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GUIDELINES TO INCREASE THE RESILIENCE OF AGRICULTURAL SUPPLY CHAINS

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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FOREWORD

The effects of the COVID-19 pandemic on food and agriculture have been felt all over the world, as the measures to contain it have harmed economic activity, impacted food systems, disrupted agricultural supply chains and increased food insecurity by undermining the livelihoods and capacity to access food for millions of people. In particular, low- and middle-income countries have been severely affected, as large shares of their populations depend on agriculture for their livelihoods. As the COVID-19 pandemic unfolded, considerable attention began to be paid to the resilience of agricultural supply chains in a time of crisis.

The agricultural commodity supply chain is a complex network that connects the production system with the consumer through a series of operations such as production, manufacturing, packaging, distribution, retailing and storage. At the same time, it connects companies that provide inputs (such as seeds, fertilizers and others) and producers. Agricultural commodity and input supply chains have needed to adjust rapidly in response to demand-side shocks, including panic buying and changes in food-purchasing patterns, as well as to plan for any supply-side disruptions caused by potential labour shortages and disruptions in logistics.

In addition, the COVID-19 crisis worsened food insecurity by undermining informal food chains. There is now considerable concern about food production, processing, distribution and demand. COVID-19 resulted in the restricted movement of workers, changes in consumer demand, the closure of food–production facilities, restricted food–trade policies and financial pressures on food supply chains. There is also concern that shocks, including those triggered by COVID-19, frequently amplify social deprivation and political stresses associated with poverty and inequality.

Although COVID-19-related shocks have some unique characteristics, a wide variety of other potential shocks, including droughts, floods, pests, diseases, earthquakes and tsunamis, have simultaneously threatened agricultural supply chains, with damaging impacts on food security and nutrition, trade balances, government revenues, employment, incomes, growth, and poverty reduction. Besides these “natural disasters”, “human-induced” disasters such as conflicts – which are also occurring in many parts of the world – can be equally detrimental. The incidence of some “natural disasters”, notably extreme weather events, pests, and plant and animal diseases, has increased as a result of climate change and the ever increasing pressures on natural resources, bringing heightened urgency to debates on resilience and how to strengthen it. This urgency is amplified by potential feedback links between insecurity and conflict and some natural disasters, in particular climate change and variability, and resource constraints. Efforts to strengthen resilience need to be based on a detailed consideration of the nature of the hazards likely to give rise to shocks, including the probability that shocks will occur, and of the levels of supply chain exposure and vulnerability to the likely impacts of shocks on supply chains that together determine the expected losses.

Drawing on its experience and expertise in agricultural markets and economic analysis of agricultural policies, the Food and Agriculture Organization of the United Nations (FAO), following a request and financial support from the Japanese Government, has undertaken research on the

impacts of the COVID-19 crisis and natural disasters on agricultural supply chains and markets, and prepared guidelines for increasing the resilience of agricultural supply chains. These guidelines are intended for policymakers and other stakeholders who need a broad grasp of the concepts, issues and possible approaches involved. The guidelines build on and complement *The State of Food and Agriculture 2021 – Making agrifood systems more resilient to shocks and stresses*, written within the context of the call for concrete actions made by the first ever United Nations Food Systems Summit in September 2021.

Efforts to strengthen resilience to risks need to be based on a thorough analysis of the exposure and vulnerability of supply chains to them, and on a cost–benefit assessment of damages versus interventions. In addition, not all decisions can be based on commercial and economic considerations, as political priorities will also play a role. Further empirical studies are valuable, but stakeholder processes are a fundamental requirement for any realistic assessment of supply chain risks and for informed discussions on formulating measures to build supply chain capacities for greater resilience. Governments need to create effective mechanisms for facilitating the necessary sharing of information and dialogue.

Governments may take the lead in setting policy priorities based on assessments of risk and resilience capacities, but it is actors throughout the supply chain from primary production through transport, storage, processing to retail who are directly affected and who need to consider business strategies and interventions to adapt and transform for the future. Governments play an essential supporting role, facilitating and supporting the efforts of supply chain businesses to prevent, anticipate, absorb, adapt and transform, especially towards greater resilience and longer-term sustainability. Governments build general resilience through a myriad of actions to build an appropriate policy and institutional environment and through the investments they make in physical infrastructure, in putting social protection in place, and in facilitating and promoting collaboration and cooperation. Enhancing general resilience against future risks is important as new risks emerge, notably new zoonoses, and the frequency and intensity of known risks grow with climate change and increasing pressure on natural resources. More importantly, the relationship between resilience and sustainability means that policies for each of these need to be considered together.

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ACRONYMS AND ABBREVIATIONS

AMIS	Agricultural Market Information System
CIS	climate information systems
COVID-19	novel coronavirus disease
DCS	dairy cooperative society
EMPRES	Emergency Prevention System
FAO	Food and Agriculture Organization of the United Nations
FCC-ICU	Food Chain Crisis – Intelligence and Coordination Unit
GIEWS	Global Information and Early Warning System
GDP	gross domestic product
GHG	greenhouse gas
ICT	information and communications technology
KCMMF	Kerala Cooperative Milk Marketing Federation
MILKFED	Punjab State Cooperative Milk Producers Federation Limited
NPPO	National Plant Protection Organizations
R&D	research and development
TR4	tropical race 4
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WOAH	World Organisation for Animal Health
WTO	World Trade Organization

The main wholesale market in Chile continues to provide the public during the COVID-19 pandemic with all the protective measures for the collaborators and the community.

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1 INTRODUCTION

These guidelines are concerned with the resilience of agricultural supply chains to natural disasters such as droughts, earthquakes or epidemics. Excluded from natural disasters, although there is a close relationship in some cases, are stresses such as climate change or rising population pressures.[1] The guidelines are not prescriptive, and they are not specific policy recommendations. Rather, as the title suggests, they are intended to provide *guidance* to help policymakers in defining their policy objectives and strategic priorities and in making informed decisions on what measures to implement against an evolving variety of hazards. The aim is to help improve *preparedness* in order to prevent potential future shocks where possible, be robust against actual shocks so as to limit their severity and maintain supply chain functionality, to recover quickly and where relevant build back better, and to support impacted populations efficiently and effectively.

In very broad terms, the resilience of supply chains involves their robustness to external shocks and their ability to adapt and transform in order to recover quickly. The demand-and supply-side shocks resulting from the COVID-19 pandemic and the responses to it were widely seen as a serious challenge to this resilience. In practice, in many instances the resulting disruptions have been relatively short-lived, with agricultural supply chains apparently more resilient than might have been assumed. The continuity of food supply chains was ensured in many countries because these chains were exempted from some COVID-19-related restrictions. Nevertheless, the pandemic prompted concerns that the resilience of agricultural supply chains could not be taken for granted and that their efficiency and functionality could be compromised by unexpected shocks either directly or indirectly through disruptions in other chains, such as from the input side.

While the COVID-19 shock has some unique characteristics, a wide variety of other potential shocks, including droughts, floods, pests, diseases, earthquakes and tsunamis, threaten agricultural supply chains with potentially damaging impacts on food security and nutrition, trade balances, government revenues, employment, incomes, growth, and poverty reduction. Often these shocks, including COVID-19, bring into stark contrast the poverty and inequality that already exist in a country, reflecting the broader challenges of structural deprivation faced by vulnerable populations (Upton *et al.*, 2021). Besides these "natural disasters", "human-induced" disasters such as conflicts can be equally damaging. The incidence of some "natural disasters", notably extreme weather events, pests, and plant and animal diseases, has increased as a result of climate change and increasing pressure on natural resources, bringing heightened urgency to debates on resilience and how to

[1] Stresses and their relationship to natural disasters are further discussed in the text.

strengthen it. This urgency is amplified by potential feedback links between insecurity and conflict and some natural disasters, in particular climate change and variability, and resource constraints. Efforts to strengthen resilience need to be based on a detailed consideration of the nature of hazards likely to give rise to shocks, including the probability that shocks will occur, and on the levels of supply chain exposure and vulnerability to the likely impacts of shocks on supply chains that together determine the expected losses.

The biological basis of agricultural production and its dependence on soil, land, water, biodiversity and climate make primary production particularly vulnerable to shocks and stresses arising from natural hazards. However, agricultural supply chains also include input supply, imports, exports, processing, marketing and distribution, retail, food service, storage, and the transport and communications that sustain the linkages between these various stages. The negative effects of shocks are not confined to primary production but can impact throughout the supply chain either directly on these upstream and downstream stages or by being propagated via the linkages between them. The effects of supply chain shocks can also spill over into related sectors and the economy at large, with broader consequences for employment, incomes and growth. With the increasing prevalence of global value chains, shocks can also be propagated across international borders. Supply chains can be traditional, modern or transitional, short or long with few or many stages, entirely domestic, even local, or spread across different countries. Understanding these linkages and supply chain behaviour is essential to designing effective and targeted interventions to manage risks and enhance resilience.

Governments, businesses and communities need to be prepared to ensure resilience and, to this end, they need to understand the nature of hazards that might lead to supply chain shocks. They also need to evaluate the threats these pose, judge whether supply chains have the necessary attributes to be resilient or not and make informed decisions on effective actions that might be taken to build resilience. These guidelines are intended to support policymakers tasked with identifying and implementing measures to build capacities for greater resilience in agricultural supply chains. They, in their turn, can help guide the actions of supply chain participants on whom much depends to take the steps necessary in adjusting business structures and practices to enhance resilience.

Agricultural supply chain resilience involves not only the capacity to be robust against shocks but also the capacity to recover from them and to develop greater resilience against future shocks. There are many different hazards and even more potential shocks to consider, and many supply chains for different commodities with widely different characteristics and importance. The range of policy choices is correspondingly wide. With limited resources, policymakers will inevitably need to prioritize in terms of which aspects of resilience to address and which shocks and supply chains or even which groups of stakeholders to focus on. To make such a prioritization, policymakers will need detailed assessments of the risks faced and the capacity to be resilient against them. The guidelines provide briefing material on the nature of hazards likely to give rise to supply chain shocks (Section 2), the capacities that are needed to make supply chains resilient against them (Section 3), and the measures that might be taken to build this resilience (Section 4).

These guidelines build on, complement and are aligned with the recently published FAO flagship publication *The State of Food and Agriculture 2021 – Making agrifood systems more resilient to shocks and stresses* (FAO, 2021a). That report provides evidence and guidance on actions that can help actors in agrifood systems manage their vulnerability to shocks and stresses, and is therefore much broader. In that report, FAO 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 guidelines are also based on research findings and practical experiences to inform policymakers. More research is necessary, especially on export commodities of importance to low- and middle-income countries and on supply chain stages other than primary production and the propagation of shocks between them. The broader project of which these guidelines form one output has therefore undertaken new empirical research into a range of relevant policy issues and experiences and made detailed case studies of how shocks, especially those associated with the COVID-19 pandemic, have affected the supply chains for specific commodities. The practical lessons of this research are summarized in a series of boxes attached to the main text. In addition, Table 2 in Chapter 4 provides a summary of recommended policy measures to strengthen different resilience capacities.

Desert locust swarms fly in northeastern Kenya.

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AGRICULTURAL SUPPLY CHAIN SHOCKS

Efforts and strategies to build supply chain resilience need to begin from a clear understanding of the nature of the main hazards faced in terms of location, intensity, frequency and probability. This information can be combined with an assessment, sometimes referred to as a "disaster risk" assessment, of the exposure, vulnerability and capacity of the supply chain and its elements to estimate the potential direct and indirect losses associated with each hazard, and these can be compared with the costs of risk reduction.

2.1 WHAT ARE HAZARDS, SHOCKS AND STRESSES?

Agricultural supply chains are exposed to a wide range of hazards that can potentially give rise to shocks leading to disruptions and economic damage, and, in extreme cases, can cause disasters. Hazards can be natural or human-induced or a combination of the two and there can also be important feedback links between them. Most of the hazards of concern to agricultural supply chains are "natural", which is a convenient term to encompass all those hazards not caused directly by human activities. Natural hazards arise from natural processes and phenomena and can be biological or geophysical, or climatological, hydrological and meteorological.[2] Biological hazards including plants and diseases, transboundary animal diseases, zoonoses and viruses are of organic origin and are spread by biological vectors. Geophysical hazards, arising from earth processes, include earthquakes, tsunamis, volcanic activity, landslides and mudflows. Climatological, hydrological and meteorological hazards are related to extreme weather and include droughts, floods, storms, typhoons and hurricanes. Human-induced hazards arise from human activity and choices and include conflict, policy shifts and financial crises, and technological hazards such as pollution, nuclear radiation, bioterrorism and cyber-attacks. Hazards can be single or multiple – drought, pests and conflict, for example – where one leads to others or several exist simultaneously

[2] We note that the lists of hazards are not meant to be exhaustive.

and can interact to generate even greater risk. Lack of preparedness or poor policy responses can also exacerbate damages and losses. Each hazard can be defined in terms of its location, its intensity or magnitude, its frequency of occurrence and the probability that it will generate shocks.

The various types of hazards with which agricultural supply chains contend, together with some specific examples, are summarized in Table 1, which also includes some of the underlying stressors.

▶ TABLE 1
Agricultural supply chain hazards

Natural – associated with natural processes and phenomena
Biological – organic origin
Plant pests and disasters, transboundary animal diseases, zoonoses, viruses, epidemics
Geophysical – earth processes
Earthquakes, volcanic activity, landslides, tsunamis
Climatological, hydrological and meteorological – short- and long-lived atmospheric, hydrological or oceanographic processes
Droughts, extreme temperatures, floods, storms, typhoons, hurricanes, wildfires
Human-induced – human activity or choices
Conflict, protracted crises, trade embargoes, financial crises, nuclear events, industrial pollution, oil spills, bioterrorism, cyber-attack, weak governance
Underlying stressors
Climate change, population growth, urbanization, natural resource degradation, deforestation, biodiversity loss, weak governance, misinformation

Sources: Adapted from Integrated Research on Disaster Risk. 2014. *Peril classification and hazard glossary (IRDR DATA Publication No. 1).* Beijing, IRDR; Centre for Research on the Epidemiology of Disasters. 2023. *EM-DAT*. Brussels, School of Public Health, UC Louvain. Cited 23 March 2022. www.emdat.be

Although a hazard is in some ways an abstract but present threat, it can become a real event or shock at a particular location and time, causing damage and losses or, in extreme cases, a disaster. Damage and losses resulting from agricultural supply chain shocks include not only physical damage to assets and critical infrastructure but also a loss of value added as a result of that damage and disruption. The direct economic losses are relatively easily identified and assessed. However, the consequent indirect economic losses may take time to emerge fully and be spread beyond the immediate supply chain even to the macroeconomic level, for example, in the case of export crop earnings. A majority of African countries are classified as being highly dependent on export commodities and lacking economic diversification. For these countries, lower commodity exports lead to lower government revenue and expenditure, lower growth, a worsening trade balance, currency depreciation and inflation, all of which ultimately mean increased unemployment, lower incomes, higher cost of living and possibly less government expenditure on food imports and social welfare.

However, the existence of a hazard does not necessarily lead to shocks or disasters, and not all shocks will necessarily lead to extensive damage and losses. The expected damage and losses resulting from a shock depend on exposure, vulnerability and resilience capacity, and these can be influenced by measures to enhance resilience and thus reduce losses. Exposure refers to who and what – people, capital and infrastructure – would be potentially impacted by a shock. Vulnerability refers to the extent to which people and assets would be negatively impacted and the conditions that influence it. Capacity, or coping capacity, refers to the overall ability of the affected human and physical capital to prevent, absorb or adapt to negative shocks.

How disruptive shocks are to supply chains depends on the nature, magnitude and persistence of the shock and the robustness and adaptability of the supply chain; together, these determine the extent to which shocks are attenuated through the supply chain. The agility of supply chain participants to "pivot", changing business and marketing practices, for example, and the opportunities for them to do so can maintain supply chain functionality in the face of shocks.

The dependency of agriculture on natural and environmental conditions means the continuous variability in these will have an effect on primary production and elsewhere through agricultural supply chains. However, not all variability can be regarded as shocks as opposed to stresses. Both hinder supply chain functionality. Shocks are typically sudden onset with an immediate impact and are largely unexpected, as in the case of earthquakes or floods. Stresses typically have a longer-term gradual effect that can usually be countered by adjustments on the part of supply chain participants. However, the distinction is not entirely clear-cut. Some shocks, such as drought or pandemics, can also be slow onset, building over time. Stresses arise from a variety of underlying trends such as climate change, increasing population pressure, urbanization or natural resource degradation and build up gradually over a longer period. They contribute to the level of risk by increasing the probability of shocks, exposure and vulnerability, and by reducing coping capacity. Climate change in particular has been linked to the increasing incidence of extreme weather events, pests and diseases. Measures to reduce underlying stresses can reduce the probability of shocks occurring. However, weak governance and policy are stress factors in themselves.

A further distinction to be made is with regard to predictability, a factor to take into account in defining appropriate responses to shocks and building resilience. For example, it may be feasible to prepare for more predictable shocks depending on the costs and benefits of the investments necessary to enhance resilience. Droughts and locust swarms, for example, are more predictable and amenable to early warning than other threats.

The nature of some hazards and associated shocks are sufficiently well understood that potential damages and losses can be estimated more easily based on past experience and existing knowledge. Appropriate resilience strategies can in principle be defined and implemented accordingly, provided the needed capacity and resources are available. Some hazards are so well known that they can be explicitly and specifically targeted, while for some animal diseases eradication is a realistic possibility, once again provided resources are available. However, some, and perhaps most, shocks are inherently unpredictable, with the potential to inflict major damage and are beyond the control of supply chain participants – so called "black swans" – and even where hazards and probabilities are well understood, there will remain some degree of "residual uncertainty".[3] Even in the case of black swan events, although the timing and exact nature of specific shocks cannot be predicted, there is an increasing probability that they will happen, and preparations for that eventuality can

[3] Risk refers to situations when all potential outcomes and their likelihood of occurrences are known, and uncertainty refers to situations under which either the outcomes and/or their probabilities of occurrences are unknown.

be made by taking broad-based measures to build general resilience, making supply chains more robust against shocks and quicker to recover and ensuring that effective social protection measures are in place to support affected populations.

2.2 WHAT ARE THE SHOCKS IMPACTING AGRICULTURAL SUPPLY CHAINS?

The recent discussion of agricultural supply chain resilience has understandably been dominated by the effects of the COVID-19 pandemic. However, the continuing incidence of other shocks and threats, including those occurring simultaneously, should not be overlooked. The COVID-19 pandemic has presented a unique challenge to agricultural supply chains, unlike those associated with other natural hazards, even other zoonoses. It does have a number of particular characteristics: the extended duration and unpredictable scale of disruption; the simultaneous spread of disruptions through supply chains and the spread of the pandemic through the population; the disruptions being caused more by the restrictive measures taken to control the pandemic than by the virus itself; and the simultaneous disruptions not only of supply but also of demand occurring throughout supply chains, including internationally. Understanding the differences and similarities between different hazards is important in terms of exploiting knowledge and experience to help identify appropriate practical and effective responses to enhance robustness and support rapid recovery.

The most striking difference between COVID-19 and other shocks is the sheer scale of its impacts spatially and through time, reflecting the high levels of exposure and vulnerability to the virus. Extreme weather events and biophysical shocks tend to be more localized with a sudden one-off impact that can involve the total destruction of production and a slow recovery before the shock is eventually overcome. The easy transmissibility of some zoonotic infections where vaccines do not exist, combined with the large amount of movement of peoples and goods in our global world, facilitate their spread at the regional and global level. The same also applies to some plant diseases. COVID-19 is global in reach, including developed countries that are often insulated from most shocks.

The propagation of supply chain disruptions and that of the COVID-19 pandemic through the population are linked partly through morbidity and mortality resulting from the virus itself, creating labour supply bottlenecks and reduced productivity throughout the supply chain, but are mainly a result of control measures to limit the spread of the disease. As the pandemic spread and the death toll rose, so measures to control movement and interaction became more restrictive, further disrupting supply chains. The Ebola Virus disease outbreak gave some indications of what could be expected on a regional scale, and the same might also apply to future zoonotic disease outbreaks. The risk of human infection and the need to control their spread mean that zoonoses also attract greater public concern than other threats, informed and misinformed by media coverage, adding to the potential for more widespread disruption of supply chains. If novel zoonoses are indeed a major threat for the future, the lessons of COVID-19 on supply chain impacts and the importance of robustness and adaptability to attenuate vulnerability need to be better understood.

For geophysical shocks, extreme weather events and pests and diseases, the initial impact is seen mainly on primary production. These sudden and unexpected shocks can lead to the destruction of crops, livestock, productive capital and infrastructure or, at the very least, to the reduction of productivity. The morbidity and mortality that arise from most natural hazards affect labour availability and hence primary production. Negative shocks to primary production can translate into reductions in food availability and food and nutrition security, compounding risks to labour availability. Agricultural supply chains upstream and downstream of farm production are indirectly

affected by farm production shocks and more generally face the same risks as any other supply chain. Impacts can range from minor interruptions to supply chain functioning, requiring similarly minor adjustments by participants, through to complete stoppages in activities at some or all stages and breakages in the linkages between them that challenge the ability of the supply chain to function.

Most shocks are indiscriminate in terms of which supply chains they impact, with only plant and animal diseases such as TR4 banana Fusarium wilt or African swine fever, for example, being intrinsically commodity specific. Others, while causing widespread damage, can also have particular impacts on specific sectors, as in the case of COVID-19 and tourism. The characteristics of certain crops or crop varieties might also single them out as being particularly affected or unaffected by different shocks. Therefore, it is important to consider commodities' specificities when designing measures to improve resilience.

One crucial difference between shocks is in the balance between direct economic losses caused by the physical destruction of supply chain capital and infrastructure and indirect economic losses caused by reduced flows through the chain. Extreme weather events and geophysical shocks impose both. Despite not causing direct damage to physical supply chain capital and infrastructure, the COVID-19 pandemic and the responses to it have been widely and persistently disruptive of supply chains, simultaneously impacting all components and spilling over into related supply chains on a global scale.

Most discussion of agricultural supply chain resilience focuses on resilience against supply-side shocks. This is understandable given the vulnerability of agriculture to natural hazards. However, demand-side shocks are also possible. The impacts of COVID-19 and the various responses to it were not confined to the supply side, as is the case with most other shocks, but they also influenced the demand for agricultural products. For example, lockdowns in European countries led to the collapse of demand for cut flowers, causing considerable losses in export revenue and household incomes in exporting countries, such as Ethiopia, Kenya and Uganda. Retail and food service demands were constrained and purchasing and consumption patterns shifted because of reduced employment, incomes caused by business closures, and restrictions on movement. Intermediate demands were constrained by reduced processing and transport capacity, and market closures. Business losses as a result of falling demands and shifting preferences can prove difficult to recover, especially in the changed circumstances where new sales channels, such as greater direct selling, have evolved.

The focus of discussions of agricultural supply chain resilience has also been on natural hazards, again understandably. However, human-induced hazards and the possibility that human action or inaction make natural hazards more damaging should not be overlooked. It is sometimes difficult to separate human-induced from natural hazards as the distinction between them is not always clear-cut. War and civil conflicts are obviously human-induced, as are financial crises, trade wars and embargoes, and other policy shocks. However, it is recognized that feedback links between insecurity, conflict, climate change and variability, as well as resource constraints, are possible. Other shocks are less clearly demarcated. Bioterrorism, for example, deliberately uses plant and animal pests and diseases to disrupt agricultural supply chains. Similar issues are raised by the possibility of cyber-attacks on modern food supply chains heavily reliant on automation and digitalization. While arguably an increasing threat, deliberately inflicted damage to food supply chains has been little researched.

Shocks at any one stage of the supply chain are not only propagated through other stages but can also spill over into related supply chains and the economy at large, with broader consequences for employment, incomes and growth. This also works in reverse. The increasing interconnectedness of agriculture to other economic sectors means that shocks can spread quickly from sectors such as energy, shipping or finance to agrifood systems. For example, fertilizer supply chains have been badly disrupted by the COVID-19 pandemic and the related disruptions of transport and energy

markets.[4] Natural gas is a key ingredient in the production of nitrogen fertilizer, and the rapid increase in energy prices in 2021 led to higher fertilizer prices as well as spiralling transport costs and longer transit times. The recovery in demand, coupled with transport bottlenecks, also drove up the prices of agricultural goods. This, in turn, initially stimulated demand for fertilizer, which at that point was more affordable. Low levels of fertilizer stocks, export restrictions by some countries, the imposition of sanctions on Belarus (an important producer of potash) and the Ukraine war have added to supply constraints and pushed fertilizer prices further up, raising serious concerns about the availability and affordability of fertilizer, especially in low- and middle-income countries (FAO, 2022; Hebebrand and Laborde, 2022). The adverse developments in fertilizer markets highlight the need for research and analysis across the supply chain, the importance of information and transparency, and the imperative need for international cooperation towards finding solutions to the crisis, which ultimately threatens the food security of many countries.[5]

This interconnectedness needs to be taken into account by national policymakers in defining policies and strategies for agricultural supply chain resilience. The increasingly global nature of agricultural production and trade makes agricultural supply chain resilience an international issue calling for action or at least coordination on an international scale.

Agricultural supply chains and systems are not only affected by the various hazards but can also contribute to them, and especially to underlying stresses such as climate change (FAO, IFAD, UNICEF, WFP and WHO, 2018). Agricultural production, notably livestock production, and land-use conversion following deforestation together account for approximately 23 percent of global net greenhouse gas emissions while agrifood systems more generally account for around a third (Crippa *et al.*, 2021). Agrifood systems occupy 37 percent of the Earth's land area and continue to contribute significantly to deforestation. Livestock production, markets and processing under poor hygiene and working conditions have been a major source of zoonotic diseases, including COVID-19 and Ebola, which account for 75 percent of newly discovered or emerging infectious diseases (FAO, 2021a). The nature of modern agricultural supply chains can also magnify risks. The trends towards greater scale, specialization and market concentration in pursuit of greater efficiency and lower costs can go against those features of supply chains associated with greater resilience such as diversity and "redundancy", whereby critical supply chain elements are duplicated.

2.3 ARE SHOCKS BECOMING MORE FREQUENT?

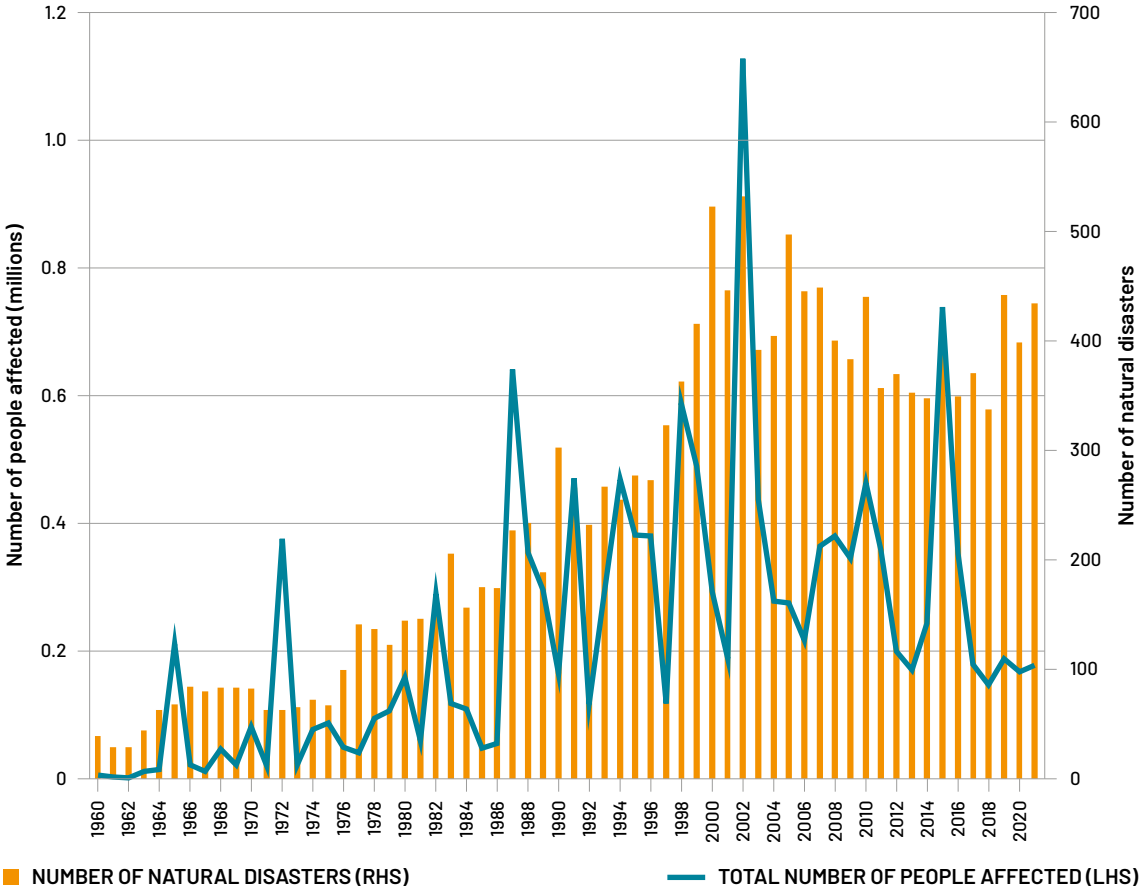
There is evidence that the incidence of shocks has increased over the last fifty years as a result of the underlying stresses of climate change and increasing pressure on natural resources. While the range of hazards has remained the same, with the possible exception of new zoonoses, it appears that the probabilities of shocks associated with them have increased. Figure 1 shows trends in the incidence of natural disasters; the increase and persistently higher frequency in the incidence of shocks has added to current concerns about resilience and how it might be enhanced. Within the aggregate of natural disasters, the incidence of extreme weather events such as droughts, floods and storms associated with climate change has increased significantly, by a factor of four over the last fifty years, and at an increasing rate. The incidence of earthquakes and other geophysical shocks has remained fairly stable. Plant pests and diseases have increased dramatically in frequency

[4] A considerable amount of fertilizer is traded internationally: 38 percent of nitrogen, 50 percent of all phosphorous and 80 percent of all potash.
[5] The 20th Session of the Global Food Market Information Group of the Agricultural Market Information System (AMIS) expressed interest in the greater availability of market information and analysis of input costs.

although there has been some progress in early warning and control. Dramatic increases have also been reported for transboundary animal diseases and, especially, zoonoses (FAO, 2021b). It is likely that these underlying stresses have also led to an increase in exposure and vulnerability, as well as probabilities. For instance, population growth has increased population densities and closer proximity between human and animal populations, for example, facilitating the spread of zoonoses.

▶ FIGURE 1

Natural disasters: frequency and total number of persons affected, 1960–2021



Source: Centre for Research on the Epidemiology of Disasters. 2023. *EM-DAT*. Brussels, School of Public Health, UC Louvain. Cited 23 March 2022. www.emdat.be

Statistics on the incidence of shocks and their economic damage are likely to understate their true extent as only those of significant magnitude are considered. It is estimated that for each such catastrophic event in the Caribbean and Latin America there were 177 minor events or "extensive phenomena" (FAO, 2017). Many shocks that have significant local impacts may be overlooked. Estimates of economic damages in the agriculture and food sector will also underestimate their significance where they are estimated on the basis of comparisons of actual primary production during shocks with expected trend production. Primary production is just one element in the agricultural commodity supply chain, and losses calculated in this way tell only part of the story.

2.4 MORE RESEARCH ON THE IMPACT OF SHOCKS ACROSS ENTIRE SUPPLY CHAINS IS NEEDED

Policymakers need a detailed understanding of how different shocks impact on agricultural supply chains in order to support the formulation and implementation of policies and strategies to strengthen resilience. This should be based on empirical research. The number of relevant empirical studies is growing, but there are gaps to be filled. The main issues relate to the limited commodity coverage and the only partial coverage of different supply chain components. Research gaps are also a reflection of data limitations, and closing these data gaps should be considered a policy priority.

The research literature on shocks to agricultural supply chains focuses particularly on primary producers and consumers. Studies of complete supply chains for different commodities, including downstream and upstream activities and the links between them such as prices, intermediate markets, and vertical integration and contracting, which propagate shocks, are less common. There have been no detailed supply chain studies for a broad enough range of commodities to indicate what kinds of supply chains are most resilient or which strategies to enhance resilience are the most effective. There are few studies on those cash crops, especially agricultural raw materials that are of particular economic importance to low- and middle-income countries. This points to the need for detailed supply chain case studies. Particular account needs to be taken of the role of shipping and the transport bottlenecks that have been highlighted by commodity exporters but remain under-researched.

Overall, it would be beneficial to have more empirical and case study research into how supply chains for different agricultural commodities have been impacted by different shocks and how effective the various policy and strategic measures have been.

3 DEFINING RESILIENCE

3.1 WHAT IS RESILIENCE?

Definitions of resilience tend to describe an ideal against which existing states can be compared and used as a standard to achieve through different policies and strategies. In practice the issue is not so much whether there is resilience or not as how much resilience there is. The United Nations defines resilience as:

> By resilience is meant 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.
> (United Nations, 2017, p. 25).

More operational definitions of resilience depend on the context but typically introduce the idea of either or both of the following: (i) simple continuity of function or (ii) continuity in the achievement of desired goals by resistance to shocks or by adaptation to overcome them. Much of the discussion of the impacts of COVID-19 and other shocks has focused on the resilience of food **systems** in their ability to deliver food and nutrition security in the face of shocks. In this case, the functional goal of ensuring food security when exposed to shocks is easily specified (Tendall *et al.*, 2015). While food consumption may not be explicitly considered, resilience in food products' **supply chains** is crucial to at least the availability, access and stability dimensions of food security. For non-food products, including raw materials of interest to developing country exporters, the functional goal of resilience is less easily specified but might include maintenance of export revenues and trade balance, government revenues, employment, incomes, growth and poverty reduction, as well as food security and nutrition. Whatever the products concerned, the interests of producers as well as consumers should not be overlooked. For producers, the minimization of losses may be the key consideration in defining resilience, and this may not be entirely captured by simply requiring continuity of supply chain functions.

Continuity is the bridge between resilience and sustainability. Resilience implies a capacity to continue to function and to achieve goals in spite of exposure to shocks while sustainability

implies a capacity to continue to function in the future. In the face of disturbances and shocks, therefore, resilience is a necessary condition for sustainability. As the Sendai Framework for Disaster Risk Reduction pointed out, disasters undermine efforts to achieve sustainable development and compromise progress towards greater sustainability (UNISDR, 2015).

Continuity of function in supply chains may not always be a desirable feature of resilience without also referring to costs and efficiency, as trade-offs may be involved. Diversity and redundancy, for example, may improve resilience but may also reduce supply chain efficiency and raise costs. Not all resilience is necessarily desirable, and unqualified continuity may therefore also not be welcome where there is a need to overcome "undesirable resilience" obstructing necessary adaptations and transformations (Oliver *et al.*, 2018).

Based on the considerations above, a working definition of agricultural supply chain resilience with general applicability might be: "The ability of the supply chain to continue to fulfil its functions efficiently when exposed to disturbances and shocks based on its capacities to anticipate and absorb those that cannot otherwise be prevented, and to recover from them by adapting the nature of their behaviour and practices or transforming them so as to build back better".

3.2 WHAT CAPACITIES ARE NEEDED FOR RESILIENCE?

This definition encompasses the various dimensions of resilience and preparedness, implying a dynamic through a sequence of phases in relation to the incidence of a shock: the robustness of supply chains to resist shocks and absorb their impacts followed by recovery to normal functioning and the development of more resilient structures against future shocks. Thus, resilience requires that the supply chain demonstrates strength across five capacities: **preventive**, **anticipative**, **absorptive**, **adaptive** and **transformative.**[6]

- **Anticipative capacity** is the ability to predict coming shocks through, for example, early warning and, to take pre-emptive action to avoid or reduce their potential negative impacts. Obviously, not all shocks can be predicted or avoided.
- **Preventive capacity** is the ability to take measures to reduce exposure and vulnerability to shocks and stresses so as to reduce existing risks and avoid creating new ones. This might include the elimination of risks, such as plant and livestock disease, through research or the construction of flood defences.
- **Absorptive capacity** is the innate ability of the supply chain to absorb shocks and stresses so as to maintain normal functioning without the need for discrete remedial action. Stocks and trade, for example, can offset shortfalls in supply in the immediate and short term following a shock.
- **Adaptive capacity** is the ability to make more significant adjustments to the behaviour of the supply chain over the short and medium term in order to restore its normal functions following a shock and to ensure that it is more resilient against future shocks. This would include such examples as the switch to direct selling and online sales during the COVID-19 restrictions.
- **Transformative capacity** is the ability to make major changes over the longer term to the structure and conduct of supply chains where the scale and impact of shocks are beyond their capability to absorb or adapt. Such transformations can effectively create fundamentally new structures and ways of working.

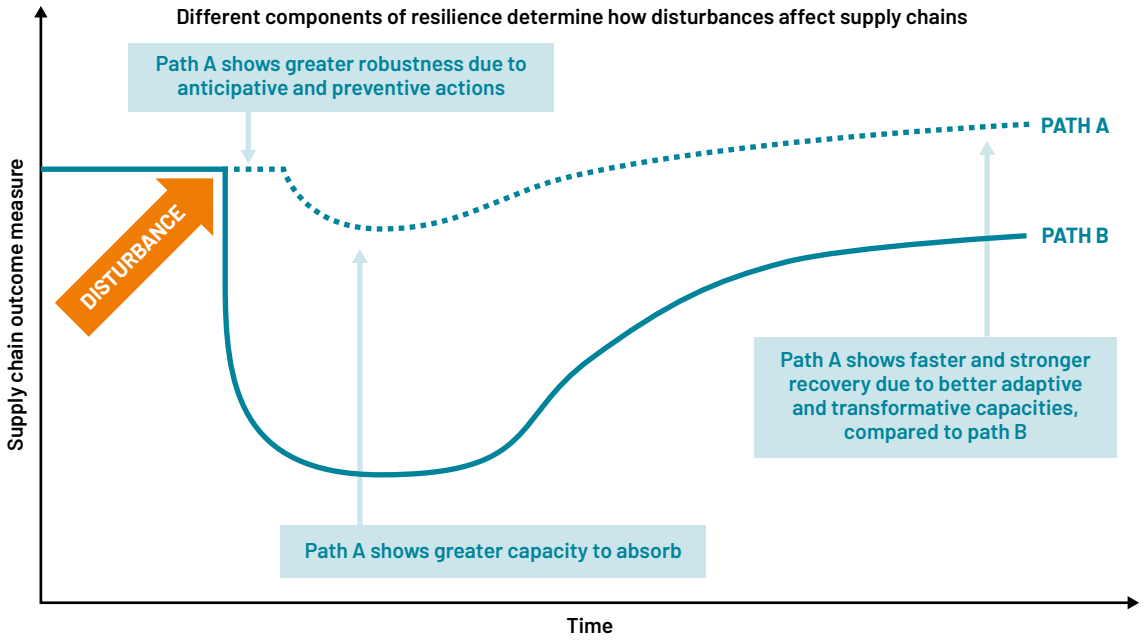
[6] The terminology and concepts used follow FAO (2021a).

In practice, these five capacities will overlap to some extent, and the sequence of when they come into play is not always clear, although some generalization is possible: in general, prevention is immediate, absorption is short to medium term, adaptation is short, medium and longer term, and transformation is longer term. Preventive, anticipative, absorptive and adaptive capacities all contribute to the state of preparedness for likely or imminent shocks and the robustness of supply chains to withstand them. Adaptive and transformative capacities support eventual recovery from current shocks and the reduction or prevention of future shocks. Actions to build resilience aim to strengthen these capacities either directly or by reinforcing certain attributes of agricultural supply chains, notably diversity, redundancy and connectivity, which have been identified as contributing to the different capacities, especially absorptive and adaptive capacities, and as underpinning resilience. Building resilience is a long-term, continuous process, but actions addressing different dimensions of resilience have a different timescale of effects, illustrated in Figure 2.

Agricultural supply chain resilience involves the whole supply chain and each element within it. It might be desirable for each element to be resilient individually as one weak link can weaken the whole chain. However, resilience of the supply chain need not require all its elements to be resilient as there is always scope for adaptation and innovation to bypass failing elements. Nevertheless, all supply chain actors have a role and responsibility in securing resilience. In fact, the diverse linkages of agricultural supply chains with other sectors, including the international sector, mean that resilience also depends on many issues and actors outside the specific supply chain. Effective communication, collaboration and connectivity among all these interested parties are additional attributes supporting the five capacities for resilience. Promoting them can be an important part of government support.

▶ FIGURE 2

Resilience capacities and response to a shock



Source: Adapted from Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Kruetli, P., Grant, M. & Six, J. 2015. Food system resilience: defining the concept. *Global Food Security*, 6: 17–23.

An irrigation canal built to reinforce the capacity of producers and to improve the livelihoods of vulnerable populations.

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4 BUILDING RESILIENCE

Measures to build greater resilience in agricultural supply chains have four broad overlapping objectives. The first concerns an understanding of to whom the resilience process should be directed. This requires a mix of actions that refer to a retrospective evaluation based on the existing evidence, a forward-looking simulation of the shock and an *ex ante* predictive procedure aimed at targeting the most vulnerable actors. The second is better preparedness for and robustness against eventual shocks to allow their negative effects to be averted or absorbed and to ensure that supply chain functionality be maintained as much as possible. The third is support for rapid recovery from shocks, including support to affected populations. The fourth is a forward-looking measure to transform supply chains towards greater resilience against future shocks. These broad objectives match the different resilience dimensions: prevention, anticipation, absorption, adaptation and transformation.

Strengthening resilience is a continuous process and a moving target as supply chains evolve and new threats emerge. In short, measures are intended to reduce exposure and vulnerability and to build preventive, anticipative, absorptive, adaptive and transformative capacities. Governments have a primary role in reducing risks, but all other stakeholders contribute towards the same goal, including supply chain participants who take practical steps towards creating more resilient business structures and practices in order to enhance resilience. Government involvement is essential to foster collaboration among stakeholders in the public and private sectors. Global threats, such as transboundary diseases, call for international collaboration and action.

4.1 DEFINING RESILIENCE POLICY STRATEGIES

Five different resilience capacities as well as general resilience and preparedness, many different hazards and potential shocks, and many supply chains for different commodities with different characteristics and varying economic, social and political importance mean that policymakers face a bewildering array of policy choices. With limited resources at their disposal, policymakers will need to define strategic priorities: for example, to focus on building particular resilience capacities or selected strategic commodities, or on carrying out specific interventions such as cooperative development with cross-cutting benefits. Priorities will be shaped by broader political and economic objectives and guided by detailed assessments of the risks faced and the capacity to be resilient against them. A similarly wide variety of specific policy measures can be assigned to the strategic priorities defined.

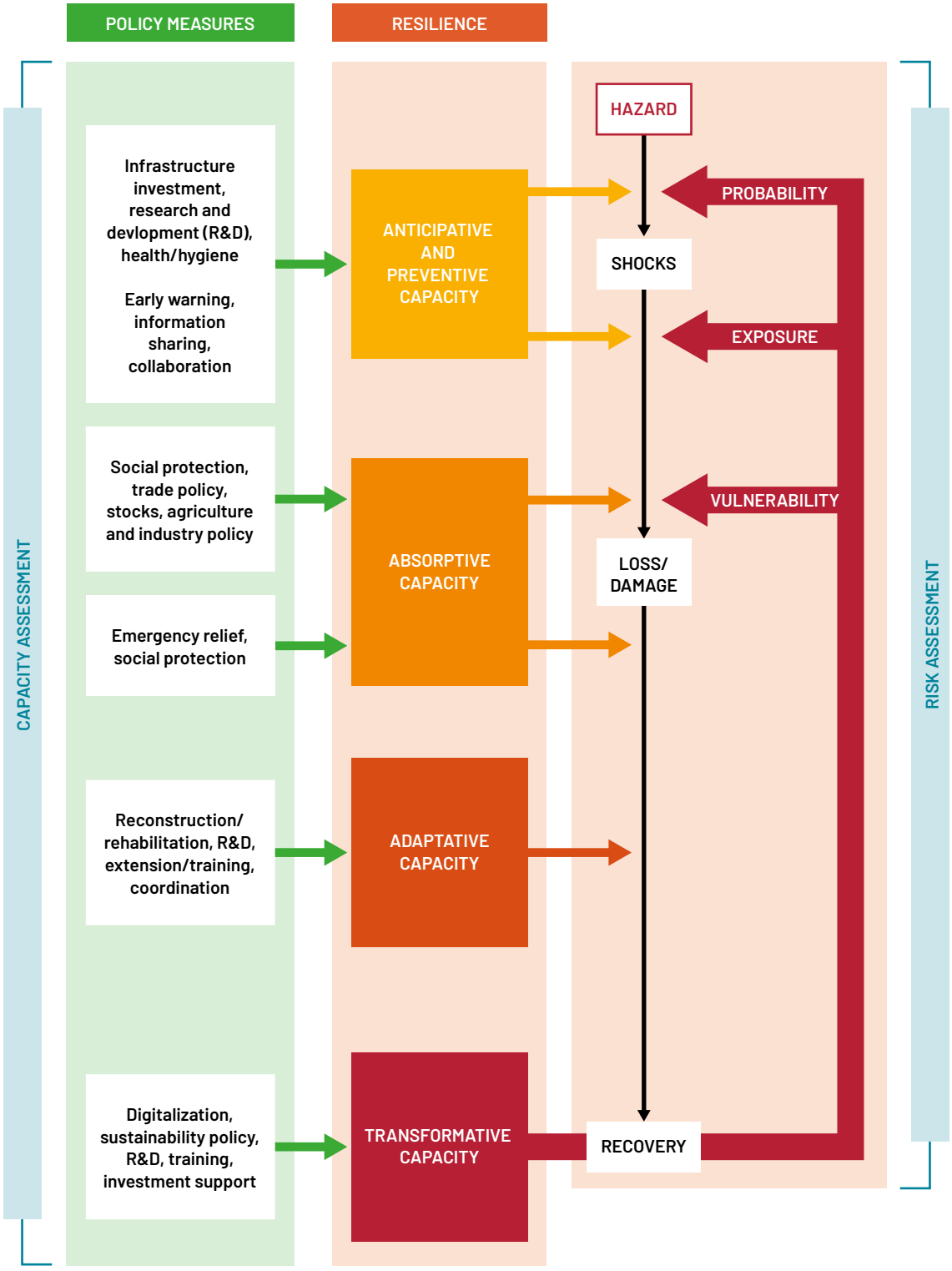
Figure 3 summarizes the different elements of the policy environment and the connections between them. The central part of the diagram shows the timeline from hazards to the incidence of shocks, the inflicting of damage and losses, and eventual recovery. The right-hand side shows how the incidence of shocks, damages and losses are determined by probability, exposure and vulnerability, elements that are the focus of risk assessment. The left-hand side shows how the five resilience capacities modify the incidence of shocks, damages and losses, and recovery both directly and indirectly via their effects on probability, exposure and vulnerability. This set of relationships is the focus of capacity assessment. The left-hand side also shows some of the wide range of policies that can strengthen the five resilience capacities.

Risk is a function of probability and impact. In its turn, impact depends on the size of the shock but also on the degree of exposure, i.e. the situation of people and physical assets in hazard-prone areas, as well as the degree of vulnerability, i.e. the physical, social, economic and environmental factors or processes that determine the susceptibility of people, communities or assets to the adverse impact of a shock. Interventions that strengthen resilience capacities can also modify the probability and exposure of, and vulnerability to, shocks. For example, some shocks are, at least in part, endogenous (for example, climate change and the emergence and spread of COVID-19 are rooted in human behaviour), and appropriate policies may be able to influence their probability and impact. Altering consumer behaviour to affect greenhouse gas (GHG) emissions and vaccination programmes, for instance, can change the dynamics of climate change and of a zoonotic outbreak. Other interventions, such as building sea defences or drainage systems, early warning systems and social protection will impact exposure and vulnerability but not necessarily the probability of a shock.

Different measures contributing to improving each resilience capacity are summarized in Table 2, which complements Figure 3 by providing examples of policy measures. Some of these measures come from the research undertaken for this project; however, as indicated in Table 2, other sources are also drawn on. The assignments to the different capacities cannot be definitive as many of the measures relate to more than one dimension and hence overlap. In addition to measures with a specific focus, many different policy areas can contribute to enhancing supply chain resilience, including trade, agriculture, food, industry, environment, employment, health, social and infrastructural areas, and regional, fiscal and monetary policies. Boxes 1 and 2 provide illustrative examples of strategic priorities identified by stakeholders for the cotton sector in Burkina Faso and the cocoa sector in Ghana.

FIGURE 3

Policy environment for strengthening resilience



Source: Author's own elaboration.

▶ **BOX 1**

Bottlenecks, stresses and risks in the cotton supply chain in Burkina Faso: recommendations to increase its resilience

Cotton plays an important role in the economy of Burkina Faso. About 20 percent of the population derives its income directly from cotton and related activities. The cotton sector accounts for more than 4 percent of GDP and about 14 percent of the country's export earnings. The COVID-19 pandemic resulted, especially in 2020, in an unprecedented change in global economic conditions which affected the international cotton markets and supply chains. A paper by Artavia Oreamuno (forthcoming) analysed the resilience of cotton supply chains in Burkina Faso and determined that the following recommendations were key to strengthening them:

1. Improve income margins and liquidity to build absorptive resilience.
   - Make the domestic price-setting mechanism transparent and improve the representation of farmers' interests in the price-setting process.
   - Provide customized financial options (e.g. warehouse receipt systems, saving groups) to increase the liquidity of farmers, to allow for the purchase of agricultural inputs and continuous access to basic services (payment of school fees, medical services, transport, repayment of debts).
2. Build adaptive resilience through changes in natural, physical, human, social, financial and institutional capital.
   - Promote sustainable land-use intensification and rehabilitation of degraded soils.
   - Research and implement affordable and environmentally friendly pest management approaches.
   - Provide low-cost irrigation options with low-maintenance requirements where water resources are available.
   - Study different customized mechanization options especially for poor farmers (two-wheel tractors, animal draft power), and offer different options to provide access (rental markets, sharing options through cooperatives, loans using the already established cotton companies – cooperative management system, saving groups).
   - Build trust in the governing institutions and encourage a more equitable distribution of powers (improve representation of farmers' interests).
3. Build transformative and anticipative resilience through the generation of value-added markets and the preparation for climate change.
   - Continue to develop local textile and garment industries towards output market diversification.
   - Invest in Climate Information Services (CIS) that help farmers to make informed decisions and thereby raise yields with little additional effort.

Source: Artavia Oreamuno, M.A. (forthcoming). *Bottlenecks, risks and stresses in the cotton supply chain in Burkina Faso – Recommendations to increase its resilience.* Rome, FAO.

▶ BOX 2

Bottlenecks, stresses and risks in the cocoa supply chain in Ghana: recommendations to increase its resilience

Cocoa is a key sector of Ghana's economy, contributing about 2 percent of GDP as well as providing a livelihood, or part thereof, for about 30 percent of the population. A paper by Artavia Oreamuno and Croppenstedt (forthcoming) determined that the following recommendations were key to strengthening the cocoa supply chain in Ghana:

- Build preventive and anticipative resilience by investing in Climate Information Services (CIS) that help farmers make informed decisions and thereby raise yields with little additional efforts. Promote dynamic agroforestry as a production system option reducing pest pressure, providing income diversification, increasing the variety of food groups available to households (promoting healthier, more nutritious diets), and increasing the fertility of soils and reducing soil degradation (through higher biodiversity). Design and implement customized early warning systems for the types of risks which can be prevented, such as wildfires and, to a certain extent, also pests and diseases.
- Build absorptive resilience through providing customized financial options, agriculture and weather insurances, soil management programmes, and income diversification possibilities. Customized financial options are key to addressing the problem of financing high production costs (labour and land) as well as to providing access to new technologies and to a sustainable upscaling of production, necessary to increase profitability. Agricultural and weather insurances provide a safety net for farmers who heavily depend on income from cocoa, contributing to food security and helping them avoid falling into poverty.
- Build adaptive resilience through irrigation and youth programmes. Irrigation has the capacity of addressing the strongest stresses and constraints (irregular rainfall, extreme temperatures and droughts), and it has the advantage of presenting high stakeholder interest. However, options are often costly. Furthermore, irrigation programmes must be accompanied by thorough institutional management ensuring the responsible use of the resource. A stronger involvement of youth would address the aging problem of cocoa farmers and has the potential to improve yields and enhance technology adoption, which are key to coping with future challenges such as climate change.
- Build transformative and adaptive resilience by improving roads and ICT systems, and by increasing domestic capacities for processing cocoa beans. Improving roads enhances smallholder productivity (better market integration, more use of farm inputs) and reduces forest encroachment. Improved ICT systems help farmers to make informed decisions and thereby raise yields with little additional effort. Increasing domestic processing capacities would diversify output markets and result in the generation of value added. Raising yields through improved pest and disease management, investment in irrigation, and ensuring the availability and accessibility of inputs such as fertilizer and tractors is essential to boost incomes and it is also essential to continue to invest in research and development of new varieties that are more responsive to fertilizer and that are more resistant to drought, temperature extremes, and pests and diseases.

Source: Artavia Oreamuno, M.A. & Croppenstedt, A. (forthcoming). *Bottlenecks, stresses and risks in the cocoa supply chain in Ghana – Recommendations to increase its resilience*. Rome, FAO.

▶ TABLE 2

Measures to strengthen resilience capacities

RESILIENCE CAPACITY	EXAMPLES
Anticipative	
Establish effective early warning and forecasting systems Implementation: **medium to long term** Impact: **short term**	Establish monitoring systems to alert when agrifood systems and the associated agricultural value chains are nearing vulnerability thresholds. For example, FAO's Global Information and Early Warning System on Food and Agriculture (GIEWS), established following the generalized food crisis of the 1970s, continuously monitors food supply and demand and other key indicators in order to assess the overall food security situation in all countries of the world. With regard to emerging diseases, investments in surveillance and in coordinated human, animal and environment health services are also needed to ensure that zoonotic outbreaks do not turn into full-scale epidemics, or pandemics (for more details, see FAO [2021a]).
Promote knowledge generation, information-sharing, transparency and collaboration Implementation: **medium term** Impact: **medium to long term**	For example, with banana Fusarium wilt TR4, early warning, the implementation of strict preventive measures, experience and lessons from concerned countries and investment into research and development are critical in strengthening resilience (Altendorf, forthcoming). Prevention and control of zoonotic diseases can be strengthened through better interdisciplinary science. In particular, it is important to include the study of the impact of human social behaviour on the natural world, as well as the emergence and spread of disease. For example, the *One Health* approach is a collaborative effort across multiple disciplines and is considered the optimal method for preventing as well as responding to zoonotic disease outbreaks and pandemics (United Nations Environment Programme and International Livestock Research Institute, 2020). Strengthen global, regional and country level collaboration and coordination on building climate resilience through, *inter alia*, climate risk assessments. This includes strengthening coherence among different platforms such as the Sendai Framework for Disaster Risk Reduction and the UNFCCC Paris Agreement (FAO, IFAD, UNICEF, WFP & WHO, 2018).
Undertake resilience capacity assessment at national and firm level Implementation: **short to medium term** Impact: **short term**	Possible policy actions at national level include assessing countries' economic, financial, environmental, social and physical assets within the context of risk preparedness and exploring the possibility of stress testing key supply chains to assess their robustness and their ability to return to normal functioning following shocks (FAO, 2021a). Possible policy actions at firm level include identifying and evaluating risks at various stages in their supply chains and commissioning quantitative assessments on the relative importance of different segments in the value chain as a means to set priorities.
Address underlying stresses such as climate change, urbanization and natural resource degradation Implementation: **medium to long term** Impact: **medium to long term**	Addressing country and supply chain-specific risks and stressors as a resilience measure could positively impact supply chain resilience and, more generally, livelihoods and food security. Raising awareness and understanding, through public education and communication, of disasters and adaptation among suppliers/producers/retailers by drawing on market knowledge and technical capacity is essential to address the underlying stresses.

▶ TABLE 2 (CONT.)

RESILIENCE CAPACITY	EXAMPLES
Building resilience into systems Implementation: **long term** Impact: **short to medium term**	Promoting diffusion of digital technology can improve risk management. Promoting Responsible Business Conduct (RBC) principles and standards could help reduce risks of supply disruption and minimize the negative social and environmental impacts through providing a common framework for public-private collaboration and improving businesses' knowledge of their supply chains and build the capacity to anticipate and respond to future markets (OECD, 2020). Improving implementation of biosecurity measures, especially among small-scale livestock keepers, helps prevent and control zoonotic disease outbreaks and facilitate rapid and adequate emergency responses (FAO, 2021b).
Preventive	
Build infrastructure that reduces vulnerability and exposure to shocks Implementation: **medium to long term** Impact: **short term**	When possible, public infrastructure should be disaster proofed. One example of this is to use seismic engineering designs to ensure survival and function of critical buildings during earthquakes (United Nations, 2016). Putting appropriate infrastructure in place can help reduce risks and impacts. Examples include dams and embankments. Reservoirs and other water storage facilities/methods can serve a preventive role as well as an absorptive one.
Making trade policy preventive Implementation: **medium term** Impact: **short term**	Introducing trade-promoting measures on a more regular long-standing basis can improve the resilience of global agricultural markets and might help prevent major disruptions in future crises.
Strengthening farmer productivity Implementation: **medium to long term** Impact: **short to medium term**	Targeting farmer inefficiency through training, education, extension services and so forth can help farmers cope with shocks. More efficient farmers can expect to enjoy both higher profits, lower poverty levels and higher food security, on average, thereby increasing their resilience to external shocks on agrifood supply chains. Higher profits also allow for greater savings and investment, further strengthening resilience. In addition, improving efficiency strengthens farmers' absorptive and transformative capacities (Nano, forthcoming). Pre-planting advice may also help farmers avoid constraints and use resources efficiently, for example, providing advice on appropriate fertilizer use or helping farmers to switch to crops that use less fertilizer.
Absorptive	
Strengthen infrastructure Implementation: **medium to long term** Impact: **short term**	Enhance the diversity and redundancy of networks that connect ports and key transport nodes.* Develop market efficiency through investing in rural infrastructure, removing market barriers, establishing clear and enforceable property rights and creating better access to financial instruments.
Providing emergency financial assistance Implementation: **short term to medium term** Impact: **short term**	Facilitating access to short-term finance to actors along the chain will help avoid the collapse of the supply chain. Other options include emergency finance and loan forgiveness, as well as the provision of insurance.
Establishing fall-back options Implementation: **medium to long term** Impact: **short term**	Creating redundancy, i.e. the duplication of critical components and functions, may be optimal, although costly, when continuity of production has a very high priority. It is important to be aware that redundancy and supply chain diversity can be costly and can involve a trade-off with efficiency (FAO, 2021a). Establishing national food stocks can buffer the impact of shocks affecting staple foods. To increase their effectiveness, they should be integrated with social and food security safety nets and other food assistance programmes.

▶ TABLE 2 (CONT.)

RESILIENCE CAPACITY	EXAMPLES
	They must also be carefully designed, adequately funded and supported by effective early warning systems. FAO developed the dietary sourcing flexibility index 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.** Social protection measures help vulnerable households absorb and adapt to shocks. 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. Governments should aim to identify and target the worst affected groups in advance, i.e. identify vulnerable hotspots, groups and communities, distributed across supply chains before the shock occurs, and take preventive action accordingly.
Diversification is important Implementation: **medium to long term** Impact: **short term**	Policy options include diversifying production, imports and exports. Import diversification helps restrict potential domestic market shocks originating in international markets. Keeping a wide portfolio of trade partners is imperative to ensure a stable food supply chain (see FAO [2021a]). In addition, creating domestic demand and looking for new export markets could be strategies to diversify output markets. Investing in final processing and higher value products are additional ways to diversify. This has a preventive element (reducing exposure and vulnerability) as well as building absorptive resilience. At household level, education, income diversification and cash transfers are key to strengthening resilience capacity. This also has an element of building preventive resilience. Firms may invest in supplier relationships if supplier diversification is difficult. Strong relationships are more resilient.
Facilitate continuity Implementation: **short term** Impact: **short term**	Continuity can be enhanced by identifying and targeting key nodes along the supply chain.
Trade policy can lessen or worsen the impact of a shock Implementation: **medium to long term** Impact: **short term**	Keeping trade routes open is critical as border closures and supply chain disruptions, including through delays at the border, can result in losses when commodities are highly perishable (Altendorf, forthcoming). Despite the very short-lived nature of export restrictions, their disruptive effect on agricultural trade should not be disregarded. Export restrictions were unequally imposed across key exporting countries (Soguero Escuer, forthcoming). Governments should aim to facilitate trade by removing trade barriers and ensuring the smooth functioning of international transportation and customs. Trade agreements can facilitate continuity in trade in times of crisis. Existing trade frameworks suffer gaps in dealing with a shock like COVID-19. Going forward, regional trade agreements should be revisited and greater emphasis placed on trade-facilitating measures, while mitigating the effects of trade-restrictive measures. Essential goods and services should be given priority treatment during times of crises (Kuhlmann, 2021).

▶ TABLE 2 (CONT.)

RESILIENCE CAPACITY	EXAMPLES
Adaptive	
Promote collaboration, information, sharing, transparency and risk-sharing across chains **Implementation: medium to long term** **Impact: short term**	Scale is important for adaptive capacity and can also be achieved by firms engaging in collective action. Governments can facilitate establishing cooperatives or other forms of intra-firm collaboration through a supportive policy environment. Creating strong networks will help resolve challenges along the supply chain. Formal mechanisms to share information and facilitate collective action can be effective.
Transformative	
Innovation can strengthen resilience in the long term **Implementation: medium to long term** **Impact: medium to long term**	Policy options include investing in 1) online platforms, e-commerce, innovative ICT applications, livestreaming videos and social media, online stores, contactless delivery; 2) innovative marketing of produce such as direct delivery at business location, e-commerce and delivery; 3) ePhyto certificates and digital documentation; and 4) creating new markets using social media and online farmers markets (FAO, 2021a; FAO, 2021c). Investment in research and development to address stressors (e.g. poor soil quality, climate change, poor governance, unavailable or expensive inputs) is important for transformation in many areas. Examples include crops that do well under hot and dry growing, and tools, such as variable rate fertilizer application methods and precision agriculture. Disasters can even offer new opportunities to build back better, whereby people can be assisted to transition from unsustainable practices towards a more risk-sensitive and viable management of resources that enhance resilient and sustainable livelihoods. Increasing downstream processing capacities generates value added and leads to the diversification of output markets. Transforming food systems so that they increasingly rely on natural synergies and harness biological diversity for food production while protecting important wildlife habitats helps strengthen supply chain resilience over the longer term.

Notes: * *The State of Food and Agriculture 2021* developed develop indicators of resilience of transport networks specifically in relation to food systems. These are available for 90 countries (FAO, 2021a). ** The indicator was developed for *The State of Food and Agriculture 2021* and is explained and presented in that publication (FAO, 2021a).

Source: Authors' own elaboration.

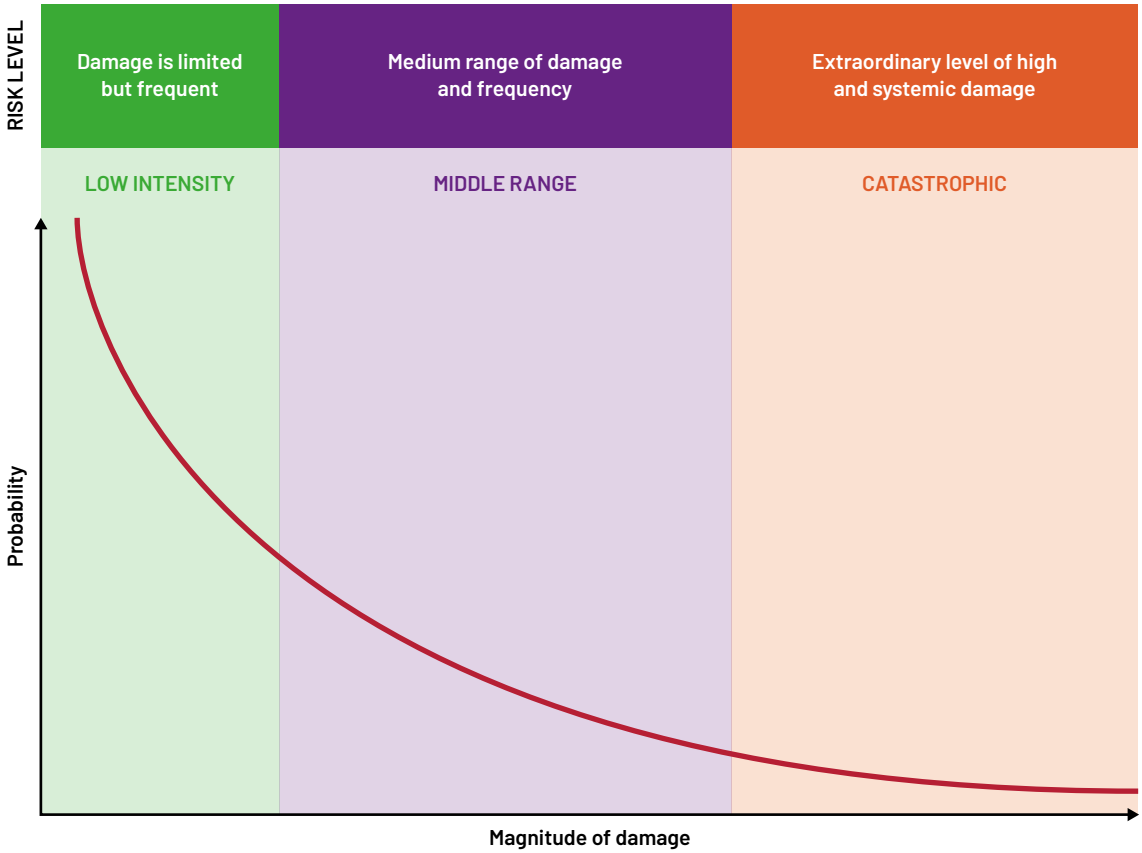
As improving resilience also involves costs, any necessary investments require careful appraisal. The benefits need to be judged against their costs, taking into account the frequency and intensity of the shock, and the background of political priorities. Costs can also be non-monetary, for example, where reducing exposure to risk might require the replacement of traditional supply chain elements preferred by consumers. There may also be a trade-off between resilience and efficiency: diversity and redundancy may contribute to greater resilience, for example, but go against recent supply chain trends towards greater specialization and greater production and market concentration in search of increased efficiency and lower costs. In fact, those trends may have increased certain risks. The potential side effects of any measures taken also need to be taken into account. In the case of pandemics, for example, unavoidable containment measures rather than the disease itself can cause supply chain disruptions and negative effects on employment, incomes and trade.

4.2 ASSESSING RISKS

Efforts to build resilience begin by identifying and assessing the risks faced by supply chains and their vulnerability. This detailed risk assessment includes the identification of hazards and an analysis of their frequency and intensity, and the exposure and vulnerability of the supply chain in question, which could disrupt or prevent its normal functioning. This information can be summarized graphically in a risk map (Figure 4 and Table 3) showing the probability of occurrence and the extent of damage associated with different risks faced by the supply chain. Risk management options for different combinations of probability and the extent of damage or intensity can be set out as in Table 3 (this precedes the detailed policy measures proposed in Table 2). Those situations combining high probability and major damage are the most demanding of specific attention or, if possible, are to be avoided. Those combining lower probability with less significant damage might be accepted within the supply chain as part of the normal business environment. Combinations in between these call for a blend of efforts to control the risk through prevention or absorption, for example, or to transfer its financial consequences. Risk transfer might be made to a specialist insurance provider or to other related participants in the supply chain or through more informal arrangements.

▶ FIGURE 4

Risk map of probability and intensity



Source: Adapted from Foudi, S., Osés-Eraso, N. & Tamayo, I. 2015. Integrated spatial flood risk assessment: The case of Zaragoza. *Land Use Policy*, 42: 278–292.

▶ TABLE 3

Risk management options under different intensity and frequency

INTENSITY	FREQUENCY		
	LOW	MEDIUM	HIGH
Minor	Accept	Accept and transfer	Accept and transfer
Medium	Transfer	Control and transfer	Control and transfer
Major	Transfer	Control and transfer	Avoid

Notes: Accept: Every business is affected by the shock. If the losses are not large, they can be assumed by the business. Transfer: If the frequency and intensity lead to moderate losses, these can be transferred. Control: For all the risks that affect the operation of the company and have a high average frequency, measures can be implemented to reduce their impact. Avoid: If disasters are catastrophic and common in this location, it is better not to operate in this area.

Source: Hatch, D.C., Núñez, M., Vila, F. & Stephenson, K. 2012. *Los seguros agropecuarios en las Américas: un instrumento para la gestión del riesgo*. San José, Costa Rica, IICA (Instituto Interamericano de Cooperación para la Agricultura).

Risk assessment needs to be based on an understanding of the complexity of the supply chains, including stages and linkages, how shocks are propagated, and feedback and spill-over effects, in order to identify particular weaknesses and chokepoints. This could include **quantitative assessments** on the relative importance of different segments in the value chain as a means to set priorities. It also needs to **identify the critical infrastructure** essential to supply chain functioning. Assessments of vulnerability need to **identify vulnerable populations** to allow the targeting of social safety nets. Businesses in the supply chain can also identify and evaluate risks to their own activities in order to improve their reactions to shocks. The United Nations Office for Disaster Risk Reduction (UNDRR's) "ARISE" initiative supports the private sector in collecting and sharing information. The assessment can also include the capacity of supply chains and the participants in them to cope with shocks and priorities for improvement.

The overall resilience of the supply chain to shocks might in principle be summarized by resilience indicators based on the extent to which key attributes contributing to resilience, such as diversity, redundancy, buffering capacity, capital and infrastructure, are present. However, drawing conclusions from these indicators requires detailed knowledge of how the various attributes affect resilience and a ranking of their relative importance in order to weight them.

A variety of **qualitative and quantitative tools** are available to assist in risk assessment. Historical analyses of past shocks and actions taken in response can provide information concerning familiar shocks but are obviously less useful for "black swans". Risks of all kinds, including those where there is little past experience to learn from, can be evaluated and potential policy responses identified using **scenario analyses** involving stakeholder and expert knowledge or **model-based simulation** studies. Simulation models of supply chains accommodating expert stakeholder knowledge and insights can be valuable where the supply chain is complex and might provide a framework for supply chain stress testing. Collectively defining such a model can be a valuable exercise in itself with regard to reaching a better understanding of supply chains.

Stakeholder-inclusive processes are a fundamental part of any realistic risk assessment methodology given the multidimensionality and complexity of agricultural supply chains' risk

and capacity assessments. They can provide broad qualitative conclusions based on a shared understanding of risks and vulnerability and alternative strategies. The process itself can be used to build institutional resilience. Stakeholders include not only supply chain actors and experts but also the communities likely to be affected by shocks or measures to control them. However, comprehensive risk analysis can be demanding of expert opinion and may not by itself provide sufficient detail on the impacts of shocks to set priorities for measures to improve resilience.

Risk maps set out the assessed risks in a way that guides priorities for managing those risks and provide a matrix of risk management options and responsibilities to prevent or reduce them and to build general resilience. Some of those options might involve adaptations and transformations, such as the adoption of process innovations or capital investments in the supply chain and infrastructure to improve robustness against future shocks. Others might involve immediate actions such as trade policy adjustments or social protection programmes to absorb and recover from ongoing shocks and maintain supply chain functioning. The appropriate action depends on the nature of the assessed risks, building general resilience against less-defined risks and more targeted measures to build resilience against known specific threats. In each case the objective, scope, implementation responsibility, financing needs and sources, and timing need to be specified.

4.3 PREPAREDNESS AND BUILDING GENERAL RESILIENCE

The mapping of supply chain risks provides a basis for the preparedness of governments, supply chain participants and other stakeholders to anticipate, absorb and recover from different current and future shocks. Preparedness requires a thorough assessment of risks and reliable forward-looking information and analysis, including early warning and analyses of plausible shock scenarios, so that shocks can be quickly understood or anticipated. On this basis, **contingency plans** can be formulated and resources and arrangements put in place to respond to, or even prevent, eventual shocks with effective and timely actions. Lack of preparedness will aggravate supply chain disruptions caused by shocks and may also increase the likelihood of insecurity and conflict. Preparedness is fundamental if countries are to build robust supply chains and respond through swift action to mitigate the impacts of shocks. Some measures, like **emergency reserves** or social protection programmes, cannot easily be activated in response to a shock and so need to remain in place.

To ensure that risks are better understood and more predictable, preparedness implies a knowledge and advance preparation of specific targeted responses to address shocks if they occur. Business practices of supply chain participants will often include preparedness to deal with the type of small-scale shocks that regularly impact agricultural supply chains. For shocks that are inherently unpredictable, beyond the control of supply chain participants and with the potential to inflict major damage, preparedness involves building general resilience to make supply chains more robust against, and quicker to recover from, such shocks, should they occur. In fact, building general resilience is desirable in all cases and can supplement and provide a framework for more targeted measures in a multirisk management context. However, decision-making on preparedness also needs to consider the frequency and intensity of the possible shocks and the costs of protecting against them.

A wide range of factors contribute to preparedness by promoting general supply chain resilience. These include a conducive policy and institutional environment giving priority to agricultural supply chains and with **functioning input and output markets, trade possibilities** and **effective health and hygiene legislation**. Climate-change mitigation and adaptation measures should be in place. Supply

chains themselves need to be technically and economically efficient with strong storage, processing and transportation infrastructure, and to be technologically progressive, including digitalization. Supply chain participants and involved institutions need strong resilience capacities supported by education, extension and training for greater adaptability and agility. **Risk transfer mechanisms** need to be accessible to supply chain participants and social protection systems must be in place. More generally, the various attributes needed for supply chain resilience – diversity, redundancy, connectivity, stocks – should be present.

A similar range of factors underpins the individual resilience dimensions – prevention, anticipation, absorption, adaptation and transformation – discussed below. Different measures contribute to improved capacity under each dimension. These are summarized in Table 2 together with examples of specific policies. The assignments to the different dimensions of resilience cannot be definitive as many of the measures relate to more than one dimension and hence overlap.

4.4 ANTICIPATING AND PREVENTING SHOCKS

Anticipation refers to prior information and knowledge about future shocks that permit actions to be designed and implemented to prevent them or to absorb their negative effects. Early warning, monitoring and forecasting systems such as the FAO Food Chain Crisis-Intelligence and Coordination Unit (FCC-ICU) or its Emergency Prevention System (EMPRES) play an important role in the prevention and anticipation of risks. The availability of accurate and up-to-date information can help public and private actors respond better and in a timely manner. Also in FAO, the Global Information and Early Warning System (GIEWS) can provide forewarning of emerging food supply shortfalls, for example, while the Agricultural Market Information System (AMIS) enhances the transparency of markets and helps ensure effective policy responses to avoid crises. Even if the onset of a shock cannot be anticipated, advance knowledge of its likely impacts can be useful. Anticipating which population groups will be most vulnerable can guide the design of targeted social protection programmes. Box 3 describes recent research in this area.

▶ BOX 3
Targeting policy interventions

Evidence-based policy targeting is a crucial prevention tool to identify the most-in-need population groups for which to tailor development interventions. Several models exist, but their accuracy is difficult to assess *ex post*, especially during rapidly evolving crises. Letta *et al.* (forthcoming) exploit the unique context of the COVID-19 pandemic to test the reliability of the current profiling methodologies utilized as policy targeting tools to predict household vulnerability to income losses and food insecurity. The results show that the predictive performance of these different methodologies varies significantly. It is therefore important to refine the targeting mechanisms and develop better profiling methodologies on which preventive interventions are to be based. Ideally, such profiling should be livelihood specific and should also be expanded at the community level. These efforts would enable policymakers to implement early warning systems for vulnerability hotspots in anticipation of food crises, improve the ▼

▶ **BOX 3 (CONT.)**

cost-effectiveness and efficacy of resilience-building programmes, and potentially pre-empt the impact of future shocks. In light of the relatively poor data available it is also important to invest in improved survey instruments and their interoperability with non-conventional data sources. Along these lines, Nano (forthcoming) studies how targeting development policies to agricultural population groups with specific characteristics can have ripple effects on multiple dimensions of resilience. The paper finds that improving farmers' technical efficiency has a large negative impact on food insecurity in Nigeria. More efficient farmers can expect to enjoy both higher profits and greater food security, thereby increasing their resilience to external shocks. Targeting farmers' inefficiencies through, for example, education, aid programmes, land-use regulations and extension services not only helps farmers mitigate and cope with food crises but can also have important spill-over effects on how they react to shocks.

Sources: Nano, E. (forthcoming). *The agricultural technical efficiency and food security nexus – Evidence from Nigeria*. FAO Agricultural Development Economics Working Paper. Rome, FAO; Letta, M., Montalbano, P., Morales Opazo, C. & Petruccelli, F. (forthcoming). *Targeting vulnerability hotspots along the food system – A stress test for Ethiopia and Nigeria*. FAO Agricultural Development Economics Working Paper. Rome, FAO.

Some risks can be identified even if specific instances cannot be predicted. These risks can be targeted with measures to reduce or eliminate them where technically and economically possible. Prevention refers to measures to avoid the negative impacts of shocks by eliminating risks completely or, where that is not possible, by reducing exposure and vulnerability. Prevention is the only efficient strategy for dealing with locust emergencies, for example. There has been some success in the control and eradication of some livestock diseases, such as rinderpest, albeit with substantial government and international support. Plant and animal breeding can develop varieties and breeds more resistant to drought or diseases, thereby reducing vulnerability. Hygiene and food safety legislation can be used to eliminate dangerous components of supply chains by imposing stricter standards and better design in food markets and processing plants and so reduce if not eliminate the risk of zoonotic infections and reduce exposure and vulnerability. The *One Health* initiative, led by the World Health Organization (WHO), FAO and the World Organization for Animal Health (WOAH), is a collaborative effort across multiple sectors working locally, nationally and globally to attain optimal health for people, animals and the environment.

Meteorological and geophysical risks cannot normally be prevented although exposure and vulnerability to their effects can be reduced. Dams and embankments can help reduce vulnerability to flood risks, for example. Longer-term actions for climate-change adaptation and mitigation can reduce but not eliminate the risks of extreme weather events and vulnerability. Some supply chain shocks can be predicted and, if justified, action can be taken to enhance resilience against them. Droughts for example are "slow-onset" and so can be predicted to some extent through early-warning systems and measures put in place to enhance resilience and provide social protection. Similarly, invasions of pests such as locusts can be predicted through surveillance and monitoring and, if controlled through pesticides or biologically at an early stage, the risk of

destruction of crops can be avoided. Plant diseases can be less tractable than pests given their ability to evolve new, more damaging strains, requiring new fungicides and plant varieties to combat them. The latest strain of banana Fusarium wilt, tropical race TR4, can reduce yields to zero, and there is no effective fungicide treatment to prevent its spread to the major global banana suppliers in Latin America (see Box 4).

▶ BOX 4

The potential impact of the spread of TR4 in global banana production

TR4 is a strain of the fungus that causes Panama disease of bananas, *Fusarium oxysporum f. sp. cubense*. It is considered among the most destructive of all plant diseases and there is currently no effective fungicide or other eradication method available. A paper by Altendorf (forthcoming) analyses the impact of an assumed rapid spread to Ecuador, Colombia and Peru, which account for about 9 percent of global banana output and over 40 percent of global banana exports. The simulation shows that the spread of TR4 to these countries would lead to a fall in world exports of 9 percent in the first year. The world reference prices for bananas would rise initially by 30 percent, and consumers in all countries with open markets would face rising costs caused by higher prices, as market effects would transmit across borders.

Assuming an average of 1.5 workers per hectare, the estimated reduction in a harvested area of approximately 200 000 hectares globally would imply the loss of direct employment for around 300 000 banana workers. In affected producing countries, consumer prices could rise significantly as a result of possible border controls designed to protect domestic producers. Meanwhile, producers in unaffected countries would gain from the higher prices and capture higher export revenues resulting from higher volumes of shipments at higher unit values.

The scenario indicates the potential costs of a continuous TR4 spread and its potential to wreak havoc in markets in the short term if it is not monitored and contained successfully. Close coordination of the capacity-development and extension activities of all concerned national institutions will be beneficial to the development of proper policies, regulations and strategic measures to address the challenges of TR4 in a comprehensive way. Strong National Plant Protection Organizations (NPPOs) with a defined action plan, legal framework and procedures on prevention, preparedness, detection, response and recuperation reduce the risk of a potential incursion and its socioeconomic impact. Recent experience in Colombia shows that phytosanitary measures have prevented the spread of the pest and facilitated the declaration of disease-free zones. In addition, national support schemes drawn up in strategic collaboration with different stakeholders and designed to assist in the implementation of adequate biosecurity measures, as well as in the facilitation of diversified production systems that have shown to be less susceptible to TR4 infection than monocropping systems, may also serve as responses that can alleviate the problem. Such compensating or support schemes may further contribute to containment of the disease by easing the moral-hazard problem of farmers not reporting and not treating infected plantations properly.

Source: Altendorf, S. (forthcoming). *Strengthening the resilience of agricultural supply chains – The case of fresh fruits and vegetables*. Rome, FAO.

4.5 ABSORPTION OF SUPPLY CHAIN SHOCKS

Absorption refers to the ability of the supply chain and its participants to maintain their normal functions and outputs in the short run in spite of disruptions and damage to input and output flows and supply chain investments and infrastructure. Absorption relies on basic robustness to withstand shocks, rebalance between different supply chain elements to avoid those from being disrupted, or bring fall-back capacity into play.

Supply chain activities may be sufficiently robust to anticipate and accommodate some risks. Explicit allowances can be made in the design of "disaster-proof" critical infrastructure, and networks and governments have a role in protecting these. Frequent, minor, localized shocks are normal for supply chain businesses and can be absorbed by spreading risks across different outputs, storage, savings or informal risk transfer such as family support. For more significant, less frequent risks, more formal risk transfer mechanisms, including index insurance, can help to avoid business failure or distress coping mechanisms such as forced assets sales. Governments can support risk transfer and also facilitate access to short-term and emergency finance and credit to tide over temporary revenue losses and allow productive activities to continue. Social protection measures can help more vulnerable households absorb and adapt to shocks. Identifying and targeting worst affected groups can allow for a more efficient use of limited funds, as illustrated in Box 3. Stronger businesses are obviously better able to withstand shocks: as Box 3 also explains, greater technical efficiency leads to increased output, revenues and profit, and hence resilience. Providing access to finance and credit, education and extension, and support to collaboration and cooperation can increase business resilience by increasing efficiency, as well as adaptability and flexibility. These are all part of a conducive enabling environment for general resilience.

If shocks cannot be withstood then rebalancing between supply chain elements such as trade and stocks can quickly compensate for shortfalls in supply. Enhancing resilience through international trade requires that trade can flow without hindrance and requires **effective trade rules** to ensure this (see Box 5). Governments can also encourage trade through tariff reductions and trade facilitation to reduce trade costs, for example, by digitalization of customs procedures. Trade from outside areas affected by shocks also plays an important role. Stocks held nationally or within supply chains, including at farm level, provide another mechanism to compensate for unexpected temporary supply shortfalls. **Efficiently-managed strategic reserves** can buffer the impact of shocks affecting staple foods. Targeting and integration with social and food security safety nets can increase their effectiveness at supporting the vulnerable populations. They must also be carefully designed, adequately funded and supported by effective early warning systems. Establishing fall-back options through "redundancy", whereby critical supply chain elements are duplicated, may be relevant when continuity in functioning has very high priority. However, this type of investment requires careful assessment of the trade-off between the cost and the benefits involved. Redundancy can also be introduced by keeping excess stock throughout the supply chain.

The possibility of rebalancing relies on an element of diversity through supply chains beginning with the product mix in primary production. Diversification in products, input supply, markets and trade is a key attribute for supply chain resilience. Falling export demand can be offset by rebalancing towards growing domestic markets, for example, as happened with the Kenyan coffee industry. However, like redundancy, supply chain diversity can be costly and can involve a trade-off with efficiency. As an alternative, businesses may choose to build vertical supplier relationships to ensure reliability of supplies.

▶ **BOX 5**

Policy interventions and market dynamics

Agrifood markets were relatively more resilient than other sectors during the COVID-19 pandemic. According to World Trade Organization (WTO) figures, the value of agricultural exports grew by 0.9 percent during the year 2020, compared to a 5.2 percent decline in exports of manufactured goods. With the aim of examining how policy interventions during the COVID-19 pandemic contributed to the resilience of global markets, Soguero Escuer (forthcoming) looks at the behaviour of international markets based on the implementation of new trade measures. The author tests the hypothesis that governments' trade interventions played a positive role in keeping food flowing across borders. In addition, Consoli *et al.* (2023) carry out a series of case studies about price incentives in the markets for rice, wheat and maize of 27 low- and middle-income countries.
Both studies conclude that during the pandemic governments tried to keep domestic markets open to international trade. The results reflect the dominance of tariff reductions and other import-facilitating measures over other policy interventions. However, excessive downward pressure on prices limits farmers' income, acting as a disincentive to produce. These findings fit well with the theory that a single market-clearing food price cannot satisfy all consumers and producers simultaneously. Therefore, finding policies that can benefit both sides of the supply change, such as infrastructure development and digitalization, is of the utmost importance. On the other hand, export restrictions imposed by key cereal exporters led to market access limitations for those countries with the highest dependence on cereal imports. The results reinforce the idea that countries with high sensitivity to trade distortions should develop an effective stockpiling system for key staples that can buffer future crises.

Sources: Soguero Escuer, J. (forthcoming). *Resilience of agricultural markets during the COVID-19 crisis from a trade policy perspective – A multi-country analysis.* FAO Agricultural Development Economics Working Paper. Rome, FAO; Consoli S., Egas Yerovi, J.J., Machiorlatti M. & Morales Opazo C. 2023. Real-time monitoring of food price policy interventions during the first two years of COVID-19. *Food Policy*, 115: 102405. https://doi.org/10.1016/j.foodpol.2023.102405

4.6 ADAPTATION AND TRANSFORMATION: RECOVERY AND "BUILDING BACK BETTER"

Besides supporting the rehabilitation and reconstruction of supply chains following a shock, policies and other interventions should also facilitate and support the efforts of supply chain businesses in adapting to changing circumstances, especially towards greater robustness and longer-term sustainability. Agricultural supply chain businesses from primary production to transport, storage, processing and retail bear the brunt of supply chain shocks. They need to be agile in adapting their structures and business models to changed circumstances by diversifying upstream supply channels and downstream sales channels, for example, by adopting more resilient farming systems, or by applying digitalization, e-commerce and e-procurement. Many businesses, including small- and medium-sized enterprises, successfully made these adjustments to secure their survival in the face of the challenges of the COVID-19 pandemic. While building resilience inevitably focuses on the supply side, which is the most disrupted, the demand side can also contribute. Adapting buying and consumption patterns, such as

shifting towards long-life products and embracing online and direct selling, as happened during the COVID-19 pandemic, can promote greater supply chain resilience and sustainability.

Collaboration and cooperation, strong networks, information-sharing, transparency and risk-sharing through supply chains can all contribute to creating greater adaptive capacity and can be facilitated by governments through a supportive policy environment. Scale is important to adaptive capacity to access new opportunities. Collective action through cooperatives and other forms of collaboration, vertically as well as horizontally, can compensate for lack of scale and can integrate and strengthen the different supply chain links. This applies especially to small-scale primary producers whose market access can be weak (see Box 6). It can also provide a vehicle for risk-sharing along the chain.

▶ BOX 6

Resilience of the dairy sector in India

The COVID-19 pandemic and lockdowns to contain the spread posed multiple challenges to the dairy sector in India, including feed shortages, increased input costs and decreased milk sales. However, anecdotal evidence suggests that the Indian dairy sector was remarkably resilient and farmers' income did not fall as much as in many other countries.

A paper by Upali Wickramasinghe and Adeeth Cariappa (forthcoming) on dairy cooperative society (DCS) wholesale and retail milk prices, price spreads, procurement and sales, found that the market lockdown had not caused a statistically significant change in wholesale milk prices. In contrast, retail prices increased, and some dairy product sales plummeted during the crisis across all milk production zones. The study found disruption in milk marketing channels, logistics and transportation in the eastern milk zone. In this zone, the cooperative institutional structure is less widespread and active, and the zone accounts for only 6 percent of milk procured and 9 percent of milk sold by DCSs. By contrast, the DCSs in the northern, western and southern zones account for 32 percent, 31 percent and 28 percent, respectively, of the milk sold by cooperatives in the country.

For milk procurement, the study focused on two DCSs, namely the Kerala Cooperative Milk Marketing Federation (KCMMF) located in the southern milk zone and the Punjab State Cooperative Milk Producers Federation Limited (MILKFED) located in the northern milk zone. KCMMF has 3 315 primary cooperative societies at the village level and 977 000 dairy farmers as members. KCMMF dairy product sales, especially fresh milk, curd, peda (a sweet), ice cream and flavoured milk, declined from 10 to 62 percent during the lockdown. Despite the decline in sales, KCMMF continued to procure milk from farmers, temporarily absorbing the shock. In 2019, MILKFED had a network of 7 385 milk producer cooperative societies organized at the village level with about 373 000 producer members. After controlling for seasonal and other factors, milk procurement by MILKFED still showed a 5 percent increase, despite declines in retail milk prices by 8 percent and in dairy product sales by up to 35 percent for some products such as curd. However, since the lockdown, milk procurement prices and dairy product sales, especially ultra-high temperature (UHT) milk, have been on a downward trend. The analysis of milk prices, procurement and sales confirms that dairy cooperatives have played a critical role in strengthening the resilience of India's dairy sector during the COVID-19 crisis.

Source: Upali Wickramasinghe, G.A. & Adeeth Cariappa, A.G. (forthcoming). *Improving the resilience of the agricultural sector to external shocks – The impact of the COVID-19 pandemic on the dairy industry with particular reference to India.* Rome, FAO.

Transformation refers to more significant changes in supply chain technologies, structures and ways of working, all towards greater resilience and sustainability. New technologies emphasize the sustainable management and use of natural capital, efficient water management and climate smartness. Many of the government actions to support supply chain adaptation through, for example, **finance and credit**, **advice and extension**, and **cooperative development**, are equally relevant here. In addition, investment in **research and development** and support for the adoption of new technologies can support transformation. As noted above, the COVID-19 pandemic encouraged a number of innovations in how agricultural supply chains work, notably through greater applications of e-commerce, online platforms and direct selling. Governments can also support these developments by ensuring their accessibility to all supply chain participants through training and advice and by promoting effective and appropriate collaboration, communication and connectivity among them.

The disruptions caused by the COVID-19 pandemic revived the question of what types of supply chains – modern, traditional or transitional – are most resilient to shocks and best equipped to make these kinds of innovations. This prompts the further question of whether governments should favour particular types of supply chains. The existing evidence is limited and mixed, and no conclusions can be drawn in favour of any particular type. There are numerous examples of all types of supply chains innovating in directions favourable to greater resilience. In any case, this is not an either-or question. With suitable upgrading of health and hygiene standards in traditional and transitional supply chains, which is fundamental in any circumstance, modern, traditional and transitional supply chains can exist side by side and provide diversification. A more relevant question is what factors contributed to successful innovation regardless of the type of supply chain and what support governments can provide.

Cracked earth because of drought.

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5 CONCLUDING COMMENTS

These guidelines provide briefing material and a broad introduction to the topic of agricultural supply chain resilience and the measures that might be taken to strengthen this resilience against an evolving variety of natural hazards. The guidelines are intended for policymakers and their advisers, who need a broad grasp of the concepts and issues involved, but this document is not a critical policy review or a set of specific policy recommendations for responding to individual supply chain shocks. Rather, it outlines an approach for assessing supply chain risks and describes governments' roles in managing them.

Efforts to strengthen resilience need to be based on a thorough analysis of the nature of risks, including the probability that they will inflict actual shocks, and the exposure and vulnerability of supply chains to them. Evaluating exposure and vulnerability requires a detailed understanding of the nature and functioning of supply chains that policymakers and their advisers are unlikely to possess. More empirical research, especially detailed case studies, on agricultural supply chains and how they have been disrupted by shocks would certainly be valuable. However, stakeholder processes are a fundamental requirement for any realistic assessment of supply chain risks and informed discussions on formulating measures to build supply chain capacities for greater resilience. Governments need to create effective mechanisms for facilitating the necessary sharing of information and dialogue.

Governments have a clear active role in the event of major shocks providing support to affected populations and businesses and organizing rehabilitation and reconstruction. With respect to building resilience more generally, governments may take the lead in setting policy priorities based on assessments of risk and resilience capacities. However, they share responsibility for enhancing resilience with supply chain participants. Businesses throughout the supply chain, from primary production to transport, storage, processing and retail, bear the brunt of supply chain shocks and are required to absorb the impacts, to adapt their structures and business models to changed circumstances and to transform them for the future. The strength of supply chain businesses is the first line of defence against shocks, with efficiency underpinning resilience.

Governments play an essential supporting role facilitating and supporting the efforts of supply chain businesses to prevent, anticipate, absorb, adapt and transform, especially towards greater resilience and longer-term sustainability. Governments can provide a conducive policy and institutional environment, with working markets, trade facilitation, effective health and hygiene legislation, and climate-change mitigation and adaptation measures in place. They can provide investment support for technically and economically efficient supply chains with strong storage,

processing and transportation infrastructure, and advanced technologies and access to finance and credit. They can support stronger resilience capacities, adaptability and agility of supply chain participants and involved institutions through education, extension and training, promote collaboration and cooperation, and ensure that risk transfer mechanisms are accessible and social protection systems are in place. These measures all underpin general resilience and are in any case desirable.

The expected damage and losses associated with a risk can be significant where levels of exposure and vulnerability are high and the coping capacity of the supply chain is low. In principle, prevention and absorption appear preferable to cure. However, measures to ensure resilience can also be costly for governments, for example, where major infrastructure investments are involved, and especially where probabilities are low even if exposure and vulnerability are high. A cost–benefit comparison thus needs to be made. There can also be a trade-off between resilience and efficiency, discussed earlier, which must be weighed carefully. Not all decisions can be based on commercial and economic considerations, as political priorities will also play a role.

There is also a need to consider whether policies towards strengthening resilience should look beyond seeking better preventive, anticipative, absorptive, adaptive and even transformative capacities to achieve greater robustness and restore supply chain functioning. Enhancing general resilience against future risks is important as new risks emerge, notably new zoonoses, and the frequency and intensity of known risks grow with climate change and increasing pressure on natural resources. More importantly, the relationship between resilience and sustainability means that policies for each need to be considered together.

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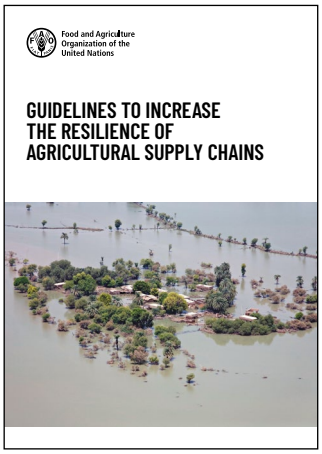

GUIDELINES TO INCREASE THE RESILIENCE OF AGRICULTURAL SUPPLY CHAINS

The effects of the COVID-19 pandemic on food and agriculture have been felt all over the world. As the pandemic unfolded, considerable attention began to be paid to the resilience of agricultural supply chains to COVID-19-related shocks, as well as to natural and human-induced shocks more generally. These *Guidelines to increase the resilience of agricultural supply chains* are intended for policymakers and other stakeholders who need a broad grasp of the concepts, issues and possible approaches involved.

Efforts to strengthen resilience to risks need to be based on a thorough analysis of the exposure and vulnerability of supply chains to them, and on a cost–benefit assessment of damages versus interventions. In addition, not all decisions can be based on commercial and economic considerations, as political priorities will also play a role. Governments may take the lead in setting policy priorities based on assessments of risk and resilience capacities, but it is actors throughout the supply chain who are directly affected and who need to consider business strategies and interventions to be able to adapt and transform for the future. Governments play an essential role by supporting the efforts of supply chain businesses and by building general resilience through establishing an appropriate policy and institutional environment, and through the investments they make in physical infrastructure, in putting social protection in place, and in facilitating and promoting collaboration and cooperation. Enhancing general resilience against future risks is important as new risks emerge, and the frequency and intensity of known risks grow with climate change and increasing pressure on natural resources.

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