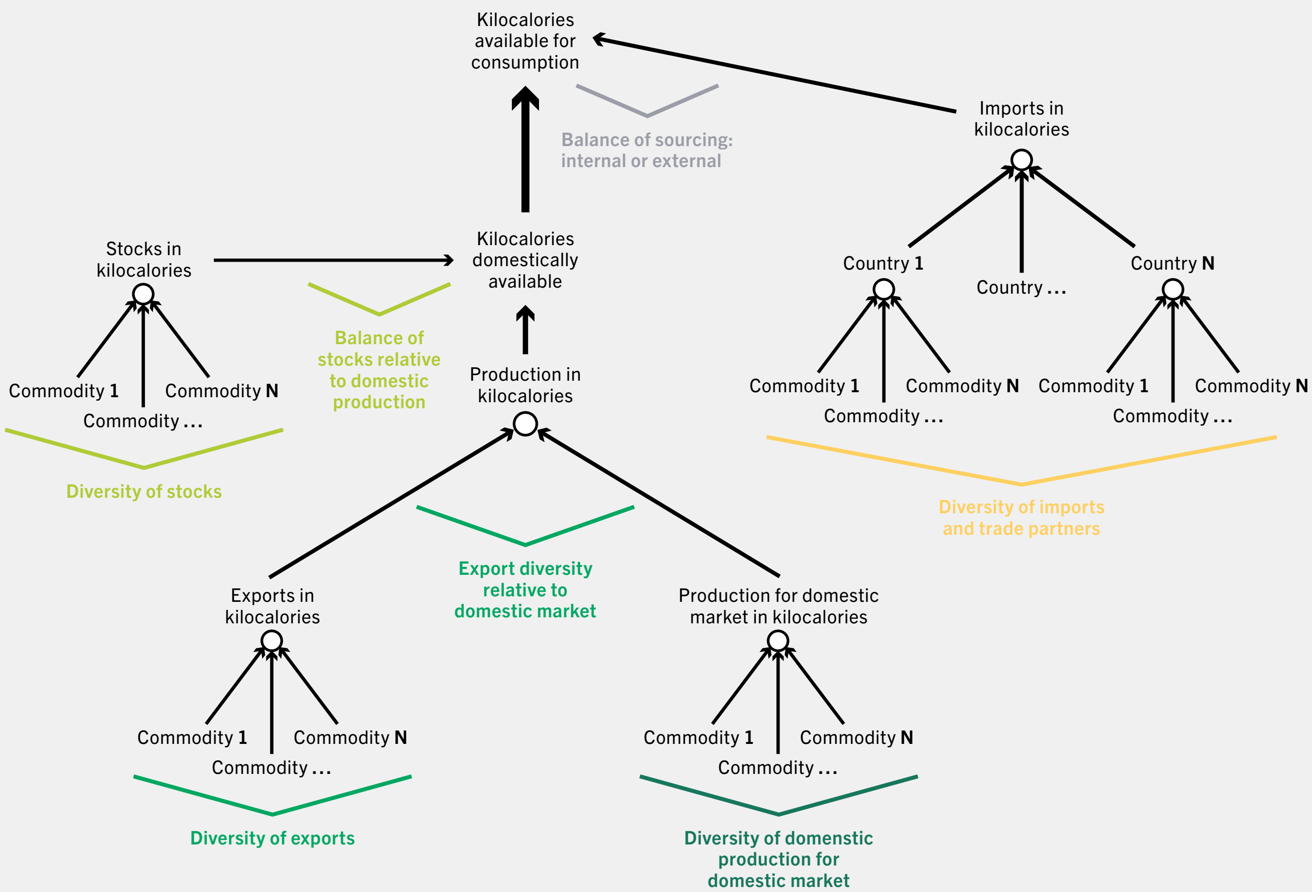
BOX 5 (CONTINUED)

The DSFI captures these multiple pathways as a snapshot in time. Over time, its different contributions may interact (e.g. imports may become stocks in the following year or stocks may become exports).

Interpreting the DSFI – The DSFI measures the redundancy of sources by capturing multiple pathways for sourcing a food unit. It is particularly useful in understanding how production, trade and stocks can help agrifood systems absorb supply shocks. The tree in the figure shows how flexible sourcing is built into agrifood systems. For households as consumers, in a situation of economic autarchy, the value of the DSFI equals the contribution of production diversity for the domestic market (dark green in the figure). If there are exports, systems have greater flexibility because this surplus can be directed to domestic markets in times of crisis. This increases the value of the DSFI by diversity of sourcing and commodities exported, generated by adding in those exports (mid green in the figure). Buffer stocks and imports also add flexibility to food systems. As for the PPFI (Box 3), a high DSFI value reflects high absorptive capacity.

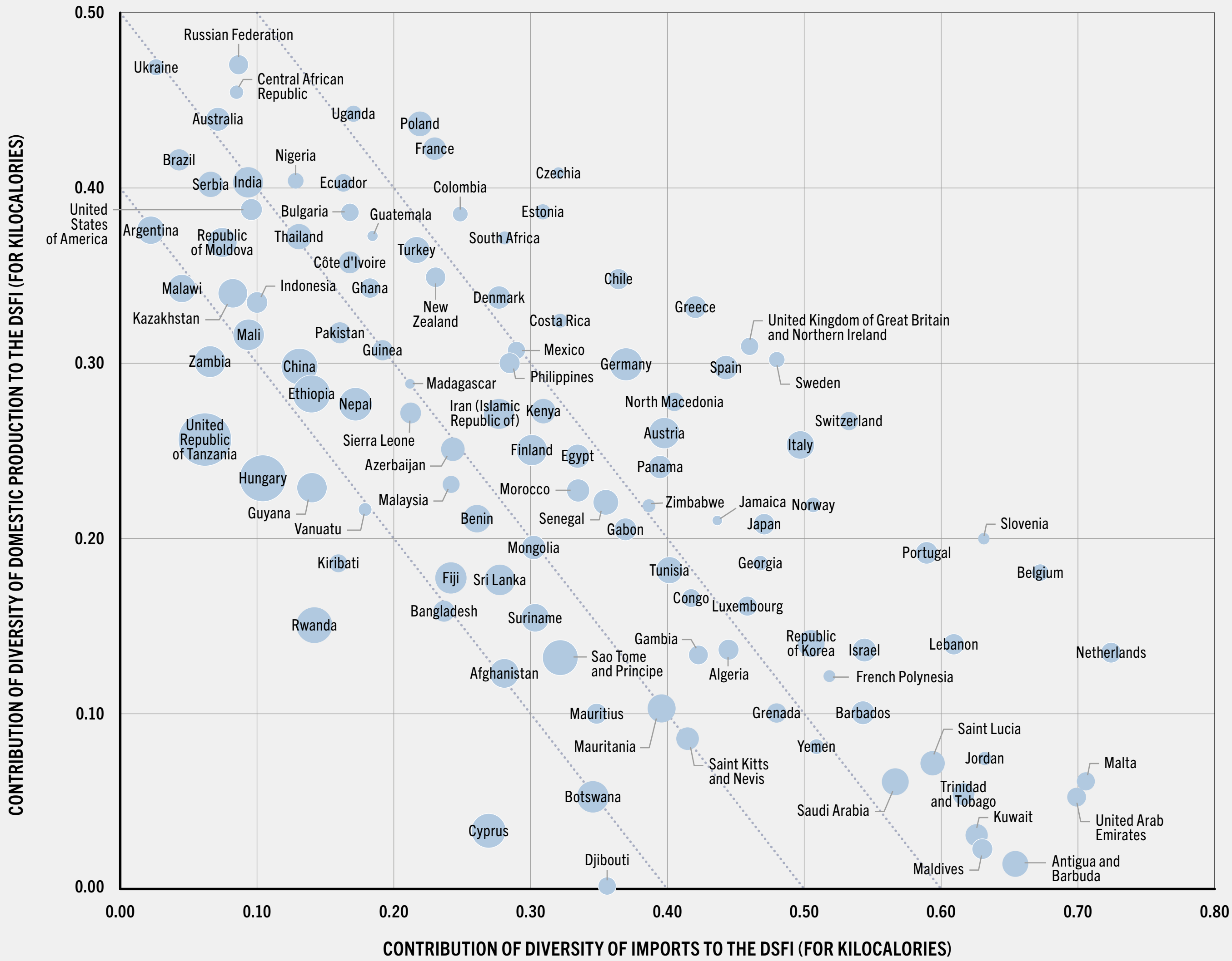
Caveats – The DSFI needs to be complemented with information on a country's size and level of development and those of its trading partners that influence agrifood systems' vulnerability. Shocks such as a flood will affect entire agrifood systems in a small country but have less impact in a larger country with different agroclimatic zones. A country's development level is also important where redundant and robust infrastructure is essential to absorb shocks.

FIGURE PATHWAYS TO SOURCE FOOD FROM STOCKS, DOMESTIC PRODUCTION OR IMPORTS, FOR KILOCALORIES



SOURCE: FAO elaboration for this report.

FIGURE 4 DSFI FOR KILOCALORIES, 2016–2018



NOTES: The graph plots the contribution of the diversity of imports (i.e. diversity of imports and trade partners plus balance of sourcing: internal or external) against the contribution of the diversity of domestic production (for both domestic market or exports), both to the total value of the DSFI, for kilocalories. The size of the blue bubbles represents the contribution of the diversity of stocks to the DSFI. Countries placed in the same diagonal line report the same value for production and import diversity – 0.4, 0.5 and 0.6, respectively. Results include all crop, fish and livestock commodities for which FAOSTAT new food balance sheets and trade data were available. Kilocalorie conversion factors are based on FAOSTAT data and then used to convert tonnes of food into kilocalories. To simplify graphic presentation, 40 countries that overlapped in the graph were dropped. Results are the three-year average of 2016, 2017 and 2018. Results for the full set of countries disaggregated by DSFI contributions are available in **Annex 3**. See **Annex 1** for methodology and data sources.
SOURCE: FAO elaboration for this report.

» provide diversity of sourcing food: domestic production, imports and stocks. The bubble chart in Figure 4 illustrates these three value dimensions of the DSFI for kilocalories: the horizontal axis is the contribution of imports and their diversity across trade partners with multiple commodities; the vertical axis is the contribution of commodities produced domestically; and the size of the bubble is the contribution of estimated stocks.[d] It is important to note that import diversity (horizontal axis) also includes the balance between imports and what is domestically available. This balance represents a country's reliance on a mix of both domestic

d Stock data are notoriously difficult to estimate accurately, therefore this contribution to domestically available food is separated from other components contributing to diversity.

production and imports. Similarly, the balance between exports and production for the domestic market – representing a country's agricultural base and capacity to produce a surplus – is incorporated under domestic production diversity.

Two results emerge clearly from Figure 4: first, countries diversify their food sources in different ways; second, the effectiveness of diversification does not depend on country size or income level. The latter is illustrated by countries with different income levels appearing on the same diagonal lines, where the sum of import and production diversity levels is the same.

A similar DSFI value can be attained by countries with a sizeable agricultural base that rely more on domestic production (e.g. India, Nigeria, Russian Federation and United States of America) and by those that diversify more through imports (e.g. Turkey, Senegal and Tunisia). Given the diversity of import options, some countries that rely on imports do so with high diversity across trade partners and multiple commodities, attaining some of the highest DSFI scores by buffering supply shocks over many partners and commodities (e.g. Japan, Jordan, Norway, Republic of Korea and United Arab Emirates). Except for France and Poland, European Union countries with free circulation of goods across borders tend to have significant diversification through imports, especially Belgium and the Netherlands.

Although reliable and consistent stock data are rarely available, results indicate stocks tend to matter more for countries with lower DSFI values (below the central diagonal line), that rely more on domestic production with relatively low import diversification. As seen in the PPFI results, unsurprisingly, low-income countries, such as in sub-Saharan Africa, are among those with the lowest import diversity (see Box 6 for a comparison between the DSFI and PPFI methodology and results), partly explained by limited trading of some staples, such as millet, sorghum and fonio. In these countries, food systems' flexibility is mostly driven by production for the domestic market. Thus, when a shock occurs, policymakers are constrained by managing production diversity to absorb it or rely on existing stocks.

Having a mix of domestic and imported food is important to minimize risk, especially for smaller countries. For countries that depend heavily on imports due to scarcity of domestic natural resources, such as countries in the Near East as well as SIDS and LLDCs, it is crucial they diversify import baskets and international trade partners, while investing in domestic stocks.

Unlike for calories, the DSFI for fruits and vegetables, which are key to a healthy diet, has a clear association with a country's income because of logistical constraints in perishable transport and storage. High-income countries in Europe, Northern America and the Persian Gulf have noticeably higher DSFI values, with some exceptions (see Annex 2). Countries with higher DSFI values for overall kilocalories than for tonnes of fruits and vegetables, such as China, Ethiopia and Uganda, probably have greater absorptive capacity for shocks affecting staple foods than for shocks affecting fruits and vegetables. ■

ENSURING PHYSICAL ACCESS TO FOOD AT SUBNATIONAL LEVEL – THE DOMESTIC FOOD TRANSPORT NETWORK

The robustness of agrifood systems depends on a confluence of factors. Guaranteeing production, availability and economic access to food will capture part of what makes it resilient. Country logistics also play a fundamental role in ensuring physical access to food and producing non-food agricultural output. Agrifood systems are supported by a network across the rural–urban continuum and how it responds to shocks will depend on connectivity within that network. During regional weather anomalies and yield losses, food supply chains can rely on the same or compensatory products from other regions in the country or combine imports with domestic purchases to ensure affordable food remains available. These alternative pathways help ensure food supply chains maintain their

BOX 6 COMPARING THE DSFI WITH THE PPFI AND IDENTIFYING THE HIDDEN MIDDLE

The PPFI and the DSFI differ in several aspects. Capturing multiple pathways through which a unit of food reaches the consumer, the DSFI measures the capacity of countries' agrifood systems to absorb a shock while ensuring food availability. The PPFI captures possible pathways by which agricultural producers can generate value, a measure of the capacity of domestic agriculture to absorb shocks and create livelihoods for primary producers. (If data were available, the PPFI could also capture the potential contribution of non-food primary commodities, such as cotton, tobacco and timber, to the primary sector's capacity to absorb shocks – see Box 4.)

In addition to the diversity of domestic production, the DSFI also captures a country's mix of imports, the diversity of trade partners, and the diversity of stockholding, which can act as a buffer during a crisis. A further difference is that the DSFI is based on various nutritional units (e.g. kilocalories, protein, fat), while the PPFI is based on production value (quantity multiplied by unit price) or on protein terms if price data are missing.

The PPFI overlaps with the part of the DSFI that captures production diversity. However, even though the rationale is the same for both, there are important differences. First, the PPFI captures not only export diversity but also the diversity of importing countries. Second, since the PPFI focuses on agricultural value, it considers crops and primary livestock products, but excludes anything processed (e.g. flour from wheat), unlike the DSFI which focuses on both processed and unprocessed. The DSFI considers any crop or animal product processed in a country to be produced in that country, even if the raw input was imported. For these reasons, the share of production diversity in the DSFI and the total value of the PPFI differ.

It is important to note that neither indicator casts light on the midstream components of agrifood systems – for example, they provide no information on whether primary producers are selling to consumers or to processors and whether processed food remains on the domestic market or is exported. Knowing more about the midstream in food supply chains matters because systems are only as resilient as their weakest link. For a more complete picture of the resilience of agrifood systems, the degree of flexibility in options for midstream actors also needs to be measured. Issues to address include access to primary inputs from domestic and imported sources, the level of diversification in processed foods, and options to sell those foods on the domestic or export markets. A midstream flexibility index (MFI) could combine these three elements to measure the diversification of the processing sector in terms of sourcing its primary inputs (domestic or imports), the types of goods it produces and market outlets. National food systems in which processors offer more latitude in food production give the option to produce for domestic and export markets, and to use diverse input sources; systems thus become more resilient and maintain productive capacity in food processing.

The report proposed the theoretical underpinning of this indicator but did not compute it as it requires data not readily available. Enhancing data collection and measuring capability will then be key to complete the set of indicators proposed in this report. For more details on how the MFI can be calculated and its data requirement, see Annex 1.

core functions. Well-functioning transport networks of non-food agricultural commodities, such as wood, reduce costs of production, labour, materials and energy. This, in turn, improves profitability and generates income for non-food agricultural producers.

Connectivity builds resilience to shocks throughout the network. Network theory, as applied to food supply chains,[24–27] provides insights into how certain aspects of agrifood systems' resilience can be measured and suggests entry points for an analysis of domestic food transport networks, for example, the criticality of transport links and the redundancy of some routes if a link is broken.[e] Such an approach can

e A link is any part of the road, rail or water transport network that forms part of the route where food transport occurs between supply and demand locations.

be useful to understand how additional network links affect agrifood systems – an important question because network density will typically increase over time.[25]

This section analyses the resilience of food transport networks in 90 countries representing 7 billion people (92 percent of the global population) in 2017. Based on these data, three national indicators are computed to capture the vulnerability of transport networks around the world (see Box 7 for the methodology). Due to lack of data, the analysis is limited to crops (except oil crops) and does not include transport of other agricultural commodities, including non-food commodities. Hence, the analysis is limited to the food component of agrifood systems, and more specifically to crops. Some food commodities considered may go to agro-industrial processing, feed or biofuel instead of consumers. The analyses do not differentiate between these destinations.

The vertical axis in Figure 5 is the proximity-based resilience indicator for 43 countries, colour-coded for country income. The horizontal axis measures the average time to transport food. Proximity-based resilience levels (vertical axis) equal to 1 indicate that production can meet demand in its specific catchment area, implying each catchment could revert to self-contained city-region agrifood systems if needed. However, no country approaches that limit, given that the complete collapse of its transport network is extremely unlikely. There is considerable variation across countries, where those with shorter average transport time (horizontal axis) generally have higher proximity-based resilience (vertical axis).

This is not surprising, as lower transport time means food is delivered close to where it is produced. This is the case for France, the Republic of Korea and Turkey. At the other extreme are much larger countries with longer distribution networks, such as Australia, Brazil and Canada. However, some large countries, such as China and Nigeria, have made their food production and distribution more compatible with short supply chains and if transport costs increase, they can easily readjust. Proximity-based resilience also seems uncorrelated with country income. These results also have sustainability implications, as shorter transport networks imply not only lower transportation and possibly network maintenance costs but possibly lower environmental costs as well, such as lower energy use and pollution. Figure 5 captures the flexibility of transport networks going local but does not consider the likelihood of a disruption, nor its location or impact on producers and suppliers.

The second indicator, route redundancy, examines the availability of alternative routes when road links are broken. The third, the relative detour cost indicator, examines the impact of disruptions to critical links. To estimate detour costs, the extra cost from closed critical links is calculated by determining the shortest routes and the difference in travel time before and after disruption. When divided by travel time, this difference captures systems' sensitivity to closed links. By this measure, for 47 countries out of 90 analysed, the closure of a critical transport route could increase travel time by 20 percent or more for food diverted from the disrupted route, potentially affecting food costs for 845 million people.[f] The effects are more local in some countries than in others: the share of population potentially affected ranges from 25 percent in Nigeria to 78 percent in South Africa.

Table 1 places the three indicators side by side. Countries with colour-coded green cells score very highly on resilience for that specific indicator, while those in dark orange have low scores. The indicators are uncorrelated with one another but deliver a more comprehensive picture of transport network resilience and its vulnerabilities when analysed together. China has the capacity to adjust to more proximity-based food systems with high redundancy (green cells under Proximity-based resilience and Route redundancy), reducing the probability of systems having to go local. If a critical link is disrupted, average travel time also does not increase by a significant amount (green cells under Relative detour cost [local »

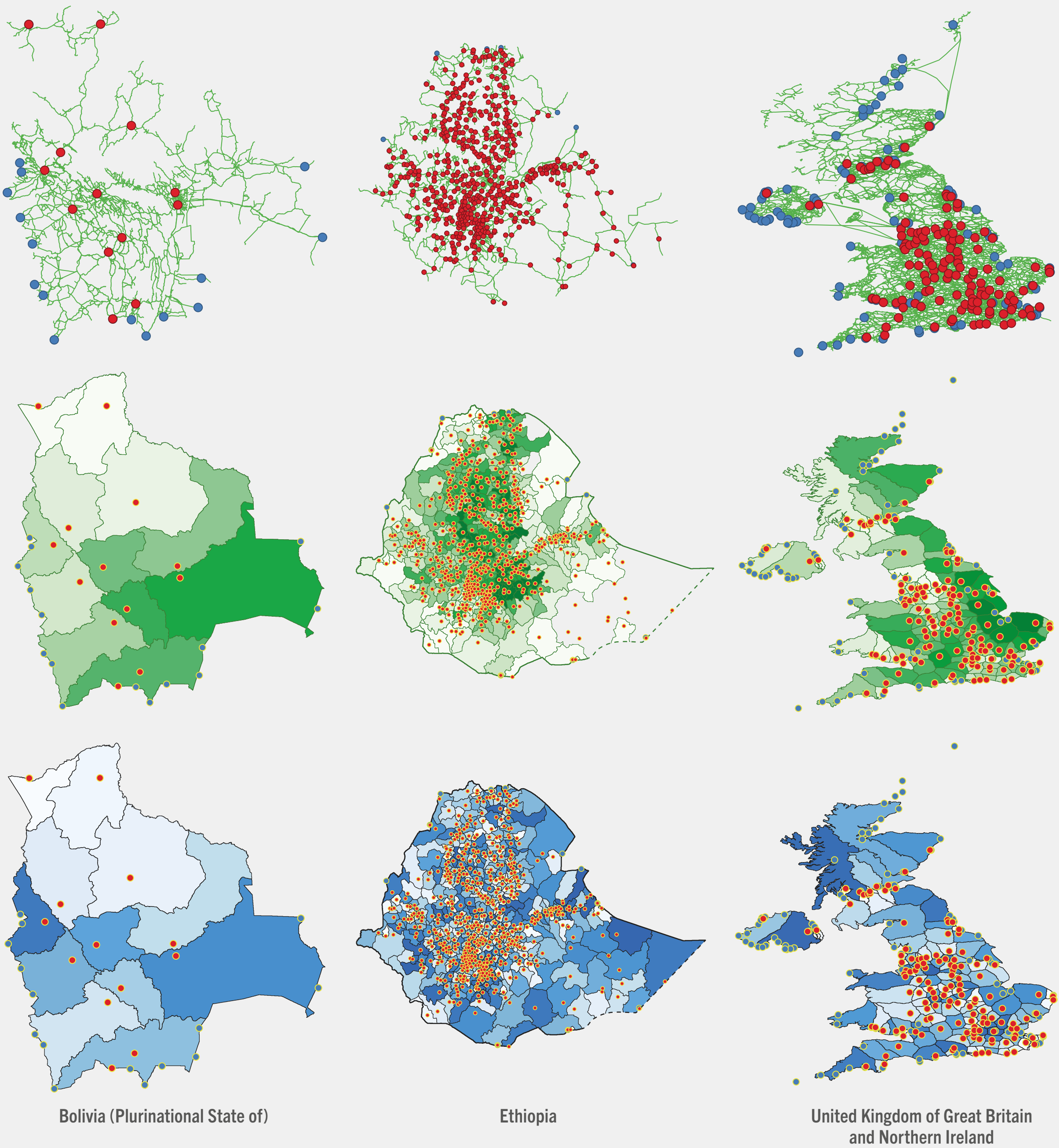
f Some of the larger countries that experience a 20 percent or more increase in travel time are Bangladesh, Ethiopia, Nigeria, the Philippines and the Russian Federation. See Annex 3 for the full list.

BOX 7 METHODOLOGY TO EXAMINE THE RESILIENCE OF DOMESTIC FOOD TRANSPORT NETWORKS

To represent food transport networks, both cities and transport modes (roads, railways, waterways and ports) are analysed. Crops were selected based on the quantity, diversity and nutritional value needed to achieve a nutritionally adequate diet. The selected crops represent, globally, 66 percent of food supply, 60 percent of calories and 58 percent of protein. Beverages, animal products and oil crops are excluded due to data constraints.

Production and demand were spatially represented to analyse transport network resilience. Spatial data for production and population are combined with tabular data for: (i) food production, spatially allocated to production zones in each country; (ii) food supply, spatially allocated based on population distribution, with per capita supply varying by commodity but remaining constant within countries; and (iii) exports and imports, allocated to trade locations based on the most likely mode of transport (ports or land border crossings).

FIGURE FOOD DISTRIBUTION NETWORKS IN BOLIVIA (PLURINATIONAL STATE OF), ETHIOPIA AND THE UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND



NOTE: Spatial zones in the middle and bottom row are catchment areas around cities. See **Annex 1** for methodology and data sources.
SOURCE: Nelson *et al.* (forthcoming).[28]

BOX 7 (CONTINUED)

The figure in this box illustrates the domestic food distribution network in three countries: Bolivia (Plurinational State of), Ethiopia and the United Kingdom of Great Britain and Northern Ireland. The top row presents the transport network, with cities in red and trading nodes in blue. The middle row presents production volumes for each country's main crop, respectively, fruits, pulses and wheat, and is obtained by superimposing production over the cities and trading nodes in the top row. The bottom row presents the final supply map for those crops. Together, the maps show how food transport networks connect production to demand. A darker shade means greater production (green in middle row) or greater demand (blue in bottom row). Overlaying urban centres and their rural catchment areas with the transport network provides a topological representation of the internal agrifood systems' distribution network.

Based on the above, there are three national indicators to capture the structural vulnerability to disruptions to food systems' transport network:

i. The **proximity-based resilience** indicator connects food production to supply to measure how food systems respond to disruptions. Systems are less vulnerable to network disruptions if food is produced locally, as it is not transported over long distances.
ii. The **route redundancy** indicator measures availability of alternative routes by calculating the percentage of tonnes over links for which there are other routes. Most countries have alternative routes for virtually every link, but exceptions exist.
iii. The **relative detour cost** indicator measures systems' sensitivity to closure of critical transport links due to shocks or stresses (e.g. floods or political instability). It calculates the extra travel time when a critical link between origin and destination closes.

» and aggregate impact]), suggesting that China has a resilient transport network. At the other extreme, in a country like Somalia, where food systems are not set up to go local and route redundancy is low (see dark orange and orange cells), disruptions to critical links may still force food systems to go local for a time, which can be challenging.

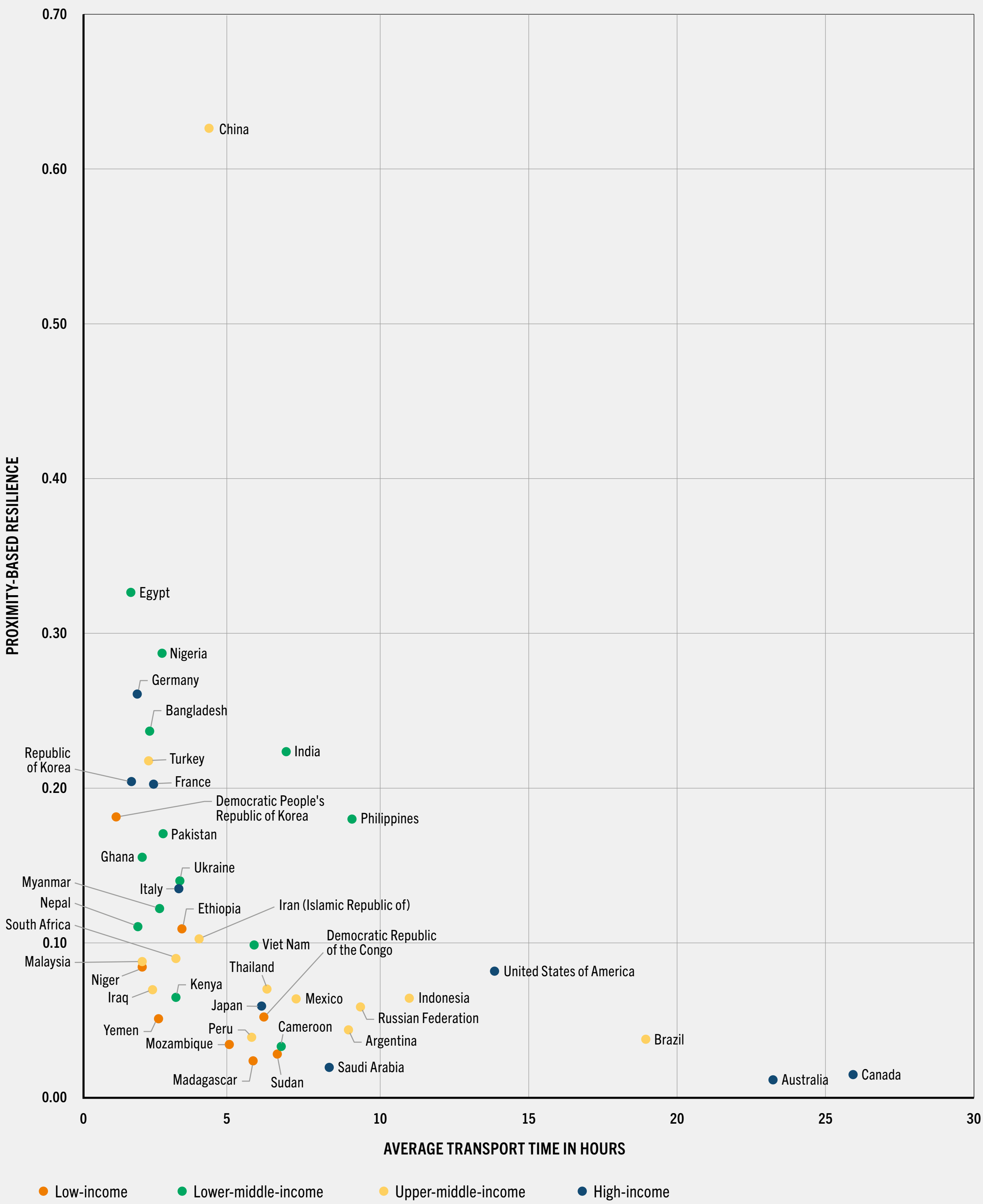
Limited redundancy does not affect only low-income countries (see Chile, Indonesia and Papua New Guinea in Table 1). Yet, it is low-income countries that face the greatest challenges in system-wide resilience measures regarding food transport networks, with a combination of low capacity to adjust to proximity-based systems, and a high number of links without practicable alternative routes in case of disruption. High-income countries like France and the United States of America are at the other end of the spectrum, although exceptions exist since proximity-based resilience depends on how production is distributed relative to demand. Australia, Canada and Chile are vulnerable in this respect.

The relative detour cost (right column) highlights how, for some countries, closure of critical links can be incredibly costly. For countries like Bangladesh, Brazil, the Democratic Republic of the Congo, Haiti, Madagascar, Niger, the Philippines, Senegal and the Sudan, travel time increases by, on average, 30 percent or more, increasing the cost of food. For some, like the Philippines and the Sudan, the impact of critical link closures is felt nationally, not just locally.

Table 1 reports only the average effect of random disruption to critical links. However, it is possible to examine the relative detour cost of specific disruptions. Box 8 analyses specific disruption scenarios in flood-prone regions of Nigeria and Pakistan.

Overall, this analysis highlights the critical importance of a robust transport network in supporting resilience of food systems to shocks and stresses and guaranteeing physical access to food at local level. A robust transport network would prevent increases in travel time with the knock-on effect on food costs, in the event of the closure of a critical transport route. ■

FIGURE 5 PROXIMITY-BASED RESILIENCE AS A FUNCTION OF THE AVERAGE TRANSPORT TIME OF FOOD IN SELECTED COUNTRIES



NOTES: Countries were selected based on population (more than 20 million). For comparability across countries, proximity-based resilience is corrected for tonnage (i.e. multiplied by the square root of the total tonnage of transported crops) to correct for the artificial effects between country size and the resilience metric. The corrected metric is considered the more appropriate system-wide estimate of the resilience of a country's food transport network because it takes into account the size of the country. The uncorrected measure would tend to overestimate resilience of small countries, where distances and volumes transported are limited, and underestimate that of large ones. See **Annex 1** for methodology and **Annex 3** for the proximity-based resilience results for the full set of countries.
SOURCE: Nelson *et al*. (forthcoming).[28]

TABLE 1 INDICATORS OF RESILIENCE AND VULNERABILITY OF FOOD TRANSPORT NETWORKS FOR SELECTED COUNTRIES

COUNTRY		SYSTEM-WIDE MEASURES		LOCALIZED DISRUPTION	
		Proximity-based resilience	Route redundancy	Relative detour cost (local impact)	Relative detour cost (aggregate impact)
Low-income	Democratic Republic of the Congo	High	Medium	Low	High
	Haiti	High	Medium	Low	Medium
	Madagascar	Medium	Medium	Low	High
	Mali	Medium	Medium	Medium	High
	Niger	High	High	Low	Medium
	Somalia	Low	Low	Medium	High
	South Sudan	Low	Low	Medium	Medium
	Sudan	Medium	Low	Low	Low
Lower-middle-income	Bangladesh	Very high	High	Low	High
	India	Very high	High	Very high	Very high
	Myanmar	High	High	Low	High
	Nigeria	Very high	Very high	Medium	Very high
	Pakistan	High	Very high	High	Very high
	Papua New Guinea	Low	Low	High	Very high
	Philippines	High	Medium	Low	Low
	Senegal	High	Very high	Low	Low
	Zambia	Medium	High	Low	Low
Upper-middle-income	Brazil	Medium	High	High	Very high
	China	Very high	Very high	Very high	Very high
	Indonesia	High	Medium	High	Very high
	Russian Federation	High	Very high	Medium	Very high
	South Africa	High	Medium	Medium	Very high
	Thailand	High	Medium	Medium	High
High-income	Australia	Low	Low	Medium	Very high
	Canada	Low	Very high	Medium	Medium
	Chile	Low	Medium	Very high	Very high
	France	Very high	Very high	High	Very high
	United States of America	High	Very high	Very high	Very high

Food transport network resilience

Low — Medium — High — Very high

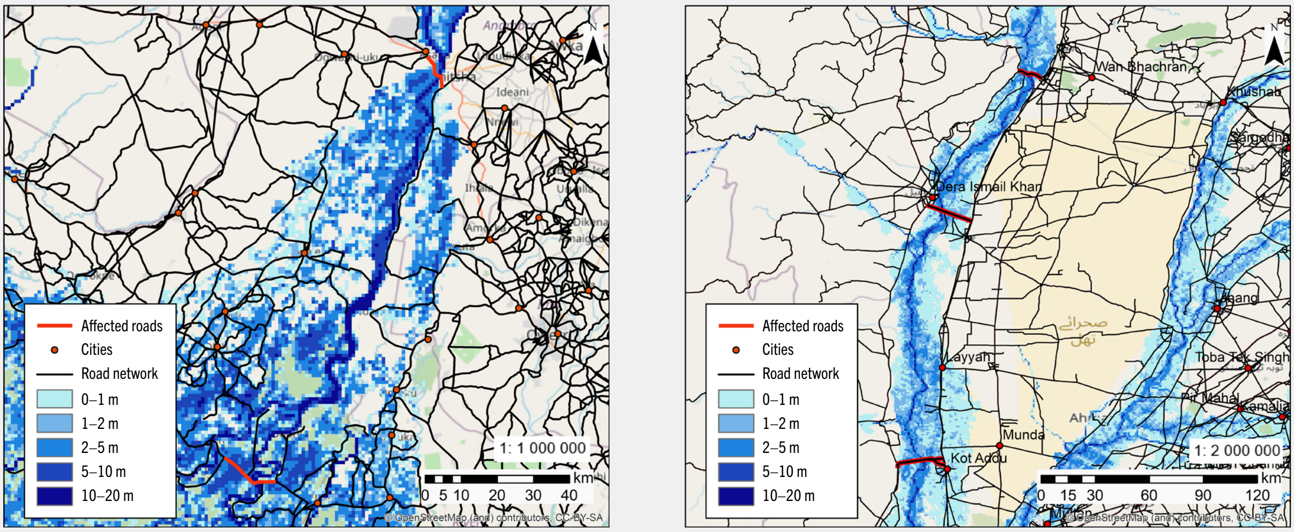
NOTE: Proximity-based resilience is measured as follows: low when values are less than or equal to 0.02; medium when values range between 0.02 and 0.05; high for between 0.05 and 0.2; and very high when it surpasses 0.2. Route redundancy is measured as follows: low when values are less than or equal to 70; medium when values range between 70 and 80; high for between 80 and 90; and very high when it surpasses 90. Relative detour cost (local impact) is measured as follows: low (resilience) when values surpass 30; medium when values range between 15 and 30; high for between 5 and 15; and very high when values are less than or equal to 5. Finally, relative detour cost (aggregate impact) is measured as follows: low (resilience) when values surpass 10; medium when values range between 5 and 10; high for between 2 and 5; and very high when values are less than or equal to 2. Proximity-based resilience is corrected for tonnage. Countries were selected based on population (more than 5 million), income group and region, so as to capture as much differentiation as possible. See **Annex 1** for methodology and **Annex 3** for the results for the full set of countries.
SOURCE: Nelson *et al.* (forthcoming).[28]

BOX 8 SIMULATING THE IMPACT OF FLOODS ON FOOD TRANSPORT NETWORKS IN NIGERIA AND PAKISTAN

Flooding, from flash floods to longer-duration stagnant waters, reduces the connectivity of transport networks. Roads may become impassable, bridges too dangerous to cross or even washed away. Once the flood subsides, direct infrastructure impacts may be short-lived if there is no material damage, but there can be long-lasting effects if repairs are delayed, often the case in less developed countries. Floods can also affect a larger area for a longer time, with traffic delays and congestion on alternative routes, increased journey distances/durations, and higher fuel consumption and GHG emissions.[29]

Nelson *et al.* (forthcoming) simulate the impact of localized flooding in Nigeria and Pakistan, considering loss of network connectivity from flooding when links become impassable. The scenarios shown in the figure are based on 1-in-10-year flood events, considering plausible losses of network connectivity due to flooding based on network links becoming impassable. Travel time for trips that rely on the damaged links would increase by 108 percent and 32 percent in the Niger River delta and Indus plain, respectively. At national level (aggregate impact), travel time would increase by 4.7 percent and 1.2 percent in Nigeria and Pakistan, respectively. These results indicate how impacts depend on the interaction between the disruption location, how food is transported, and the exposure and vulnerability of transport.

FIGURE FLOOD SCENARIOS AFFECTING CRITICAL TRANSPORT INFRASTRUCTURE IN THE NIGER RIVER DELTA IN NIGERIA (A) AND THE INDUS PLAIN IN PAKISTAN (B)



(A) Nigeria flood scenario

(B) Pakistan flood scenario

SOURCE: Nelson *et al.* (forthcoming).[28]

ENSURING ECONOMIC ACCESS TO FOOD

The goal of building resilient agrifood systems is to ensure food security, and continuous access to sufficient, safe and nutritious food for all (see Resilience for what? in Figure 2). There is little to gain from food being available if people cannot access it. This section focuses on whether food available through domestic production and international trade is *economically* accessible to all of a country's population. If there is a strong supply and diversity of food capacity in a country but the demand is vulnerable, agrifood systems are also vulnerable. Having access to food is mainly an issue of prices and income. Not having a reliable and substantial income limits households' options during shocks, such as food price spikes, crop failures or loss of assets.[30] On the supply side, factors such as low levels of agricultural productivity, insufficient diversification, inadequate food storage and poor road infrastructure all drive up the cost of healthy diets. Beyond the direct impact of agrifood systems on the cost of diets, other interconnected systems, including health, environment and social protection systems also influence access to nutritious foods. Coherence between food systems and these other systems is thus needed, as further explained in the report.[31]

Agrifood systems' resilience and food security and nutrition will be higher in countries where the greatest percentage of the population has sufficient income to ensure food security following a shock to their livelihoods. Although the focus of this report is on the food pillar of agrifood systems, non-food agricultural production also plays a key role in generating livelihoods for small-scale producers and the agro-industrial sector, enhancing economic access to food. Box 9 summarizes the benefits that people derive from forests in terms of livelihoods.

Seekell *et al.* (2017) verify the extent to which per capita income of the poor is sufficient to access food by calculating the ratio of the income of the lowest quintile of the population of each country and the average cost of food.[34] They find that lower socio-economic groups still lack access to food in many countries. But what level of reliable income does a household need to absorb shocks and ensure food security? Following the approach of *The State of Food Security and Nutrition in the World 2021*,[31] we set the target of a healthy diet that includes foods from several groups with greater diversity within food groups to help prevent malnutrition in all its forms. However, this diet – also called cheapest healthy diet – is still largely unaffordable to approximately 3 billion people.

We estimate for each country the share of the population unable to afford this healthy diet after a reduction of one-third in real incomes (see Box 10 for a description of the approach). The choice of threshold is based on recent evidence of the impact of the COVID-19 pandemic on incomes. In Cambodia, more than 60 percent of people affected suffered income loss of one-third or more, while 90 percent suffered one-fifth or more.[35] Another nine-country study found that income loss is common across study sites, with 51 percent of respondents in Myanmar and 79 percent in Liberia reporting their income "reduced a lot" or "completely stopped".[36] A study of Brazilian doctors found that, of those whose income was affected, 31 percent experienced a reduction of 25–50 percent and about 60 percent, a reduction of over 50 percent.[37] These estimates indicate the thresholds assumed here are on the low end in terms of income reduction for those affected by a shock. This means the number of people we estimate to be at risk of being unable to afford a healthy diet after a shock is likely a lower bound.

FAO *et al.* (2021) estimates about 3 billion people, around 40 percent of the world's population, cannot afford a healthy diet.[31] According to this report, almost another 1 billion people will be at risk if a shock reduces their income by one-third in the 143 countries analysed (Table 2). Of these, most live in lower- and upper-middle-income countries, comprising 16 percent and 17 percent of the population, respectively. This share is much smaller in low-income countries, where already 88 percent cannot afford a healthy diet, let alone an income buffer of 50 percent when a shock reduces their income by one-third. In these countries, the challenge is having many more people unable

BOX 9 THE CONTRIBUTION OF FORESTRY TO THE LIVELIHOODS OF SMALL-SCALE PRODUCERS

Much of human society has at least some interaction with forests and their biodiversity. In low-income countries, about 1.2 billion people rely on agroforestry farming systems.[32] There, wood and non-wood forest products provide around 20 percent of income for rural households. More than 40 million people produce commercial fuelwood and charcoal for urban centres, with the production of fuelwood generating USD 33 billion globally in 2011. Taking into account direct and indirect employment, the formal forest sector provides an estimated 45 million jobs globally and labour income of USD 580 billion per year. Small and medium forest enterprises employ around 20 million people, generating USD 130 billion per year. The informal forest sector generated an estimated USD 124 billion in 2011, providing employment for an estimated 41 million additional people. The sustainability of forests and the biodiversity they contain is extremely important to people's livelihoods.

SOURCE: FAO. 2020.[33]

BOX 10 CALCULATING THE SHARE OF POPULATION AT RISK OF NOT BEING ABLE TO AFFORD A HEALTHY DIET

The percentage of people who cannot afford a reference healthy diet in 2019 was computed using the consumer price index-inflated cost of their diet as per FAO *et al*. (2021),[31] as well as the reference year of 2019 income distribution available from the World Bank PovcalNet database.[38] Percentages are then multiplied by the 2019 population in each country using the World Development Indicators of the World Bank to calculate the number of people who cannot afford a reference healthy diet this year.[39]

A healthy diet is considered unaffordable when its cost exceeds 63 percent of a person's income. Since people do not spend all their income on food, the 63 percent accounts for a portion that can be credibly reserved for food, based on observations that the poorest in low-income countries spend, on average, that amount of their income on food.[40]

The percentage of people who cannot afford a healthy diet is obtained based on this threshold and comparing the cost of their diet with country income distributions.

An additional buffer of 50 percent was added, representing the extra income needed for a healthy diet and all basic non-food expenditures after a shock reduces income, to estimate the share of people at risk of unaffordability. To illustrate, if the cost of a healthy diet is USD 3 per day, to meet food and non-food needs, an individual needs a daily minimum of USD 4.76 (USD 3 divided by 63 percent). To continue meeting those needs if a shock reduces income by one-third, a person's starting income needs to be USD 7.14. This affordability indicator is computed for 143 countries in 2019 as follows:

$$(1+\text{Buffer}) \times \frac{\text{Cost of the diet}}{0.63}$$

to even afford a basic energy-sufficient diet meeting calorie needs if incomes are reduced by one-third (Box 11). The incidence of similar vulnerability to shocks is only 1 percent in high-income countries.

Most people at risk of not being able to afford a healthy diet after an income shock live in Eastern and South-eastern Asia (398 million), Southern Asia (303 million), Latin America and the Caribbean (85 million) and sub-Saharan Africa

(81 million). The remainder live in Northern Africa and Western Asia (60 million).

Economic access to a healthy diet is most interesting when considered at national level. Figure 6 brings together measures of economic access to a healthy diet and the DSFI for fruits and vegetables (in tonnes). The horizontal axis shows the share of the population that cannot afford a healthy diet and the vertical access those at risk of not being able to afford it if incomes drop by one-third. The size of the bubbles represents the DSFI value for tonnes of fruits and vegetables. Including the DSFI for fruits and vegetables is informative because they are essential to a healthy diet and, if availability is limited, they are likely to have an impact on the affordability of a healthy diet.

Countries are distributed along an inverted U, and in many (especially in sub-Saharan Africa), more than 80 percent of the population cannot access a healthy diet and are in dire need of greater affordability (orange oval). This challenge is compounded by limited variety of fruits and vegetables (the bubble is quite small), key to a healthy diet. As well as a large share of the population who cannot afford a healthy diet, many countries have large sectors at risk of not being able to afford one if their income drops by one-third (yellow oval). This is a particular concern in Asian countries: Bangladesh, India, Indonesia, Pakistan and the Philippines.

Other countries, mostly high-income, are better able to guarantee economic access to healthy diets (green oval). Unexpectedly, in some countries, mostly middle-income, where two-thirds or more of the population can afford a healthy diet in normal times, a large share of the population is at risk of not being able to afford one after an income drop of one-third (blue oval). This is particularly the case for Latin America and the Caribbean where it is alarming that over half of the region's workers are in the informal sector, resulting in lower-quality and more vulnerable jobs. As they lack labour contracts or access to unemployment insurance and rely on day-to-day work that cannot be carried out from home, these workers are especially vulnerable to income fluctuations following shocks, such as with the COVID-19 pandemic.[41]

These results can deliver a more comprehensive picture of the resilience of national food systems, indicating that the DSFI and buffering capacity of household incomes are complementary measures of absorptive capacity. Countries with high absorptive capacity in both are mostly high-income countries. These are less likely to put in place emergency measures to guarantee a healthy diet. Countries with low values in both are prone to major disruptions in times of crisis, especially if food prices increase. Intermediate situations warrant revisiting the strengths and weaknesses of food systems to tailor interventions.

A broad share of the world's population is vulnerable to food insecurity and malnutrition when confronted with an income shock – another strong reason to build resilient agrifood systems on the supply and demand sides. Such vulnerability is due to limited incomes, combined with the cost of a healthy diet and its unaffordability. While the problem of limited incomes for many people is not due only to what happens in agrifood systems, on the other hand, the cost drivers of a healthy diet are evident throughout the food supply chain, within the food environment and in the political economy that shapes trade, public expenditure and investment policies.

Tackling these cost drivers will require major transformations in agrifood systems, trade-offs and synergies for different countries with no one-size-fits-all solution.[42] For nutrition knowledge and behaviour change to effectively influence choices, price and income constraints must be addressed.[42] Many countries need to rebalance their agricultural and nutrition-sensitive social protection policies for efficiencies at all stages of the food supply chain and to make healthier diets more affordable for vulnerable populations. This, in turn, would help them address the problem of limited incomes which, as mentioned, is not due only to agrifood systems.
The effect of these policies and programmes in increasing affordability will depend, *inter alia*, on effective targeting, adequate transfer amounts and modalities, and integration of nutrition-specific components. ■

TABLE 2 INDICATORS OF UNAFFORDABILITY OF HEALTHY DIETS

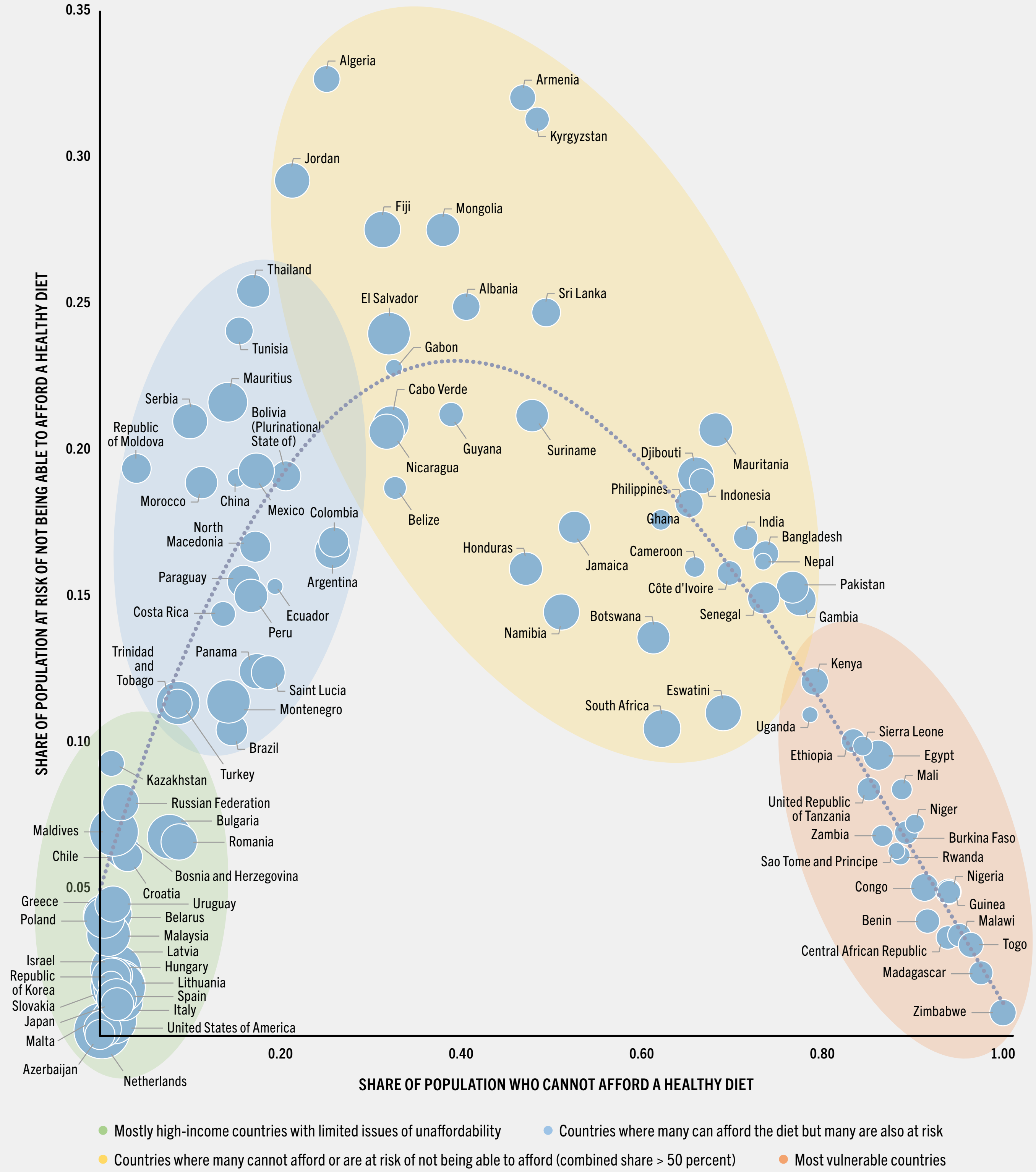
	Number of people unable to afford a healthy diet in 2019		Number of people at risk of unaffordability of a healthy diet if incomes are reduced by one-third	
	Percent	Total number (millions)	Percent	Total number (millions)
WORLD	**41.9**	**3 000.5**	**13.4**	**956.4**
Central Asia	16.9	5.8	18.1	6.2
Eastern and South-eastern Asia	23.9	530.0	18.0	398.0
Europe	1.7	12.0	3.1	22.0
Latin America and the Caribbean	19.3	113.0	14.5	85.0
Northern Africa and Western Asia	45.0	178.0	15.1	60.0
Northern America	1.4	5.1	0.5	1.7
Oceania	1.8	0.5	0.9	0.2
Southern Asia	71.3	1 282.0	16.8	303.0
Sub-Saharan Africa	84.7	875.0	7.8	81.0
COUNTRY INCOME GROUPS				
Low-income	87.6	463.0	6.9	37.0
Lower-middle-income	69.6	1 953.0	15.9	447.0
Upper-middle-income	21.1	568.0	17.1	460.0
High-income	1.4	16.0	1.1	12.0

NOTES: The table shows the number and share of people who cannot afford a healthy diet, or who are at risk of not being able to afford one if a shock reduces their income by one-third, by region and income group in 2019. The 2019 cost of a healthy diet is taken from FAO *et al.* (2021).[31] See **Annex 1** for methodology and data sources and **Annex 3** for the results for the full set of countries.
SOURCE: FAO elaboration for this report.

BOX 11 MANY CANNOT AFFORD – OR ARE AT RISK OF NOT BEING ABLE TO AFFORD – AN ENERGY-SUFFICIENT DIET

In times of crisis, it may be challenging for many to be able to afford an energy-sufficient diet, consisting mainly of starchy staples that provide adequate energy for a day's work. This diet is considerably cheaper because it does not provide all the essential nutrients of a healthy diet; yet, many cannot afford it or are at risk of not being able to afford it. The cost of the energy-sufficient diet was used to calculate its affordability, following the same approach as for the affordability of a healthy diet. Globally, about 177 million people cannot meet basic dietary energy requirements, with an additional 265 million at risk of not being able to afford as well if their incomes fall by one-third. Vulnerability to income shocks for meeting basic dietary energy requirements is concentrated in low-income countries, although not exclusively. In both South Africa (lower-middle-income) and Zambia (lower-middle-income), 14 percent of the population is at risk if their income drops by one-third (see Annex 3), on top of the 18 percent and 31 percent, respectively, who cannot afford such a diet even in normal conditions. When even the cheapest diet is beyond reach for many, increasing incomes of the vulnerable population is critical.

FIGURE 6 PLACEMENT OF SELECTED COUNTRIES BASED ON THE LEVEL OF ECONOMIC ACCESS TO A HEALTHY DIET AND DSFI FOR TONNES OF FRUITS AND VEGETABLES, 2016–2019



NOTES: The horizontal axis represents the share of population who cannot afford a healthy diet, while the vertical axis is the share of population at risk of not being able to afford one if a shock reduces their income by one-third or more. The size of each country's bubble indicates the value of the DSFI (see Box 5) for tonnes of fruits and vegetables. To simplify graphic presentation, 20 high-income countries with very low levels of unaffordability (up to 1 percent) were dropped. The DSFI refers to 2016–2018 averaged data and the economic access indicator refers to 2019 data. See **Annex 1** for methodology and data sources and **Annex 3** for the results for the full set of countries.
SOURCE: FAO elaboration for this report.

CONCLUSIONS

This chapter introduced a set of national resilience indicators that express the vulnerabilities and risks to agrifood systems' functions. It assessed four dimensions that are key for agrifood systems in dealing with a disturbance: (i) the robustness of primary production; (ii) the availability of food; (iii) physical access to food; and (iv) economic access to food.

Findings indicate that, while a large part of the world population lives in countries where food can be sourced and made available quite flexibly, there is substantial scope in many countries for improving economic access to healthy diets, especially when incomes are affected by a shock. This type of challenge has been very evident among households affected by large systemic shocks, such as the COVID-19 pandemic.[42] Many governments and donors were concerned that the pandemic would force a shutdown of supply chains and national agrifood systems more generally, requiring action to step in and replace the market. Considering the massive scale of the market and food demand, this would have been neither possible nor necessary in many cases, given the steps agrifood systems' actors took to adapt and build resilience.[43] Instead, the major impact of the pandemic on agrifood systems' actors and their food security has been on incomes and associated purchasing power.[1] In many cases, the cost of a healthy diet is higher than the international poverty line, established at USD 1.90 purchasing power parity (PPP) per day. This puts economic access to sufficient, safe and nutritious food beyond the reach of many living below or just above the official poverty line, especially in low-income and lower-middle income countries.

The availability of food in general appears far less vulnerable to shocks than consumers' economic access to food. Thus, for agrifood systems to become more resilient, the factors driving up the cost of food must be addressed. In terms of which types of diversity matter most for a country's dietary flexibility, there is considerable variation in: the mix of domestic production; the balance between imports, domestic production and stocks; and the number of trading partners. Examining the DSFI indicator, this chapter offered areas of intervention to strengthen resilience in food supply and ensure multiple pathways exist to make nutritious food available.

In terms of the capacity of the primary production sector to absorb demand shocks affecting domestic and export markets, findings indicate a significant contribution from domestic market diversity to countries' overall absorptive capacity. Countries whose agrifood systems include a significant share of exports are mostly high-income countries with a strong agricultural base. There is also a correlation between a country's primary flexibility and income and its agricultural base. However, exceptions exist, indicating other factors play a role.

Much work on the indicators remains to be done to improve our understanding of what makes agrifood systems resilient. The indicators are neutral when it comes to the resilience of midstream agrifood supply chains (see Annex 1) and do not capture the role of non-food components in determining resilience. Fisheries and aquaculture are also excluded from the production flexibility and transportation network indices due to data constraints, despite being some of the world's most diverse farming practices in terms of number of species. More work is also needed to represent other capacities that make agrifood systems resilient, namely the ability to prevent, anticipate, adapt and transform. The indicators presented in this chapter provide important new insights into the ability of national agrifood systems to absorb environmental, social and economic shocks.

At national level, resilience is, in part, understood as maintaining systems' functions during a disturbance. Since systems are typically composed of, *inter alia*, a multitude of farms, business enterprises, value chains and institutions, national agrifood systems' resilience does not necessarily reflect the resilience of individuals. How value chain actors react to shocks and stresses is a critical aspect of resilience in agrifood systems and the focus of the next chapter. ■

EGYPT
Labourers unloading a truck of tomatoes for distribution to retail.
©FAO/Heba Khamis

CHAPTER 3
RESILIENCE OF FOOD SUPPLY CHAINS

KEY MESSAGES

➔ The continuous functioning of food supply chains – as well as the input and service supply chains connected to them – is essential to ensure a smooth, stable and sustainable flow of food to all.

➔ The impacts of shocks and stresses vary by type of food supply chain. Transitional chains tend to be long with many small and medium agrifood enterprises (SMAEs) particularly vulnerable to shocks from various sources and limited resilience capacities.

➔ Diverse, redundant and well-connected food supply chains enhance agrifood systems' resilience by providing multiple pathways for producing, sourcing and distributing food.

➔ Building resilience in food supply chains requires costly investments and will entail trade-offs with efficiency and with inclusiveness; mostly large companies with sufficient investment capacities can overcome the trade-offs with efficiency while many SMAEs risk being pushed out of business as they lack these capacities.

➔ Improved food supply chain coordination and organization, through consortia and agri-territorial tools, can enable SMAEs to overcome size constraints and create synergies between resilience, inclusiveness and efficiency.

➔ Government support is key to create an enabling environment for improved coordination in food supply chains and to overcome trade-offs, for example, through public investments in infrastructure and research as well as developing mechanisms to connect an upgraded research and education system to the agrifood sector.

Chapter 2 took stock of agrifood systems' resilience at national and subnational levels. It analysed key factors that help determine the vulnerabilities of national agrifood systems: (i) the diversity of primary agricultural production and its marketing channels; (ii) the diversity of available food, including from imports and stocks; (iii) transport networks that ensure physical availability of food locally; and (iv) people's economic access to food. It concluded that diversification, in terms of trade partners and foods produced domestically, stocked and imported, coupled with robust food transportation networks, gives national agrifood systems a certain degree of latitude and overall capacity to absorb shocks.

The resilience of national agrifood systems also depends on how supply chains function. This chapter focuses on food supply chains because of their prominence in agrifood systems and because non-food agricultural products, which are also part of agrifood systems (see Chapter 1), are viewed as exiting that system once they enter non-food supply chains. The food component of agrifood systems is far larger than the non-food part: in 2018, primary food products accounted for more than 97 percent of total primary agricultural production value, excluding forestry.[1] The primary sector also only generates a small part of the total food value reaching consumers. Using data from 61 countries, over 2005–2015 and covering 90 percent of the world economy, a recent study finds that only 16–38 percent (27 percent as a global average) of the value of home-consumed foods goes to agricultural producers.[2] This is in line with a previous estimate suggesting that, in Asia and Africa, the value of primary food production is only 40 percent, while midstream and downstream segments capture 40 percent and 20 percent, respectively.[3,4]

Diverse and well-connected food supply chains are better able to absorb and recover from shocks and stresses, contributing to more resilient agrifood systems. Resilient food supply chains also enhance growth opportunities for farmers and businesses and guarantee a stable and continuous flow of food to all (see Figure 2).

Being one of the main components of agrifood systems, this chapter's focus is on food supply chains. Building on a simplified framework, it describes its main constituent elements and the interactions within. It outlines how farms and agrifood businesses, such as processors and wholesalers, source inputs and sell their outputs, and whether they are connected to consumers in ways that allow consumer preferences to be expressed and met. It also identifies the main drivers of change in food supply chains – such as credit, consumer demand, prices, logistics, risk perception, technology, policy developments and disturbances hitting systems. While the resilience of *food* supply chains is the explicit focus, it must be recognized that shocks and stresses affecting *non-food* primary production can also propagate through, and impact on, sectors of the economy that rely on primary non-food products as inputs.

Acknowledging there are different types of food supply chains around the world – classified as traditional, transitional and modern – and within them businesses of varying scales, the chapter describes business strategies and priority action areas that facilitate adjustment during a shock and contribute to resilience. It presents practical examples from around the world, with recommended policy directions and interventions that build and strengthen food supply chain resilience. ■

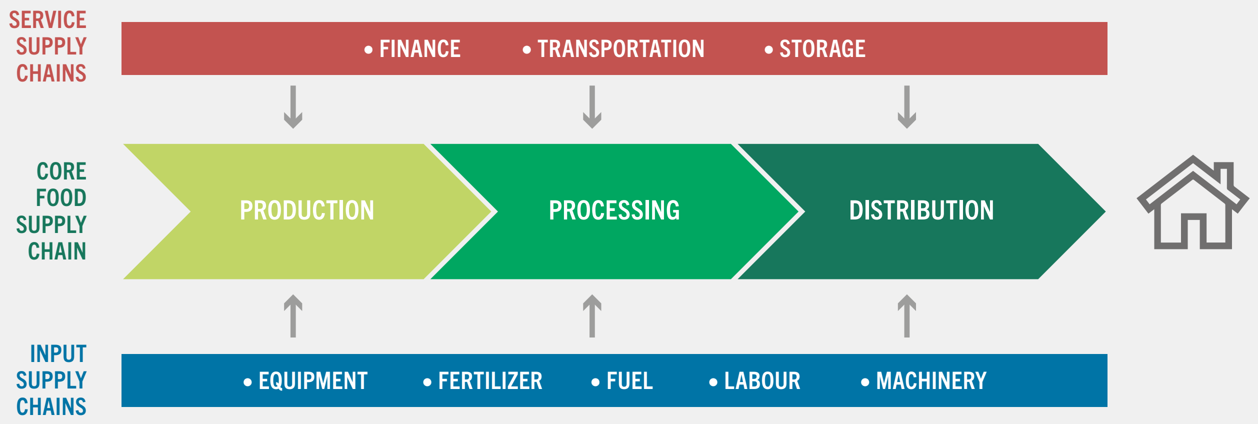
SETTING THE STAGE – A SUPPLY CHAIN PERSPECTIVE OF RESILIENCE

The importance of resilience in food supply chains is gaining increasing attention with the rise in the intensity and frequency of shocks[5] and longer, more sophisticated and potentially more vulnerable chains serving rapidly growing cities. Building resilient food supply chains is necessary to face disturbances and safeguard the livelihoods of those involved in supply chains as well as people's food security and nutrition, the ultimate goals of resilient agrifood systems.

A key point is that a food supply chain comprises interconnected activities performed by various actors within and outside the chain. All are vulnerable to diverse risks, shocks and stresses. As well as being connected along the food supply chain, farmers, processors and distributors depend on actors in lateral chains to supply inputs and logistics and transport services outside agrifood systems. These are exposed to shocks and stresses, whose impacts can disrupt food supply chains.

Primary producers and other food supply chain actors produce, process and distribute food using resources, innovations and technology for their own benefit. Their objective is to improve their well-being, subject to credit constraints and risks they face. To remain economically viable, they need to use resources efficiently but also be resilient in the face of shocks and stresses. However, the interconnection of food supply chains actors implies that resilience at any stage of a supply chain depends on the overall performance along the chain. The decisions made by one group of actors have implications for the others. A shock to any segment in the supply chain rarely stays within that segment but will probably spread to and affect other segments upstream and downstream. During the COVID-19 pandemic, lockdowns led to reductions in consumer incomes and food demand, negatively affecting supply chain

FIGURE 7 SCHEMATIC REPRESENTATION OF A FOOD SUPPLY CHAIN AND ITS CONNECTION TO INPUT AND SERVICE SUPPLY CHAINS



SOURCE: FAO elaboration based on FAO. 2017;[7] Reardon & Zilberman. 2021.[8]

actors upstream, from vendors to wholesalers and eventually to producers. Food supply chains are thus complex socio-economic systems with interactions at different levels, distances and times, all of which must be considered when addressing resilience.[6]

Since food supply chains are connected to supply chains for inputs and for services, all three must be resilient to shocks and stresses if agrifood systems are to function efficiently and deliver sufficient, safe and nutritious food. The structures of supply chains will affect how shocks and stresses impact on them and how they react to them.

Figure 7 is a schematic representation of the three supply chains. It shows how agricultural commodities are produced at upstream farm level, then supplied to the midstream agrifood businesses that process them for subsequent shipment to downstream retailers. These three main functions, crucial to almost any food supply chain, use inputs and services from input and service supply chains. A shock to any part of these interconnected supply chains can have negative impacts on the performance of the food supply chain. The responses of suppliers to disruptions are decisive for the overall functioning of the food supply chain. Resilient suppliers recover more quickly and enhance overall food supply chain resilience.

Input and service supply chains interact with food supply chains at every stage. Input supply chains provide variable inputs, such as seed, fertilizer, fuel and labour, and quasi-fixed inputs, such as farm machinery, milling machines and coolers for perishables. Service supply chains include actors and activities for movement of inputs, outputs and factors such as transport and storage operators, connecting production to consumption. For example, in Nigeria, a chain of third-party logistics providers transports 75 percent of the maize harvest almost 1 000 km from farmers in the north to wholesalers in the south. Similarly, almost all wholesalers rely on the same providers for storage.[8]

Even labour and credit can be viewed as supply chains and not just production factors, because a chain of decisions and actions beyond the control of the direct providers can influence their availability. Labour availability can depend on mobility of people over long distances and recruitment practices. This makes its availability vulnerable to various disruptions affecting, for example, transportation, recruiters or mobility as with the COVID-19 pandemic.[8] Formal and informal credit services are a function of socio-economic conditions, and availability can be affected by financial shocks and other crises, in addition to government monetary and fiscal policies.

Most research and policy debate on agrifood systems' resilience has focused on input supply chains for the farm segment.[4] However, this segment constitutes only a small part of the food economy, ranging from 16 percent to 37 percent,[2] the rest being post-harvest, processing and distribution segments.[3, 4] Each midstream segment also relies on input supply chains for labour, water, physical inputs and equipment.[3, 4]

The fact that disruptions to any of these lateral chains can have devastating impacts on food supply chains, as well as on non-food agriculture, illustrates how agrifood systems can be negatively affected by disruptions to other systems such as transport and industry. The energy sector is a clear example: a shock that stops oil freighter traffic can reduce fuel supply and bring food supply chain operations to a grinding halt. The COVID-19 pandemic provides further examples: restrictions on labour mobility in the early weeks severely affected fruit harvesting in many countries; classifying wood production as non-essential in some countries hampered fruit supplies by stopping crate production; and the decision by many governments to declare wholesale markets essential but much of the logistics supply chains non-essential caused major disruption to food supply chains.[9]

Types of food supply chains

Food is produced, processed and distributed by supply chains that are in continuous transformation, driven by changes in the socio-economic, biophysical and technological spheres. Technological innovation, demographic changes and economic development, for example, spur the creation of new food supply chains or the transformation of existing ones. They determine the conditions that shape the three broad types of agrifood systems outlined in Chapter 1: traditional, transitional and modern.

This categorization can help policymakers identify broad priority areas for action within different food supply chains, as these have distinct levels of vulnerability to shocks and stresses. Indeed, the vulnerabilities and the resilience capacities of food supply chains are largely shaped by their structural characteristics and product attributes, with supply chains relying on SMAEs experiencing shocks differently from those dominated by large-scale enterprises. Fresh produce supply chains are more susceptible to short-term market fluctuations compared to, for example, those specializing in cereals, especially if cold storage is not available. The most appropriate resilience strategy will depend on the vulnerabilities of each food supply chain to different risks.[10] Before discussing how shocks and stresses affect food supply chains, it is useful to recall the key characteristics of each one.

Traditional supply chains

Traditional food supply chains are spatially short with a small number of intermediaries. They handle seasonally produced food, mainly from local small-scale producers, marketed locally. The share of staples is high, while that of value-added produce in post-harvest segments is low. Only basic processing, such as fruit drying, flour milling or dairy processing, takes place, usually in the home. Wholesale and logistics supply chains are small-scale, since food does not move long distances and micro and small agro-processing enterprises (the smallest of the SMAEs) dominate. Food processing falls disproportionately on women: in many African countries, women spend on average four hours per day pounding grain.[11] A lack of product diversification, quality and safety standards, and economies of scale constrain traditional systems. Technology is labour-intensive, spot market relations dominate and contracts are rare. Concentration of supply chains usually only occurs when governments subsidize cereal production through parastatals to supply staples to growing urban populations.[8]

BOX 12 THE IMPACT OF THE COVID-19 PANDEMIC ON SMAEs

The resilience of SMAEs requires special attention, given their critical role in agrifood systems and food supply chains, particularly those serving vulnerable, low-income populations in low-income and middle-income countries. They connect farmers to markets, add value to local agricultural produce and create employment opportunities for women and young people. Rough estimates suggest that domestic supply chains account for 75 percent to 90 percent of food consumed in Southern Asia and sub-Saharan Africa, with around 80 percent supplied through SMAE-dominated chains and the rest through large-scale enterprises.[10]

SMAEs tend to be labour-intensive with limited capacity to manage risks associated with product perishability and seasonality.[12] Being heavily interdependent,[13, 14] disruption anywhere in the supply chain can produce a harmful cascading effect. SMAEs also have a unique strength: embedded in local communities, they are better able to adapt services, such as transport, food processing and distribution, to local needs,[15] making important grassroots investments in rural areas.

The demand- and supply-side shocks caused by the COVID-19 pandemic had devastating consequences for SMAEs, as millions of supply chain workers lost their jobs and livelihoods.[16] Labour shortages and transport interruptions had strongly negative impacts on SMAEs because of their unique characteristics, such as labour-intensive operations, resource scarcity, perishable products, seasonal production systems and greater vulnerability to weather.[12] The impacts varied for different products. For example, lockdowns in Pakistan caused the most serious disruptions in the fresh produce value chain. With harvesting and transport blocked, huge quantities of fresh fruits and vegetables were left to rot in the fields.[17]

Demand-side risks also materialized owing to gaps between a firm's projected and actual customer demand, leading to costly shortages and lost sales and market shares. In a recent survey of 363 SMAEs in 17 countries, more than 90 percent reported reduced sales, and difficulties accessing inputs and paying staff.[18] Furthermore, due to their informality, many SMAEs were excluded from government stimulus and recovery plans that favoured larger enterprises.[19, 20]

Transitional supply chains

Transitional supply chains are longer, with many midstream intermediaries such as processors, wholesalers and retailers, who add value and move food across rural and urban areas. Short supply chains still dominate in highly perishable product markets, such as dairy and leafy vegetables. The share of value-added products in post-harvest segments (wholesale, processing, logistics and retail) is moderately large, but heavily dominated by SMAEs. Processed food, mainly produced and retailed by SMAEs, is also important in diets as the opportunity cost of women's time has increased with out-of-home employment. Home processing, such as hand pounding of grain found in the traditional phase, has given way to milling SMAEs, alongside a few emerging large-scale companies.[8] SMAEs co-exist with microenterprises, mostly large numbers of street vendors selling prepared dishes;[11] these were particularly affected by mobility restrictions during the COVID-19 pandemic (Box 12).

Fragmentation is a key characteristic of transitional supply chains, which rely on a multitude of small-scale primary producers and SMAEs. Thanks to low labour costs, they use labour-intensive technologies, although machines are also used. Customized harvest and other agronomic and trading services support small-scale producers of food and non-food products to access intensification technologies, skilled labour and services – for example, traders providing sprayers for mango producers in Indonesia, or mobile teams providing combine harvesting for rice farmers in China.[21, 22] Spot market relations dominate, but contracts are beginning to emerge in domestic and export supply chains.

Cereals and other staples are a much smaller share of the total food economy because, as incomes increase, people consume fewer starchy staples and more nutrient-dense, processed and expensive foods. Food production diversification, particularly into animal and horticultural products, is therefore higher. These products have relatively long supply chains, with more rigorous transport and cold storage requirements, increasing their vulnerability to disruptions. Longer supply chains of perishables make food safety an urgent issue, as quality standards are often difficult to enforce.

Modern supply chains

Modern supply chains serve large urban populations. They can be long or short depending on the primary production to meet households' food demands. As demand for staples declines, they provide mainly perishables, such as horticultural and animal products. These may be sourced locally, but can also be produced far from cities and shipped frozen or chilled. As demand for animal products increases, there is also an increase in the vulnerability of the food supply to animal diseases, antimicrobial resistance and food safety issues.

Supermarkets and large processors transact directly among themselves and, in some cases, buy directly from producers or wholesale markets which are less important than in the transitional stage. Cold storage, packaging and private quality standards applied to suppliers are also much more common. The supply chain is highly concentrated and multinationals dominate. SMAEs can remain competitive if they diversify production or if high transaction costs discourage large companies from operating in remote or less developed areas. Technology is largely capital-intensive, and information-based tools such as global positioning system (GPS) and drones are more common. Spot market relations are found in the fruit and vegetable sector, but contracts dominate elsewhere. Downstream of modern chains is the food service sector comprising formal restaurants and fast-food chains.

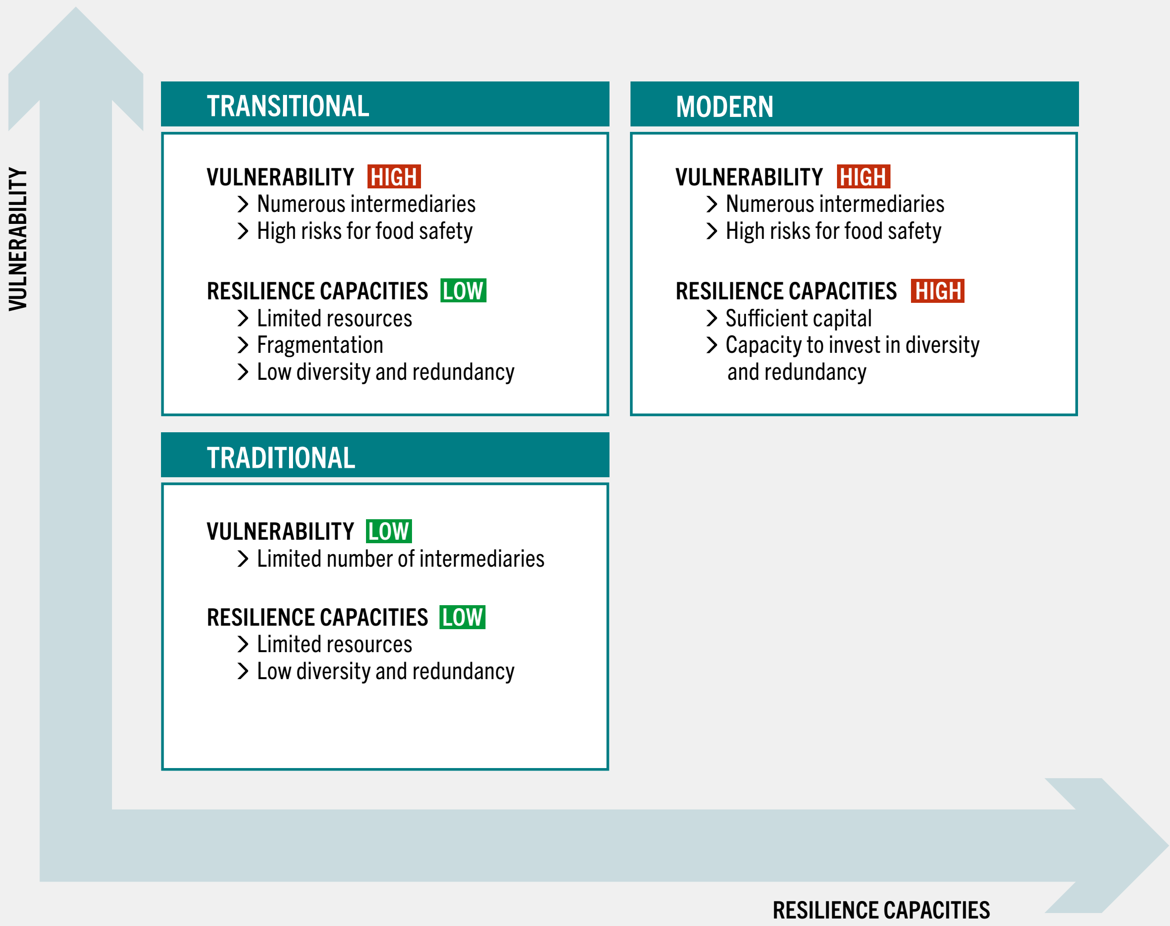
Modern supply chains have emerged, albeit unevenly, in low-income regions over the past three decades. Southern Africa, Eastern and South-eastern Asia and Latin America have seen extensive penetration by food industry multinationals and large supermarkets, although they are still only emerging in the rest of sub-Saharan Africa and in Southern Asia. Modern supply chains also dominate in international trade.

Different food supply chains are affected by, and cope with, shocks differently

Agrifood systems and their food supply chains experience various shocks and stresses. They stem from different sources in the socio-economic and natural environments and can be natural or human-made. Understanding which ones are more likely to strike a food supply chain is the key to developing resilience capacities that can mitigate impacts and help the supply chain recover.

The marked differences between the three types of food supply chains – traditional, transitional and modern – imply that the same shock or stress can have very different impacts. The vulnerability and the resilience capacities of any food supply chain will be shaped, at least partially, by its characteristics. Figure 8 illustrates, in a very simplified way, the overall levels of vulnerability and resilience to shocks for food supply chains. The impacts of shocks and stresses will be determined by the vulnerability–resilience combination of any supply chain in addition to the nature of the shock itself. For example, restrictive government policies to contain the spread of COVID-19 affected labour mobility and the supply of labour to farmers, processors and distributors along food supply chains as well as their linked input and service supply chains (see Figure 7). However, the impacts are varied among the three types of supply chains. Being short, traditional supply chains may be

FIGURE 8 A SIMPLIFIED ILLUSTRATION OF THREE TYPES OF FOOD SUPPLY CHAINS REGARDING VULNERABILITY TO SHOCKS AND STRESSES AND THEIR RESILIENCE CAPACITIES



SOURCE: FAO elaboration for this report.

least affected because they do not require much mobility. They are also less exposed to shocks caused by disruptions to midstream input and service supply and tend to rely on only a few, mostly local, intermediaries.

The recent literature on food supply chains provides interesting examples on how COVID-19 disruptions have enabled traditional supply chains to provide alternatives to long, modern and transitional chains experiencing disruptions.[23-28] With closed borders and movement restrictions within and between countries, many consumers had no alternative to traditional food sectors, which are less dependent on large-scale processing units and bulk transport and rely mostly on local labour.[29] Despite limited financial capacities, many supply chains proved to be nimble in their responses, especially in high-income countries, where capacities are higher and infrastructure is robust.[24, 25, 28]

Compared to traditional chains, transitional and modern supply chains can be seriously affected by shocks to midstream operations, which may be numerous between primary food production and its final delivery to consumers. There are also differences between transitional and modern supply chains that can determine the impact of shocks and stresses. Modern supply chains comprise mainly large-scale businesses with easier access to capital than SMAEs in transitional supply chains. Since large-scale operators are generally capital-intensive, they can more easily switch between markets and increase their capital–labour ratios to reduce dependence on hired labour.[10, 30] For this reason, modern food supply chains were more resilient than transitional ones to COVID-19 shocks – mostly labour mobility and trade restrictions – because they operate globally and can adjust to disruptions geographically and temporally and, to some extent, can adapt product composition.[10] However, their intensive use of energy for cold storage and mechanization makes them highly vulnerable to shocks that hit the energy sector.

The fragmented nature of transitional food supply chains, with their multitude of SMAEs and heavy reliance on labour, makes them especially vulnerable to labour supply shocks. Case studies in Australia, Egypt, Pakistan and the United Republic of Tanzania show this was evident in the restrictions early in the COVID-19 pandemic.[17, 20] The impact on SMAEs was uneven according to their products, diversity of destination markets and overall capacity to deal with shocks. Transport risks can potentially disrupt all SMAEs, although case studies from Australia[12] and Egypt[20] show that those dealing with perishable foods were disproportionately affected. In Egypt, fresh fruit SMAEs in domestic and multiple export markets perceived less risk from the pandemic because they could move their products from one export market to another or redirect them to the domestic market.[20]

Climate risks and shocks, highly relevant for the agrifood sector, also affect food supply chains differently. The heavy reliance of traditional food supply chains on local sourcing of inputs and local markets for produce make them the most vulnerable to climate shocks. Smaller enterprises and small-scale producers comprising traditional supply chains, lack the cost advantages of large companies. Without economies of scale, traditional supply chains incur higher production costs, making them less competitive and exposing them to exogenous supply and demand shocks, a risk that also affects transitional supply chains.[27]

Transitional and modern supply chains are less vulnerable to local shocks because they have access to more diversified input sources and output markets. Modern supply chains are generally less vulnerable to climate and environmental shocks than transitional ones, because large-scale firms can more easily impose protective measures such as biosecurity on primary suppliers.

Policy and socio-economic conditions matter for risks, and vulnerabilities and resilience capacities of food supply chains, and they vary considerably between countries. A study on the impacts of the COVID-19 pandemic in Australia, Pakistan and the United Republic of Tanzania found that, while food processing SMAEs in all three countries experienced increases in input prices, loss of buyers and shortage of skilled labour, Pakistani and Tanzanian SMAEs also suffered extreme financial pressure and difficulties accessing credit, which was not the case in Australia. As a result, many small processing plants closed in Pakistan and the United Republic of Tanzania, but not in Australia, where government support targeted the food sector and was critical to the survival of many SMAEs. The same study points to significant differences in adaptive capacity among SMAEs. Those in the United Republic of Tanzania and Pakistan continued conventional business practices due to lack of knowledge of alternatives, while most Australian SMAEs switched to e-commerce and omnichannel retailing, quickly adopting COVID-19 health measures such as social distancing and mask wearing. The capacities of Australian SMAEs, thanks in part to public support, allowed them to recover quickly from the initial shock, maintain and diversify their business, and invest in innovations. Table 3 indicates these options were very limited in Pakistan and the United Republic of Tanzania.[17]

TABLE 3 SUMMARY OF COVID-19 IMPACTS ON FOOD SUPPLY CHAINS IN THREE COUNTRIES AND SUBSEQUENT ADAPTATIONS

		Australia	Pakistan	United Republic of Tanzania
Impacts	Input price increase	x	x	x
	Labour shortages	x	x	x
	Shutdown of some SMAEs		x	x
	Loss of buyers	x	x	x
Adaptation measures	COVID-19-related safety measures	x		
	Switch to e-commerce	x		
	Business diversification	x		x
	Investment in innovations	x		

SOURCE: Ali. 2021.[17]

Traditional and transitional food supply chains are also more vulnerable because they comprise highly informal businesses. Small-scale, informal or semi-formal businesses are mostly family based and serve as the main source of revenues and incomes for many vulnerable segments of their societies, including owners and employees. They are thus unlikely to disappear, even when illegal or state-oppressed.[31] They are, however, at high risk of being hit by shocks, as seen during the COVID-19 closures. Informality also makes many actors in traditional chains invisible in national statistics, which means the impacts of shocks may go unrecorded, while crucial social protection programmes remain out of reach.[32] Although there are no official statistics on the degree of business informality in food supply chains, some estimates suggest it can be a serious challenge in low-income countries, where it is estimated that about 90 percent of food supply chain actors, including primary producers, operate informally. Informality is less common in middle-income countries, but still relatively high, at about 50 percent.[32] ■

MANAGING FOOD SUPPLY CHAIN RESILIENCE

When examining the resilience of food supply chains, it is important to note that a chain is not simply the sum of its actors or activities. Rather, it is a dynamic network of actors and activities under regular transformation, driven by factors like innovation and new technologies, demographic and income changes, and contractual and market relations. The socio-economic characteristics of agrifood firms and the way they interact with these transformations largely determine their capacities to prevent, anticipate, absorb, adapt and transform in the face of shocks and stresses. Transformation will always entail winners and losers. Similarly, shocks and stresses may have disastrous impacts on some actors in the supply chain while creating opportunities for others to transform and improve. A resilient food supply chain does not require all its actors to be resilient. One that continues to function and deliver its products in the face of disruptions can be considered resilient, regardless of what happens to individual actors.[8]

It is not enough to manage food supply chains with only business growth and optimization objectives in mind and to apply conventional risk management tools. To build effective resilience, it is necessary to: recognize that shocks, stresses and their impacts on food supply chains can be highly unpredictable; and keep pathways to adapt and transform open. Transformative capacity is particularly important, albeit not the focus of the report; it provides a new lens to explore opportunities during a crisis, reveal ways to overcome hurdles, move forward and become even more resilient in the face of future challenges.[33, 34]

Building food supply chain resilience among agrifood businesses poses dilemmas in the design of policies and interventions. First, it often entails costly investments which may require trade-offs between resilience and efficiency. These are more problematic for smaller-scale producers and SMAEs, given their limited access to credit. A second trade-off is between resilience and inclusiveness: the resilience of some supply chain actors may involve putting others out of business. The rest of this chapter addresses these strategic issues, examining the incentives for resilience building within food supply chains and how resilience investment decisions are made, taking trade-offs into consideration. It also discusses government policies and interventions that may condition the capacity of food supply chains to implement these strategies, with a focus on the role of public policies.

Resilience-building strategies may imply trade-offs between efficiency and inclusiveness

Operating in all food supply chains, agrifood businesses are heterogeneous in terms of economic scale, input composition, technology use and outputs. The goods they produce range from bulk commodities to local niche items and differentiated products. They also have different capacities to bear risk and make important resilience-building investments. These capacities depend on the level of human capital, access to information and credit, and retained earnings, all typically a function of scale.[35] Firms draw on these capacities to diversify (e.g. inputs, logistics and downstream markets) or introduce redundancy as strategies to build resilience, depending on their operations.

Businesses producing differentiated products, competing on characteristics such as quality rather than cost, are more constrained when diversifying input sources than firms sourcing bulk and undifferentiated commodities. This is because producing quality products requires sophisticated technology and specific assets, for example, high-cost machinery that can only be used for a specific product or investments that have little relevance when shifting to different products.[36] This reduces the overall flexibility of the business, as moving to a new product may involve new costly investments. Companies producing quality products need to induce their input suppliers to make the required asset-specific investments, locking in suppliers through incentives and co-investments, so they comply with the company's standards and accept monitoring.

Given the constraints to diversifying input sources, companies may explore diversification in suppliers and sourcing from different zones, while investing in redundancy. An example of this would be an agrifood business establishing a network of suppliers in secondary and tertiary zones to serve as backups if those in the primary supply zone experienced a climate shock. This entails the expense of incentivizing suppliers to make asset-specific investments and organize supply chain infrastructure in each zone. The Charoen Pokphand Group in Thailand, the world's largest rice miller, has taken this approach, building two ports upriver from its primary facility to guarantee shipping access in the event of a typhoon. Only the largest businesses can afford this level of diversity and redundancy, unlike SMAEs, especially those in fragmented supply chains, which trade off efficiency and resilience. These SMAEs face financial and logistical constraints to such investments and yet remain efficient and competitive. However, their reliance on sourcing from fewer and closer zones exposes them to ripple effects if a shock hits their suppliers.

To reduce the trade-off, businesses may seek investment partnerships with other, complementary companies, such as intermediaries, but again, this is not feasible for all. For example, in a national market for tomatoes, a business might source produce through specialized wholesalers with systematic relationships with suppliers in low-risk, high-capacity zones[37] and contractual relations with suppliers in zones with low transaction costs.[38] Investments may include search costs, setting up sourcing or input networks (including social capital investments), outlays on durable goods such as warehouses and ship berths, and market fees. These costs are a problem for most SMAEs who face the double challenge of needing to be resilient to shocks while also being competitive with larger enterprises.

Another way firms can diversify exemplifies a trade-off between resilience and inclusiveness. Large food processing companies may diversify their production mixes to include midstream supply inputs and other factors or increase their primary production to reduce reliance on small-scale producers who are vulnerable to shocks (e.g. climate or plant disease risks). This shift happened in Kenya and Zimbabwe during the 1990s, when vegetable exporters sourced half their produce from their own plantations and half from other large farms.[39] This is a trade-off between the exporters' resilience and economic inclusiveness, since small-scale producers are deprived of access to lucrative markets while large-scale firms gain agility.

Food supply chain businesses can diversify their logistics to avoid shocks such as the closure of ports and hurricane damage to transit areas. This entails, again, investment in private infrastructure or procuring space in public infrastructure (e.g. dedicated sections in shipyards, fuelling stations and ports), as well as investment in vehicles and containers, deemed too costly for most SMAEs.

Businesses may also need to address shocks that occur downstream in the food supply chain. During the COVID-19 pandemic, when food suppliers faced a sudden drop in customers shopping in stores or dining in restaurants, many diversified through e-commerce, using delivery companies who quickly adapted to the demand for home deliveries. While this was already a trend in many countries before COVID-19, the pandemic accelerated it,[10] although the pace varied according to infrastructure, managerial capacity and human capital.[17]

Essential to all these strategies is public infrastructure, such as roads, culverts, power lines, running water, irrigation schemes and ports. These are key to avert or buffer shocks, depending on the configuration and levels of robustness and redundancy. Upstream of the food supply chain, the capacity of agricultural producers to withstand shocks from climate change is at least in part determined by infrastructure availability and quality. Those in territories with well-developed infrastructure have greater capacity to bear shocks, especially when combined with farm-level access to irrigation, technology and information.

If primary food producers or agricultural territories are resilient to shocks, but partners in the food, input and service supply chains are not, the ripple effect of a shock, amplified by food supply chain connectivity and actors' interdependence, could lead to disruption to farmer livelihoods. This underscores the importance of resilience along all segments of food supply chains and their connected input and service supply chains. Public infrastructure, roads, power lines and irrigation networks need to be complemented by private or collective infrastructure provided by actors and companies in the lateral input and service supply chains, such as collection stations, large trucks and temperature-controlled warehouses. Businesses better able to make the investments and bear risks will more likely survive and outcompete those with less capacity, while those that fail to invest may be forced out of the market. The higher frequency of climate change or health shocks, such as the COVID-19 pandemic, will add further impetus to the competitive forces already leading to rapid concentration in the off-farm segments of food supply chains. Traditional and transitional chains, dominated by SMAEs and microenterprises, risk losing further ground to more advanced chains dominated by large-scale enterprises. This is a central issue when making trade-offs between resilience and inclusiveness:

the social cost of increased unemployment and lost livelihoods incurred as SMAEs are driven out of business may outweigh gains from the increased resilience of individual large-scale businesses.

Agrifood businesses, farmers and agricultural territories that are excluded lose a crucial link to urban and export markets – the main markets for their products. They find themselves in a poverty trap, where the confluence of market and climate changes can render resource-poor and infrastructure-poor territories especially vulnerable. When resilience falters, government support, including credit access, is necessary to address infrastructure failures and ease the constraints vulnerable businesses and farms face, not only to making investments to build resilience, but also to surviving in times of crisis.

The trade-offs in this section matter because efficiency and inclusiveness are both important elements of resilient agrifood systems, where the goal is to ensure food security and nutrition for all and sustain and improve the livelihoods of agrifood systems' actors. Careful consideration of trade-offs is necessary to minimize them or even, to the fullest extent possible, turn them into synergies through an enabling environment, investments and policies.

Enabling synergies between resilience, efficiency and inclusiveness for SMAEs and small-scale producers

Economic size is a key determinant of the resilience capacity of actors in the food supply chain. The limited resources of SMAEs and small-scale producers will often make their recovery more arduous when disrupted by shocks. Timely support, including access to credit, will be essential not only to help them survive in times of crisis, but to invest in interventions that address their vulnerabilities and build systematic resilience. In low-income countries, where traditional and transitional food supply chains dominate agrifood systems, better public infrastructure, and access to credit and information can create synergies between efficiency and resilience for SMAEs and small-scale producers.

Well-configured, robust and redundant public infrastructure is essential to avert or soften the impacts of shocks. For example, the installation of concrete dikes and culverts can help farmers overcome drought. But this infrastructure can also be important for resilience to extreme weather events, such as hurricanes and storms, by preventing floods from washing out roads and blocking food movements along the food supply chain.[40] While improved infrastructure enhances connectivity and reduces transaction costs, it also enhances resilience along and across food supply chains by alleviating climate shocks and enhancing the absorptive capacity of agrifood businesses.

Along with investments in physical infrastructure, large investments in strengthening institutions and in human capital are often essential. For example, during the bovine spongiform encephalopathy ("mad cow disease") crisis, which provoked a massive consumer shift towards chicken and pork in various high-income countries, beef businesses in the United States of America that could show traceable supply chains and differentiate their beef products had better chances of survival.[41] During the COVID-19 pandemic, phytosanitary institutions in South Africa, in collaboration with the private sector, were crucial in the citrus industry's response to the sudden additional biosecurity requirements of their main market in Europe.[42] Managerial capacity was also important during the pandemic for a rapid shift to e-commerce and digital tools to diversify market outlets.[17] Digital infrastructure, technology research and development, and a business enabling environment are also key areas for support.

Enhancing the resilience of food supply chains requires governments to address their high informality, especially in low-income countries. Despite their importance to rural economies, informal food enterprises – mostly micro-entities and often family based – are at risk of being left behind owing to limited resources and assets and lack of access to credit and social protection. It is assumed small-scale entrepreneurs earning a basic livelihood have no aspiration to grow nor the resources to reinvest in their businesses.[43] The policy response to the informal sector is often ambiguous and inconsistent, leading to various forms of support, repression and neglect that fluctuate over time.[44] However, survey evidence from Rwanda, Senegal and South Africa shows these businesses are held back solely by institutional barriers and lack of resources – equally true for male and female owners, who reported nearly the same level of aspiration.[43]

Governments can facilitate coordination and organization within food supply chains to allow actors to enhance their resilience capacities. One approach is to form consortia, in which SMAEs pool resources and overcome scale-related constraints, to respond better to climate risks and other shocks. While climate risks cannot be totally avoided, social capital through inter-organizational relationships in networks or strategic alliances among SMAEs could mitigate their negative effects. Such interactions among consortia can generate relational, structural and cognitive capital, promoting more robust and effective risk management through resource pooling.[45]

Access to modern technologies, know-how and equipment may be out of reach of individual SMAEs but facilitated through collective action and resource pooling. Policies to enhance SMAE resilience should encourage resource sharing and trust building to create the synergies that improve efficiency, avoid duplication of efforts and increase access to additional resources.

One way to encourage coordination and enhance relational capital is through territorial development tools.[46, 47] A study on the impact of the pandemic on SMAEs in China finds that rural counties with higher concentrations of industrial clusters were less adversely affected by the shock of COVID-19 lockdowns, as measured by the entry of new enterprises and the performance of incumbents. In these dense areas, incumbents shared risks and helped one another overcome barriers for new entrants from their home towns.[48]

Consortia or other forms of cooperation and coordination can increase the scale, visibility and influence of a small business, which may improve access to private and government funding. In countries where credit markets are imperfect or underdeveloped, enhancing industrial clusters can ease credit constraints for SMAEs.[48] The benefits of relational capital can also facilitate access for SMAEs to international markets, opening up new business horizons.[45] This can encourage marketing diversification, a valuable source of resilience in times of crisis. A study of the performance of SMAEs in Egypt found that heavy dependence on just a few destination markets left them vulnerable during rapid changes and sudden shocks. It recommended that national policy for building SMAE resilience focus on strengthening their role in national markets while also promoting export market diversification and creating an institutional and regulatory framework that supports SMAE competitiveness in global markets.[20] In this regard, as suggested in Chapter 2, establishing new free trade areas and expanding the coverage of existing ones will facilitate market diversification also for SMAEs.

Consortia and clusters are excellent facilitators for training and human development programmes and facilitate the exchange of information about the risks and remedies for dealing with calamities.[45, 48] They also function as accelerators for adopting digital technologies. Knowledge about such technologies and their operational benefits is often limited among managers, especially in low-income countries.[17] Their adoption would enable SMAEs to conduct instant data exchange before and after a crisis and help open new marketing channels. However, given the difficulties facing SMAEs in adopting innovations and new technologies, policymakers will need to develop strategies that support SMAE efforts to become more competitive and resilient.[49, 50] ■

CONCLUSIONS

Food is produced, processed and distributed by various types of supply chains that differ in composition, technology and products. The changes taking place today in food supply chains reflect changes in socio-economic conditions and technology, as well as biophysical and environmental conditions.[51] New discoveries in biology and information technology, along with demographic change and socio-economic development, are continuously transforming supply chains and driving the emergence of new chains, new products and new risks.

Although most innovations originate in more advanced economies, globalization accelerates their adoption across the world. Supermarkets, refrigeration, mobile phones, computers and e-commerce have all been essential in transforming agrifood systems. Food supply chains will continue to generate more differentiated products, as the result also of demographic, income, climatic and sociocultural changes. As modernization and globalization advance, differentiation may create new vulnerabilities and capacities in the face of systemic disturbances, such as climate change, biodiversity loss or pandemics. Food supply chain actors need to adapt and transform to remain economically viable and actively engage in agrifood systems. At the same time, governments should act to create enabling conditions for these transformations to be environmentally sustainable and socially inclusive.

The process of innovation in food and information technologies is enhancing human capital and local capacity to manage multiple risks and adapt to changing realities. An upgraded research and education system has a key role to play, helping to develop capacities to capture value within supply chains and risk-proof them. The linkage between academia and industry needs to be strengthened to foster entrepreneurship as well as capacities for prevention, anticipation, absorption, adaptation and transformation. Equally important is promoting institutional, social and financial innovations in value chains, market access and delivery.

The interaction between different actors within and across supply chains will be key regarding how agrifood systems respond to shocks and stresses. Agricultural producers are highly vulnerable to shocks affecting the sector directly as well as those affecting suppliers and customers. Primary agricultural producers and consumers will be affected by the adaptation of intermediaries to shocks, and all actors along the food supply chain will be impacted by how shocks hit lateral input and service supply chains. Although the shocks and stresses may threaten their viability, they can also favour the emergence of better adapted, more resilient supply chains. Because of the importance of interactions within and across supply chains, improving their overall capacity to deal with shocks calls for integrated approaches. Central to this is applying existing global policy frameworks, such as the Sendai Framework for Disaster Risk Reduction 2015–2030[52] and the related UN Common Guidance on Resilience,[53] valid across and within sectors.

The COVID-19 pandemic has illustrated the high cost of coping and adapting once a shock occurs. While global supply chains coped and adapted quite well, the overall cost of absorbing and responding to the crisis was immense in terms of loss of life and livelihoods and damage to the economy. Low-income countries often paid the highest price. This underscores the urgency of investing in risk management and building resilience capacities, especially against disruptions caused by climate change, future pandemics and economic crises, in ways that minimize the trade-offs and make the most of potential synergies.

Planning and investments are needed to ensure resilience of food supply chains with all their five main capacities: to prevent, anticipate, absorb, adapt and transform in the face of shocks and stresses. Investments in infrastructure (roads, storage and emergency systems) and economic support mechanisms are essential. In some cases, long-term shocks may lead to relocating farm production and SMAEs. Developing plans that take into account the choices and interests of multiple players within supply chains, as well as the capacity of the public and private sectors to manage multiple risks, should be major priorities.

Households, the focus of Chapter 4, are at the end of food supply chains and exposed to varying degrees of shocks that affect their demand for food and consequently their food security and nutrition. The most vulnerable consumers are in households who work within food systems as small-scale farmers, fishers, pastoralists and landless agricultural workers, along with the urban poor and populations that suffer greater inequality and marginalization, such as women and Indigenous Peoples. In any society, the extent and stability of such households' food security is a crucial determinant of agrifood systems' resilience. The following chapter analyses the livelihoods of these households and how they shape their access to sufficient and nutritious food. ■

PHILIPPINES
Beneficiaries of FAO's livelihood restoration efforts apply their knowledge and skills to improve rice patty productivity and to better cope with shocks.
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CHAPTER 4
ENHANCING THE RESILIENCE OF RURAL LIVELIHOODS

KEY MESSAGES

➔ Building resilience of rural households is an objective in its own right – it helps improve their livelihoods, but it also renders agrifood systems more resilient.

➔ Rural households experience shocks and stresses differently based on their socio-economic characteristics, social protection and other support programmes, and whether they primarily sell or buy food. Predominantly female households are worst affected by shocks and stresses, due, in most part, to lack of access to land and other assets.

➔ Damage to infants and young children may be irreversible and has long-term economic costs to individuals and society; social safety programmes with limited resources should give priority to infants and children to prevent malnutrition impacts such as childhood stunting and wasting.

➔ Education and income diversification are powerful factors in enhancing the resilience of rural livelihoods in low-income countries. For those living in harsh conditions, such as pastoral households, access to basic services like clean water and sanitation is key.

➔ Creating or strengthening producer associations and cooperatives and adopting more sustainable production practices – including agroecology, climate-smart agriculture and biodiversity conservation – are important to enhance resilience.

➔ By easing restraints on credit, savings and liquidity, risk-informed and shock-responsive social protection helps vulnerable households avoid negative coping strategies and reduces their vulnerability to shocks.

➔ Policies must build on agricultural households' own resilience to ensure inclusive and sustainable livelihoods, combining regular social protection with productive support.

Chapter 1 presented a framework for analysing agrifood systems' resilience and Chapter 2 analysed agrifood systems' resilience at national and subnational levels. Chapter 3 then analysed the resilience of food supply chains and agrifood businesses. This chapter complements the analysis so far by focusing on rural livelihoods and household resilience capacities. Rural livelihoods are the capabilities, assets and activities that rural people require to make a living[1] and may include farm and non-farm activities, although agriculture is crucial to most of them.

The impacts of shocks and stresses on livelihoods, food security and nutrition play out essentially within households, making them a key focus of resilience analysis. Many rural households play an important role as producers in agrifood systems – either in agriculture or running small agrifood businesses. Hundreds of millions of family farms of different sizes, as well as the fishers and pastoralists whose livelihoods depend on primary production, form the backbone of agriculture in most countries. Rural households that engage in diverse and multiple activities to improve their livelihoods can better cope with and recover from stresses and shocks, thus rendering agrifood systems more resilient. By maintaining or enhancing capabilities and assets without undermining the natural resource base, rural livelihoods also contribute to more sustainable agrifood systems.

This chapter focuses on the livelihoods of rural households and the higher incidence of poverty in rural areas. The most recent estimate of multidimensional poverty finds that, of the 1.3 billion people who are multidimensionally poor worldwide, 84.2 percent live in rural areas.[2] Thus, the majority of the 3 billion people who cannot afford a healthy diet, together with the other 1 billion people at risk of joining their ranks if their incomes fall by one-third (see Chapter 2), are likely to be in rural areas and depend to a large extent – directly or indirectly – on agriculture for their livelihoods. For this reason, given the central role of agriculture in reducing poverty and ensuring food security and nutrition, the focus of the chapter extends also to agricultural households in rural areas (see Glossary). In fact, billions of people around the world are linked to agrifood systems in one way or another through their livelihoods. A nuanced understanding of household-level vulnerabilities, and the various ways households are linked to agrifood systems through their livelihoods, will help in developing policies that positively influence food security and nutrition outcomes for millions of people in the face of shocks and stresses.

Based on empirical analysis, the chapter starts with a discussion of the resilience determinants of rural livelihoods to shocks and stresses. It then focuses on the constraints faced by agricultural households in rural areas and small-scale producers in managing risks and building capacities to cope with shocks and stresses. The chapter then proposes solutions to address the needs of vulnerable households and enhance synergies between household resilience, efficiency and sustainability.

Because the impacts of shocks on households are among the main drivers of poverty and food insecurity, the ability to cope with them has been the subject of intense research and policy debate. Shocks that affect households may be *idiosyncratic*, that is, affecting only one individual or household in the case of illness or death, or they may be *covariate*, that is, the shock is widespread and affects many (e.g. droughts, floods, conflicts, or pest and disease outbreaks) (see Glossary).[3–5] Households' coping strategies differ according to the type of shock. Preparation for idiosyncratic shocks can be ensured at household and community levels, while coping with covariate shocks may require risk-pooling across larger areas and populations.[6] However, regardless of whether shocks are idiosyncratic or covariate, household capacities to prevent, anticipate, absorb, adapt and transform – in short, their resilience capacities – are strongly linked to their socio-economic status (e.g. income level) and social and support networks, and to social protection and productive support programmes. ■

DETERMINANTS OF RESILIENCE OF RURAL LIVELIHOODS

Rural livelihoods depend to a large extent on agriculture and agrifood activities. They are exposed not only to shocks caused by price fluctuations and disruptions in input and food supply chains (see Chapter 3), but also to adverse events such as floods, droughts, soil erosion and pests.[4] According to the 2014 *Human Development Report* of the United Nations Development Programme (UNDP), between 2000 and 2012, more than 200 million people, most of them in low-income countries, were hit every year by environmental disasters, especially floods and droughts.[7] A drought can reduce the local food supply and increase market prices, hurting especially households that predominantly buy, rather than sell, food in the market.[8] In Malawi, a recent study found that weather shocks such as drought and floods during an agricultural season can reduce household food consumption by 9 percent. Stresses such as poor infrastructure can aggravate the negative impacts of weather shocks. The same study finds that the combined impact of extreme weather events and poor infrastructure caused a 17 percent drop in food consumption.[3] Even in countries that are not low-income, shocks can have a major impact on livelihoods. A study using panel data from 1994–2004 showed that more than 50 percent of Russian households were hit by shocks that forced them to make rapid and large adjustments in their food spending. The most affected were rural households which had less access to income-smoothing mechanisms such as credit and insurance.[9]

A recent global FAO study finds that the economic loss associated with all disasters – climatological, hydrological, biological and geophysical – averaged roughly USD 170 billion a year over the past decade. Data from 71 post-disaster needs assessments conducted between 2008 and 2018 showed that agriculture, including crops, livestock, forestry, fisheries and aquaculture, absorbed 26 percent of the overall impact of medium- to large-scale disasters in low-income and lower-middle-income countries and 63 percent of damage and loss in the combined agriculture, industry, commerce and tourism sectors.[10]

In response to this risky environment, rural agricultural households, especially in low-income countries, use a set of strategies to manage risks *ex ante* and cope with shocks *ex post*. They can diversify income either by on-farm crops or livestock diversification or by engaging in the rural non-farm economy. They manage their agricultural risks by investing in risk reduction strategies such as irrigation, drainage management and pest control. They adapt their agricultural land-use practices to reduce soil erosion and landslides, and change cropping mixes and planting dates in response to adverse climatic conditions. When shocks occur, they use savings, liquidate assets and borrow to cope. Some rural households use insurance via formal insurance providers or informal inter-household insurance based on community networks.[11]

Households differ in their ability to use any, or a combination, of these strategies. Resilience is a dynamic process, meaning it is important that strategies to reduce risks or cope with shocks do not diminish the household's overall ability to deal with subsequent shocks. Decisions on how to manage risks and cope with shocks depend, to a large extent, on the household's socio-economic well-being and support programmes. Findings from India's national household survey indicate that non-poor households actively anticipate shocks by strengthening their safety nets as a precautionary measure. They are also more likely to draw on support from informal credit sources. These options are more limited for poor households, especially extremely poor households who face high food insecurity.

To explore the resilience capacities of rural households, FAO's resilience index measurement and analysis (RIMA) model was applied (Box 13) to data from 46 household surveys covering 23 countries (two surveys per country) from the United Nations Children's Fund (UNICEF) multiple indicator cluster surveys (MICS) (see Annex 4 for the list of countries). Despite being in rural areas, some households may not be involved in agriculture, deriving livelihoods exclusively from non-farm activities. The findings indicate that it was mostly education, income diversification and transfers (both formal and informal) that drove improvements over time in rural household resilience capacities. For agropastoralist households, the most important drivers of resilience capacity were greater access to basic services such as schools, health and sanitation. Shocks, especially of high intensity, lead to a reduction in resilience capacity over time. Price shocks seem to have the greatest detrimental effect on household resilience, producing a greater impact than more frequent shocks such as health and environmental shocks.[12]

The RIMA model was also applied to agricultural households (i.e. engaged in farming, pastoralism or agropastoralism), covering another 12 countries and 17 additional surveys (see Annex 4 for the full list). Despite all households being agricultural, some rely partly on the rural non-farm economy for their livelihoods. Figure 9 summarizes results for 12 countries using four

BOX 13 RIMA IN BRIEF

In 2008, FAO pioneered the RIMA model, a quantitative approach to a rigorous analysis of how households cope with shocks and stresses. An enhanced version of the model, RIMA-II, directly measures resilience through its resilience capacity index (RCI). RIMA builds on four pillars of resilience, listed in the table, which determine the food security resilience of households as measured by the RCI.

TABLE RIMA PILLARS OF RESILIENCE

Pillars of resilience	Definition
Adaptive capacity	The ability of a household to adapt to a new situation and develop new livelihood strategies.
Social safety nets	The ability of a household to seek help from relatives and friends, support from government, and timely and reliable assistance from international agencies, charities and non-governmental organizations (NGOs).
Assets	*Productive assets* are key livelihood elements, enabling households to produce consumable or tradable goods (e.g. land, livestock and durables). Context-specific sets of productive assets that determine household income are evaluated. *Non-productive* assets such as a house, vehicle or household amenities reflect living standards and wealth.
Access to basic services	The ability of a household to meet basic needs, and to access and make effective use of basic services (e.g. schools, health facilities, infrastructure and markets).

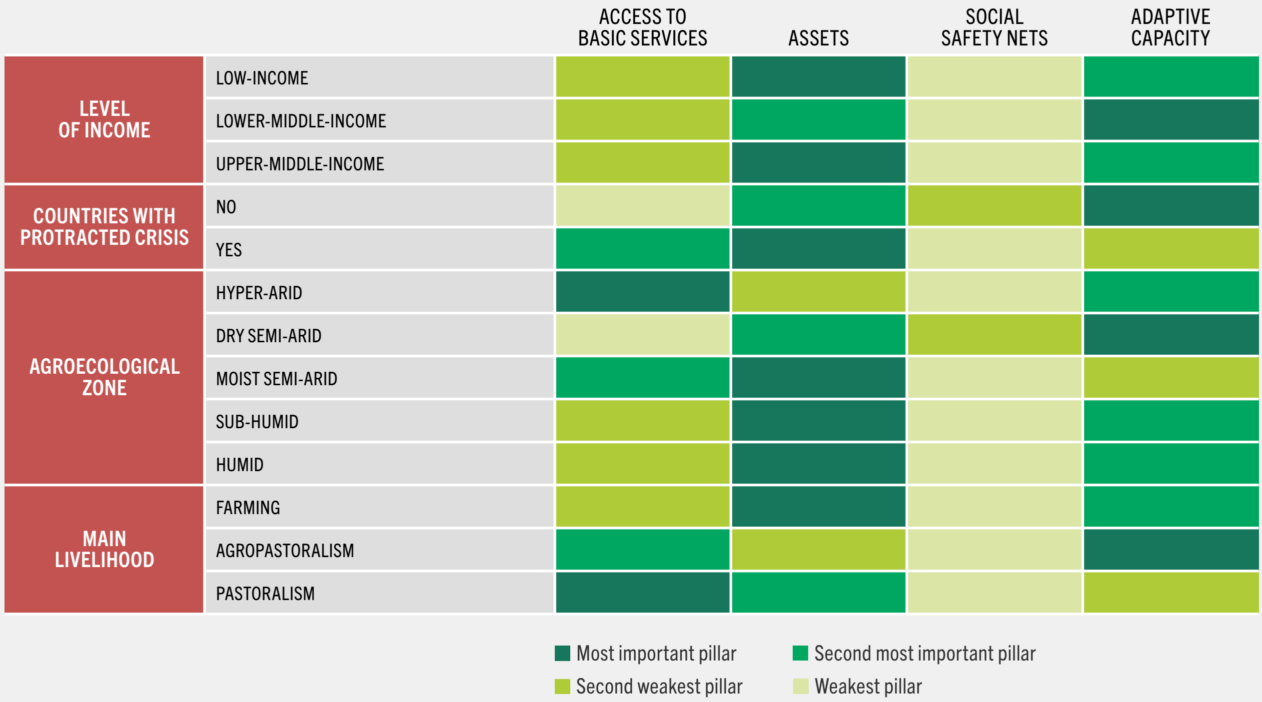
SOURCE: d'Errico *et al.* 2021.[12]

pillars of household resilience – access to basic services, assets, social safety nets and adaptive capacity – to identify the most important factors for the resilience of agricultural households (see Box 13 for a description of the RIMA model and the four pillars). The findings are presented for different profiles: country level of income, whether a country is affected by a protracted crisis, agroecological zone, and the main household livelihood source. The colour coding from dark to light green illustrates the importance of each pillar in determining the resilience of agricultural households, the darkest being the most important, the lightest the least important.

In just over half of Figure 9 classifications, assets (productive and non-productive) is the most important pillar to ensure households' capacity to bounce back after a shock. At any time, asset ownership plays an important role in sustaining household livelihoods and generating income. During a crisis, it is essential to their coping strategies of last resort, allowing them to buffer against shocks by selling off productive and non-productive assets. However, this strategy can lead some households, especially the poorest, into a poverty trap if they are left with too few assets.

Figure 9 shows that the adaptive capacity of households is also a significant pillar of their resilience. A household's capacity to adapt is closely linked to the education level within the household and to human capacity building, which give the members more value on the labour market. Access to basic services such as improved sanitation and sources of water and to primary services, in particular schools, hospitals and agricultural markets, is crucial to support their resilience, particularly in hyper-arid zones and for pastoralist households.

FIGURE 9 RIMA RESILIENCE PILLARS BY COUNTRY PROFILE



NOTE: Protracted crises are contexts in which a significant proportion of the population is acutely vulnerable to hunger, disease and disruptions to livelihoods over prolonged periods.[13]
SOURCE: d'Errico *et al.* 2021.[12]

Table 4 summarizes the drivers of household resilience across the 35 countries covered by the two sets of data (MICS covering 23 countries and RIMA covering 12 countries; see Annex 4) and the main policy implications for building the resilience of rural households.

The RIMA analysis also shows that rural households comprising mainly women suffer the most during and after shocks. Women tend to have much less access than men to land and other assets – important drivers of resilience. Their main coping strategy is often to sell their assets; this is risky in the long term as it reduces income-generating capacity. Providing women with greater access to social protection and assets could counterbalance this. Access to productive assets will allow women to restock and bounce back after a shock without any threat to their food security. Education plays a key role in strengthening women's resilience capacity, underscoring the importance of expanding access to education for all, especially girls. Women with more education have wider access to the labour market and can expand their available options for income-generating activities.[12]

Children are also vulnerable to shocks and stresses. In terms of nutrition, infants and young children bear the brunt of shocks. A recent review found that covariate shocks have a permanent effect on child growth in low-income countries, with most studies showing that widespread shocks increase the prevalence of stunting and underweight among children under two years of age.[14] Evidence of

TABLE 4 DRIVERS OF RURAL HOUSEHOLD RESILIENCE AND POLICY IMPLICATIONS

Indicators of resilience	Role in enhancing resilience	Policy implications
Productive and non-productive assets (e.g. agricultural tools, land, livestock)	Asset ownership is key to ensuring households' capacity to bounce back after a shock. It plays an important role not only in sustaining households' livelihoods, but also as a buffer in case of shocks – selling productive and/or non-productive assets is a common coping strategy.	Interventions should expand access to productive and non-productive assets, and support the diversification of income sources, especially for the poorest households. It is important to help households avoid negative coping strategies, which can lead to a low level of asset holdings and, ultimately, a poverty trap.
Access to education	When combined with income-generating activities and diversification strategies, household members with a higher level of education can improve their livelihoods as they are more valued on the labour market. When a shock negatively affects households' livelihoods, they can adapt more easily if they can rely (temporarily or not) on another source of income.	Policies supported by investments are needed to expand access to education and post-education capacity-building programmes, especially for women.
Access to basic WASH services (e.g. improved sanitation and sources of water) **and primary services** (e.g. schools, hospitals and agricultural markets)	The harsher the environment in which the household lives (e.g. arid agroecological zone, a country affected by a protracted crisis, or low-income country), the more resilience depends on access to basic services.	Long-term policies to improve the availability and quality of infrastructure can sustainably increase household resilience. Large infrastructure projects to expand primary services are especially needed for households located, for example, in countries in the Sahel region.

NOTE: WASH: water, sanitation and hygiene.
SOURCE: d'Errico *et al*. 2021.[12]

the effects on acute undernutrition (standardized weight-for-height or wasting status) is much less consistent – probably because it can be reversed with weight gain after the shock and therefore is not captured by studies unless measured immediately. The effects of stunting are largely irreversible: children simply cannot recover height in the same way they can gain weight. Evidence of the effect of shocks on micronutrient deficiency is quite limited and merits further research. Child nutrition status is associated with performance in cognitive tests, school attainment and labour market outcomes later in life,[15, 16] suggesting that shocks may generate substantial, long-term economic costs to both individuals and society.[14] ■

SMALL-SCALE AGRICULTURAL PRODUCERS BEAR A DOUBLE BURDEN

Agricultural production – crops and livestock, aquaculture, fisheries and forestry – is a risky business. All agricultural sectors depend on natural processes and limited natural resources and are more exposed to natural hazards than food processing and trade. Agriculture increasingly faces new shocks, stresses and risk drivers from a variety of sources, including: more frequent and extreme climatic events, biodiversity erosion, new diseases, climate change, natural resource degradation, an ageing farm population, seasonal labour shortages, food safety scares and commodity price volatility.[17]

However, the capacities of rural households to handle risks are not equal. Those running small-scale businesses operate under greater constraints due to more limited access to land and water, resources, information, technology, capital and assets.[18, 19] They bear a double burden of vulnerability to risks and shocks: in addition to risks intrinsic to agriculture, they also face the risk of being excluded from productive assets and lucrative markets in the transformation process of food supply chains (see Chapter 3).[20]

The impact of shocks on the food security and nutrition of agricultural households depends also on the extent of their engagement in agriculture and food production. Shocks and stresses that hit agricultural and food production, such as pests, diseases, drought and disruptions to food supply chains, impact more on households which are net food producers (see Glossary). On the other hand, net food consumer households rely more on the non-farm economy, and for them farming is a part-time activity; they are more prone to shocks that affect their purchasing power as consumers, such as price spikes and general economic crises.

Regardless of how agricultural households are categorized, there is clearly no single strategy to build their resilience against shocks. Most agricultural risk management tools are not available to agricultural households – especially those operating small-scale businesses – owing to a lack of multi-risk governance and related policies and investments, market failures, and the absence or underdevelopment of markets. In an ideal world, small-scale agricultural households could use risk-sharing tools, such as credit, crop and livestock insurance, and forwards, options and futures, to transfer their risks to the wider economy and operate more efficiently. However, tools such as agricultural insurance need active government support – not yet feasible in all countries – while others (e.g. futures and options) are practised in limited cases, even in high-income countries, as they require specific skills not available to the majority of agricultural households.

Risk management schemes are particularly underdeveloped in aquaculture and fisheries compared to other food producing sectors.[21] Although aquaculture provided 52 percent of fish for human consumption in 2018,[22] the sector is still inherently more risky than other food production activities, owing to higher variability in yields and revenues and sensitivity to multiple biological hazards (disease and food safety events).[23–25] As a result, in low-income countries, the livelihoods of 20.5 million people, most of them small-scale aquaculture workers engaged full-time, part-time or occasionally, may be in jeopardy if a shock occurs.[22] Similar conditions apply to small-scale fishing households in low-income countries disproportionately affected in times of shock or crisis; they are least prepared due to low rates of savings and inadequate credit or insurance facilities.[26] Their unpredictable earnings (dependant on whether they catch fish or not) and lack of assets for use as collateral make their access to favourable credit or insurance schemes extremely difficult.[27]

Due to the range of market failures involving risk-sharing tools, agricultural households employ other strategies to manage the multiple challenges they face. They diversify production mixes to reduce risks and mitigate the impacts of shocks before they occur. They also accumulate savings and assets as coping mechanisms in the aftermath of shocks. At farm level, agricultural households respond to the unpredictable interplay between natural, technological and social factors by reconfiguring and using available resources in novel ways.[28] This process helps them navigate foreseen and unforeseen change,[28] strengthening their capacity to prevent, anticipate, absorb, adapt and transform.

With climate change and greater frequency of disasters the new normal, the resilience capacities of agricultural households are increasingly put to the test. An assessment of the climate resilience of pastoralists and agropastoralists in sub-Saharan Africa found that while their capacities and knowledge helped them cope with unexpected shocks and climate variability, there is much need for improvement (Box 14). The most vulnerable bear the true burden of climate change and disasters disproportionately.[10] During the COVID-19 pandemic, small-scale producers have experienced reduced access to inputs, labour and farmland, resulting in production losses, lower household incomes and declining nutrition levels. The severity of the damage caused depends on multiple factors, such as the timing of the spread of COVID-19 and how containment measures disrupted the agricultural calendar, input prices and demand.[29–31] ■

BOX 14 THE CLIMATE RESILIENCE OF PASTORALISTS AND AGROPASTORALISTS IN SUB-SAHARAN AFRICA

Climate-related shocks cause crop, animal and asset losses, displacement, and water scarcities, all of which affect the livelihoods of pastoralists and agropastoralists in sub-Saharan Africa. As the intensity of these shocks increases, the impacts include a deterioration in food security, affecting the most vulnerable households disproportionately.

A recent FAO assessment looked at the degree of resilience to climate change among small-scale pastoralists and agropastoralists in Angola, Burkina Faso, Burundi, the Gambia, Kenya, Mozambique, Niger, South Sudan and Uganda.[32] The survey reached 1 466 household heads, of whom 20 percent were female.

The study finds that while resilience to climate change is low, both strengths and weaknesses exist. Social factors, including trust and cooperation, as well as household composition and types of production, scored highly as drivers of resilience. Other factors are identified as being at risk, such as savings – half the respondents have some savings but two-thirds reported having fewer savings than five years earlier. The study highlights the reduced capacity to rely on both financial assets and physical assets (e.g. seed and livestock) in the case of unexpected shocks. The assessment also uncovered weaknesses in other areas – for example, agronomic and production practices, animal disease control, access to veterinary services and livestock husbandry practices – indicating the need for improved animal breeding, breed diversity, animal safety mechanisms and better livestock nutrition.

SOURCE: Hernandez Lagana & Savino. 2018.[32]

POTENTIAL SOLUTIONS FOR RESILIENT RURAL LIVELIHOODS

The ultimate goal of agrifood systems' resilience is to ensure sufficient, safe and nutritious food for all in the face of any disruption, and to sustain the livelihoods of agrifood systems' actors. The rest of this chapter focuses on potential solutions that can guide policy and interventions to strengthen the livelihood resilience of rural households. The solutions can be grouped into three main categories: institutional solutions, technical solutions and cross-cutting policy interventions.

Institutions for improved resilience

The resilience capacity of rural households depends on contextual factors and local circumstances. The economic impact of drought depends on a host of local factors: soil quality, cropping patterns, irrigation infrastructure, and the flexibility of credit providers and supply chain partners.[33] Access to products, inputs and credit – which shape resilience capacities – largely depends on physical distance to urban centres and markets. Rural households are embedded in local networks and interact formally and informally with other actors in specific agroecological, socio-economic and territorial contexts. These interactions constitute their production and livelihood systems.[17, 34] Livelihoods and resilience also depend on how they interact with their surroundings. Social networks are crucial for resilience of poor households, providing access to informal credit and saving mechanisms to help face emergencies and shocks. However, covariate shocks will affect most households and social networks may fail to provide support. Policies and strategies to enhance the resilience of the vulnerable rural poor should build on existing informal safety nets and address their weaknesses, for example, by encouraging the formalization of social networks and linking them to productive enterprises and financial services.[27]

The integration of producers into food supply chains and lateral input and service supply chains varies (see Chapter 3). While consumption of produced food is the main objective of subsistence farmers, it is less important in agricultural households that are well connected with agribusinesses for sourcing inputs, securing credit and selling outputs. Large-scale farmers may even provide jobs and informal credit. Small-scale agricultural households have weaker linkages to food supply chains and rely heavily on their community networks for informal credit, information, technology and marketing. This marginalized position and their exclusion from access to more lucrative markets leaves small-scale producers more exposed to risks and shocks and unable to operate efficiently and productively. Small-scale agricultural households face constraints that weaken their livelihoods and narrow their opportunities for growth, thus undermining their resilience and that of agrifood systems; their three weaknesses – small scale, limited access to resources, and weak market power – may create a vicious circle.

Policies that create or strengthen producer associations and cooperatives can contribute to breaking this cycle and improving livelihoods by: pooling resources to achieve scale; providing access to productive resources such as machinery, equipment and credit; and enhancing market power. By purchasing inputs and selling outputs as a group, small-scale producers protect themselves from market fluctuations and obtain better input and higher output prices. FAO's Dimitra Clubs are community-based groups, often established in remote or conflict-affected areas, which come together on a voluntary basis to discuss common challenges and organize forms of collective action to improve the livelihoods of rural communities and empower rural people, especially women.[35]

Coordination with other actors in the food supply chain is also key to managing market risks in order to enable trust, networking, cooperation and information exchange between small-scale producers and other value chain actors. This can lead to mutual benefits through mechanisms such as contract farming[36] where small-scale agricultural producers involved in crops, livestock and aquaculture receive guaranteed prices for their outputs, while processors and distributors receive produce of the desired quality.[37]

Enhancing resilience through agroecology and adaptation to climate change

Adopting more sustainable production practices is another important resilience-enhancing strategy for agricultural households. The proposed practices are highly relevant to agricultural households running small-scale businesses. They create synergies between enhancing resilience and improving productivity, sustainably, in addition to being accessible to small-scale producers because they do not entail large risky investments. Agroecology is one approach that can help small-scale producers adapt to and mitigate climate change. There is increasing evidence of its benefits for the environment, biodiversity, farmers' incomes, adaptation to climate change, and resilience to multiple shocks and stresses. However, this evidence remains fragmented across case studies, isolated experiences and field observations, based on heterogeneous methods and data, as well as different scales and time frames.[38]

To overcome the lack of systematic data, FAO and a large number of partners have developed the tool for agroecology performance evaluation (TAPE), an innovative framework that consolidates global evidence on how agroecology supports the transformation to more sustainable and resilient agrifood systems.[39] Resilience is one of the elements explicitly measured, using the following descriptive scales:

- overall diversification of the production system – diversity of crops, animals, trees and economic activities;
- economic resilience – stability of production and income and the capacity to recover from disturbances;
- social resilience – social mechanisms to reduce vulnerability; and
- environmental resilience – the capacity of the agroecosystem to adapt to climate change.

Across the 25 countries in five continents where TAPE has been applied, there is a strong link between agroecology and biological and economic diversity: more advanced agroecological farms are more diverse in terms of crops, trees and animals, but also in terms of economic activities, leading to enhanced economic and environmental resilience. Improved resilience has often translated into better diets and food security. Animals in particular have a key role in enhancing resilience[40] – TAPE's results show that more advanced agroecological farms have more diverse species and breeds of well-adapted, healthy animals, associated with higher biodiversity and improved soil health, which in turn contribute to better ecological resilience and enhanced ecosystem services.

A TAPE evaluation in Mali showed that more advanced agroecological farms have higher net revenues than conventional farms using high levels of chemical inputs. Indeed, agroecological farms incur much lower costs because they rely more on biological synergies that substitute for external inputs.[41, 42] Examples include using manure as fertilizer and crop residues as livestock feed. At the same time, greater biodiversity in agroecological farms leads to greater capacity to resist pest and disease attacks.[43]

Beyond its benefits to agricultural producers, agroecology, if widely adopted, can help reverse trends of biodiversity loss and enhance biodiversity for food and agriculture (BFA). Dominant production systems have contributed to biodiversity loss through habitat destruction, monocropping, excessive use of inputs such as fertilizers and chemicals, and replacement of diverse crop and livestock genetic resources with a narrow range of species, breeds and varieties.[44]

Based on BFA, agroecology can create various synergies that lead to resilient livelihoods while enhancing environmental sustainability. It helps stabilize and increase yields, fosters growth of local crops and animal breeds, enhances income and diversifies household diets.[45] BFA also contributes to building resilient rural livelihoods indirectly by providing rural people with wild foods and other resources such as wood for fuel. Box 15 contains examples of how approaches aligned with agroecology and biodiversity can generate resilient livelihoods for rural mountain populations.

Climate-smart agriculture (CSA) is another resilience-enhancing approach, which aims to promote food security, resilient livelihoods and climate-resilient agriculture.[48, 49] The concept recognizes that conventional mainstream agriculture cannot feed the growing world population sustainably, because it degrades the environment and depletes scarce natural resources.[50] A review of the applications of CSA in Africa shows that it provides multiple benefits. It has helped small-scale agricultural producers implement sustainable land management, slowed desertification and improved resistance to drought, while achieving higher productivity and income. It has also enhanced the capacity of agricultural households – especially those that are female-headed – to adapt to climate change.[51]

One successful example of CSA implementation comes from the Kodroka Forest Reserve in the Northern State of the Sudan. Much of the forest has been severely degraded by a combination of factors, including desert expansion, climate change and inefficient water management. Many of the farmers had already begun adapting to climate change by adjusting planting and harvest times to longer summers and unpredictable rainfall. FAO worked with the communities around the forest to plant rows of crops and trees (e.g. acacia and eucalyptus) on the degraded land. Within a few harvest cycles, the area became verdant and productive again. The trees act as a buffer against the expanding desert, crops improve farmers' livelihoods and careful harvesting of the trees at appropriate intervals generates additional income.[52]

Social protection – an important tool to enhance rural household resilience

The precarious condition of many rural livelihoods means they are more vulnerable to shocks, which may further undermine their asset base as well as their capacity to manage future shocks effectively.[53] Hundreds of millions of rural families are trapped in a cycle of hunger, poverty and low productivity, causing unnecessary suffering and impeding agricultural development and broader economic growth. Breaking this cycle requires action in two complementary domains: social protection and the productive sectors of the economy. In many developing

BOX 15 SYNERGIES BETWEEN PRODUCTIVITY, RESILIENCE AND SUSTAINABILITY: THE MOUNTAIN PARTNERSHIP PRODUCTS INITIATIVE

The Mountain Partnership Products initiative (MPP initiative) provides concrete examples of how aligning agricultural practices with agroecology and BFA can lead to synergies between improved productivity, environmental sustainability and resilient livelihoods. The MPP initiative aims to strengthen the resilience of mountain peoples, their economies and ecosystems. It is a certification and labelling scheme that promotes local and short supply chains while ensuring transparency and trust between producers and consumers, fair returns for primary producers, conservation of agrobiodiversity and preservation of ancient techniques. Currently, the initiative operates in eight countries and includes 20 products.

A prominent product example is Jumla mixed beans, produced using agroecological practices in the Sinja Valley in Nepal at an altitude of 2 300 metres. Due to the product's high nutritional and cultural value, the producers were able to increase the price of the beans by more than 25 percent and they now sell in national supermarkets; there has been a major increase in sales with production scaled up four times in three years. Another example is Melipona honey, produced by stingless bees and harvested by six honeybee associations in Bolivia's Serranía del Iñao National Park, at the foot of the Eastern Cordillera. Perfectly adapted to the local environment, these bees are crucial pollinators; their loss would lead to a decrease in biodiversity in Bolivian forests. The producers were able to increase their sales price by more than 80 percent.

In both cases, there has been a significant improvement in food security and nutrition in the local community, with benefits for women, who have been increasingly engaged in farming, but also for many young people who have been able to resume education.

SOURCE: FAO. 2018;[46] Li, El Solh & Siddique. 2019.[47]

countries, most of the poor live in rural areas and agriculture is the most important productive sector. Linking social protection with agricultural development is, therefore, a potentially powerful means of breaking the cycle of rural poverty.[54]

Social protection policies in developing countries emerged initially to help groups of people harmed by structural adjustment programmes in the 1980s and early 1990s. They now extend beyond welfare concerns, with increasing emphasis on reducing risks and the harmful effects of shocks on vulnerable livelihoods, as well as supporting economic and productive inclusion.[55] When designed to be gender-, nutrition- and risk-sensitive, as well as shock-responsive, social protection policies help raise incomes and make up for consumption shortfalls of poor households, allowing them to invest and engage in productive activities. The role of social protection combined with adopting climate-smart approaches in climate risk management strategies is particularly interesting (see the FAO studies summarized in Box 16).

There is substantial evidence to show that social safety nets can be effective in protecting well-being, assets and food security.[56–58] When guaranteed at regular, predictable intervals, they also have productive impacts, providing some degree of insurance and liquidity, and allowing households to take advantage of economic opportunities. Furthermore, social protection may have positive multiplier effects on local communities and economies.[59]

Social protection has evolved to encompass both public and private initiatives to support communities, households and individuals in managing risk. It has three components: (i) social assistance (such as cash or in-kind transfers and public works programmes); (ii) social insurance; and (iii) labour market programmes.[64] Social protection relief facilitates recovery after a shock by enhancing incomes and overall household capabilities.[55] Where they are already established, they can, in relatively short time, deliver additional social assistance to beneficiaries and expand services to newly vulnerable households.[65]

Evidence on the use of social protection during the COVID-19 pandemic indicates that countries have responded in part by increasing the generosity of existing programmes and reaching new participants. The number of new programmes has become significant, such that 63 percent of the cash transfer responses to the pandemic are newly introduced schemes.[66] The adequacy of these responses in terms of speed, coverage, generosity and duration of the social protection varied across regions and countries. On average, responses lasted for only three months, far less than the duration of the crisis, while roughly 40 percent of programmes were one-off payments.[66] Countries with more developed social protection systems were better prepared to protect people's incomes, underscoring the importance of investing in strengthening social protection systems in normal times, so as to expand them easily in response to the needs of the vulnerable in times of crisis.[67]

Social protection can support small-scale agricultural households to adopt more profitable livelihood strategies otherwise beyond their reach due to the additional risks involved.[54] It provides poor rural households, reliant mostly on agriculture, with an alternative to negative coping strategies, such as drawing down assets, which aggravate their vulnerability and undermine future income-generating capacity. By alleviating constraints to credit, savings and liquidity and providing cash and in-kind support, it reduces the vulnerability of rural households. Regular and predictable social protection instruments enable households to better manage risks and to engage in more profitable livelihood and agricultural activities. If well designed, social protection can establish synergies with productive activities and investments, which strengthen both the resilience and sustainability of small-scale producers' livelihoods.[68]

Programmes that provide social protection and productive support are highly complementary and their implementation is increasing in rural areas. An FAO review of enabling policies in the period 2007–2018 found that these programmes have contributed to combating rural poverty.[64] It identified ways of creating further synergies, specifically:

- Globally, unconditional cash transfers and school feeding programmes were the most widely used social assistance programmes. However, few focused on rural communities, where needs are greatest. National programmes should include components that are specifically designed to address the challenges of rural poverty.
- Most social assistance programmes with an agricultural support component involved public procurement schemes, mainly for school feeding programmes and food subsidies. But there is still scope to improve links between social protection and public procurement.
- Apart from public procurement programmes, social assistance components in productive support programmes are still rare. Linkages between cash transfers and programmes related to production factors (e.g. inputs, credit and irrigation) should be strengthened.
- There is a growing trend towards agricultural insurance programmes; acceleration is crucial, considering their potential to boost production and reduce poverty and vulnerability in rural areas.

The focus of existing programmes needs to be refined to address the unique challenges of rural poverty and harness the potential links between social protection and productive support programmes. Social protection should be linked to good agricultural approaches and practices, such as agroecology and CSA, to create synergy gains and enhance the impacts of both types of support, as illustrated by a case study in Zambia.[69] Risk-informed and shock-responsive social protection programmes can create synergies with public spending on agricultural and rural development, leading to greater inclusiveness for both types of support. Targeted programmes have had positive outcomes, particularly in health,

BOX 16 DIRECT AND INDIRECT IMPACTS OF SOCIAL PROTECTION PROGRAMMES ON HOUSEHOLD RESILIENCE TO MULTIPLE SHOCKS

Social protection programmes are increasingly seen as a mechanism to reduce household vulnerability to multiple shocks, including food shortages and climate shocks. Through transfer of cash or in-kind resources, they directly support vulnerable households facing food insecurity. They can also encourage those receiving transfers to invest in economic activities. An FAO study of refugee communities in Uganda found that both cash and food transfers helped beneficiaries stabilize household food consumption and reduce reliance on negative coping strategies, such as asset liquidation or going into debt. Cash transfers also encouraged investment in agricultural activities, if the land plots were large enough to produce positive returns.[60]

Social protection programmes can also reduce vulnerability to shocks indirectly by enabling poor farmers to adopt strategies that reduce their sensitivity to rising temperatures, erratic rainfall and the spread of new pests and diseases. An FAO study in Malawi and Ethiopia showed that food aid provided to resource-poor farmers removed constraints to investing in improved, CSA practices.[61] Smallholders participating in the Malawi Social Action Fund, the country's major public works programme, were more likely to adopt CSA practices and technologies over multiple agricultural seasons, achieving greater productivity returns in the medium term.[62] In Ethiopia, households participating in the public works component of the Productive Safety Net Programme were less likely to suffer agricultural losses, food shortages and crop failure due to drought or other shocks.[63]

Such experiences demonstrate the effectiveness of social protection programmes in supporting households following shocks and during emergencies. However, these programmes are seldom complemented by explicit resilience-enhancing strategies. Breaking down silos and improving coordination and coherence between social protection and resilience-enhancing initiatives will contribute to a better use of resources and, at the same time, improve gains in productivity and food security.

nutrition and school attendance. Well-designed programmes can also help prevent the use of child labour, as families are more likely to keep their children in school. Expanding social protection to small-scale producers, including those in fisheries and aquaculture as well as informal workers, should be a top priority in efforts to enhance the resilience of vulnerable households in rural and urban areas.

Particular attention should be given to expanding social protection coverage to small-scale fishers and informal fishworkers. A comprehensive FAO review finds that these categories face multiple risks, against which they are inadequately protected or totally unprotected. They face unique economic vulnerabilities compared to other small-scale agricultural activities, and social vulnerabilities can be overwhelming. Therefore, innovative interventions are needed to provide protection across the specific set of challenges that these categories face in each national and local context.[70]

To enhance inclusiveness, social protection must be flexible enough for geographical and sectoral mobility, enabling households to seize opportunities emerging across sectors and spaces. This is especially crucial in countries and areas with rapid economic growth, where structural transformations may increase inequality and exclude more vulnerable and marginalized households.

The costs of such programmes cannot be sustained over a long period of time unless accompanied by sustainable productivity and economic growth and increased government revenues. A balanced approach is required: agroterritorial investments and policies must aim to achieve growth and create employment, while tax and social protection must aim to reduce inequality and enhance inclusiveness, while also ensuring programme fiscal viability and sustainability.

Achieving long-term economic inclusion is contingent on a comprehensive social protection system that proposes a full range of preventive, protective, promotive and transformative measures to, not only address the wide range of vulnerabilities faced by the rural poor, but also support livelihoods. For example, national cash transfer programmes in sub-Saharan Africa have helped poor and marginalized agricultural households build assets, empower themselves and generate economically productive activities. This strengthens the case for social protection as an investment for better livelihoods. Features such as the level of transfers, the predictability and regularity of payments and the type of associated messaging are other critical factors for enhancing economic and productive impacts. Combining predictable and reliable social protection with agricultural support interventions – such as easing access to productive assets and training – can maximize the impacts and increase the likelihood of success for sustainable economic inclusion processes.[71]

Poverty and vulnerability have a territorial dimension; some areas risk isolation and impoverishment if they lose crucial links to urban and export markets. Such areas will benefit from investments in public and private infrastructure to stimulate value chain development. In the long run, facilitating access to credit, productive assets and technical training will be essential to boost rural livelihoods and increase productivity; otherwise, social protection programmes will become unsustainable. However, economic inclusion requires a more long-term and holistic approach, with gradual interventions to provide intensive support for a certain period with the objective of graduating progressively to sustainable livelihoods. The combination of social assistance and social insurance can play an important role in building resilience of rural livelihoods and ensuring gradual progress of the rural poor into economic inclusion pathways, reducing the need for social protection.[71] ■

CONCLUSIONS

This chapter analysed what drives the resilience of rural households. Empirical findings from 35 countries highlight assets (productive and non-productive), income diversification, and access to education and basic services such as sanitation as important determinants of household resilience. Expanding access to productive and non-productive assets and supporting the diversification of farm and non-farm income is therefore essential. Wider access to education also emerged as a fundamental intervention to enhance resilience, improving people's chances of engaging in stable, remunerative jobs. Access to water, sanitation and hygiene (WASH) services played a critical role in enhancing resilience for households, particularly those involved in pastoralism, generally located in a harsh environment. Interventions to improve the availability of quality infrastructure are highly recommended for pastoralist households.

The chapter also uncovered a wide range of experiences from the literature focused on building resilient livelihoods, with the aim of overcoming potential trade-offs and create synergies, improving efficiency and promoting the sustainability of small-scale agricultural production. The chapter underscored the role of collective action, strengthening networks and cooperation among small-scale producers and other value chain actors, such as producer associations and cooperatives, as a cornerstone of resilient rural livelihoods. Agroecology, climate-smart agriculture and biodiversity conservation can also contribute to building resilience to climate shocks and generating rural livelihoods, while improving environmental sustainability.

Regular and predictable risk-informed and shock-responsive social protection instruments, complemented by productive support programmes, can enable households to better manage risks and engage in more profitable, sustainable agricultural activities. Insurance or emergency schemes can also provide critical supplies – such as seed for farmers and cattle for herders – after a disaster hits, to provide protection and kick-start their recovery.

Policies to safeguard food security and nutrition need to consider the segments of the population most vulnerable to shocks and stresses and who work informally; social protection programmes need to be inclusive. Ensuring the latter may require innovative measures to connect households with services and information and build their self-confidence. When a shock occurs, a comprehensive social protection system should offer the rural poor different types of interventions and schemes to enable them to engage in productive activities with decent employment and to prevent them from being pushed back into subsistence mode.

Households comprising mainly women and girls are among the most vulnerable and need greater attention when designing social protection and support programmes. Their marginalization from resources and productive assets is the major driver of their vulnerability, underscoring the need for empowerment programmes that build and enhance their resilience through access to resources and education. Infants and young children are uniquely vulnerable: their health can be irreversibly damaged by shocks that affect their food security and nutrition. When social safety nets have limited resources, priority should be given to infants and children to prevent childhood stunting, wasting and other forms of malnutrition.

Policies aimed at building resilient livelihoods should take account of the specific conditions and multiple risks surrounding targeted households. Policy measures should not simply replace households' own resilience strategies, making them policy-dependent and thereby even more vulnerable if those policies are discontinued. For example, policies that cap food prices can render households dependent on that support and at risk of losing their resilience strategies. Policies that maintain macroeconomic stability, on the other hand, can enhance household resilience by facilitating self-insurance mechanisms such as savings.

Where agriculture dominates the economy, the development of the rural non-farm economy and other urban sectors is crucial to provide farmers and rural communities with more attractive and diversified income sources. Developing the non-farm economy is particularly important where agricultural households operate very small farms that are at risk of becoming economically unviable. There is a pressing need for major public involvement in technological development, if low-income farmers are to benefit from agricultural innovations. More attention must also be given to investments in public goods that reduce risks, such as irrigation and drainage systems and high-yielding, resistant crop varieties.

In conclusion, rural livelihood resilience depends on context-specific, often highly local, conditioning factors, ranging from socio-economic development to environmental and agroclimatic conditions. The success of household resilience strategies also depends on a wide range of interventions to improve risk management and resilience capacities at multiple levels of agrifood systems, including interventions directed at food supply chains, governance and institutions, as well as the infrastructure necessary to support them. These will be further discussed in the next, and final, chapter of the report. ■

DEMOCRATIC REPUBLIC OF CONGO
A woman carrying a load of Chinese cabbage through a field in Katanga province.
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CHAPTER 5
BUILDING RESILIENT AGRIFOOD SYSTEMS: GUIDING PRINCIPLES

KEY MESSAGES

➔ Building resilient agrifood systems should be a key policy objective in itself; it is a precondition for sustainable, functioning agrifood systems.

➔ The COVID-19 pandemic has taught us that resilient agrifood systems depend on factors beyond agrifood systems themselves; it has highlighted the close connections between human, animal and environmental health and the need for a holistic approach, for example, the One Health approach of the World Health Organization (WHO).

➔ The absorptive capacity of agrifood systems, key in confronting shocks and stresses, is strengthened by greater diversity of commodities, actors and sources of food, redundant and robust transport networks, and greater affordability of healthy diets.

➔ Risk management strategies – including multi-risk assessments, timely forecasts, early warning systems and early action plans – complement absorptive capacity by helping all agrifood systems' actors prevent and anticipate major disruptions.

➔ Traditional, transitional and modern food supply chains, long and short, play different roles within national agrifood systems, but all can act as buffers against different shocks and stresses.

➔ Rural households can be made more resilient through increased access to risk management tools – including early warning systems and insurance, social protection and social services, such as education and sanitation – as well as through income and asset diversification.

➔ Understanding the functioning of agrifood systems, including their resilience capacities and how they are affected by contextual factors, can inform the design of appropriate policies and help avoid unintended policy consequences.

Throughout history, agrifood systems have not been exempt from harm caused by different shocks and stresses. The COVID-19 pandemic delivered a massive shock to agrifood systems in many countries, with impacts felt most by the poor and vulnerable. Government lockdowns reduced their access to employment and income-earning opportunities, leading in turn to reductions in food spending. This, in turn, negatively affected the livelihoods of food supply chain actors, from vendors to wholesalers, processors and eventually, producers.
Losses in income and purchasing power pushed as many as 118 million people into becoming undernourished.[1] The impact of the pandemic on food security has created both the demand and

the momentum for action to make the world's agrifood systems more resilient to shocks and stresses. This requires policies that strengthen agrifood systems' capacity to prevent, anticipate, absorb, adapt and transform. To put the policy priorities into context, it is useful to return briefly to Chapter 1's three essential questions:

- **Resilience to what?** Shocks and stresses, often unforeseen, arise within and outside agrifood systems and impair how they function by disrupting the operations of related institutions and actors.
- **Resilience of what?** The central focus is national agrifood systems, the entire range of actors and interlinked value-adding activities, in the production, storage, distribution and consumption of food.
- **Resilience for what?** Building resilience aims at sustainably ensuring availability of and access to sufficient, safe, nutritious food for all, in the face of any disturbance. It enhances the livelihoods of actors in agrifood systems – producers, intermediaries and consumers – and promotes sustainability.

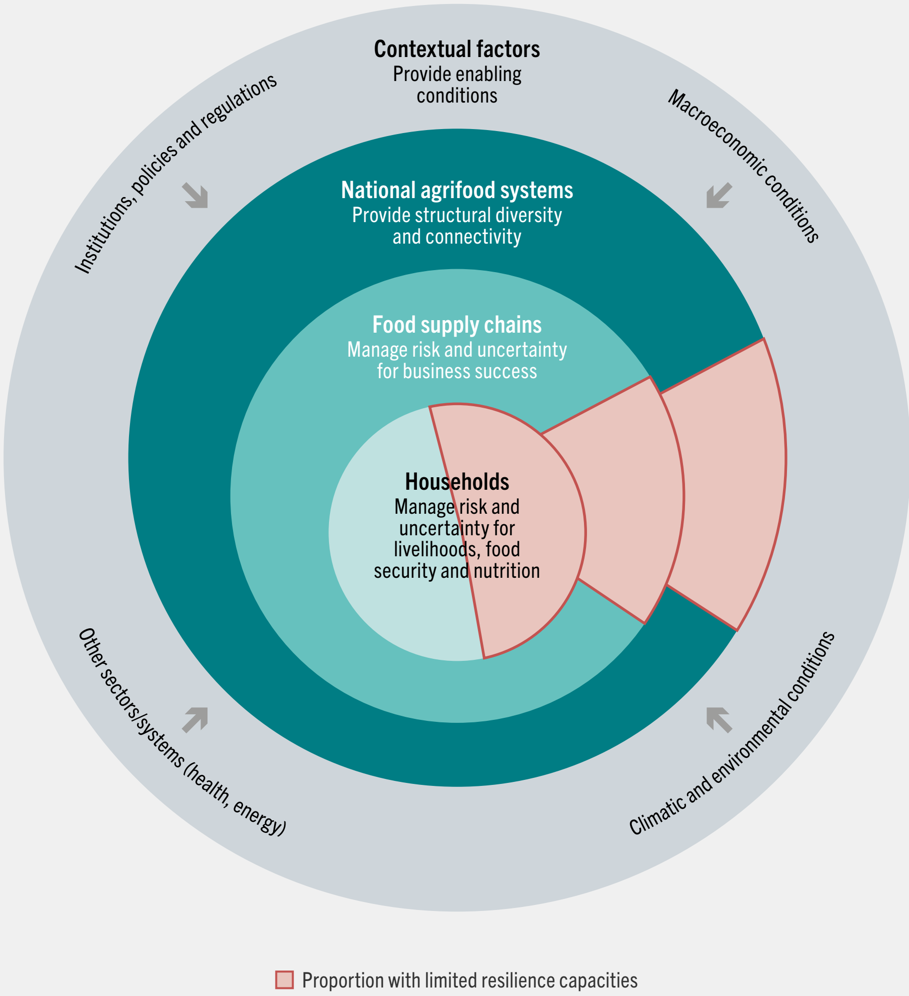
This chapter addresses the key question of ***How?*** A challenge to improve resilience is that any change to agrifood systems can generate unintended consequences and feedbacks, affecting systems' actors and activities, and may have positive or negative outcomes. Reconciling conflicting objectives will require policies (including strategies and budgets) that align the activities and decisions of different actors (public, private and civic) and promote innovative and sustainable practices that help to enhance resilience and address malnutrition, climate change and inclusion.[1, 2]

Figure 2 in Chapter 1 highlights the interlinkages between different levels and actors in agrifood systems. Policymakers need to be aware of these linkages well before a shock to a country's agrifood systems creates the need for corrective interventions or emergency measures. Overall systems' performance depends on these links and interactions between contextual factors, including institutions and regulations, and systems' components. The characteristics of the components determine not only their ability to adapt to shocks but the absorptive capacity of entire systems – the aspect of resilience that is the main focus of this report. For example, a food supply chain that reacts quickly to shocks by switching trading partners is more resilient and contributes to more resilient agrifood systems. Rapid, effective actions require collaboration between different supply chain actors. During the COVID-19 pandemic, many agrifood businesses switched to e-commerce through logistics firms that had not previously operated in the food sector.

Approaches to building resilience will need to be tailored to the wide range of shocks and stresses agrifood systems may face and to the different ways these spread through systems. The evidence in earlier chapters indicates that in order to build agrifood systems' resilience, it is important that policies, strategies and programmes adhere to **three guiding principles**:

1. **Resilience involves preparing for disruptions.** In a multi-risk environment, resilience includes preparing for both disruptions that are predictable and those that cannot be foreseen as they are surrounded by uncertainty. Preparing for the unknown requires assessing the structural characteristics of agrifood systems, including their absorptive capacity, provided by their diversity of pathways and connectivity (see Chapter 2), as well as their adaptive capacity, provided by a diversity of actors and responses (see Chapter 3). This allows systems to maintain their functions even in the presence of unforeseen disturbances.
2. **Resilience building is a system-wide multi-risk, multi-actor and multisectoral approach.** It therefore requires analysis of systems' components and the specific risks they face. This means focusing on food supply chains, small-scale producers and vulnerable households, and identifying risk-informed policies, practices and enabling conditions that improve their resilience. Mapping linkages is necessary for efficient agrifood systems' governance, optimal coordination among systems' components and their effective alignment with multiple objectives.
3. **Broader policy issues have important implications for resilience.** It is necessary

FIGURE 10 AGRIFOOD SYSTEMS' COMPONENTS AND CONTEXTUAL FACTORS



SOURCE: FAO elaboration for this report.

to consider the need for risk-informed policy measures beyond agrifood systems, promoting, for example, gender equality and women's inclusion, better and more inclusive health systems, more sustainable energy systems and sustainable use of natural resources in general. This requires comprehensive multi-risk assessments and coherent policies and practices within and across sectors and levels.

Figure 10 recalls the complexity of agrifood systems, which needs to be recognized when applying the principles and building resilience. Based on the conceptual framework of Chapter 1 (Figure 2), it represents agrifood systems and their linkages to contextual factors. The red–blue concentric circles illustrate the different components of agrifood systems discussed in Chapters 2–4 – national agrifood systems, food supply chains and households – along with the main challenges they face with respect to building resilience. The shades of red illustrate the preparedness of agrifood systems to shocks and stresses, or rather the parts of the different agrifood systems' components and related actors (e.g. agricultural producers and SMAEs, households and the national agrifood systems in general) that lack the means to prepare for disruptions. The arrows in the outer circle indicate contextual factors outside agrifood systems – climatic and environmental, and macroeconomic conditions; as well as those in other sectors; in addition to institutions, policies and regulations – that have important implications for agrifood systems and their resilience.

Thus, with reference to the three guiding principles, the red shades in Figure 10 highlight the importance of preparing for disruptions (first principle) also for those agrifood systems' actors and parts of agrifood systems that currently do not possess the means to do so. The blue and red concentric circles illustrate the need to analyse the different components of agrifood systems and the linkages between them embedded in the second principle. The third principle, which draws attention to the importance of broader policy issues, is recalled by the contextual factors in the outer circle.

This chapter draws on the three principles to explore policies and investments that build the resilience of national agrifood systems, as well as individual food supply chains, activities and actors. The initial focus is on reducing risks and vulnerabilities of agrifood systems as a whole and safeguarding its various functions. Key concerns are the diversity of sources and supplies and the closely linked concept of connectivity to ensure a constant flow of goods in times of disturbance. The chapter then addresses the resilience of agricultural producers, agribusinesses, food supply chains and vulnerable households in terms of their capacities to prevent, anticipate, absorb, adapt and transform in the face of shocks and stresses. Resilience considerations within a broader policy environment and framework are then examined before the final conclusions are presented, summarizing the guidance provided in the chapter. ■

MEANS OF ENHANCING NATIONAL AGRIFOOD SYSTEMS' RESILIENCE: STRUCTURAL CHARACTERISTICS

Policies and investments aimed at improving the resilience of agrifood systems need to consider both risk and uncertainty. In the case of risk, a probability distribution can be assigned to possible outcomes; uncertainty, on the other hand, is characterized by an unknown probability of an outcome, either because of lack of information or because it is completely unforeseeable. Managing risk typically involves reducing exposure and vulnerability to a specific identifiable adverse event, such as through drought preparedness. By combining prevention, mitigation and preparedness actions, multi-risk management strategies also help agrifood systems become more resilient and better able to deal with the unforeseen.

Managing risk, however, must be complemented with the sufficient diversity of responses that make up absorptive capacity, as agrifood systems generally face simultaneous uncertainties and multiple risks originating from various sources. Building absorptive capacity is about guaranteeing diversity and being prepared for disruption in agrifood systems; it does not target a specific event, but provides options once a disruptive event occurs. Combining diversity with risk management will thus allow agrifood components and actors to adapt to unforeseen disruptions, while maintaining agrifood systems' core functions and potentially transforming towards a more sustainable and resilient status.

Ensuring diversity is a cornerstone of resilience

As mentioned throughout this report, and highlighted in Chapter 2, a diversity of actors and responses is essential to agrifood systems' resilience in the face of multiple risks and uncertainty. Diversity provides a network for learning and transformation, for preventing risks and buffering shocks, and for ensuring agility in responses to varying needs and opportunities. Diversity in agrifood systems is characterized by the production of different commodities and reliance on different sources of supply and demand, both domestic and external. Food supply chains with access to more diversified input sources and output markets are less vulnerable. Likewise, reliance on multiple trading partners can enhance resilience by "importing" from different sources of supply or "exporting" to diverse demand outlets, thus diluting the impact that synchronous shocks in one place can have in other regions and sectors. In local civil society, diverse market channels – from cooperatives to community-supported and urban agriculture – can provide food security and nutrition to citizens.[3] Other buffering strategies include alternative food sources, such as food stocks.[4]

Chapter 2 provided a new perspective on the potential synergies and trade-offs generated by balancing food self-sufficiency with international trade. It highlighted the importance of incorporating redundancy in systems. On the one hand, agricultural producers benefit from redundancy in demand channels by producing for the domestic market or exporting to a diverse set of trading partners. On the other hand, consumers benefit from having food available on store shelves from various sources – domestic production, imports and food stocks.

While internal supply makes up a significant share of agrifood systems, having a mix of nutritious food available from both domestic and import sources is an important strategy to diversify risk, especially for smaller countries. For countries with a limited agricultural base, and thus higher reliance on food imports, managing trade connectivity by importing a diversified basket of nutritious foods from countries with heterogeneous socio-economic and climatic profiles is crucial to diversify the risks and reduce vulnerability to external shocks.

However, the dietary sourcing flexibility index (DSFI) presented in Chapter 2 illustrates how international trade is not neutral when it comes to sourcing nutritious foods: for many low-income countries, imports provide flexibility in sourcing kilocalories, but very little for fruits and vegetables – partly due to logistical constraints in transport and perishable storage. In these countries, policies and investments may be needed to facilitate international trade in nutritious foods to ensure their availability during disruptions.[1] Trade barriers also reduce flexibility in sourcing food. International efforts to establish new free trade areas and expand the commodity and product coverage of existing ones can provide mutual benefits to all participants and enhance resilience.

There is concern that diversification is less efficient than specialization and optimization (e.g. of transport logistics). However, diversification of the agrifood sector does not necessarily limit efficiency. Very often, different types of supply chains and stakeholders fill specific market niches and complement each other. Diversification in this broad sense does not mean that producers should not specialize. Instead, it means that at national level they should not *all* specialize in the *same* product, since this would increase systems' vulnerability to a shock affecting that specific product. If trade-offs exist, the appropriate choice of diversification will depend on the balance between the costs in terms of efficiency losses and the benefits of increased resilience in terms of higher revenues and reduced damage and losses from potential disruptions. It will also depend on the balance between short-term losses and the long-term – and potentially significant – gains from being more resilient and thus more able to manage unpredictable shocks.[5]

Choosing the most effective diversification strategy will enhance the gains from increased resilience. Building on information about exposure and vulnerability to disruptions contained in the set of flexibility indicators presented in Chapter 2 can help policymakers select an appropriate strategy, by allowing them to predict more accurately the vulnerabilities of each component and act upon it to improve systems' absorptive capacity (Box 17).

BOX 17 PUTTING THE DSFI AND PPFI TO USE

The flexibility indices for dietary sourcing (DSFI) and primary production (PPFI) presented in Chapter 2 (see Boxes 3 and 5 for a brief description of their methodology) measure the absorptive capacity of agrifood systems to shocks by capturing the multiple pathways to source food and generate value for primary producers. Covering more than 150 countries, the indicators do not capture, however, the level of exposure and vulnerability to disruptions of each pathway in each country. Rather, the approach is threat-agnostic. However, policymakers who have information on threats and their likelihood, as well as the pathways affected, may include this to derive a risk-adjusted set of indicators.

Since the indicators can be broken down into components representing a set of pathways (see the stacked bars in the figure in Box 4), this can be done by adding the probability of disruption to each component in the indicators' formula (see Annex 1 for a demonstration). The probabilities express, for each component, the likelihood that a set of pathways may not be available, and therefore cannot be relied upon when a disruption occurs. By way of illustration, if stocks in a given country are readily available when a shock occurs, then the probability would be zero, but if stocks cannot be used, the probability would take the value of 1. In reality, probabilities will fall somewhere in between. In the case of stocks, these may only be used if supply falls by a certain amount, in which case, the probability equals the likelihood that a shock does not cut supply by that amount.

Because it is unlikely that all pathways in a country are readily available during disruptions, the risk-adjusted set of indicators will be lower than the values presented in this report. How much lower depends on the (perceived) reliability of different pathways.

In complex systems, it is difficult to manage what one cannot measure. These indicators can help quantify the resilience of agrifood systems and provide important guidance on how to transform them to make them more resilient.

Connectivity is a cornerstone of diversity

In addition to being connected to international trade partners, agrifood systems rely on connectivity to physical and other infrastructures, such as communications and transport networks, crucial for ensuring supply diversity and rapid adaptation to shocks. Well-connected agrifood systems can overcome and recover from disturbances faster and more easily by shifting sources of supply and routes of transport and commercialization of food products, agricultural inputs and labour, as well as channels for knowledge and financial resources. Connectivity to international markets through infrastructure, as well as strong commercial relations, are part and parcel of this.

Developing and maintaining a robust and diversified domestic food transport network can facilitate physical access to food across a country's terrains and urban landscapes. Similarly, physical infrastructure that ensures international trade connectivity (ports, international railway systems, etc.) is important. During the COVID-19 pandemic, many governments provided support and adopted a coordinated approach to keep food shipments functioning. For example, the International Maritime Organization (IMO) called on governments to consider seafarers and marine personnel key workers providing an essential service and thus exempt them from movement restrictions, allowing them to join or leave ships and transit to an airport.[6] In Europe, private ports and terminals urged European Union Member States to consider ports as critical infrastructure and provide appropriate support to avoid disruption and prevent significant job losses.[7] China opened a green channel for fresh agricultural products and used e-delivery platforms to resolve the logistical challenges connected to small-scale producers accessing urban communities, while minimizing the potential risk of infection from visiting crowded food markets.[8]

Guaranteeing connectivity is also about managing the risks that can disrupt it. Disasters and crises can significantly affect infrastructure and services, such as roads, transport or storage facilities, in agriculture and food supply chains. The result can be catastrophic damage and loss to people's livelihoods, the environment and the economy. It is important to assess, protect and risk-proof connectivity, and to plan, design and develop new risk-sensitive and climate-resilient infrastructure; achieving climate resilience requires assessing physical vulnerabilities. Land use planning should also be enhanced to prevent or reduce risks in the face of hazards.

Another important risk-related dimension of connectivity is the need for an effective and pervasive food safety management system that ensures food safety vigilance throughout agrifood systems. Assurance on meeting food safety standards greatly facilitates any shift in sourcing supplies in the case of shocks. The COVID-19 pandemic has underscored the close connections between human, animal and environmental health and the urgent need to address them in a holistic manner. Recent studies showed that the landscape of emerging and re-emerging infectious diseases is closely associated with changes in ecological factors, climate and human behaviours.[9–11] It is estimated that 75 percent of newly discovered or emerging infectious diseases are zoonotic (i.e. transmitted from animals to humans).[12]

Stronger international institutions and cooperation for contagious disease detection and containment and food security are needed.[13] WHO's One Health approach to programmes, policies, legislation and research to achieve better public health outcomes is a case in point.[14] It involves coordination across various sectors, from plant and animal health, food safety, nutrition and biodiversity, to climate change, forestry and environmental protection. It also requires embedding the principles of gender equality and economic and social responsibility into normative and operational capacity development. Legislation creates an enabling environment to promote and enforce such practices, with the regulatory basis to strengthen animal and plant health in agriculture and wildlife, as well as ensure food safety. It also contributes to safeguarding and restoring ecosystems by introducing mechanisms to prevent and control environmental contamination, biodiversity loss, degradation of forests and impacts of climate change.[15] ■

POLICY MEASURES THAT ENHANCE FOOD SUPPLY CHAIN RESILIENCE

As discussed in Chapter 3, the resilience of national agrifood systems is also strongly shaped by how diverse and well-connected food supply chains are, and how farms and agrifood businesses along those chains source inputs and sell outputs. This section identifies the main policy interventions that enhance the resilience of food supply chains. A resilient supply chain does not necessarily mean all its actors are resilient. Shocks and stresses may cause disastrous damage to some actors, but also create opportunities for others to transform and grow. Such dynamics will always entail winners and losers – some actors may grow and others may perish. The important point is that, when supply chains are resilient, shocks and stresses should lead to improvement in their functioning and delivery as a whole. Subsequent socio-economic costs should be minimized through measures such as social protection or use of existing food stocks.

An important consideration when assigning policy priorities is, therefore, the potential trade-offs in food supply chains between resilience on the one hand, and efficiency, inclusiveness and equity on the other. For example, trade-offs may be possible between incorporating some duplication and redundancy, which strengthen resilience, and minimizing costs, which produces short-term efficiency benefits. Similarly, a food supply chain may be resilient, but not inclusive, if the enhanced resilience excludes vulnerable, small-scale agricultural producers. The challenge is to implement the right mix of policies and interventions that help build capacities to minimize trade-offs and create synergies that lead to resilient but also efficient and inclusive food supply chains.

Diversity is a source of resilience, but requires risk reduction measures

Maintaining diversity within and between food supply chains is important for ensuring agrifood systems' resilience. Chapter 3 categorized food supply chains into three broad types: traditional, transitional and modern, each with its own strengths and weaknesses when facing shocks and stresses. Policies and interventions to strengthen resilient food supply chains should do the following:

Allow for a mix of traditional, transitional and modern food supply chains. These supply chains play different roles within national agrifood systems, but all can act as buffers against shocks and stresses of different types. Transitional and modern supply chains, being long and serving wide geographical areas, can more easily respond to local shocks and ensure food availability in the directly affected areas. Large-scale agrifood companies, which dominate the modern food supply chains, have more access to capital and resources. Their financial strength enables them to buffer against shocks for long periods. In addition, they play a central role in international trade – key for diversifying food sourcing to enhance agrifood systems' resilience and buffer against domestic shocks.

However, traditional and local chains, particularly those based on small-scale producers and SMAEs, can play an important role in improving the resilience of food supply chains in the face of large-scale disruptions. For example, FAO found that, thanks to their close proximity to production areas and shorter supply chains, agrifood systems in small villages were more resilient to shocks than those serving larger urban areas over longer chains.[16] This was also evident during the COVID-19 pandemic, when many local supply chains proved to be quite nimble in their response to demand shifts.[17] SMAEs can also be sophisticated, efficient and resilient when they have access to adequate credit sources and infrastructure.

The COVID-19 pandemic created an opportunity to promote further interest in local food, made available by local supply chains.[17] With a small number of intermediaries and shorter distribution time, local food supply chains are often capable of providing consumers with fresher, more nutritious food, in addition to the perceived development and sustainability benefits of reduced fossil fuel consumption and increased support for the local economy.[17–19] Improved rural–urban infrastructure and building the capacities of actors within traditional food supply chains to use digital tools can create synergies between efficiency, inclusiveness and sustainability, while enhancing the diversity of overall agrifood systems. Home food delivery and other e-platforms, linking buyers and sellers through various digital tools, accelerated greatly during the pandemic to compensate for losses of traditional market outlets (see Chapter 3).

Modern, but short, food supply chains can also strengthen the diversity of food availability based on future foods such as micro-algae and cultured meat. Produced in closed environments, these foods provide various benefits in terms of resilience, namely: reducing exposure to biotic and abiotic risk factors; and providing nutritious foods through decentralized and local food supply chains. Although future food technologies require large-scale financial investments and new technical expertise, they can respond to local needs, providing an additional path for diversity in sourcing food – especially for countries with limited agricultural resources.[20]

Acknowledge the heterogeneity of farms and businesses along the urban–rural continuum. Addressing vulnerabilities and enhancing resilience at different scales requires a territorial perspective. For example, a recent worldwide FAO assessment showed that the shortage of labour in agriculture and food-related activities caused by COVID-19 mobility restrictions varied greatly by size of urban agglomeration.

In general, small towns between 5 000 and 25 000 inhabitants, where workers needed to travel shorter distances, were less affected, while cities of more than 5 million inhabitants were more vulnerable to disruptions.[16]

Diversity is also a trait of resilience at the producer level, and agriculture will most likely continue to comprise units of varying scales. Historically, agricultural producers have learned to cope with the impacts of multiple and simultaneous shocks which may be transient or lasting. Because producers' resilience capacities are strongly linked to farm characteristics and how they interact with their surroundings, policies and interventions need to focus on the regional context in which farming systems operate.[21] Enhancing producers' resilience needs to build on their strengths and address critical factors that constrain productivity growth, such as limited access to credit and markets. Policies should also avoid replacing producers' own strategies or making them policy dependent.

Account for context and heterogeneity. Different types of agricultural producers, agrifood enterprises and food supply chains have different degrees of exposure or vulnerability to shocks and stresses. Measures to reduce vulnerabilities, including livelihood diversification and alternatives, need to be adapted to the local context and take into account heterogeneity. Disaster risk reduction, good practices for climate change adaptation, technologies and innovations can all help reduce the underlying causes of vulnerability where exposure to disasters and climate-related shocks is highest. Climate-resilient practices and technologies at the level of the farm and/or business and the territory can help increase yields and support production sustainability, enhance diversification, and reduce risks of production failure caused by climate shocks and stresses.[22]

Practices that contribute to reducing vulnerabilities and risks in agrifood systems include the promotion of crop, livestock, tree and fish varieties that are more resilient to floods, droughts or saline conditions.[23] Soil and water practices, such as conservation agriculture, agroforestry, fodder conservation and improved seed storage are other examples of sound climate-resilient practices.[24, 25] According to a 2019 study of the benefit–cost ratio of good practices in disaster risk reduction, they generated, on average, benefits 2.2 times higher than did practices previously used by farmers under hazard conditions.[26]

Creating an enabling environment for food supply chains

The performance of any food supply chain is the outcome of numerous decisions taken by the various actors – also in connected input and services supply chains (see Chapter 3) – and how these decisions interact and change under diverse conditions. Designing and implementing strategies for resilient food supply chains requires an enabling environment for individual actors. Key enabling conditions that provide this infrastructure of supply chain resilience include the following:

Leveraging of information and communications technology (ICT) and digital tools for logistics. Central and local governments, together with the private sector, NGOs and international development agencies, have an important role to play in supporting ICT. Scale-appropriate ICT can provide tools for detecting early risk signals, making timely forecasts, adopting early warning strategies and realizing response diversification.[27] ICT and digital tools can also dramatically increase access to information in the agriculture sector, opening the way to substantially improve the effectiveness of agricultural extension, advisory services and learning.[28] They also contribute to informed decision-making regarding natural resources, cropping systems, pests, diseases, etc. Following the COVID-19 pandemic, there has been a global trend to create more online direct distribution links between farmers and consumers, such as e-commerce, which can improve access to fresh food, including fruits and vegetables.[29]

Improvements in risk management and early warning capacities. An integrated approach for agrifood systems' resilience can help predict the likelihood of shocks and how they impact on lives, livelihoods, food security and nutrition. This will include components such as agroclimatic monitoring, disaster and crisis risk and vulnerability assessments (including pests and diseases), and agricultural damage and loss data.[30–32] To enhance risk- and crisis-informed decision-making, governments at various levels, in coordination with academia, research centres and the private sector, should make these data available for analysis throughout agrifood systems.[33] An early warning system combines monitoring and risk assessments with communication and preparedness systems and processes that enable anticipatory action to mitigate the effects of disasters and crises.[34] Public–private partnership is essential to put in place early warning systems to cope with multiple hazards occurring simultaneously or cumulatively over time, as well as any potential cascading impacts. Multi-risk early warning systems need to be coupled with actionable alerts which trigger immediate action and emergency response mechanisms. This implies connecting the early warning system to a range of government institutions and local stakeholders through clear anticipatory action and contingency plans with funding to take the necessary actions based on the warning system.

Inclusive governance and institutions for better risk management. Governance is the combination of processes through which public and private actors articulate their interests, frame and prioritize issues, and make, implement, monitor and enforce decisions.[35] Inclusive governance is at the core of preparedness that focuses on the knowledge and capacities to respond effectively to shocks and stresses. In combination with sound analysis of risks and potential crises and with early warning systems, governance is crucial to ensure quick and appropriate response and recovery, when needed.[34] Besides these national policy instruments, subnational and local multi-risk management strategies should also be developed to address underlying vulnerabilities and risk drivers, strengthening institutional capacities according to the local context. When several governing bodies on different levels work well together, they enable coordinated actions in the face of risks and uncertainty, and provide flexibility to deal with issues at the appropriate level.[36] One example is the city-region food systems approach, which recognizes the connection between urban centres and rural areas, while acknowledging the linkages between economic, environmental and social sustainability and the need to adopt a multisectoral view (see FAO. 2021).[37]

National disaster and risk management tools tailored to food supply chains. Envisaging these tools in national laws, policies, regulations and strategies for food supply chains will enable stakeholders to function effectively and collaboratively within and across sectors. Promoting diversity in sourcing food from multiple markets and regions (see Chapter 2), supporting a multisectoral approach to decision-making, and putting in place protocols that reduce specific risks (e.g. weather-related, biological) will enable stakeholders to reduce the risks and adverse impacts of multiple shocks and stresses. Diversifying sources of inputs and distribution networks also has the potential to improve the availability of food when disruptions occur. Government regulatory agencies also need to ensure that available products and services are of high quality and provided by a thriving and competitive private sector. WHO's One Health approach, explained above, is very relevant for resilience in food supply chains because it enhances productivity while reducing risks from biological threats along the food supply chain. The rationale is to integrate agrifood and health sectors for more efficient coordination of pest and disease emergencies through improved pest and disease prevention, early warning and management of national and global health risks, including appropriate use of antimicrobials to mitigate antimicrobial resistance.[25]

Innovation in distribution strategies and broad participation. To achieve the long-term objectives of agrifood systems' sustainability and resilience, the ability of food supply chains to consistently deliver food efficiently and effectively must be enhanced. Finding appropriately scaled market channels is particularly challenging for medium and small-scale producers and many SMAEs. They are often too small to distribute products economically through large, vertically integrated grocery chains, but their volumes are too great for direct-to-consumer channels, such as farmers' markets.[38] Creating an enabling environment and encouraging coordination along food supply

BOX 18 LOGISTICS CENTRE IN KEMIN, KYRGYZSTAN

The Logistics Centre in Kemin, Kyrgyzstan, an FAO pilot programme established in 2018, ensures schools have a sustainable supply of crops raised by local producers, thereby contributing to improved nutrition in school meals and increasing small farmers' income, as well as the economic development of the district. It supplies diverse and nutritious food from local producers to 29 schools in the Kemin district of Chui Province to improve the diet of 12 000 schoolchildren and provide a market for at least 50 small farmers. The Logistics Centre is a centralized procurement, storage and quality control facility; it has a capacity of 250 tonnes and a warehouse area of 270 m^2. It has equipment for cool storage and laboratory quality control of agricultural products. It also has a truck equipped with a thermobox, which maintains the quality of agricultural products delivered to schools in the most remote parts of the region.

The Logistics Centre is an example of successful unification within one programme of measures in the fields of agriculture, nutrition and social protection. A mid-term economic analysis found the Logistics Centre model could be sustainable with a return on investment in five years while charging a fee of 5 percent of the stored farm products in-kind to cover the cost of storage and distribution services. It improves resilience through greater connectivity and capacity to store stocks and provides a cost-efficient supply chain between local producers and schools, while respecting food quality standards.

SOURCE: Shuvaeva & Belova. 2019. [41]

chains can help them overcome scale-related constraints in accessing markets. Promoting the active participation of small-scale producers and SMAEs in producer associations, cooperatives, consortia and agro-industrial clusters, with policies that create an enabling environment to facilitate coordination, can help them access markets and adopt business strategies that improve resilience and efficiency.

Transporting food from rural and dispersed farming areas to distant urban demand centres is often too costly, especially for refrigerated or frozen goods. Most small-scale agricultural producers lack the expertise, capital or access to credit to acquire and use these logistics. Their distribution systems tend to be fragmented and less efficient than the centralized networks of modern food supply chains,[39] making regionally produced food more expensive. Efficiency-enhancing logistics best practices can bring down costs and increase consumers' access to food produced in regions lacking access to supermarkets. Improved logistics will be particularly important in helping small-scale producers and SMAEs to remain competitive once the COVID-19 pandemic is over, especially since many consumers have enjoyed the convenience of one-stop-shopping, home delivery and value-added products.[40] Logistics can be improved through optimized routing and scheduling and consolidation of delivery routes; development of logistic centres (Box 18); appropriate vehicle types and sizes to meet supply chain objectives; punctual and frequent deliveries; outsourced transportation; horizontal collaboration; and facility location (i.e. the optimum number and location of warehouses).[17]

Wider access to business tools that enhance agility and flexibility. Policies also need to focus on helping producers and agribusinesses adopt business tools that enhance resilience. Recommended measures include:

- *Enhancing business literacy* throughout the supply chain and developing and promoting business innovation and incubation services, as well as training on *ex ante* measures in preparation for short-term or long-term shocks.
- *Expanding access to and adoption of tools and resources* (e.g. internet, credit, insurance) to help producers and businesses build their capacities. Governments and development partners could support innovations in e-commerce by investing in hard and soft infrastructure and creating an enabling business and commercial environment for both large companies and SMAEs.
- *Funding research and development (R&D) and agricultural extension services* focused on agricultural adaptation strategies, including climate change adaptation and best agronomic practices, such as improved varieties, proper crop planting and harvesting periods and better nutrient management.[42–44] Participatory R&D builds on existing knowledge and responds to the needs of agricultural producers. ■

ENHANCING THE RESILIENCE CAPACITIES OF SMALL-SCALE PRODUCERS AND VULNERABLE HOUSEHOLDS

Resilient livelihoods are a key element of resilient agrifood systems as they ensure access to food even in the face of shocks. Among the households most vulnerable to shocks, those involved in small-scale primary production activities – such as crops, livestock, pastoralism, fisheries and aquaculture – will benefit most from the logistical support, production innovations and inclusive governance of food supply chains described in the previous section. Beyond support to those households, it is important to ensure physical and economic access to healthy diets for all. This report estimates that in addition to the nearly 3 billion people who cannot afford a healthy diet,[1] about another 1 billion are at risk of not being able to afford it if a shock reduces their income by one-third. Even in high-income countries, households can be hit by shocks that threaten their food security.[45]

However, households in low-income countries are disproportionately affected. The rural poor are among those who face the greatest challenges. They rely heavily on self-employment and family labour, as well as natural resource-based livelihoods. They are constrained by poorly functioning markets and lack of access to credit, insurance and adequate public services, such as health and education. This makes rural households highly vulnerable to shocks, such as: unexpected weather and environmental disasters; the effects of climate change; and financial and economic crises.[46] Such shocks affect their livelihoods and can undermine their asset base and their capacity to manage risks effectively.[47] In framing policies to build the resilience capacities of small-scale producers and vulnerable households, policymakers should seek to do the following:

Facilitate better risk management and enable household resilience capacities. This is particularly important for agricultural and rural households involved in small-scale farming, livestock, pastoralism, fisheries and aquaculture, as well as urban and rural households that earn their living in the informal food sector, for example as food processing workers or street food vendors. To be effective, policies should address the specific disadvantages of different agrifood systems' actors with a special focus on women, youth and Indigenous Peoples, and design targeted measures that build their capacities to prevent, anticipate, absorb, adapt and transform in the face of shocks.

Following the RIMA analysis in Chapter 4, other key interventions that can enhance the resilience of rural livelihoods include expanding access to productive and non-productive assets, supporting diversification of farm and non-farm income and improving access to social services (e.g. education and sanitation). The latter is highly relevant for households living in harsh conditions, for example, those involved in pastoralism. Such interventions should be supplemented by actions to strengthen local institutions and traditional support networks, reinforcing local knowledge, improving infrastructure, and enabling services for inputs and market access. Enhancing rural advisory services will help meet small-scale producers' need for advice on how best to manage crops, soil, water, nutrients, pests and diseases.

Policies and interventions that target households comprising mainly women and girls are strongly encouraged because they pay the heaviest toll during and after shocks. Due to limited access to resources such as land and other assets, they are more likely to use negative coping mechanisms in times of shock, such as selling assets – a strategy which is risky and unsustainable in the long term. Empowering women and girls by expanding their access to productive assets and decent employment means they can absorb shocks and bounce back afterwards without undermining their food security status or depleting their assets. Education plays a key role in strengthening women's resilience capacity, underscoring the importance of expanding access to education for all, especially for girls. Women with more education have better access to the labour market and can expand their options for income generation.

When focusing on households involved in primary production, it is also important to distinguish between net sellers and net buyers of food. Net sellers need support that focuses on the commercial dimension of their activities as producers and promotes their inclusive integration into food supply chains. For net buyer households, policies need to enhance and guarantee their purchasing power and facilitate diversification of sources of income and livelihoods.

As extreme climatic events become more frequent and more pronounced, producers will face increasing risks. Expanding the access of small-scale producers to agroclimatic early warning systems for disaster risk reduction is important and may require training and subsidies to make them affordable. Increasing small-scale producers' access to insurance (e.g. crop and weather insurance) enhances their ability to take out production loans and participate in more risky, higher-return farming activities.

Design social protection policies that improve household resilience in the event of a shock. Social protection programmes help vulnerable households avoid negative coping strategies that are detrimental to their livelihoods and their capacity to face future risks and shocks. They are particularly relevant for vulnerable rural households, including those involved in small-scale fisheries and aquaculture activities, as well as informal workers and the urban poor. When designed to be sensitive to gender equality and improved nutrition, as well as responsive to multiple risks and shocks, social protection programmes can provide support not only to routine beneficiaries such as pensioners, but also to at-risk and crisis-prone populations before, during and after a shock. They can expand benefits according to the emerging needs of potential beneficiaries, help to fill poor households' consumption shortfalls, and enable them to invest and engage in productive activities. Social protection systems may also allow an increase in caseloads through contingency funds triggered by early warning systems as well as standard operating procedures.[48]

In this way, social protection policies can help safeguard food availability and access in the face of shocks and prevent ripple effects through food supply chains. In Ethiopia, for example, the Productive Safety Net Programme (PSNP) focuses on chronically food-insecure households, providing cash or food transfers on a predictable basis for five years, along with financial and technical support. The goal is to help these households build assets that can sustain them through future crises, while contributing to building rural infrastructure.[49] Results from the RIMA analysis in Chapter 4 show that access to timely social protection helped women and girls in particular cope with shocks, allowing them to avoid negative coping mechanisms. If well designed, social protection enables synergies with productive support programmes and investments, which strengthen both the resilience and sustainability of small-scale producers' livelihoods.[50] Efforts and policy reforms aimed at strengthening links between social protection and productive support programmes are highly encouraged. ■

PLANNING FOR THE FUTURE – BROADER POLICY AREAS AND PRIORITIES

A range of broader policy issues and priorities, some beyond the scope of agrifood systems, can have important implications for policies aimed at promoting agrifood systems' resilience:

Guaranteeing economic access to a healthy diet needs to be a priority not just in low-income countries. Chapter 2 outlined how a broad share of the world's population is unable to afford a healthy diet, or is at risk of not being able to afford it when confronted with an income shock, as further recalled above. Such vulnerability is the result of limited incomes combined with the cost of a healthy diet. Therefore, increasing incomes and transforming agrifood systems to make healthy diets more accessible are key. Figure 6 identified four broad country profiles: at one extreme are high-income countries with limited affordability issues; at the other are countries, especially low-income countries in Asia and sub-Saharan Africa, where more than 80 percent of the population cannot access a healthy diet and are in dire need of greater affordability independently of shocks. There are also numerous countries, mostly middle-income, where many who can afford a healthy diet are nevertheless at risk. Policy focus and the investments required will depend on where a country sits on this spectrum. Some countries may place more emphasis on addressing structural issues such as income levels and distribution, while others may focus more on risk management and diversification.

Policies must impact directly on the adaptive capacity of systems' actors, especially households. One important lesson of the COVID-19 pandemic is that the food security resilience of households depends on policies and measures beyond agrifood systems themselves. The importance of social safety nets to the rural and urban poor was mentioned in the previous section. Other key policy areas with a clear impact on household resilience include strong and inclusive health insurance and medical services. Education and training are also vital for strengthening household resilience in the long run. Broader policies aimed at promoting gender equality and women's inclusion will have significant impacts on resilience at household level and more broadly within agrifood systems, thanks to the increased participation of women in all sectors of agrifood systems. Policies aimed at boosting employment can sustain livelihoods and incomes, with positive impacts on entire agrifood systems.

Policies are needed to promote agrifood systems' sustainability through stewardship of the environment. With demographic and environmental pressures increasing and huge uncertainties surrounding future shocks and stresses, the resilience of agrifood systems has become a major international concern. Building the resilience of agrifood systems must be an integral part of ensuring sustainability, particularly in the long run. Rather than aggravating climate change and natural resource degradation, agrifood systems need to become stewards of the environment. Mainstreaming biodiversity in agrifood policies is essential to protect the health and diversity of ecosystems. It is key to reducing the adverse impacts of climate-related hazards, such as drought, floods and storms. Healthy and diverse ecosystems provide essential environmental services, such as fresh water, clean air, fertile soil and pollination, which contribute to food security and resilient livelihoods,[51] protecting against climate risks as well as geophysical and biological threats. Measures that aim to promote healthy and diverse ecosystems include nature-based solutions, which protect, sustainably manage and restore ecosystems, while addressing societal challenges.[52] Practices such as watershed management, landscape approaches, agro-ecological farming and climate-smart agriculture have an important role to play in win–win scenarios that not only ensure more resilient agrifood systems, but also promote high-yielding long-term investments.[53, 54]

Green infrastructure – bushes, orchards, hedgerows, grasslands, ponds, pools, wadis and wetlands – can also reduce vulnerabilities and risks across and within agrifood systems while supporting environmental sustainability.[55] Given that Indigenous Peoples and local communities are often at the centre of natural resources management, thanks to their close links with and dependence on the environment and use of natural resources for their livelihoods, the resilience of these communities is indivisibly connected to the condition of the environment and management of its resources.[56]

Policies need to be coherent and coordinated in order to mainstream resilience in national planning across sectors. As in other domains, policy coherence is essential when addressing the needs of agrifood systems. The global impact of and response to the COVID-19 pandemic – a human health crisis thought to be caused by a virus passed from animals – highlights the fact that protecting health and preventing disruption to agrifood systems requires coordinated action across sectors relating to animals, people, plants and the environment: the One Health approach.[57]

It is also important to recognize that policymaking can have unintended consequences. To avoid implementing restrictions that hurt its agrifood systems' actors, policymakers must understand how agrifood systems function and how their actors interact. During the COVID-19 pandemic, for example, South Africa deemed the wood sector non-essential, which harmed fruit growers who rely on wooden crates to distribute their products. Conversely, in countries where agriculture was deemed essential, the sector remained relatively resilient. In Mexico, the agriculture sector was considered a priority activity and food prices remained relatively stable.[58]

Policy coherence is important with regard to subsidies and other instruments of agricultural support. While subsidies may provide immediate and short-term relief to agricultural producers, they can also reduce their capacity to adapt to shocks. Although individual producers may be protected in the short to medium term, this may be at the cost of making entire agrifood systems less resilient, with negative impacts reverting back to individual producers. This is what happened in the Syrian Arab Republic, where continuous government support for producer prices and irrigation-intensive crops (wheat and cotton) led to excessive use of groundwater and extreme depletion of the aquifers. This limited the adaptive capacity of Syrian farmers when severe drought struck the Near East in 2007–2008. Conditions worsened in 2008 when the Government lifted subsidies on diesel fuel – used in irrigation – triggering an overnight price increase of 300 percent.[59, 60] As a result, thousands of agricultural households abandoned their farms and migrated to cities. The United Nations estimated the crisis displaced more than 300 000 people in 2009, leaving 60–70 percent of villages in the regions of Hassakeh and Deir ez-Zor deserted.[61, 62] The fundamental lesson is that policies and interventions affecting agrifood systems need to be carefully assessed for their long-term sustainability and how they affect the resilience of individual actors and systems as a whole.

Another concern relates to the sustainability of social protection schemes, an essential component of resilient livelihoods among vulnerable populations. These programmes, alongside subsidies and any policies supporting agrifood systems' resilience, need to be fiscally sustainable.

To meet the challenge of policy coherence and coordination in building resilience, all sectors and layers of government institutions must be involved. More emphasis must be given to the need for vertical alignment of policies and actions at national and subnational levels. In particular, the role of local government in responding to shocks and building resilience is crucial. The FAO survey to assess the impact of the COVID-19 pandemic on urban food systems clearly highlighted the key role of local government in addressing impacts on food security and nutrition.[16] The empowerment of local government can make a big difference in preventing a food security crisis following a shock.

Many of these ideas are being mainstreamed into some countries' agricultural risk management policy frameworks, but they are rarely considered as part of a holistic strategy to improve sectoral and cross-sectoral resilience. There is a need to mainstream resilience in agrifood policies and across sectors. Resilience should be a policy objective, not just a tool to achieve other objectives. Agriculture and government institutions should collaborate across sectors to better anticipate stresses, such as water depletion and emerging zoonotic diseases that may eventually disrupt systems. Specific case studies on resilience to drought in Australia, natural disasters in Canada, and animal and plant health risks in Italy and the Netherlands provide concrete examples of how countries are conceptualizing resilience.[63] ■

CONCLUSIONS

The COVID-19 pandemic has created space for new narratives about resilience in agrifood systems. The resilience perspective presented in this report implies the preparation for shocks and future challenges as yet unknown, by building agrifood systems' capacity to prevent, anticipate, absorb, adapt and transform in the face of any disruption. The overarching objective of this preparation is to manage stresses and shocks in a way that ensures continuous availability of and access to sufficient and nutritious food for all. Preparation is furthered by identifying the means and tools that strengthen agrifood systems' resilience capacity and facilitate systems' transformation towards sustainability and inclusiveness.

This chapter has revisited the holistic framework (presented in Chapter 1) for building resilient national agrifood systems, and has offered three guiding principles for policies, strategies and programmes. The principles call for preparation, cooperation, coordination, inclusiveness and equity. They aim to promote the mainstreaming of resilience objectives into policy frameworks and create incentives to dynamic change for the different components and actors of agrifood systems.

Table 5 summarizes different entry points to manage risk and uncertainty in agrifood systems, and the contextual factors to be considered. A distinction is made between entry points tailored to coping with uncertainty (Shocks difficult to foresee) and those adapted to managing specific risks (More predictable shocks).

The resilience capacity of agrifood systems can be enhanced by policies and interventions that: encourage diversity, connectivity and flexibility; promote dialogue, transparency and collective learning in food supply chains and networks; and ensure that vulnerable households have access to healthy diets, even when incomes are affected by a shock. Acknowledging that trade-offs can arise, this chapter recommended assessing the critical roles of diversity and trade in agrifood systems in response to shocks and stresses, to help actors tailor their strategies for managing resilience.

This chapter also identified the key interventions that can enhance the resilience of individual supply chain actors, upon which the resilience of national agrifood systems depends. They include framing innovative strategies for food transport and distribution, leveraging ICTs, maintaining diversity, and promoting inclusive governance and broad participation. Public policies also need to focus on helping small-scale producers, small and medium enterprises and vulnerable households gain access to business tools they need to enhance their resilience.

One of the objectives of this edition of *The State of Food and Agriculture* is to contribute to the dialogue and debate on how to build resilient agrifood systems in the wake of the UN Food Systems Summit. It aims to help guide action on the ground with regard to building resilient agrifood systems and thus make a concrete contribution to leveraging the power of these systems to deliver progress on all 17 Sustainable Development Goals (SDGs). Building resilience is a necessary condition and intrinsically linked with achieving the SDGs and the overall 2030 Agenda for Sustainable Development. Agrifood systems'

TABLE 5 ENTRY POINTS TO MANAGE AGRIFOOD SYSTEMS' RISK AND UNCERTAINTY

	SHOCKS DIFFICULT TO FORESEE	→	MORE PREDICTABLE SHOCKS
	Ensuring diversity	Managing connectivity	Managing risks
CONTEXTUAL FACTORS	▸ Promote gender equality and support youth ▸ Pursue policies and regulation to protect the environment (water, land, biodiversity, fisheries and forests) ▸ Safeguard macroeconomic stability ▸ Ensure broad access to financial services ▸ Support indigenous knowledge systems	▸ Encourage and promote effective partnerships for sustainable development ▸ Promote an open, inclusive and equitable multilateral trading system	▸ Prepare and implement national adaptation plans for mitigating and adapting to climate change ▸ Ensure well-coordinated and coherent policies for long-term macroeconomic stability
NATIONAL AGRIFOOD SYSTEMS	▸ Ensure diversity of food production, market channels and trade partners (both domestic and external)	▸ Invest in robust and redundant food transport networks ▸ Invest in infrastructural connections to international markets (e.g. ports)	▸ Promote disaster risk reduction and disaster risk assessment ▸ Prepare national plans for drought management ▸ Invest in food safety management systems ▸ Carry out multi-risk assessments within and across sectors and levels ▸ Adopt a One Health approach
FOOD SUPPLY CHAINS AND ACTORS	▸ Allow for a mix of traditional, transitional, and modern food supply chains, including short, local food supply chains ▸ Promote inclusiveness for SMAEs	▸ Diversify sources of supply and output markets ▸ Enable and invest in stronger rural–urban linkages, especially for short supply chains ▸ Expand and improve access to ICT	▸ Ensure timely forecasts and tools for detecting early risk signals ▸ Establish and improve early warning systems
HOUSEHOLDS AND LIVELIHOODS (small-scale producers and vulnerable households)	▸ Support the diversification of on- and off-farm income sources ▸ Promote good agricultural approaches and practices ▸ Expand access to credit and insurance to the most vulnerable	▸ Expand access to ICT and agricultural extension services ▸ Support collective action by small producers to develop bargaining power	▸ Promote access to productive assets ▸ Expand access to social services and education ▸ Implement targeted and timely social protection assistance for all vulnerable groups, including small-scale producers and the urban poor ▸ Fund R&D relating to agricultural adaptation strategies (e.g. climate change)

SOURCE: FAO elaboration for this report.

resilience is directly aligned with the achievement of SDG 2, Zero Hunger, and is key to progress towards several other SDGs, both those with a socio-economic focus and others relating to environmental sustainability. Creating peace and prosperity for all people on the planet by 2030 (in line with SDG 16, Peace, Justice and Strong Institutions) will prevent many disturbances – or at least strongly mitigate their impact. This places resilience of agrifood systems in a much broader context. ■

MONGOLIA
A livestock herder, vulnerable to intensifying dzuds, pours a hot meal. FAO's interventions mitigate the impacts of climate change on Mongolia's poorest herders.

ANNEXES

ANNEX 1 DESCRIPTION, DATA AND METHODOLOGY OF THE INDICATORS IN CHAPTER 2

PRIMARY PRODUCTION FLEXIBILITY INDEX (PPFI)

Description

The PPFI examines all the different pathways through which a country primary sector can generate value from agricultural output. If it has many different pathways, the primary sector will have greater capacity to absorb shocks. This depends on two main factors: (i) the level of diversification of the produced commodities; and (ii) access to markets for these commodities. The PPFI uses both factors to measure the diversity of production across commodities and the potential to produce for domestic or export markets based on the share of each commodity and its final destination (domestic or export). It indicates which commodity an average producer is likely to plant and whether it ends up in the domestic or export market. Higher values indicate multiple paths for generating agricultural value and for placing primary production in the markets (i.e. redundancy of demand channels) and thus a higher capacity to absorb shocks. The pathways are described in Figure A1.1.

The PPFI is, therefore, a combined measure of the possibility of choosing what to produce and the redundancy of demand channels to market it. Information entropy is used as a measure of uncertainty for what is produced and where it is sold. The expression of the PPFI can be derived from first principles following the standard measure for information, or the lack thereof, termed the Shannon Entropy,[1] defined below.

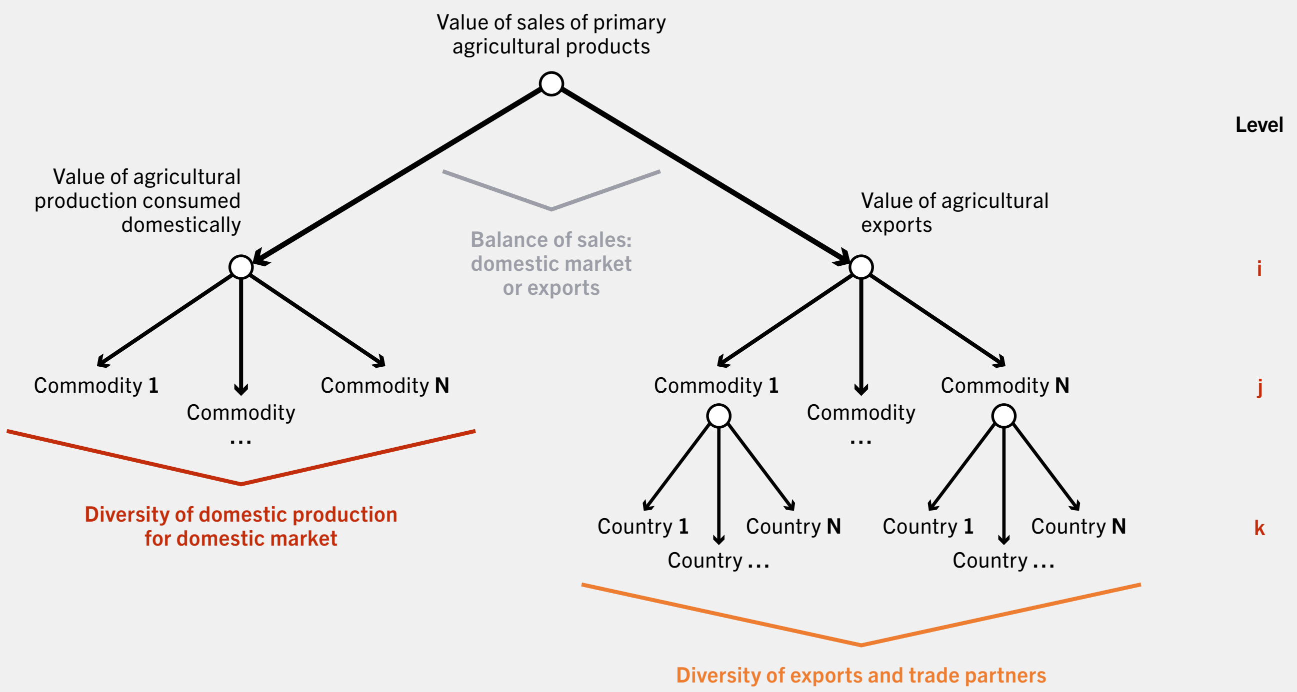
Let X be a discrete random variable taking a finite number of possible values $x_1, x_2, \dots, x_n$ with probabilities $p_1, p_2, \dots, p_n$ respectively, such that $p_i \geq 0, \sum_1^N p_i = 1$, then the information entropy associated with the uncertainty about the actual value taken on by x is:

$$H(p_1, p_2, \dots, p_N) = -\sum_1^N p_i \cdot \log(p_i)$$

Information entropy can be interpreted as the information contained in a message that reveals the value taken on by the random variable. Information entropy has three important properties (see Shannon, 1948):[1]

i. Continuity – its value is continuous in probabilities;
ii. Monotonicity – if all p_i are equal (p_i=1/N), then H is a monotonically increasing function of N; and
iii. Recursiveness – if a choice is broken down into two successive choices, the original H is the weighted sum of the individual values of H.

FIGURE A1.1 PATHWAYS TO PRODUCE AGRICULTURAL OUTPUT AND SELL IT IN DOMESTIC AND EXPORT MARKETS, FOR VALUE



SOURCE: FAO elaboration for this report.

Where p_i is the proportion (i/N) of pathways of one particular level in Figure A1.1 divided by the total number of pathways found (N), and H is the entropy of the set of probabilities.

Information entropy is the only function to satisfy all three properties. The third one is particularly important because it allows calculation of the information entropy for food units (in value terms) of different commodities for the domestic and exporting markets.

Take a country for which M commodities are produced domestically and assume that p_i is the probability that a unit value (USD) of sales comes from producing a specific commodity i. If the country has no food exports (only left branch of the tree in Figure A1.1) the information entropy associated with the diversity of domestic production for that country is:

$$H = -\sum_{i=1}^{M} p_i . log(p_i)$$

The information entropy increases if we assume that these M commodities can also be exported. How it increases can be derived according to the property of recursiveness, whereby information entropy is independent of the sequencing in Figure A1.1. The overall information entropy can be expressed as follows:

$$PPFI = \sum_{i=1}^{2} p_i \left[\sum_{j=1}^{N_i} p_{ij} \left[-\sum_{k=1}^{N_{ij}} p_{ijk} . log(p_{ijk}) \right] - \sum_{j=1}^{N_i} p_{ij} . log(p_{ij}) \right] - \sum_{i=1}^{2} p_i . log(p_i)$$

Where p_i is the share of food value that goes to the domestic market (i=1) or is exported (i=2), p_{ij} is the share of value generated by commodity j if sold domestically (i=1; j=N_1) or exported (i=2; j=N_2), and p_{ijk} is the share of value from country k if exported (i=2; j=N_2; k=N_{2j}).

Note that p_i, p_{ij} and p_{ijk} each sum up to 1, as these are calculated as shares of food, in value, exported or sold locally, or from a certain commodity (within exports, and local market), or from a certain importing country. The PPFI equation can be further disaggregated into the different contributions depicted in Figure A1.1 as follows:

1. Contribution of diversity of domestic production for domestic market:

$$p_1\left[\sum_{j=1}^{N_1} p_{1j}\left[-\sum_{k=1}^{N_{1j}} p_{1jk}.\log(p_{1jk})\right]-\sum_{ij=1}^{N_1} p_{1j}.\log(p_{1j})\right]$$

2. Contribution of diversity of exports:

$$p_2\left[\sum_{j=1}^{N_2} p_{2j}\left[-\sum_{k=1}^{N_{2j}} p_{2jk}.\log(p_{2jk})\right]-\right.$$

$$\left.-\sum_{j=1}^{N_2} p_{2j}.\log(p_{2j})\right]$$

3. Contribution of balance of sales (domestic market or exports):

$$-\sum_{i=1}^{2} p_i.\log(p_i)$$

In Figure 3 (Chapter 2), the values in the y-axis are expressed by diversity of exports, the bubbles by the balance of sales and the values in the x-axis by diversity of domestic production for the domestic market.

Data and methodology

Input data for the analysis are from FAOSTAT's production, producer prices and detailed trade matrix data.[2] The study covers 2016 to 2018. FAOSTAT's production data were converted from mass to value and protein (tonnes) using producer prices and product-, country- and year-specific protein conversion factors (based on FAOSTAT's food balance sheets), respectively. Where food balance sheets' protein contents were missing, the study uses subregional, regional, continental or global averages, depending on data availability. To account for short-term interannual fluctuation in the data, all PPFI values were averaged over the years 2016–2018. Data were also normalized between 0 and 1.

Since live animals were reported as head counts, the number of animals was transformed first to approximate weights, applying country-, animal- and year-specific yields per animal using livestock primary data, and then to value or tonnes of protein using food balance sheets' nutritional component contents for the parent product. The trade statistics do not specify the purpose of traded live animals which could be used for meat or milk production. The report assumes that once the animals are imported into a country, they will be slaughtered for food at the end of their life cycle, thus counting all imported live animals as meat.

DIETARY SOURCING FLEXIBILITY INDEX (DSFI)

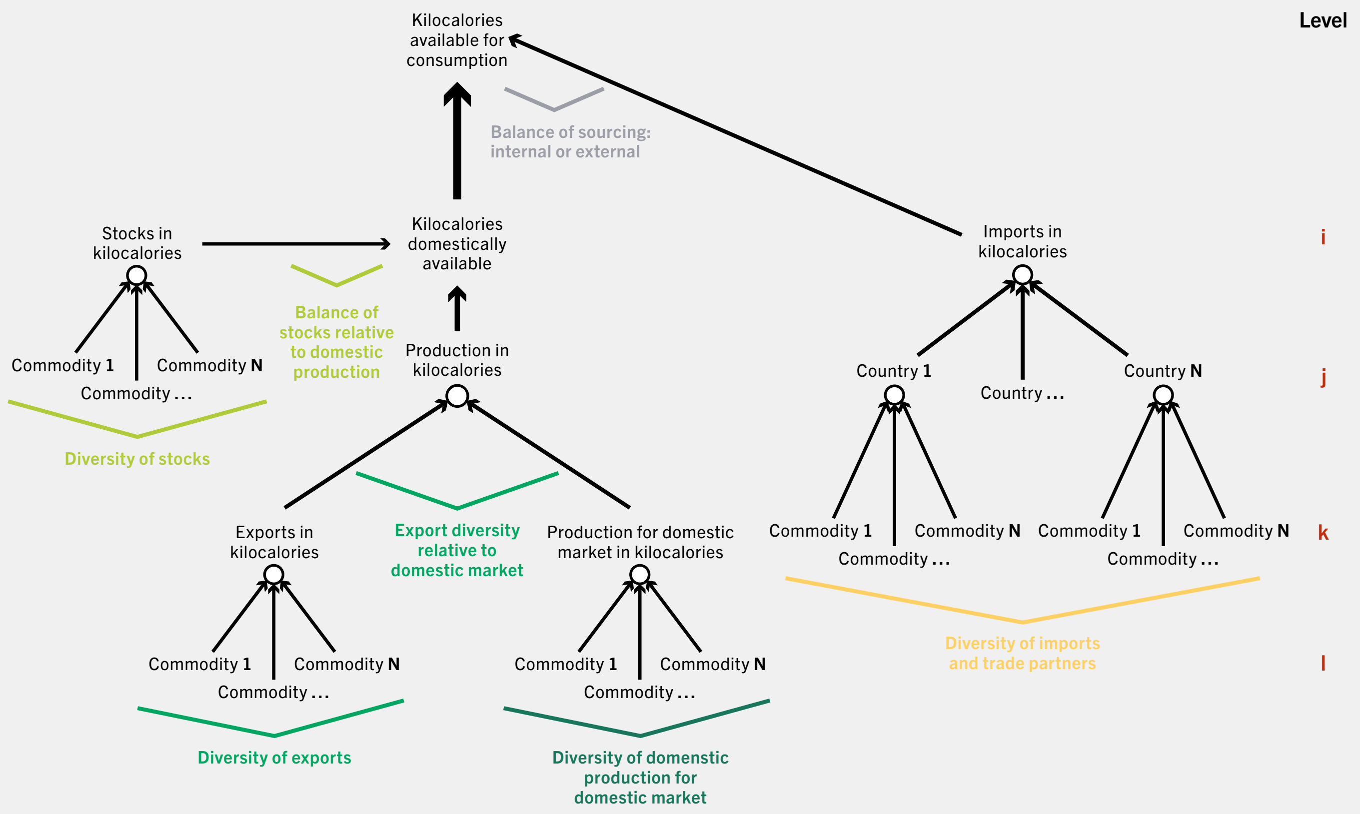
Description

The DSFI examines all the different pathways through which a unit of food (in nutritional outcomes) is available to a consumer. If it has many different origins, food systems will have greater capacity to absorb supply shocks.

The three possible pathways a unit of food, measured for kilocalories, can reach a consumer are represented as a tree in Figure A1.2 as follows: (i) food produced domestically; (ii) imported food; and (iii) reserves carried over from the previous year (imports or domestic production, public and private). Food produced domestically is further disaggregated by destination (local market or export) and subsequently by commodity. Imports are also further disaggregated into trading partners and import diversity. The balance between imports and what is produced or stocked domestically measures the role of trade in supplying food and sourcing diversity.

As for the PPFI, the expression of the DSFI can be derived from first principles following the standard measure for information, or the lack thereof, the Shannon Entropy.[1] It has the three

FIGURE A1.2 PATHWAYS TO SOURCE FOOD FROM STOCKS, DOMESTIC PRODUCTION OR IMPORTS, FOR KILOCALORIES



SOURCE: FAO elaboration for this report.

important properties of continuity, monotonicity and recursiveness.

Based on the above and on Figure A1.2, a basic entropy index of dietary sourcing flexibility is defined as:

$$DSFI = \sum_{i=1}^{2} p_i \left[\sum_{j=1}^{N_i} p_{ij} \left[\sum_{k=1}^{N_{ij}} p_{ijk} \left[-\sum_{l=1}^{N_{ijk}} p_{ijkl} \cdot \log(p_{ijkl}) \right] - \right. \right.$$

$$\left. \left. - \sum_{k=1}^{N_{ij}} p_{ijk} \cdot \log(p_{ijk}) \right] - \sum_{j=1}^{N_i} p_{ij} \cdot \log(p_{ij}) \right] - \sum_{i=1}^{2} p_i \cdot \log(p_i)$$

Where p_i is the share of food domestically available (i=1) or imported (i=2). p_{ij} is the probability that a unit of food will be produced internally (i=1; j=1) or sourced from buffer stocks (i=1; j=2) or sourced from country j if imported (i=2; j=N_2). p_{ijk} is the probability that a unit of food will go to the domestic market (i=1; j=1; k=1) or be exported (i=1; j=1; k=2); or that it will be sourced from commodity k if coming from buffer stocks (i=1; j=2; k=N_{12}) or from commodity k if coming from imports (i=2; j=N_2; k=N_{2j}). And p_{ijkl} is the probability that a unit of food will be sourced from commodity l once it is known whether it goes to the domestic market (i=1; j=1; k=1; l=N_{111}) or is meant to be exported (i=1; j=1; k=1; l=N_{112}).

Note that p_i, p_{ij}, p_{ijk} and p_{ijkl} each sum up to 1, as these are calculated as shares of food, in nutritional components that are imported, sourced from stocks (if internally available), exported (if produced domestically), or from a certain commodity (within stocks, imports, exports and local market), or from a particular exporting country.

The DSFI equation can be further disaggregated into the different contributions depicted in Figure A1.2 as follows:

1. Contribution of diversity of domestic production for domestic market:

$$p_1\left[p_{11}\left[p_{111}\left[-\sum_{l=1}^{N_{111}} p_{111l}\cdot\log\left(p_{111l}\right)\right]\right]\right]$$

2. Contribution of diversity of exports:

$$p_1\left[p_{11}\left[p_{112}\left[-\sum_{l=1}^{N_{112}} p_{112l}\cdot\log(p_{112l})\right]-\right.\right.$$

$$\left.\left.-\sum_{k=1}^{N_{11}} p_{11k}\cdot\log(p_{11k})\right]\right]$$

3. Contribution of diversity of stocks:

$$p_1\left[p_{12}\left[-\sum_{k=1}^{N_{12}} p_{12k}\cdot\log\left(p_{12k}\right)\right]-\sum_{j=1}^{N_1} p_{1j}\cdot\log\left(p_{1j}\right)\right]$$

4. Contribution of diversity of imports and trade partners:

$$p_2\left[\sum_{j=1}^{N_2} p_{2j}\left[-\sum_{k=1}^{N_{2j}} p_{2jk}\cdot\log\left(p_{2jk}\right)\right]-\sum_{j=1}^{N_2} p_{2j}\cdot\log\left(p_{2j}\right)\right]$$

5. Contribution of balance of sourcing (internal or external):

$$-\sum_{i=1}^{2} p_i\cdot\log\left(p_i\right)$$

In Figure 4 (Chapter 2), the values on the y-axis are obtained by summing the contributions of expressions 1) and 2), while the values on the x-axis are obtained by summing the contributions of expressions 4) and 5). The sizes of the bubbles represent the contribution of diversity of stocks.

Data and methodology

Input data for the analysis are from FAOSTAT's food balance sheets and detailed trade matrix.[2] Data for buffer stocks were collected from FAOSTAT's supply utilization accounts;[2] the Agricultural Market Information System (AMIS);[3] FAO's Global Information and Early Warning System on Food and Agriculture (GIEWS);[4] and the Production, Supply and Distribution (PSD) database of the United States Department of Agriculture.[5] These data were used as follows: when FAOSTAT's supply utilization accounts were lacking, the study used the average of the remaining three data sources instead. Stock data are, however, notoriously difficult to estimate accurately. The study covers the years 2016 to 2018.

FAOSTAT's food balance sheet data were converted from mass to dietary energy (kilocalories), fat (tonnes), and protein (tonnes) using product-, country- and year-specific conversion factors (also based on food balance sheets). For fruits and vegetables, the weight (tonnes) of these two food item groups were used. Trade matrix data were also transformed to nutritional components using FAOSTAT's food balance sheet data for the given "parent" product. For example, the nutritional component contents for cattle meat were derived from "bovine meat" values for the reporting country. As the live animals were reported as head counts, the number of animals was first transformed to approximate weights applying country-, animal- and year-specific yields per animal and then to kilocalories, tonnes of protein and tonnes of fat using nutritional component contents for the corresponding parent product.

To account for the short-term interannual fluctuation in the data, all DSFI values were averaged over 2016–2018. Data were also normalized between 0 and 1. Spices, non-food items and alcohol were excluded from the analysis.

ADDING THE PROBABILITY OF DISRUPTION TO THE PPFI AND DSFI

Information on threats – whether objective or perceived – could be included to derive a risk-adjusted set of indicators. Since the PPFI and DSFI can be broken down into different components, information on the probability of disruptions to different pathways can be incorporated when available. The DSFI components are: (i) the contribution of diversity of imports and trade partners; (ii) the contribution of diversity of domestic production; and (iii) the diversity of stocks. It can therefore be expressed as:

(1) ***DSFI*** *= DSFI (imports)+DSFI (domestic production)+DSFI (stocks)*

If country-level information is available on the probability that the pathways contributing to these different contributions may fail, then it is possible to define a **risk-adjusted DSFI** as follows:

$$(2)\ \mathbf{DSFI}_{risk} = (1-p_{imp})\cdot DSFI(imports)+(1-p_{dom})\cdot DSFI\ (domestic\ production)+(1-p_{stock})\cdot DSFI(stocks)$$

Where the probabilities, *p*, express for each contribution the likelihood that a set of pathways may not be available and therefore cannot be relied on as alternatives when a disruption occurs.

Alternatively, these probabilities can be interpreted as the proportion of a contribution to diversity that cannot be relied upon. For example, if p_{stock} equals 0 it means stocks will be readily available and released in case of a supply shock. If, on the other hand, p_{stock} equals 1 then stocks cannot be used. In reality, the situation will be somewhere in between. For example, stocks may be released only if the supply shock exceeds a certain threshold. In such a case, the value of p_{stock} would be the probability that the supply shock does not meet the requirement to release stocks. The risk-adjusted DSFI would always be lower than the DSFI. How much lower depends on the reliability, or perceived reliability, of different pathways.

MIDSTREAM FLEXIBILITY INDEX (MFI)

Description

The MFI could be developed using the same rationale as for the PPFI and DSFI by measuring diversity of processed foods, sourcing (domestic or imported) and output markets (internal or external). Higher values indicate multiple paths to generate and sell processed food (in value terms). The MFI indicates which processed food an average food processor will likely produce, whether it ends up in the domestic or export market, and whether the inputs used to produce it were internal or external. It thus provides useful insights on the flexibility of the food processing sector. As for the PPFI and DSFI, information entropy can be used to measure this uncertainty.

Measurement challenges

As seen in Figure A1.3, the MFI is more complex than the PPFI (Figure A1.1) and the DSFI (Figure A1.2), as both input and output markets play a role. Another challenge is the lack of data, not least on the origin of inputs for food processing (internal or external) and prices. This means that many production pathways are unaccounted for, underestimating the indicator and thus the resilience of the processing sector.

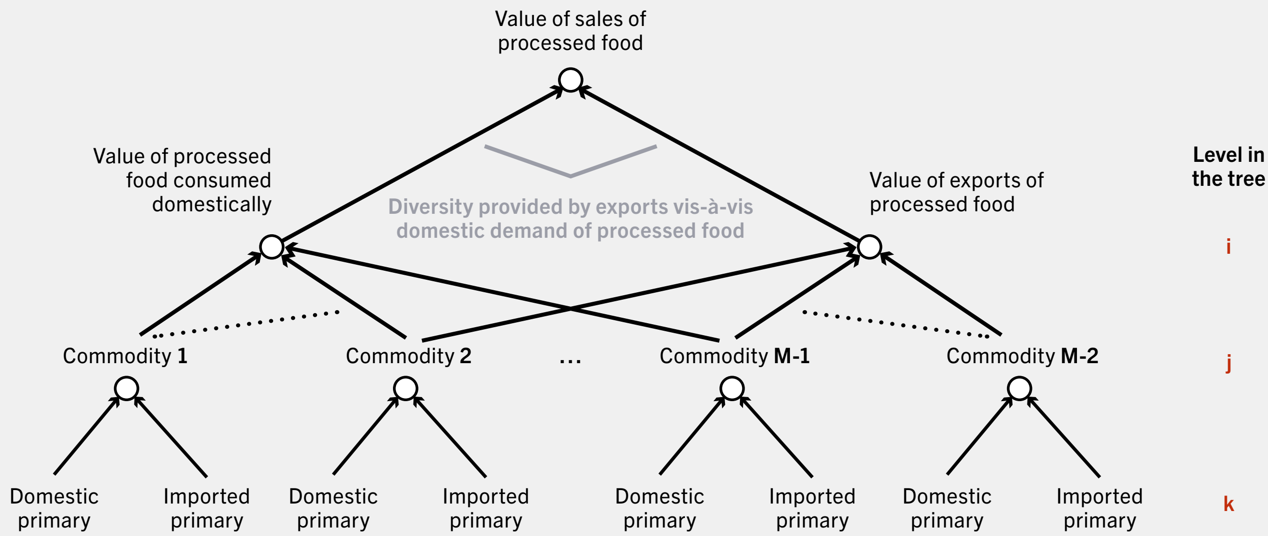
In this report, the analysis of the transport network resilience can be taken as a proxy for the broader concept of midstream resilience. However, estimating the midstream flexibility indicator will fill an important gap, highlighting the need for more and better data for an expanded analysis.

DATA AND METHODOLOGY FOR THE ECONOMIC ACCESS INDICATOR

A healthy diet provides not only adequate calories but also adequate levels of all essential nutrients for a healthy and active life. It ensures consumption of a wide variety of foods from different food groups. The cost of this diet is taken from the 2021 report on *The State of Food Security and Nutrition*.[6] For a full description of the cost methodology and data sources, see Annex 3 of FAO *et al*. (2020).[7]

To estimate the number of people at risk of not being able to afford a healthy diet if a shock reduces their income by one-third, we define

FIGURE A1.3 PATHWAYS TO SOURCE PRIMARY COMMODITIES AS INPUTS TO PRODUCE PROCESSED FOODS AND SELL THEM IN DOMESTIC AND EXPORT MARKETS, IN VALUE



SOURCE: FAO elaboration for this report.

income needed as that required for a healthy diet, other non-food needs (such as housing) plus a 50 percent income buffer in case of a shock. We compare this level of income with the estimated income distribution in a given country, using 2019 income distributions from the World Bank PovcalNet interface.[8] A diet is considered unaffordable when its cost (including the buffer) exceeds 63 percent of average income in a given country. The 63 percent accounts for a portion of the poverty line that can be credibly reserved for food, based on observations that the poorest people in low-income countries spend, on average, 63 percent of their incomes on food.[9–12] This affordability indicator is computed for 143 countries in 2019 as follows:

(1+0.5) × *Cost of the diet*/0.63

To illustrate, if the cost of a healthy diet in a given country is USD 3 per day, to be able to afford both food and non-food needs, an individual needs a daily minimum income of USD 4.76. To continue to meet those needs in the event of a shock that reduces income by one-third, the person's starting income needs to be USD 7.14.

This measure provides estimates of the share of people who cannot afford a healthy diet if a shock reduces their income by one-third. Percentages are then multiplied by the 2019 population in each country using the World Development Indicators of the World Bank to obtain the number of people who are at risk of not being able to afford such a diet.[13]

Figure 6 (Chapter 2) presents the results from this measure, that is, the share of people at risk of not being able to afford a healthy diet (vertical axis) crossed against the share of people who cannot afford a healthy diet without income reduction (horizontal axis).

DESCRIPTION OF THE INDICATORS OF TRANSPORT NETWORK RESILIENCE

Nelson *et al.* (forthcoming) developed three national indicators to capture the structural vulnerability to disruptions to food systems' transport networks: (i) proximity-based resilience; (ii) route redundancy; and (iii) relative detour cost.[14] These indicators are described in detail below.

Proximity-based resilience

Proximity-based resilience is an indicator of food transport network resilience and is related to the food matrix, that is, the way food is distributed from where it is produced to where it is consumed.[g] The food matrix estimates the tonnage of crops between origin zones (where crops are produced) and destination zones (where crops are consumed). The zones are catchment areas around all cities. The total attraction in the model is based on the total supply of crops (in tonnage, excluding exports). This total is distributed proportionally to the population of each zone. Specific crops are distinguished, as each crop may have different transport requirements. For example, highly perishable foods such as fruits may be transported over shorter distances than non-perishable foods like rice. The distribution function describes the propensity to transport food between A and B, irrespective of production and attraction, respectively, as follows:

$$f(c)=e^{-\beta c}$$

Where c is the travel cost between origin and destination and β is the slope of the distribution function.

Travel time is used as the best available option to express cost of transport. The coefficient β describes how fast the attractiveness drops with travel time (cost). In principle, it is most economic to supply food where it is produced. However, due to factors such as market mechanisms and consumer preferences, the distribution function can have a relatively small β.

g Although reference is made here to consumption nodes for convenience, it would be more accurate to refer to nodes where food is supplied, either for consumption or for export.

Irrespective of β, systems will be more resilient when there is a balance between production and consumption. When production and consumption zones are the same, crops do not need to travel very far. Systems will thus be more resilient against network disturbances, as there is the possibility to supply locally. In contrast, if production occurs far from consumption, transportation time is longer even if β is large, increasing the vulnerability of the network to disturbances. In other words, when average travel time is greater than for the optimal situation of balanced production and consumption, systems are less resilient. The indicator for proximity-based resilience is the ratio of the average trip duration in the optimal situation of balanced production and consumption to the average trip duration in the actual situation where crops have to travel distances to reach consumers in various zones.

When analysing the results, there is a clear correlation between this resilience metric and country size. For example, the average trip length, and hence the proximity-based resilience, of a small country is high because of its size. Similarly, detours will on average be smaller for small countries, but relative detours will on average be larger. This is simply because there are (in general) more alternatives for longer trips. These patterns are not linked to the actual resilience of a transport network based on the investments made, but the geographical context. To adjust for this, proximity-based resilience is multiplied by the square root of the total tonnage of transported crops and divided by the average scale factor to keep the same order of magnitudes in both metrics. This is done to allow meaningful comparison of proximity-based resilience across countries.

Route redundancy

This indicator is the ratio of the tonnage that passes through links for which there is an alternative route over the total tonnage for all links:

$$\frac{T_{links\ with\ alternative\ route}}{T_{all\ links}}$$

It is thus a second route-based resilience metric. The higher the indicator, the more resilient the transport network is. For most countries, this value lies above 0.80 indicating that alternative routes are readily available. However, for Somalia, this value lies around 0.31; in other words, 69 percent of the tonnage is over links for which there are no alternative routes, indicating very low resilience.

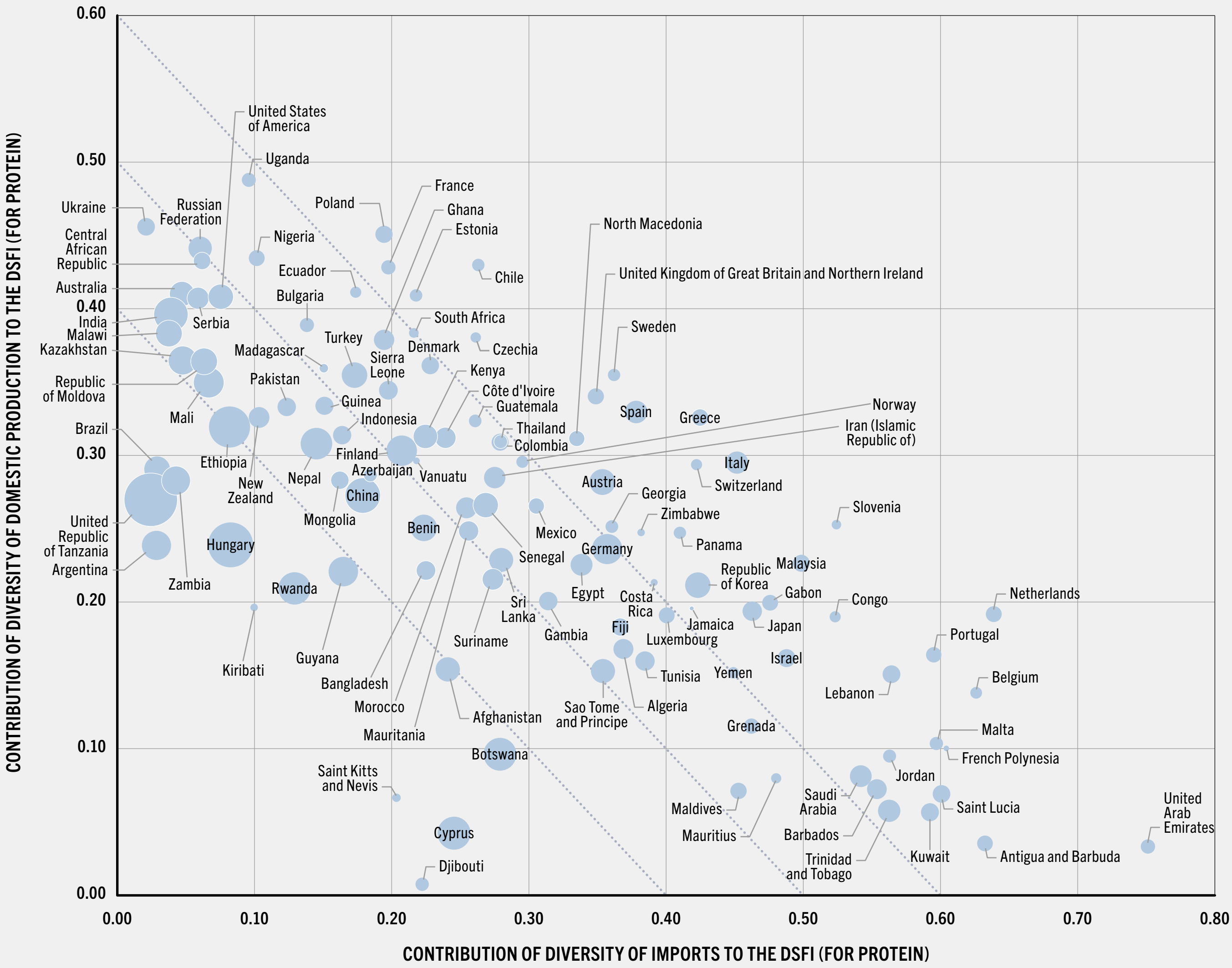
Relative detour cost

This indicator calculates how many extra tonnage-minutes result from closing 1 out of 20 important links. Selecting the most important links requires: (i) closing each link with traffic and calculating the travel time (cost) on the alternative route between the closed link's start and end node; and (ii) multiplying this travel time by the link's intensity. The higher this value, the higher the impact of the link removal. The links with the highest impact values are selected. However, one cannot simply select the 20 links with highest intensity, because to do so would possibly result in the selection of a number of links along the most important route, simulating a similar closure multiple times. Therefore, all origin–destination relations over the link with the highest impact value are selected. The exercise is repeated: disregarding transportations over already selected origin–destination relations from the previous iteration(s); and iterating back to the first step and repeating this procedure until 20 links are selected. This route-based resilience metric, called **relative detour cost**, is the average relative difference (in percentage) between the tonnage-minutes of the normal situation and the situation with one of the 20 high-intensity links removed.

The closure of high-intensity links (in the relative detour cost metric) will have an impact on the population that consumes travel-delayed food. The impact on the population purely in terms of people affected by the delay in food transport is estimated by considering each closed link in turn and determining which (origin–destination) pairs of nodes (i.e. catchments) are involved when the link is removed, and whether they are origin or destination catchments (it can be both if goods are moving both ways across the link). Then, without double counting, the average number of people in the destination catchments (consumers) affected across all link closures is computed, based on the known population per catchment. This metric does not consider the delayed food quantity, meaning that the number of people affected in a catchment is the same regardless of the quantity of food delayed.

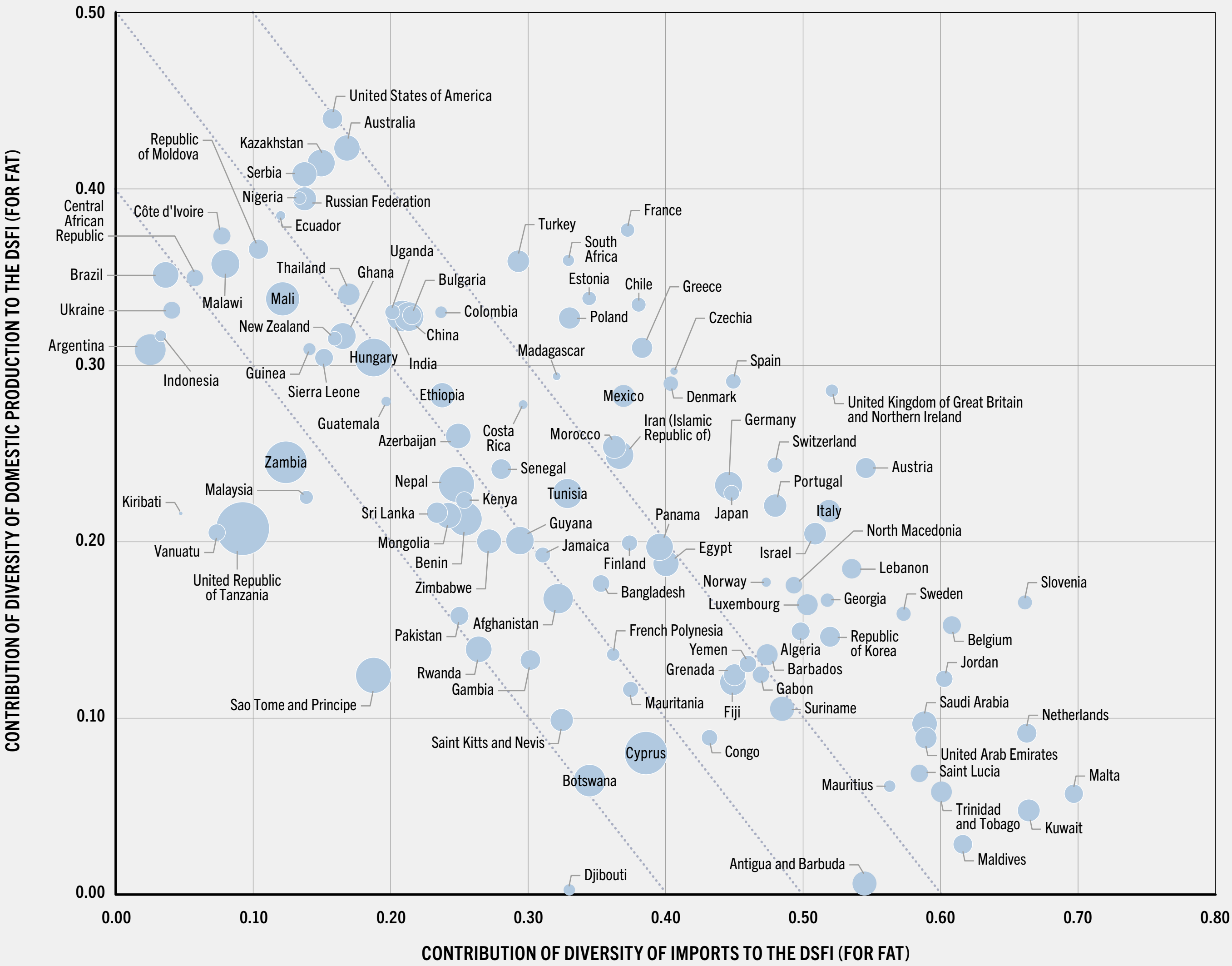
ANNEX 2
ADDITIONAL FIGURES TO CHAPTER 2

FIGURE A2.1 DIETARY SOURCING FLEXIBILITY INDEX (DSFI) FOR PROTEIN, 2016–2018



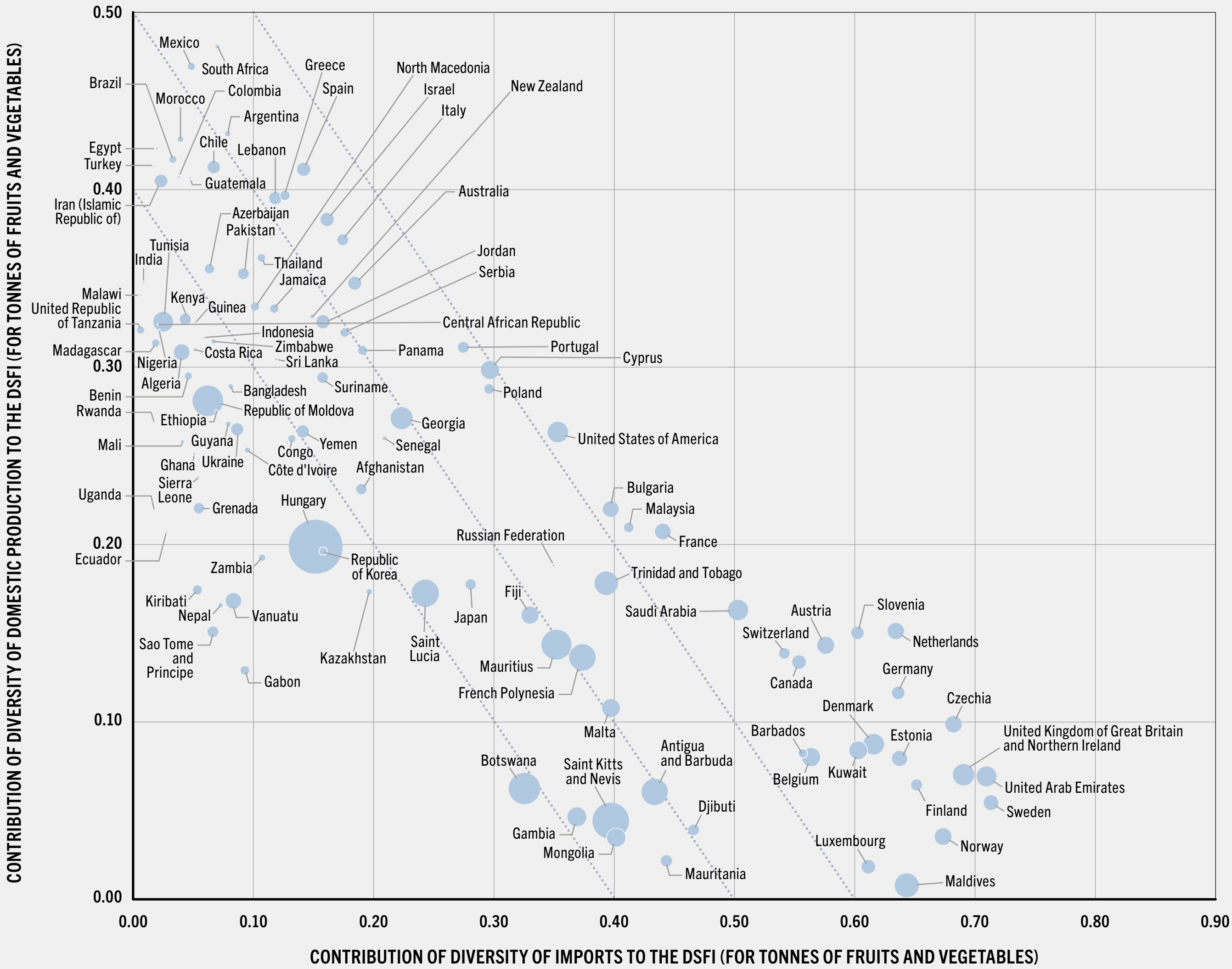
NOTES: The graph plots the contribution of the diversity of imports (i.e. diversity of imports and trade partners plus balance of sourcing: internal or external) against the contribution of the diversity of domestic production (for both domestic market or exports), both to the total value of the DSFI, for protein. The size of the blue bubbles represents the contribution of the diversity of stocks to the DSFI. Countries placed in the same diagonal line report the same value for production and import diversity – 0.4, 0.5 and 0.6, respectively. Results include all crop, fish and livestock commodities for which FAOSTAT new food balance sheets and trade data were available. Protein conversion factors are based on FAOSTAT data and then used to convert tonnes of food into protein. Results are the three-year average of 2016, 2017 and 2018. To simplify graphic presentation, 40 countries that overlapped in the graph were dropped. Results for the full set of countries disaggregated by DSFI contributions are available in **Annex 3**. See **Annex 1** for methodology and data sources.
SOURCE: FAO elaboration for this report.

FIGURE A2.2 DIETARY SOURCING FLEXIBILITY INDEX (DSFI) FOR FAT, 2016–2018



NOTES: The graph plots the contribution of the diversity of imports (i.e. diversity of imports and trade partners plus balance of sourcing: internal or external) against the contribution of the diversity of domestic production (for both domestic market or exports), both to the total value of the DSFI, for fat. The size of the blue bubbles represents the contribution of the diversity of stocks to the DSFI. Countries placed in the same diagonal line report the same value for production and import diversity – 0.4, 0.5 and 0.6, respectively. Results include all crop, fish and livestock commodities for which FAOSTAT new food balance sheets and trade data were available. Fat conversion factors are based on FAOSTAT data and then used to convert tonnes of food into fat. Results are the three-year average of 2016, 2017 and 2018. To simplify graphic presentation, 40 countries that overlapped in the graph were dropped. Results for the full set of countries disaggregated by DSFI contributions are available in **Annex 3**. See **Annex 1** for methodology and data sources.
SOURCE: FAO elaboration for this report.

FIGURE A2.3 DIETARY SOURCING FLEXIBILITY INDEX (DSFI) FOR TONNES OF FRUITS AND VEGETABLES, 2016–2018



NOTES: The graph plots the contribution of the diversity of imports (i.e. diversity of imports and trade partners plus balance of sourcing: internal or external) against the contribution of the diversity of domestic production (for both domestic market or exports), both to the total value of the DSFI, for tonnes of fruits and vegetables. The size of the blue bubbles represents the contribution of the diversity of stocks to the DSFI. Countries placed in the same diagonal line report the same value for production and import diversity – 0.4, 0.5 and 0.6, respectively. Results include all fruits and vegetables for which FAOSTAT new food balance sheets and trade data were available. To simplify graphic presentation, 40 countries that overlapped in the graph were dropped. Results are the three-year average of 2016, 2017 and 2018. Results for the full set of countries disaggregated by DSFI contributions are available in **Annex 3**. See **Annex 1** for methodology and data sources.
SOURCE: FAO elaboration for this report.

ANNEX 3
STATISTICAL TABLES

TABLE A3.1 PRIMARY PRODUCTION FLEXIBILITY INDEX (PPFI) FOR PROTEIN, 2016–2018

COUNTRY/TERRITORY	Contribution of different components to the PPFI (for protein)			
	Diversity of domestic production for domestic market	Diversity of exports and trade partners	Balance of sales (domestic market or exports)	Total PPFI value
WORLD				
AFRICA				
Northern Africa				
Algeria	0.54	0.00	0.00	0.54
Egypt	0.54	0.02	0.02	0.58
Libya	0.57	0.00	0.01	0.59
Morocco	0.48	0.01	0.02	0.51
Tunisia	0.55	0.02	0.02	0.59
Sub-Saharan Africa				
Eastern Africa				
Burundi	0.46	0.00	0.01	0.48
Comoros	0.42	0.02	0.03	0.47
Djibouti	0.17	0.29	0.13	0.59
Eritrea	0.53	0.00	0.00	0.53
Ethiopia	0.54	0.03	0.03	0.60
Kenya	0.49	0.04	0.05	0.58
Madagascar	0.42	0.02	0.03	0.46
Malawi	0.49	0.02	0.03	0.54
Mauritius	0.27	0.01	0.03	0.32
Rwanda	0.47	0.02	0.03	0.53
Réunion	0.28	0.00	0.00	0.28
Seychelles	0.39	0.00	0.02	0.40
Somalia	0.40	0.06	0.08	0.54
South Sudan	0.44	0.00	0.00	0.44
Uganda	0.45	0.08	0.08	0.62
United Republic of Tanzania	0.54	0.02	0.03	0.59
Zambia	0.37	0.03	0.05	0.44
Zimbabwe	0.45	0.01	0.02	0.48
Middle Africa				
Cameroon	0.55	0.01	0.02	0.59
Central African Republic	0.51	0.00	0.02	0.53
Congo	0.55	0.00	0.00	0.55
Democratic Republic of the Congo	0.46	0.00	0.00	0.47
Equatorial Guinea	0.35	0.00	0.01	0.37
Gabon	0.49	0.00	0.00	0.49
Sao Tome and Principe	0.39	0.04	0.08	0.51

TABLE A3.1 (CONTINUED)

COUNTRY/TERRITORY	Contribution of different components to the PPFI (for protein)			
	Diversity of domestic production for domestic market	Diversity of exports and trade partners	Balance of sales (domestic market or exports)	Total PPFI value
Southern Africa				
Botswana	0.39	0.01	0.03	0.43
Eswatini	0.30	0.02	0.05	0.37
Namibia	0.32	0.10	0.12	0.54
South Africa	0.40	0.07	0.06	0.53
Western Africa				
Benin	0.47	0.02	0.03	0.51
Burkina Faso	0.43	0.04	0.05	0.52
Cabo Verde	0.50	0.00	0.00	0.50
Côte d'Ivoire	0.42	0.11	0.10	0.63
Gambia	0.35	0.00	0.01	0.37
Ghana	0.49	0.04	0.05	0.58
Guinea	0.47	0.01	0.03	0.50
Mali	0.51	0.01	0.02	0.54
Mauritania	0.54	0.01	0.02	0.56
Niger	0.38	0.01	0.03	0.41
Nigeria	0.54	0.01	0.01	0.57
Senegal	0.42	0.01	0.02	0.45
Sierra Leone	0.45	0.00	0.02	0.47
Togo	0.41	0.03	0.04	0.48
AMERICA				
Latin America and the Caribbean				
Caribbean				
Antigua and Barbuda	0.39	0.00	0.01	0.40
Bahamas	0.43	0.01	0.04	0.49
Barbados	0.35	0.02	0.03	0.41
Cuba	0.57	0.00	0.00	0.57
Dominica	0.52	0.02	0.03	0.57
Grenada	0.54	0.03	0.04	0.61
Guadeloupe	0.26	0.00	0.00	0.26
Jamaica	0.50	0.01	0.01	0.52
Martinique	0.26	0.00	0.00	0.26
Puerto Rico	0.22	0.00	0.00	0.22
Saint Kitts and Nevis	0.42	0.00	0.01	0.43
Saint Lucia	0.48	0.05	0.08	0.60
Saint Vincent and the Grenadines	0.43	0.11	0.11	0.64
Trinidad and Tobago	0.31	0.01	0.02	0.34
Central America				
Belize	0.39	0.07	0.08	0.54
Costa Rica	0.33	0.19	0.12	0.64
El Salvador	0.37	0.02	0.06	0.44
Guatemala	0.42	0.08	0.07	0.57
Honduras	0.35	0.13	0.10	0.57
Mexico	0.44	0.06	0.07	0.57

TABLE A3.1 (CONTINUED)

COUNTRY/TERRITORY	Contribution of different components to the PPFI (for protein)			
	Diversity of domestic production for domestic market	Diversity of exports and trade partners	Balance of sales (domestic market or exports)	Total PPFI value
Nicaragua	0.43	0.08	0.08	0.59
Panama	0.42	0.03	0.05	0.51
South America				
Argentina	0.19	0.15	0.11	0.45
Bolivia (Plurinational State of)	0.29	0.01	0.02	0.32
Brazil	0.21	0.17	0.14	0.52
Chile	0.53	0.06	0.05	0.64
Colombia	0.48	0.02	0.03	0.53
Ecuador	0.42	0.10	0.08	0.61
French Guyana	0.25	0.00	0.00	0.25
Guyana	0.29	0.09	0.09	0.47
Paraguay	0.14	0.26	0.14	0.54
Peru	0.52	0.04	0.03	0.59
Suriname	0.23	0.10	0.10	0.43
Uruguay	0.24	0.24	0.14	0.62
Venezuela (Bolivarian Republic of)	0.54	0.00	0.00	0.54
Northern America				
Canada	0.19	0.42	0.14	0.75
United States of America	0.33	0.20	0.11	0.64
ASIA				
Central Asia				
Kazakhstan	0.35	0.16	0.11	0.63
Kyrgyzstan	0.49	0.02	0.04	0.55
Eastern Asia				
China	0.55	0.01	0.01	0.56
China, Hong Kong SAR	0.00	0.49	0.01	0.50
China, Macao SAR	0.22	0.05	0.07	0.34
China, mainland	0.59	0.01	0.01	0.60
Japan	0.50	0.00	0.00	0.51
Mongolia	0.39	0.02	0.06	0.46
Republic of Korea	0.51	0.00	0.01	0.52
Taiwan Province of China	0.53	0.01	0.01	0.55
South-eastern Asia				
Brunei Darussalam	0.22	0.00	0.02	0.24
Cambodia	0.30	0.02	0.03	0.36
Indonesia	0.43	0.02	0.02	0.46
Malaysia	0.33	0.13	0.10	0.56
Philippines	0.45	0.00	0.01	0.46
Singapore	0.03	0.61	0.11	0.76
Thailand	0.36	0.14	0.09	0.59
Southern Asia				
Afghanistan	0.35	0.02	0.03	0.39
Bangladesh	0.35	0.00	0.00	0.36
Bhutan	0.44	0.00	0.02	0.46
India	0.57	0.02	0.02	0.61

TABLE A3.1 (CONTINUED)

COUNTRY/TERRITORY	Contribution of different components to the PPFI (for protein)			
	Diversity of domestic production for domestic market	Diversity of exports and trade partners	Balance of sales (domestic market or exports)	Total PPFI value
Iran (Islamic Republic of)	0.50	0.02	0.03	0.55
Maldives	0.34	0.00	0.00	0.34
Nepal	0.54	0.00	0.01	0.55
Pakistan	0.45	0.03	0.03	0.52
Sri Lanka	0.42	0.05	0.05	0.51
Western Asia				
Armenia	0.49	0.01	0.02	0.51
Azerbaijan	0.42	0.01	0.01	0.44
Bahrain	0.26	0.07	0.06	0.39
Cyprus	0.46	0.03	0.04	0.54
Georgia	0.40	0.10	0.09	0.59
Israel	0.43	0.04	0.04	0.51
Jordan	0.37	0.18	0.11	0.66
Kuwait	0.28	0.15	0.12	0.56
Lebanon	0.52	0.06	0.05	0.64
Oman	0.41	0.17	0.11	0.69
Palestine	0.58	0.01	0.01	0.60
Qatar	0.42	0.02	0.06	0.51
Saudi Arabia	0.41	0.04	0.04	0.49
Syrian Arab Republic	0.52	0.02	0.02	0.57
Turkey	0.50	0.04	0.04	0.58
United Arab Emirates	0.12	0.67	0.11	0.90
Yemen	0.60	0.01	0.02	0.63
EUROPE				
Eastern Europe				
Belarus	0.47	0.03	0.04	0.54
Bulgaria	0.17	0.44	0.13	0.75
Czechia	0.22	0.30	0.14	0.66
Hungary	0.24	0.37	0.14	0.75
Poland	0.42	0.17	0.10	0.69
Republic of Moldova	0.26	0.30	0.14	0.70
Romania	0.22	0.42	0.14	0.78
Russian Federation	0.39	0.21	0.11	0.71
Slovakia	0.20	0.38	0.14	0.72
Ukraine	0.26	0.39	0.14	0.78
Northern Europe				
Denmark	0.27	0.24	0.13	0.63
Estonia	0.18	0.38	0.14	0.69
Faroe Islands	0.17	0.00	0.00	0.17
Finland	0.38	0.08	0.08	0.54
Iceland	0.25	0.02	0.04	0.31
Ireland	0.22	0.07	0.07	0.37
Latvia	0.10	0.54	0.11	0.76
Lithuania	0.21	0.39	0.14	0.74
Norway	0.42	0.00	0.01	0.43

TABLE A3.1 (CONTINUED)

COUNTRY/TERRITORY	Contribution of different components to the PPFI (for protein)			
	Diversity of domestic production for domestic market	Diversity of exports and trade partners	Balance of sales (domestic market or exports)	Total PPFI value
Sweden	0.37	0.14	0.10	0.61
United Kingdom of Great Britain and Northern Ireland	0.39	0.11	0.07	0.57
Southern Europe				
Albania	0.50	0.01	0.01	0.52
Bosnia and Herzegovina	0.41	0.05	0.06	0.52
Croatia	0.28	0.29	0.13	0.71
Greece	0.54	0.09	0.07	0.69
Italy	0.53	0.07	0.05	0.65
Malta	0.40	0.02	0.06	0.48
Montenegro	0.35	0.01	0.02	0.38
North Macedonia	0.48	0.05	0.05	0.58
Portugal	0.29	0.20	0.14	0.63
Serbia	0.33	0.16	0.11	0.60
Slovenia	0.12	0.47	0.12	0.71
Spain	0.49	0.16	0.08	0.74
Western Europe				
Austria	0.35	0.24	0.12	0.72
Belgium	0.12	0.47	0.13	0.73
France	0.31	0.30	0.13	0.74
Germany	0.32	0.22	0.12	0.67
Luxembourg	0.09	0.31	0.12	0.52
Netherlands	0.10	0.56	0.12	0.78
Switzerland	0.42	0.01	0.02	0.45
OCEANIA				
Australia and New Zealand				
Australia	0.22	0.43	0.14	0.79
New Zealand	0.22	0.08	0.07	0.36
Melanesia				
Fiji	0.48	0.02	0.02	0.52
New Caledonia	0.41	0.00	0.02	0.44
Papua New Guinea	0.48	0.04	0.05	0.57
Solomon Islands	0.42	0.00	0.04	0.46
Vanuatu	0.33	0.00	0.02	0.35
Micronesia				
Kiribati	0.17	0.00	0.00	0.17
Marshall Islands	0.00	0.00	0.00	0.00
Micronesia (Federated States of)	0.27	0.00	0.00	0.27
Nauru	0.21	0.00	0.01	0.22
Polynesia				
Cook Islands	0.39	0.00	0.00	0.39
French Polynesia	0.38	0.00	0.00	0.38
Niue	0.34	0.00	0.00	0.35
Tokelau	0.11	0.00	0.00	0.11
Tonga	0.47	0.01	0.04	0.52
Tuvalu	0.35	0.00	0.00	0.35

TABLE A3.2 DIETARY SOURCING FLEXIBILITY INDEX (DSFI) FOR KILOCALORIES AND FOR TONNES OF FRUITS AND VEGETABLES, 2016–2018

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Kilocalories				Fruits and vegetables			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
WORLD								
AFRICA								
Northern Africa								
Algeria	0.14	0.44	0.13	0.71	0.31	0.04	0.05	0.40
Egypt	0.25	0.33	0.15	0.73	0.42	0.02	0.01	0.45
Morocco	0.23	0.33	0.15	0.71	0.43	0.04	0.02	0.49
Tunisia	0.18	0.40	0.17	0.75	0.33	0.03	0.07	0.42
Sub-Saharan Africa								
Eastern Africa								
Comoros	0.06	0.08	0.00	0.14				
Djibouti	0.00	0.36	0.11	0.47	0.04	0.47	0.04	0.54
Ethiopia	0.28	0.14	0.24	0.66	0.27	0.07	0.01	0.36
Kenya	0.27	0.31	0.15	0.74	0.33	0.04	0.04	0.41
Madagascar	0.29	0.21	0.06	0.56	0.31	0.02	0.02	0.36
Malawi	0.34	0.05	0.18	0.57	0.34	0.01	0.00	0.35
Mauritius	0.10	0.35	0.13	0.58	0.14	0.35	0.10	0.60
Rwanda	0.15	0.14	0.23	0.52	0.27	0.02	0.00	0.29
Seychelles	0.03	0.13	0.00	0.16				
Uganda	0.44	0.17	0.10	0.71	0.22	0.02	0.00	0.24
United Republic of Tanzania	0.26	0.06	0.34	0.65	0.32	0.01	0.02	0.35
Zambia	0.30	0.07	0.20	0.57	0.19	0.11	0.02	0.32
Zimbabwe	0.22	0.39	0.08	0.69	0.31	0.07	0.01	0.40
Middle Africa								
Cameroon	0.40	0.14	0.15	0.69	0.30	0.01	0.00	0.31
Central African Republic	0.45	0.09	0.09	0.63	0.32	0.02	0.01	0.35
Congo	0.17	0.42	0.12	0.70	0.26	0.13	0.02	0.42
Gabon	0.21	0.37	0.14	0.72	0.13	0.09	0.03	0.25
Sao Tome and Principe	0.13	0.32	0.23	0.68	0.15	0.07	0.04	0.25
Southern Africa								
Botswana	0.05	0.35	0.20	0.60	0.06	0.33	0.11	0.49
Eswatini	0.21	0.19	0.07	0.47	0.30	0.20	0.04	0.54
Namibia	0.16	0.42	0.18	0.75	0.17	0.25	0.12	0.54
South Africa	0.37	0.28	0.08	0.74	0.48	0.07	0.01	0.56
Western Africa								
Benin	0.21	0.26	0.17	0.65	0.29	0.05	0.02	0.36
Burkina Faso	0.29	0.18	0.18	0.64	0.17	0.16	0.02	0.35
Cabo Verde	0.07	0.56	0.13	0.76	0.16	0.30	0.09	0.54
Côte d'Ivoire	0.36	0.17	0.14	0.66	0.25	0.10	0.02	0.36
Gambia	0.13	0.42	0.12	0.68	0.05	0.37	0.06	0.48
Ghana	0.34	0.18	0.13	0.65	0.25	0.05	0.01	0.31
Guinea	0.31	0.19	0.13	0.63	0.33	0.05	0.00	0.38
Mali	0.32	0.09	0.20	0.61	0.26	0.04	0.01	0.31

TABLE A3.2 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Kilocalories				Fruits and vegetables			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Mauritania	0.10	0.40	0.18	0.68	0.02	0.44	0.04	0.50
Niger	0.30	0.11	0.11	0.52	0.25	0.02	0.01	0.28
Nigeria	0.40	0.13	0.10	0.63	0.32	0.02	0.01	0.35
Senegal	0.22	0.35	0.16	0.74	0.26	0.21	0.01	0.48
Sierra Leone	0.27	0.21	0.13	0.62	0.24	0.05	0.00	0.30
Togo	0.26	0.28	0.14	0.68	0.20	0.15	0.03	0.37
AMERICA								
Latin America and the Caribbean								
Caribbean								
Antigua and Barbuda	0.01	0.65	0.16	0.83	0.06	0.43	0.09	0.58
Bahamas	0.06	0.62	0.11	0.79	0.22	0.26	0.05	0.54
Barbados	0.10	0.54	0.15	0.79	0.08	0.56	0.03	0.67
Cuba	0.27	0.34	0.08	0.69	0.32	0.01	0.02	0.34
Dominica	0.20	0.31	0.20	0.71	0.31	0.05	0.01	0.37
Grenada	0.10	0.48	0.12	0.70	0.22	0.05	0.03	0.31
Jamaica	0.21	0.44	0.07	0.71	0.33	0.12	0.03	0.48
Saint Kitts and Nevis	0.09	0.41	0.14	0.64	0.04	0.40	0.12	0.56
Saint Lucia	0.07	0.59	0.15	0.82	0.17	0.24	0.09	0.51
Saint Vincent and the Grenadines	0.10	0.36	0.19	0.64	0.21	0.06	0.02	0.29
Trinidad and Tobago	0.05	0.62	0.14	0.81	0.18	0.39	0.08	0.65
Central America								
Belize	0.31	0.16	0.12	0.59	0.26	0.04	0.04	0.34
Costa Rica	0.32	0.32	0.09	0.73	0.31	0.05	0.01	0.37
El Salvador	0.24	0.35	0.10	0.68	0.14	0.46	0.04	0.64
Guatemala	0.37	0.18	0.07	0.63	0.41	0.05	0.00	0.46
Honduras	0.34	0.23	0.09	0.66	0.37	0.13	0.01	0.50
Mexico	0.31	0.29	0.11	0.71	0.47	0.05	0.02	0.54
Nicaragua	0.36	0.21	0.14	0.71	0.38	0.13	0.02	0.53
Panama	0.24	0.39	0.15	0.78	0.31	0.19	0.03	0.53
South America								
Argentina	0.38	0.02	0.18	0.58	0.43	0.08	0.02	0.53
Bolivia (Plurinational State of)	0.42	0.07	0.12	0.62	0.38	0.06	0.01	0.45
Brazil	0.42	0.04	0.13	0.59	0.42	0.03	0.02	0.47
Chile	0.35	0.36	0.13	0.84	0.41	0.07	0.04	0.52
Colombia	0.39	0.25	0.10	0.73	0.41	0.04	0.01	0.45
Ecuador	0.40	0.16	0.11	0.68	0.21	0.03	0.00	0.24
Guyana	0.23	0.14	0.19	0.56	0.27	0.08	0.02	0.36
Paraguay	0.37	0.02	0.13	0.52	0.33	0.15	0.01	0.49
Peru	0.35	0.27	0.12	0.74	0.47	0.02	0.01	0.50
Suriname	0.15	0.30	0.18	0.64	0.29	0.16	0.04	0.49
Uruguay	0.29	0.12	0.19	0.59	0.34	0.18	0.03	0.54

TABLE A3.2 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Kilocalories				Fruits and vegetables			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Venezuela (Bolivarian Republic of)	0.23	0.36	0.17	0.76	0.38	0.02	0.00	0.40
Northern America								
Canada	0.40	0.10	0.18	0.68	0.13	0.55	0.05	0.73
United States of America	0.39	0.10	0.14	0.62	0.26	0.35	0.07	0.69
ASIA								
Central Asia								
Kazakhstan	0.34	0.08	0.19	0.61	0.17	0.20	0.02	0.39
Kyrgyzstan	0.35	0.16	0.14	0.66	0.24	0.10	0.02	0.36
Eastern Asia								
China	0.30	0.13	0.23	0.66	0.26	0.02	0.00	0.28
China, Hong Kong SAR	0.02	0.90	0.06	0.98	0.00	0.59	0.03	0.63
China, Macao SAR	0.01	0.71	0.11	0.83	0.00	0.45	0.02	0.47
China, mainland	0.32	0.13	0.20	0.65	0.26	0.01	0.02	0.28
Japan	0.21	0.47	0.13	0.81	0.18	0.28	0.03	0.49
Mongolia	0.19	0.30	0.15	0.65	0.03	0.40	0.06	0.50
Republic of Korea	0.14	0.51	0.17	0.82	0.20	0.16	0.03	0.38
Taiwan Province of China	0.15	0.48	0.13	0.76	0.26	0.18	0.08	0.51
South-eastern Asia								
Cambodia	0.23	0.09	0.15	0.46	0.21	0.06	0.02	0.30
Indonesia	0.33	0.10	0.13	0.57	0.32	0.06	0.00	0.38
Malaysia	0.23	0.24	0.11	0.58	0.21	0.41	0.03	0.65
Philippines	0.30	0.28	0.13	0.72	0.36	0.05	0.01	0.42
Thailand	0.37	0.13	0.16	0.66	0.36	0.11	0.03	0.49
Southern Asia								
Afghanistan	0.12	0.28	0.19	0.59	0.23	0.19	0.04	0.46
Bangladesh	0.16	0.24	0.13	0.53	0.29	0.08	0.02	0.39
India	0.40	0.09	0.19	0.69	0.35	0.01	0.00	0.36
Iran (Islamic Republic of)	0.27	0.28	0.19	0.74	0.40	0.02	0.04	0.47
Maldives	0.02	0.63	0.13	0.78	0.01	0.64	0.08	0.73
Nepal	0.28	0.17	0.21	0.66	0.17	0.07	0.01	0.25
Pakistan	0.32	0.16	0.13	0.61	0.35	0.09	0.04	0.48
Sri Lanka	0.18	0.28	0.19	0.65	0.30	0.12	0.01	0.43
Western Asia								
Armenia	0.24	0.33	0.12	0.69	0.30	0.07	0.01	0.39
Azerbaijan	0.25	0.24	0.15	0.64	0.36	0.06	0.03	0.45
Cyprus	0.03	0.27	0.22	0.52	0.30	0.30	0.06	0.66
Georgia	0.19	0.47	0.10	0.75	0.27	0.22	0.07	0.57
Israel	0.14	0.54	0.15	0.83	0.38	0.16	0.04	0.59
Jordan	0.07	0.63	0.08	0.79	0.33	0.16	0.04	0.53

TABLE A3.2 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Kilocalories				Fruits and vegetables			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Kuwait	0.03	0.63	0.14	0.80	0.08	0.60	0.06	0.75
Lebanon	0.13	0.61	0.13	0.88	0.40	0.12	0.04	0.55
Oman	0.08	0.65	0.10	0.82	0.19	0.38	0.03	0.60
Saudi Arabia	0.06	0.57	0.17	0.80	0.16	0.50	0.07	0.73
Turkey	0.36	0.22	0.17	0.75	0.41	0.02	0.00	0.43
United Arab Emirates	0.05	0.70	0.12	0.87	0.07	0.71	0.07	0.85
Yemen	0.08	0.51	0.10	0.69	0.26	0.14	0.04	0.45
EUROPE								
Eastern Europe								
Belarus	0.40	0.14	0.19	0.73	0.21	0.37	0.06	0.64
Bulgaria	0.39	0.17	0.11	0.67	0.22	0.40	0.05	0.67
Czechia	0.41	0.32	0.07	0.80	0.10	0.68	0.06	0.84
Hungary	0.23	0.10	0.30	0.63	0.20	0.15	0.18	0.53
Poland	0.44	0.22	0.16	0.81	0.29	0.30	0.03	0.62
Republic of Moldova	0.37	0.07	0.19	0.63	0.28	0.06	0.10	0.45
Romania	0.39	0.17	0.12	0.68	0.24	0.27	0.04	0.54
Russian Federation	0.47	0.09	0.13	0.68	0.19	0.35	0.01	0.54
Slovakia	0.32	0.29	0.18	0.79	0.09	0.68	0.05	0.82
Ukraine	0.47	0.03	0.11	0.60	0.26	0.09	0.04	0.39
Northern Europe								
Denmark	0.34	0.28	0.15	0.76	0.09	0.62	0.07	0.77
Estonia	0.39	0.30	0.10	0.78	0.08	0.64	0.05	0.77
Finland	0.25	0.30	0.20	0.75	0.06	0.65	0.04	0.75
Iceland	0.27	0.36	0.07	0.69	0.01	0.78	0.05	0.83
Ireland	0.19	0.32	0.14	0.65	0.06	0.64	0.06	0.76
Latvia	0.26	0.32	0.12	0.70	0.11	0.60	0.06	0.76
Lithuania	0.37	0.24	0.14	0.75	0.10	0.64	0.03	0.77
Norway	0.22	0.51	0.10	0.82	0.04	0.67	0.06	0.77
Sweden	0.30	0.48	0.10	0.88	0.05	0.71	0.05	0.82
United Kingdom of Great Britain and Northern Ireland	0.31	0.46	0.11	0.88	0.07	0.69	0.07	0.83
Southern Europe								
Albania	0.30	0.27	0.11	0.69	0.34	0.07	0.00	0.41
Bosnia and Herzegovina	0.21	0.38	0.13	0.72	0.20	0.24	0.02	0.46
Croatia	0.34	0.28	0.16	0.78	0.13	0.22	0.10	0.45
Greece	0.33	0.42	0.14	0.90	0.40	0.13	0.03	0.56
Italy	0.25	0.50	0.18	0.93	0.37	0.17	0.04	0.58
Malta	0.06	0.71	0.11	0.88	0.11	0.40	0.06	0.56
Montenegro	0.08	0.61	0.07	0.76	0.17	0.44	0.04	0.65
North Macedonia	0.28	0.41	0.12	0.80	0.33	0.10	0.03	0.46
Portugal	0.19	0.59	0.14	0.92	0.31	0.27	0.04	0.62

TABLE A3.2 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Kilocalories				Fruits and vegetables			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Serbia	0.40	0.07	0.16	0.63	0.32	0.18	0.03	0.52
Slovenia	0.20	0.63	0.07	0.90	0.15	0.60	0.04	0.79
Spain	0.30	0.44	0.15	0.89	0.41	0.14	0.04	0.60
Western Europe								
Austria	0.26	0.40	0.20	0.85	0.14	0.58	0.06	0.78
Belgium	0.18	0.67	0.11	0.96	0.08	0.56	0.06	0.71
France	0.42	0.23	0.14	0.80	0.21	0.44	0.05	0.70
Germany	0.30	0.37	0.21	0.88	0.12	0.64	0.04	0.79
Luxembourg	0.16	0.46	0.13	0.75	0.02	0.61	0.05	0.68
Netherlands	0.13	0.72	0.13	0.99	0.15	0.63	0.05	0.84
Switzerland	0.27	0.53	0.12	0.92	0.14	0.54	0.04	0.72
OCEANIA								
Australia and New Zealand								
Australia	0.44	0.07	0.15	0.66	0.35	0.18	0.04	0.57
New Zealand	0.35	0.23	0.13	0.71	0.33	0.15	0.01	0.49
Melanesia								
Fiji	0.18	0.24	0.20	0.62	0.16	0.33	0.06	0.55
New Caledonia	0.07	0.58	0.11	0.77	0.12	0.35	0.08	0.54
Papua New Guinea	0.35	0.17	0.07	0.60	0.21	0.01	0.00	0.22
Solomon Islands	0.31	0.18	0.11	0.60	0.09	0.09	0.04	0.21
Vanuatu	0.22	0.18	0.09	0.48	0.17	0.08	0.05	0.30
Micronesia								
Kiribati	0.19	0.16	0.11	0.46	0.17	0.05	0.03	0.26
Polynesia								
French Polynesia	0.12	0.52	0.07	0.71	0.14	0.37	0.09	0.60

TABLE A3.3 DIETARY SOURCING FLEXIBILITY INDEX (DSFI) FOR PROTEIN AND FOR FAT, 2016–2018

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Protein				Fat			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
WORLD								
AFRICA								
Northern Africa								
Algeria	0.17	0.37	0.12	0.66	0.15	0.50	0.11	0.76
Egypt	0.23	0.34	0.13	0.70	0.19	0.40	0.15	0.74
Morocco	0.26	0.25	0.13	0.65	0.25	0.36	0.14	0.75
Tunisia	0.16	0.38	0.12	0.66	0.23	0.33	0.18	0.73
Sub-Saharan Africa								
Eastern Africa								
Comoros	0.07	0.08	0.00	0.15	0.05	0.08	0.00	0.13
Djibouti	0.01	0.22	0.08	0.31	0.00	0.33	0.07	0.40
Ethiopia	0.32	0.08	0.25	0.65	0.28	0.24	0.15	0.67
Kenya	0.31	0.22	0.15	0.68	0.22	0.25	0.10	0.58
Madagascar	0.36	0.15	0.06	0.57	0.29	0.32	0.05	0.66
Malawi	0.38	0.04	0.16	0.58	0.36	0.08	0.17	0.61
Mauritius	0.08	0.48	0.06	0.62	0.06	0.56	0.07	0.70
Rwanda	0.21	0.13	0.19	0.53	0.14	0.26	0.16	0.56
Seychelles	0.01	0.13	0.00	0.15	0.04	0.13	0.00	0.17
Uganda	0.49	0.10	0.08	0.67	0.33	0.20	0.09	0.62
United Republic of Tanzania	0.27	0.02	0.32	0.62	0.21	0.09	0.32	0.62
Zambia	0.28	0.04	0.17	0.50	0.25	0.12	0.25	0.62
Zimbabwe	0.25	0.38	0.04	0.67	0.20	0.27	0.15	0.62
Middle Africa								
Cameroon	0.38	0.14	0.17	0.68	0.39	0.08	0.13	0.60
Central African Republic	0.43	0.06	0.10	0.60	0.35	0.06	0.10	0.51
Congo	0.19	0.52	0.07	0.78	0.09	0.43	0.10	0.62
Gabon	0.20	0.48	0.10	0.77	0.12	0.47	0.10	0.69
Sao Tome and Principe	0.15	0.35	0.15	0.65	0.12	0.19	0.21	0.52
Southern Africa								
Botswana	0.10	0.28	0.20	0.57	0.06	0.34	0.19	0.60
Eswatini	0.18	0.33	0.07	0.58	0.16	0.41	0.11	0.68
Namibia	0.27	0.29	0.09	0.65	0.16	0.37	0.15	0.68
South Africa	0.38	0.22	0.06	0.66	0.36	0.33	0.07	0.76
Western Africa								
Benin	0.25	0.22	0.16	0.63	0.21	0.25	0.20	0.67
Burkina Faso	0.33	0.12	0.14	0.59	0.32	0.11	0.20	0.64
Cabo Verde	0.12	0.49	0.12	0.73	0.07	0.56	0.10	0.73
Côte d'Ivoire	0.31	0.24	0.13	0.68	0.37	0.08	0.10	0.55
Gambia	0.20	0.31	0.11	0.63	0.13	0.30	0.12	0.55
Ghana	0.38	0.19	0.12	0.70	0.32	0.17	0.16	0.64
Guinea	0.33	0.15	0.11	0.59	0.31	0.14	0.07	0.52
Mali	0.35	0.07	0.18	0.60	0.34	0.12	0.20	0.66
Mauritania	0.25	0.26	0.12	0.62	0.12	0.37	0.09	0.59

TABLE A3.3 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Protein				Fat			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Niger	0.30	0.05	0.10	0.45	0.31	0.14	0.11	0.56
Nigeria	0.43	0.10	0.10	0.63	0.39	0.13	0.08	0.60
Senegal	0.27	0.27	0.15	0.69	0.24	0.28	0.12	0.64
Sierra Leone	0.34	0.20	0.11	0.66	0.30	0.15	0.11	0.56
Togo	0.33	0.21	0.09	0.63	0.21	0.29	0.12	0.62
AMERICA								
Latin America and the Caribbean								
Caribbean								
Antigua and Barbuda	0.04	0.63	0.09	0.76	0.01	0.54	0.14	0.69
Bahamas	0.07	0.60	0.05	0.73	0.03	0.59	0.09	0.70
Barbados	0.07	0.55	0.12	0.75	0.14	0.47	0.12	0.73
Cuba	0.17	0.45	0.06	0.68	0.17	0.44	0.07	0.68
Dominica	0.19	0.34	0.15	0.69	0.12	0.33	0.13	0.58
Grenada	0.12	0.46	0.09	0.67	0.12	0.45	0.13	0.70
Jamaica	0.20	0.42	0.03	0.64	0.19	0.31	0.09	0.60
Saint Kitts and Nevis	0.07	0.20	0.05	0.32	0.10	0.32	0.14	0.56
Saint Lucia	0.07	0.60	0.11	0.78	0.07	0.58	0.10	0.76
Saint Vincent and the Grenadines	0.09	0.33	0.15	0.57	0.07	0.41	0.21	0.69
Trinidad and Tobago	0.06	0.56	0.13	0.75	0.06	0.60	0.12	0.78
Central America								
Belize	0.34	0.15	0.11	0.61	0.16	0.33	0.14	0.62
Costa Rica	0.21	0.39	0.04	0.65	0.28	0.30	0.05	0.63
El Salvador	0.22	0.33	0.10	0.65	0.16	0.48	0.08	0.71
Guatemala	0.32	0.26	0.08	0.66	0.28	0.20	0.06	0.53
Honduras	0.30	0.28	0.06	0.64	0.27	0.15	0.07	0.49
Mexico	0.27	0.31	0.10	0.67	0.28	0.37	0.13	0.78
Nicaragua	0.42	0.20	0.07	0.69	0.32	0.26	0.12	0.70
Panama	0.25	0.41	0.07	0.73	0.20	0.40	0.16	0.75
South America								
Argentina	0.24	0.03	0.18	0.44	0.31	0.03	0.18	0.52
Bolivia (Plurinational State of)	0.29	0.05	0.05	0.39	0.35	0.03	0.11	0.49
Brazil	0.29	0.03	0.16	0.48	0.35	0.04	0.16	0.54
Chile	0.43	0.26	0.08	0.77	0.33	0.38	0.09	0.80
Colombia	0.31	0.28	0.08	0.67	0.33	0.24	0.07	0.64
Ecuador	0.41	0.17	0.07	0.65	0.38	0.12	0.06	0.56
Guyana	0.22	0.16	0.18	0.56	0.20	0.29	0.17	0.66
Paraguay	0.29	0.01	0.08	0.38	0.32	0.02	0.12	0.45
Peru	0.35	0.24	0.07	0.66	0.34	0.28	0.07	0.69
Suriname	0.22	0.27	0.13	0.62	0.11	0.48	0.14	0.73
Uruguay	0.28	0.07	0.18	0.52	0.20	0.10	0.17	0.48

TABLE A3.3 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for: Protein				Fat			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Venezuela (Bolivarian Republic of)	0.25	0.35	0.11	0.70	0.26	0.30	0.12	0.68
Northern America								
Canada	0.37	0.06	0.18	0.61	0.35	0.10	0.15	0.60
United States of America	0.41	0.08	0.15	0.64	0.44	0.16	0.12	0.72
ASIA								
Central Asia								
Kazakhstan	0.36	0.05	0.17	0.59	0.41	0.15	0.16	0.73
Kyrgyzstan	0.40	0.10	0.12	0.61	0.28	0.26	0.14	0.68
Eastern Asia								
China	0.27	0.18	0.21	0.67	0.33	0.21	0.17	0.71
China, Hong Kong SAR	0.02	0.83	0.03	0.88	0.03	0.80	0.07	0.90
China, Macao SAR	0.02	0.70	0.06	0.78	0.02	0.66	0.10	0.78
China, mainland	0.30	0.18	0.17	0.65	0.37	0.22	0.12	0.71
Japan	0.19	0.46	0.12	0.77	0.23	0.45	0.09	0.77
Mongolia	0.28	0.16	0.11	0.56	0.21	0.24	0.15	0.61
Republic of Korea	0.21	0.42	0.15	0.79	0.15	0.52	0.12	0.79
Taiwan Province of China	0.12	0.43	0.10	0.65	0.18	0.42	0.08	0.69
South-eastern Asia								
Cambodia	0.28	0.05	0.14	0.47	0.36	0.16	0.16	0.68
Indonesia	0.31	0.16	0.11	0.59	0.32	0.03	0.07	0.42
Malaysia	0.23	0.50	0.10	0.83	0.23	0.14	0.08	0.45
Philippines	0.30	0.35	0.09	0.74	0.24	0.26	0.13	0.64
Thailand	0.31	0.28	0.10	0.69	0.34	0.17	0.13	0.64
Southern Asia								
Afghanistan	0.15	0.24	0.15	0.54	0.17	0.32	0.18	0.67
Bangladesh	0.22	0.22	0.12	0.56	0.18	0.35	0.10	0.63
India	0.40	0.04	0.21	0.64	0.33	0.21	0.19	0.72
Iran (Islamic Republic of)	0.28	0.28	0.13	0.69	0.25	0.37	0.17	0.78
Maldives	0.07	0.45	0.10	0.62	0.03	0.62	0.11	0.76
Nepal	0.31	0.15	0.19	0.64	0.23	0.25	0.21	0.69
Pakistan	0.33	0.12	0.11	0.57	0.16	0.25	0.11	0.52
Sri Lanka	0.23	0.28	0.14	0.65	0.22	0.23	0.12	0.57
Western Asia								
Armenia	0.30	0.24	0.09	0.63	0.20	0.42	0.07	0.70
Azerbaijan	0.29	0.18	0.08	0.55	0.26	0.25	0.15	0.66
Cyprus	0.04	0.25	0.20	0.49	0.08	0.39	0.25	0.72
Georgia	0.25	0.36	0.08	0.69	0.17	0.52	0.08	0.76
Israel	0.16	0.49	0.11	0.76	0.20	0.51	0.13	0.85
Jordan	0.09	0.56	0.08	0.74	0.12	0.60	0.10	0.83
Kuwait	0.06	0.59	0.11	0.76	0.05	0.66	0.13	0.85

TABLE A3.3 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Protein				Fat			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Lebanon	0.15	0.56	0.11	0.82	0.18	0.54	0.12	0.84
Oman	0.13	0.59	0.09	0.81	0.08	0.53	0.09	0.70
Saudi Arabia	0.08	0.54	0.13	0.75	0.10	0.59	0.15	0.84
Turkey	0.35	0.17	0.15	0.68	0.36	0.29	0.13	0.78
United Arab Emirates	0.03	0.75	0.09	0.87	0.09	0.59	0.13	0.81
Yemen	0.15	0.45	0.07	0.67	0.13	0.46	0.10	0.69
EUROPE								
Eastern Europe								
Belarus	0.36	0.10	0.18	0.65	0.30	0.17	0.19	0.66
Bulgaria	0.39	0.14	0.09	0.61	0.33	0.22	0.11	0.66
Czechia	0.38	0.26	0.06	0.70	0.30	0.41	0.04	0.75
Hungary	0.24	0.08	0.27	0.59	0.30	0.19	0.23	0.72
Poland	0.45	0.19	0.10	0.75	0.33	0.33	0.13	0.79
Republic of Moldova	0.36	0.06	0.16	0.59	0.37	0.10	0.12	0.59
Romania	0.40	0.15	0.10	0.65	0.41	0.19	0.13	0.72
Russian Federation	0.44	0.06	0.14	0.64	0.39	0.14	0.14	0.67
Slovakia	0.32	0.23	0.16	0.71	0.24	0.41	0.16	0.81
Ukraine	0.46	0.02	0.11	0.58	0.33	0.04	0.10	0.47
Northern Europe								
Denmark	0.36	0.23	0.11	0.69	0.29	0.40	0.09	0.78
Estonia	0.41	0.22	0.08	0.70	0.34	0.34	0.08	0.77
Finland	0.30	0.21	0.18	0.69	0.20	0.37	0.09	0.67
Iceland	0.25	0.17	0.03	0.44	0.29	0.25	0.04	0.59
Ireland	0.25	0.26	0.10	0.61	0.25	0.36	0.15	0.75
Latvia	0.30	0.27	0.10	0.66	0.29	0.39	0.10	0.77
Lithuania	0.40	0.17	0.12	0.68	0.31	0.42	0.09	0.82
Norway	0.30	0.30	0.07	0.66	0.18	0.47	0.05	0.70
Sweden	0.35	0.36	0.07	0.79	0.16	0.57	0.08	0.82
United Kingdom of Great Britain and Northern Ireland	0.34	0.35	0.10	0.79	0.29	0.52	0.08	0.88
Southern Europe								
Albania	0.32	0.21	0.08	0.61	0.28	0.28	0.10	0.65
Bosnia and Herzegovina	0.26	0.34	0.11	0.70	0.16	0.42	0.11	0.69
Croatia	0.40	0.23	0.11	0.75	0.30	0.38	0.16	0.85
Greece	0.33	0.42	0.10	0.85	0.31	0.38	0.12	0.82
Italy	0.30	0.45	0.13	0.88	0.22	0.52	0.13	0.87
Malta	0.10	0.60	0.08	0.78	0.06	0.70	0.11	0.87
Montenegro	0.11	0.55	0.06	0.72	0.06	0.59	0.07	0.72
North Macedonia	0.31	0.33	0.10	0.74	0.18	0.49	0.10	0.77
Portugal	0.16	0.60	0.09	0.85	0.22	0.48	0.14	0.84
Serbia	0.41	0.06	0.13	0.60	0.41	0.14	0.15	0.69
Slovenia	0.25	0.52	0.06	0.83	0.17	0.66	0.08	0.91
Spain	0.33	0.38	0.14	0.84	0.29	0.45	0.09	0.83

TABLE A3.3 (CONTINUED)

COUNTRY/ TERRITORY	Contribution of different components to the DSFI for:							
	Protein				Fat			
	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value	Diversity of domestic production	Diversity of imports	Diversity of food stocks	Total DSFI value
Western Europe								
Austria	0.28	0.35	0.16	0.79	0.24	0.55	0.12	0.91
Belgium	0.14	0.63	0.07	0.84	0.15	0.61	0.11	0.87
France	0.43	0.20	0.09	0.71	0.38	0.37	0.08	0.83
Germany	0.24	0.36	0.18	0.78	0.23	0.45	0.17	0.84
Luxembourg	0.19	0.40	0.10	0.69	0.16	0.50	0.12	0.79
Netherlands	0.19	0.64	0.10	0.93	0.09	0.66	0.12	0.87
Switzerland	0.29	0.42	0.07	0.78	0.24	0.48	0.09	0.82
OCEANIA								
Australia and New Zealand								
Australia	0.41	0.05	0.15	0.61	0.42	0.17	0.15	0.75
New Zealand	0.33	0.10	0.12	0.55	0.32	0.16	0.09	0.56
Melanesia								
Fiji	0.18	0.37	0.11	0.66	0.12	0.45	0.16	0.73
New Caledonia	0.10	0.56	0.06	0.72	0.06	0.62	0.10	0.77
Papua New Guinea	0.32	0.22	0.07	0.61	0.27	0.08	0.02	0.37
Solomon Islands	0.31	0.21	0.08	0.60	0.31	0.07	0.07	0.45
Vanuatu	0.30	0.22	0.04	0.55	0.21	0.07	0.10	0.38
Micronesia								
Kiribati	0.20	0.10	0.05	0.34	0.22	0.05	0.02	0.28
Polynesia								
French Polynesia	0.10	0.60	0.03	0.74	0.14	0.36	0.08	0.58

TABLE A3.4 INDICATORS OF RESILIENCE AND VULNERABILITY OF FOOD TRANSPORT NETWORKS

COUNTRY/ TERRITORY	System-wide measures		Localized disruption			
	Proximity-based resilience	Route redundancy	Relative detour cost (local impact)	Relative detour cost (aggregate impact)	People affected (millions)	People affected (percent)
WORLD						
AFRICA						
Northern Africa						
Algeria	0.12	99.81	16.20	1.27	13.83	34.09
Egypt	0.33	93.97	12.96	1.03	36.87	39.03
Morocco	0.11	99.71	8.76	1.29	18.10	51.52
Sudan	0.03	54.74	93.57	20.60	15.89	39.88
Tunisia	0.13	99.43	16.79	1.73	6.42	56.82
Sub-Saharan Africa						
Eastern Africa						
Burundi	0.23	98.00	42.28	2.70	4.55	43.38
Ethiopia	0.11	73.72	26.07	1.88	77.63	74.92
Kenya	0.06	92.24	13.50	2.43	12.83	26.15
Madagascar	0.02	73.07	32.04	4.86	18.30	73.48
Malawi	0.09	97.05	13.81	2.23	6.60	38.38
Mozambique	0.03	71.86	25.43	5.63	15.22	54.65
Rwanda	0.11	100.00	21.31	2.73	5.73	49.11
Somalia	0.00	31.23	20.60	4.26	6.85	48.24
South Sudan	0.01	47.82	21.98	5.54	4.58	42.36
Uganda	0.11	94.59	26.84	2.57	14.26	35.93
United Republic of Tanzania	0.04	90.36	23.47	2.20	22.65	42.67
Zambia	0.03	87.93	58.97	12.08	9.60	58.69
Zimbabwe	0.05	81.81	32.42	4.63	4.00	28.49
Middle Africa						
Angola	0.04	93.37	36.44	4.38	10.45	36.22
Cameroon	0.03	95.19	13.44	2.46	7.35	30.72
Central African Republic	0.03	99.77	38.11	2.73	1.42	31.25
Chad	0.03	81.18	51.95	7.32	6.59	45.26
Congo	0.03	94.15	28.90	7.99	2.83	56.84
Democratic Republic of the Congo	0.05	70.78	41.06	4.29	42.55	53.99
Gabon	0.02	92.26	68.16	29.03	1.57	78.28
Southern Africa						
South Africa	0.09	72.28	16.11	1.44	30.71	54.64
Western Africa						
Benin	0.06	89.74	17.46	3.27	4.97	45.68
Burkina Faso	0.09	97.47	25.96	3.26	8.69	46.58
Côte d'Ivoire	0.11	97.68	18.43	2.37	6.68	28.04
Ghana	0.16	97.83	23.31	2.34	18.21	63.93
Guinea	0.08	83.85	40.24	3.81	5.81	49.44
Guinea-Bissau	0.03	89.03	31.06	12.09	0.80	44.65
Liberia	0.06	99.93	31.80	5.86	1.44	31.44
Mali	0.05	75.29	19.19	2.64	8.24	45.84
Niger	0.08	83.91	33.98	8.33	11.52	55.41
Nigeria	0.29	92.08	25.67	1.79	45.69	24.56

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TABLE A3.4 (CONTINUED)

COUNTRY/ TERRITORY	System-wide measures		Localized disruption			
	Proximity-based resilience	Route redundancy	Relative detour cost (local impact)	Relative detour cost (aggregate impact)	People affected (millions)	People affected (percent)
Senegal	0.06	92.54	148.68	26.60	7.42	49.47
Sierra Leone	0.15	99.99	43.07	2.45	3.37	46.03
Togo	0.08	87.62	45.86	6.16	4.71	62.73
AMERICA						
Latin America and the Caribbean						
Caribbean						
Dominican Republic	0.11	84.81	18.16	3.16	9.22	88.63
Haiti	0.07	77.77	95.97	9.61	7.54	69.54
Jamaica	0.07	100.00	55.85	2.50	1.76	60.46
Central America						
Guatemala	0.07	66.68	24.84	4.82	7.54	47.62
Mexico	0.06	94.03	15.18	2.20	74.04	60.04
South America						
Argentina	0.04	84.09	9.92	1.13	16.69	38.30
Bolivia (Plurinational State of)	0.03	95.06	14.59	1.67	3.34	30.27
Brazil	0.04	83.46	14.02	1.28	149.62	72.58
Chile	0.02	71.11	4.57	0.66	11.12	61.06
Colombia	0.05	90.32	22.25	3.40	33.61	69.73
Ecuador	0.08	98.98	58.37	7.38	7.81	47.36
Peru	0.04	67.22	25.39	3.83	15.24	49.24
Venezuela (Bolivarian Republic of)	0.06	82.33	15.97	2.19	15.75	52.90
Northern America						
Canada	0.01	90.91	20.15	7.50	16.92	46.86
United States of America	0.08	97.18	4.97	0.34	123.55	38.27
ASIA						
Central Asia						
Kazakhstan	0.02	91.26	12.96	2.76	11.03	61.98
Uzbekistan	0.14	97.69	18.47	2.15	14.12	44.35
Eastern Asia						
China	0.63	97.73	4.50	0.16	920.71	66.78
Democratic People's Republic of Korea	0.18	99.80	33.33	2.39	7.87	31.09
Japan	0.06	99.09	4.56	0.72	101.73	80.12
Republic of Korea	0.20	100.00	8.44	0.94	11.17	21.81
South-eastern Asia						
Cambodia	0.10	99.11	28.02	3.26	9.00	57.06
Indonesia	0.06	77.38	5.49	0.47	179.79	68.75
Lao People's Democratic Republic	0.06	90.06	42.57	5.54	3.50	51.19
Malaysia	0.09	92.75	11.89	2.18	12.14	39.56
Myanmar	0.12	84.88	36.88	2.95	23.64	44.57
Philippines	0.18	78.39	55.04	17.39	63.80	61.55
Thailand	0.07	78.02	17.43	4.38	34.79	50.44
Viet Nam	0.10	95.40	3.95	0.80	57.20	61.09

TABLE A3.4 (CONTINUED)

COUNTRY/ TERRITORY	System-wide measures		Localized disruption			
	Proximity-based resilience	Route redundancy	Relative detour cost (local impact)	Relative detour cost (aggregate impact)	People affected (millions)	People affected (percent)
Southern Asia						
Afghanistan	0.08	88.74	28.11	3.28	16.92	47.85
Bangladesh	0.24	84.13	31.75	3.25	96.56	61.13
India	0.22	89.43	4.92	0.20	570.01	43.04
Iran (Islamic Republic of)	0.10	98.03	19.74	1.28	56.74	71.30
Nepal	0.11	90.13	23.07	3.08	11.12	40.74
Pakistan	0.17	94.92	10.81	0.74	92.04	45.20
Sri Lanka	0.13	100.00	10.98	1.19	5.63	26.56
Western Asia						
Azerbaijan	0.08	98.93	41.00	4.19	4.88	50.05
Iraq	0.07	92.09	11.15	1.49	23.93	65.43
Saudi Arabia	0.02	81.49	6.92	1.38	12.66	39.04
Syrian Arab Republic	0.07	99.21	10.96	2.35	4.74	27.07
Turkey	0.22	98.32	11.96	0.77	58.01	72.68
Yemen	0.05	68.86	25.62	2.83	11.04	40.62
EUROPE						
Eastern Europe						
Russian Federation	0.06	91.61	21.75	2.00	103.96	72.04
Ukraine	0.14	89.67	17.01	1.85	16.90	37.56
Northern Europe						
United Kingdom of Great Britain and Northern Ireland	0.20	98.87	10.31	0.72	17.84	27.20
Southern Europe						
Italy	0.14	93.92	20.25	2.01	30.67	50.59
Western Europe						
France	0.20	98.53	8.93	0.85	25.65	38.45
Germany	0.26	98.81	7.95	0.39	17.26	20.99
OCEANIA						
Australia and New Zealand						
Australia	0.01	57.47	15.90	2.50	8.15	33.68
Melanesia						
Papua New Guinea	0.01	37.63	9.69	2.29	3.42	41.32

TABLE A3.5 AFFORDABILITY OF ENERGY-SUFFICIENT AND HEALTHY DIETS IN 2019

COUNTRY/ TERRITORY	Population	People unable to afford a healthy diet	People at risk of not being able to afford a healthy diet if incomes are reduced by one-third	People able to afford a healthy diet even if incomes are reduced by one-third	People unable to afford an energy-sufficient diet	People at risk of not being able to afford an energy-sufficient diet if incomes are reduced by one-third	People able to afford an energy-sufficient diet even if incomes are reduced by one-third
	Thousands	Percent	Percent	Percent	Percent	Percent	Percent
WORLD							
AFRICA							
Northern Africa							
Algeria	43 053	0.25	0.33	0.42	0.00	0.00	1.00
Egypt	100 388	0.85	0.10	0.05	0.00	0.01	0.99
Morocco	36 472	0.11	0.19	0.70	0.00	0.00	1.00
Sudan	42 813	0.93	0.05	0.02	0.11	0.22	0.67
Tunisia	11 695	0.15	0.24	0.61	0.00	0.00	1.00
Sub-Saharan Africa							
Eastern Africa							
Burundi	11 531	0.97	0.02	0.01	0.31	0.27	0.41
Comoros	851	0.80	0.11	0.09	0.15	0.13	0.72
Djibouti	974	0.65	0.19	0.16	0.03	0.04	0.93
Ethiopia	112 079	0.83	0.10	0.07	0.01	0.06	0.92
Kenya	52 574	0.78	0.12	0.10	0.09	0.15	0.76
Madagascar	26 969	0.97	0.02	0.01	0.24	0.23	0.53
Malawi	18 629	0.94	0.03	0.02	0.02	0.06	0.93
Mauritius	1 266	0.14	0.22	0.64	0.00	0.00	1.00
Mozambique	30 366	0.93	0.03	0.04	0.08	0.12	0.80
Rwanda	12 627	0.88	0.06	0.06	0.02	0.08	0.90
Seychelles	98	0.06	0.08	0.86	0.00	0.00	1.00
Uganda	44 270	0.78	0.11	0.11	0.01	0.06	0.93
United Republic of Tanzania	58 005	0.84	0.08	0.07	0.05	0.16	0.80
Zambia	17 861	0.86	0.07	0.07	0.31	0.14	0.54
Zimbabwe	14 645	0.99	0.01	0.00	0.83	0.08	0.09
Middle Africa							
Angola	31 825	0.93	0.04	0.03	0.38	0.17	0.45
Cameroon	25 876	0.65	0.16	0.19	0.03	0.06	0.91
Central African Republic	4 745	0.93	0.03	0.04	0.36	0.19	0.45
Chad	15 947	0.80	0.11	0.09	0.08	0.10	0.82
Congo	5 381	0.90	0.05	0.05	0.41	0.19	0.40
Democratic Republic of the Congo	86 791	0.95	0.03	0.02	0.15	0.17	0.68
Gabon	2 173	0.32	0.23	0.45	0.01	0.03	0.97
Sao Tome and Principe	215	0.87	0.06	0.06	0.19	0.19	0.62
Southern Africa							
Botswana	2 304	0.61	0.14	0.26	0.01	0.02	0.98
Eswatini	1 148	0.68	0.11	0.21	0.13	0.15	0.72
Lesotho	2 125	0.78	0.12	0.10	0.07	0.09	0.84
Namibia	2 495	0.51	0.14	0.35	0.10	0.10	0.80
South Africa	58 558	0.62	0.10	0.28	0.18	0.14	0.68

TABLE A3.5 (CONTINUED)

COUNTRY/ TERRITORY	Population	People unable to afford a healthy diet	People at risk of not being able to afford a healthy diet if incomes are reduced by one-third	People able to afford a healthy diet even if incomes are reduced by one-third	People unable to afford an energy-sufficient diet	People at risk of not being able to afford an energy-sufficient diet if incomes are reduced by one-third	People able to afford an energy-sufficient diet even if incomes are reduced by one-third
	Thousands	Percent	Percent	Percent	Percent	Percent	Percent
Western Africa							
Benin	11 801	0.91	0.04	0.05	0.19	0.10	0.72
Burkina Faso	20 321	0.88	0.07	0.05	0.00	0.01	0.99
Cabo Verde	550	0.32	0.21	0.47	0.00	0.01	0.99
Côte d'Ivoire	25 717	0.69	0.16	0.15	0.03	0.06	0.91
Gambia	2 348	0.77	0.15	0.08	0.03	0.09	0.88
Ghana	30 418	0.61	0.18	0.21	0.05	0.05	0.90
Guinea	12 771	0.93	0.05	0.02	0.09	0.17	0.74
Guinea-Bissau	1 921	0.93	0.03	0.04	0.36	0.22	0.42
Liberia	4 937	1.00	0.00	0.00	0.47	0.25	0.28
Mali	19 658	0.88	0.08	0.04	0.03	0.13	0.84
Mauritania	4 526	0.67	0.21	0.12	0.02	0.04	0.94
Niger	23 311	0.89	0.07	0.03	0.01	0.04	0.95
Nigeria	200 964	0.93	0.05	0.02	0.23	0.23	0.54
Senegal	16 296	0.73	0.15	0.12	0.07	0.12	0.81
Sierra Leone	7 813	0.84	0.10	0.07	0.00	0.04	0.96
Togo	8 082	0.95	0.03	0.01	0.63	0.16	0.21
AMERICA							
Latin America and the Caribbean							
Caribbean							
Dominican Republic	10 739	0.15	0.20	0.65	0.00	0.01	0.99
Haiti	11 263	0.85	0.09	0.06	0.09	0.12	0.78
Jamaica	2 948	0.52	0.17	0.31	0.01	0.03	0.97
Saint Lucia	183	0.18	0.12	0.69	0.04	0.03	0.94
Trinidad and Tobago	1 395	0.09	0.11	0.80	0.00	0.00	1.00
Central America							
Belize	390	0.32	0.19	0.49	0.09	0.08	0.84
Costa Rica	5 048	0.13	0.14	0.72	0.01	0.01	0.99
El Salvador	6 454	0.32	0.24	0.44	0.02	0.04	0.94
Honduras	9 746	0.47	0.16	0.37	0.11	0.10	0.79
Mexico	127 576	0.17	0.19	0.64	0.00	0.01	0.99
Nicaragua	6 546	0.31	0.21	0.48	0.05	0.07	0.88
Panama	4 246	0.17	0.12	0.70	0.01	0.02	0.98
South America							
Argentina	44 939	0.25	0.17	0.58	0.01	0.01	0.98
Bolivia (Plurinational State of)	11 513	0.20	0.19	0.61	0.04	0.04	0.92
Brazil	211 050	0.14	0.10	0.75	0.02	0.02	0.96
Chile	18 952	0.02	0.06	0.91	0.00	0.00	1.00
Colombia	50 339	0.26	0.17	0.58	0.03	0.04	0.93
Ecuador	17 374	0.19	0.15	0.65	0.03	0.04	0.92
Guyana	783	0.38	0.21	0.40	0.04	0.02	0.95

TABLE A3.5 (CONTINUED)

COUNTRY/ TERRITORY	Population	People unable to afford a healthy diet	People at risk of not being able to afford a healthy diet if incomes are reduced by one-third	People able to afford a healthy diet even if incomes are reduced by one-third	People unable to afford an energy-sufficient diet	People at risk of not being able to afford an energy-sufficient diet if incomes are reduced by one-third	People able to afford an energy-sufficient diet even if incomes are reduced by one-third
	Thousands	Percent	Percent	Percent	Percent	Percent	Percent
Paraguay	7 045	0.16	0.16	0.69	0.00	0.01	0.99
Peru	32 510	0.17	0.15	0.68	0.00	0.01	0.99
Suriname	581	0.47	0.21	0.31	0.16	0.03	0.80
Uruguay	3 462	0.01	0.05	0.94	0.00	0.00	1.00
Northern America							
Canada	37 589	0.00	0.00	0.99	0.00	0.00	1.00
United States of America	328 240	0.01	0.00	0.98	0.01	0.00	0.99
ASIA							
Central Asia							
Kazakhstan	18 514	0.01	0.09	0.89	0.00	0.00	1.00
Kyrgyzstan	6 457	0.48	0.31	0.21	0.00	0.01	0.99
Tajikistan	9 321	0.27	0.26	0.47	0.00	0.02	0.98
Eastern Asia							
China	1 397 715	0.15	0.19	0.66	0.00	0.00	1.00
Japan	126 265	0.02	0.01	0.97	0.01	0.01	0.99
Mongolia	3 225	0.38	0.28	0.35	0.00	0.00	1.00
Republic of Korea	51 709	0.01	0.02	0.97	0.00	0.00	1.00
South-eastern Asia							
Indonesia	270 626	0.66	0.19	0.15	0.00	0.06	0.94
Lao People's Democratic Republic	7 169	0.81	0.11	0.08	0.00	0.04	0.96
Malaysia	31 950	0.01	0.03	0.96	0.00	0.00	1.00
Myanmar	54 045	0.52	0.28	0.20	0.00	0.01	0.99
Philippines	108 117	0.65	0.18	0.17	0.02	0.10	0.88
Thailand	69 626	0.17	0.25	0.58	0.00	0.00	1.00
Viet Nam	96 462	0.23	0.24	0.54	0.00	0.02	0.98
Southern Asia							
Bangladesh	163 046	0.73	0.16	0.11	0.00	0.01	0.99
Bhutan	763	0.45	0.22	0.33	0.00	0.02	0.98
India	1 366 418	0.71	0.17	0.12	0.00	0.04	0.95
Maldives	531	0.02	0.07	0.91	0.00	0.00	1.00
Nepal	28 609	0.73	0.16	0.11	0.01	0.06	0.93
Pakistan	216 565	0.76	0.15	0.09	0.00	0.02	0.98
Sri Lanka	21 803	0.49	0.25	0.26	0.00	0.01	0.99
Western Asia							
Armenia	2 958	0.46	0.32	0.22	0.00	0.02	0.98
Azerbaijan	10 023	0.00	0.00	1.00	0.00	0.00	1.00
Cyprus	1 199	0.00	0.00	1.00	0.00	0.00	1.00
Iraq	39 310	0.53	0.27	0.20	0.00	0.03	0.96
Israel	9 053	0.01	0.02	0.97	0.00	0.00	1.00
Jordan	10 102	0.21	0.29	0.50	0.00	0.00	1.00

TABLE A3.5 (CONTINUED)

COUNTRY/ TERRITORY	Population	People unable to afford a healthy diet	People at risk of not being able to afford a healthy diet if incomes are reduced by one-third	People able to afford a healthy diet even if incomes are reduced by one-third	People unable to afford an energy-sufficient diet	People at risk of not being able to afford an energy-sufficient diet if incomes are reduced by one-third	People able to afford an energy-sufficient diet even if incomes are reduced by one-third
	Thousands	Percent	Percent	Percent	Percent	Percent	Percent
Palestine	4 685	0.90					
Turkey	83 430	0.09	0.11	0.80	0.00	0.00	1.00
EUROPE							
Eastern Europe							
Belarus	9 467	0.01	0.04	0.95	0.00	0.00	1.00
Bulgaria	6 976	0.08	0.07	0.86	0.00	0.00	1.00
Czechia	10 670	0.00	0.00	1.00	0.00	0.00	1.00
Hungary	9 770	0.02	0.02	0.96	0.00	0.00	1.00
Poland	37 971	0.00	0.04	0.95	0.00	0.00	1.00
Republic of Moldova	2 658	0.04	0.19	0.77	0.00	0.00	1.00
Romania	19 357	0.09	0.07	0.85	0.00	0.01	0.99
Russian Federation	144 374	0.02	0.08	0.90	0.00	0.00	1.00
Slovakia	5 454	0.02	0.02	0.96	0.00	0.00	1.00
Northern Europe							
Denmark	5 819	0.00	0.00	1.00	0.00	0.00	1.00
Estonia	1 327	0.01	0.01	0.99	0.00	0.00	1.00
Finland	5 520	0.00	0.00	1.00	0.00	0.00	1.00
Iceland	361	0.00	0.00	1.00	0.00	0.00	1.00
Ireland	4 941	0.00	0.00	1.00	0.00	0.00	1.00
Latvia	1 913	0.02	0.02	0.96	0.00	0.00	1.00
Lithuania	2 787	0.02	0.02	0.96	0.00	0.00	1.00
Norway	5 348	0.00	0.00	0.99	0.00	0.00	1.00
Sweden	10 285	0.01	0.00	0.99	0.01	0.00	0.99
United Kingdom of Great Britain and Northern Ireland	66 834	0.00	0.00	0.99	0.00	0.00	1.00
Southern Europe							
Albania	2 854	0.40	0.25	0.35	0.00	0.00	1.00
Bosnia and Herzegovina	3 301	0.03	0.06	0.91	0.00	0.00	1.00
Croatia	4 068	0.03	0.06	0.91	0.00	0.00	1.00
Greece	10 716	0.01	0.04	0.94	0.00	0.00	1.00
Italy	60 297	0.03	0.01	0.96	0.01	0.00	0.99
Malta	503	0.00	0.00	0.99	0.00	0.00	1.00
Montenegro	622	0.14	0.11	0.74	0.01	0.00	0.99
North Macedonia	2 083	0.17	0.17	0.66	0.01	0.01	0.97
Portugal	10 269	0.01	0.01	0.98	0.00	0.00	1.00
Serbia	6 945	0.10	0.21	0.69	0.00	0.00	1.00
Slovenia	2 088	0.00	0.00	1.00	0.00	0.00	1.00
Spain	47 077	0.02	0.01	0.97	0.01	0.00	0.99
Western Europe							
Austria	8 877	0.01	0.00	0.99	0.00	0.00	1.00
Belgium	11 484	0.00	0.00	1.00	0.00	0.00	1.00

TABLE A3.5 (CONTINUED)

COUNTRY/ TERRITORY	Population	People unable to afford a healthy diet	People at risk of not being able to afford a healthy diet if incomes are reduced by one-third	People able to afford a healthy diet even if incomes are reduced by one-third	People unable to afford an energy-sufficient diet	People at risk of not being able to afford an energy-sufficient diet if incomes are reduced by one-third	People able to afford an energy-sufficient diet even if incomes are reduced by one-third
	Thousands	Percent	Percent	Percent	Percent	Percent	Percent
France	67 060	0.00	0.00	1.00	0.00	0.00	1.00
Germany	83 133	0.00	0.00	1.00	0.00	0.00	1.00
Luxembourg	620	0.00	0.00	0.99	0.00	0.00	1.00
Netherlands	17 333	0.00	0.00	1.00	0.00	0.00	1.00
Switzerland	8 575	0.00	0.01	0.99	0.00	0.00	1.00
OCEANIA							
Australia and New Zealand							
Australia	25 364	0.01	0.00	0.99	0.00	0.00	1.00
Melanesia							
Fiji	890	0.31	0.28	0.42	0.00	0.00	1.00

ANNEX 4
ADDITIONAL TABLES TO CHAPTER 4

TABLE A4.1 LIST OF COUNTRIES IN THE FAO-RIMA DATA SET

Country	Coverage	Year 1	Sample
Chad	National	2015	6 949
Democratic Republic of the Congo	Rutshuru (Nord-Kivu)	2017	1 719
Democratic Republic of the Congo	Rutshuru (Nord-Kivu)	2019	1 643
Mali	National	2014	3 804
Mauritania	National	2017	2 826
Myanmar	Rakhine State	2019	304
Niger	Maradi, Zinder	2018	2 300
Nigeria	Borno State	2018	2 049
Senegal	Matam	2015	414
Somalia	Jowhar district (Middle Shabelle)	2019	599
Somalia	Marka district (Lower Shabelle)	2019	622
South Sudan	Lakes State, Central Equatoria (Terekeka)	2019	777
Uganda	Karamoja	2016	1 965
Uganda	Karamoja	2019	1 965
Uganda	North	2017	3 034
Uganda	Southwest	2018	705
Venezuela (Bolivarian Republic of)	Portuguesa State	2020	839

TABLE A4.2 LIST OF COUNTRIES IN THE MICS DATA SET

Country	Coverage	Year 1	Year 2	Sample
Bangladesh	National	2012	2019	1 109
Democratic Republic of the Congo	National	2010	2017	748
Gambia	National	2010	2018	520
Ghana	National	2011	2017	430
Guinea-Bissau	National	2014	2018	527
Iraq	National	2011	2018	2 190
Kazakhstan	National	2010	2015	313
Kyrgyzstan	National	2014	2016	307
Lao People's Democratic Republic	National	2012	2017	1 186
Mali	National	2009	2015	885
Mauritania	National	2011	2015	543
Mongolia	National	2010	2018	252
Nepal	National	2014	2019	319
Nigeria	National	2011	2016	1 914
Pakistan	Punjab	2011	2017	3 728
Serbia	National	2010	2019	111
Sierra Leone	National	2010	2017	531
Sudan	National	2010	2014	878
Thailand	National	2012	2019	471
Togo	National	2010	2017	380
Tunisia	National	2011	2018	137
Viet Nam	National	2010	2013	255
Zimbabwe	National	2014	2019	490

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CHAPTER 5

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ANNEX 1

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2021
THE STATE OF FOOD AND AGRICULTURE

MAKING AGRIFOOD SYSTEMS MORE RESILIENT TO SHOCKS AND STRESSES

The COVID-19 pandemic exposed the vulnerability of agrifood systems to shocks and stresses and led to increased global food insecurity and malnutrition. Action is needed to make agrifood systems more resilient, efficient, sustainable and inclusive.

The State of Food and Agriculture 2021 presents country-level indicators of the resilience of agrifood systems. The indicators measure the robustness of primary production and food availability, as well as physical and economic access to food. They can thus help assess the capacity of national agrifood systems to absorb shocks and stresses, a key aspect of resilience.

The report analyses the vulnerabilities of food supply chains and how rural households cope with risks and shocks. It discusses options to minimize trade-offs that building resilience may have with efficiency and inclusivity. The aim is to offer guidance on policies to enhance food supply chain resilience, support livelihoods in the agrifood system and, in the face of disruption, ensure sustainable access to sufficient, safe and nutritious food to all.

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