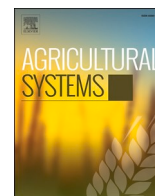




Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



Review

The immediate impact of the first waves of the global COVID-19 pandemic on agricultural systems worldwide: Reflections on the COVID-19 special issue for agricultural systems

Emma Stephens^{a,*}, Jagadish Timsina^b, Guillaume Martin^c, Mark van Wijk^d, Laurens Klerkx^e, Pyatrik Reidsma^f, Val Snow^g

^a Agriculture and Agri-Food Canada, Lethbridge Research and Development Centre, Lethbridge, Alberta, Canada

^b Institute for Study and Development Worldwide, Sydney, Australia

^c French National Institute for Agricultural Research INRAE, Paris, France

^d International Livestock Research Institute, Nairobi, Kenya

^e Knowledge, Technology and Innovation Group, Wageningen University, The Netherlands

^f Plant Production Systems, Wageningen University & Research, the Netherlands

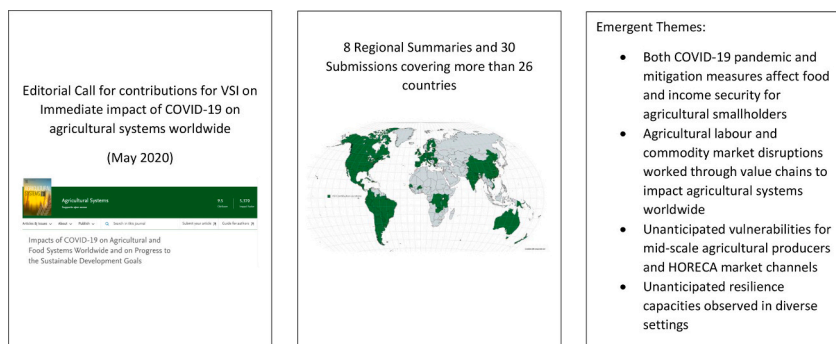
^g AgResearch Ltd, Lincoln Research Centre, Lincoln, New Zealand



HIGHLIGHTS

- 8 regional summaries, 30 research papers on agricultural systems responses to the initial waves of the pandemic
- The Special Issue primarily highlights immediate impact of COVID-19 mitigation measures on agricultural systems
- Emerging impacts include widespread impacts on food security for vulnerable populations engaged in agriculture
- Additional impacts via disruptions to agricultural labour and trade, agricultural incomes and livelihoods
- Evidence of resilience capacities within many agricultural systems to the pandemic, but not universal

GRAPHICAL ABSTRACT



ARTICLE INFO

Editor: Dr. Daniel Rodriguez

Keywords:

COVID-19 pandemic
 COVID-19 mitigation
 Resilience
 Food insecurity
 Agricultural and food value chains
 Inequality

ABSTRACT

CONTEXT: In May 2020, approximately four months into the COVID-19 pandemic, the journal's editorial team realized there was an opportunity to collect information from a diverse range of agricultural systems on how the pandemic was playing out and affecting the functioning of agricultural systems worldwide.

OBJECTIVE: The objective of the special issue was to rapidly collect information, analysis and perspectives from as many regions as possible on the initial impacts of the pandemic on global agricultural systems. The overall goal for the special issue was to develop a useful repository for this information as well as to use the journal's international reach to share this information with the agricultural systems research community and journal readership.

* Corresponding author.

E-mail address: emma.stephens@agr.gc.ca (E. Stephens).

<https://doi.org/10.1016/j.agsy.2022.103436>

Received 8 February 2022; Accepted 19 May 2022

Available online 30 May 2022

0308-521X/Crown Copyright © 2022 Published by Elsevier Ltd. All rights reserved.

METHODS: The editorial team put out a call for a special issue to capture the initial effects of the pandemic on the agricultural sector. We also recruited teams from eight global regions to write papers summarizing the impacts of the first waves of the pandemic in their area.

RESULTS AND CONCLUSIONS: The work of the regional teams and the broader research community resulted in eight regional summary papers, as well as thirty targeted research articles. In these papers, we find that COVID-19 and global pandemic mitigation measures have had significant and sometimes unexpected impacts on our agricultural systems via shocks to agricultural labour markets, trade and value chains. And, given the high degree of overlap between low income populations and subsistence agricultural production in many regions, we also document significant shocks to food security for these populations, and the high potential for long term losses in terms of human, natural, institutional and economic capital. While we also documented instances of agricultural system resilience capacities, they were not universally accessible. We see particular need to shore up vulnerable agricultural systems and populations most negatively affected by the pandemic and to mitigate pandemic-related losses to preserve other agricultural systems policy objectives, such as improving food security, or addressing climate change.

SIGNIFICANCE: Despite rapid development of vaccines, the pandemic continues to roll on as of the time of writing (early 2022). Only time will tell how the dynamics described in this Special Issue will play out in the coming years. Evidence of agricultural system resilience capacities provides some hopeful perspectives, but also highlights the need to boost these capacities across a wider cross section of agricultural systems and encourage agri-food systems transformation to prepare for more challenges ahead.

1. Overview

In May 2020, four months into the world's experience with the COVID-19 pandemic, the editorial team of *Agricultural Systems* put out a call for a special issue to capture the effects of the pandemic on the agricultural sector. Given the global reach of the journal's readership and the scope of the journal, we realized there was an opportunity to collect valuable information from all over the world and from a diverse range of agricultural systems on how the pandemic was playing out and provide a forum for the research community.

Little did we know, back in May 2020, that some 19 months later in early 2022, the pandemic would still be ongoing with subsequent and more serious waves hitting almost every country in the world. This Special Issue thus primarily reflects important observations from the first waves of the pandemic from April 2020 to June 2021. At that time, much less was known about COVID-19 itself, the eventual duration and severity of the pandemic (still unknown), whether vaccines would be developed, and what types of mitigation strategies would be most effective. Many of these questions are still being researched and debated around the world. As of this writing (January 2022):

- new variant strains are emerging,
- multiple vaccines have been developed and deployed,
- there are concerns about global vaccine access and distribution systems, and
- there are ongoing questions about how to mitigate the virus to control the pandemic.

In particular, there are unknowns as how to navigate the trade-offs between mitigation strategies, economic activity, public health, education, and much more.

In terms of the agricultural sector, the reflections in this Special Issue are made up of a wealth of global expert knowledge and firsthand accounts of the impacts of the first waves from members of the research community who were able to quickly pivot towards including studying the impact of the pandemic in their ongoing work. However, they are also reflective of the high level of uncertainty during the initial months of the pandemic. The papers represent the best knowledge at the time, and in some cases some speculation was necessary.

As those first shocks to human health and free movement of people and goods then translated to myriad impacts to our agricultural systems, unfolding in real time for some submissions during their ongoing research projects, many revealed unanticipated or unknown vulnerabilities in our agricultural systems to human health shocks like the coronavirus pandemic. In other instances, these first pandemic waves

highlighted previously undocumented adaptive capacities within some agricultural systems.

We hope this Special Issue can serve as a useful foundation from which these interactions between the pandemic and global agricultural systems can be examined in future research.

2. Structure of the special issue

In order to make sure we covered as many global regions as possible, we took a two-pronged approach. First, making use of research community connections of the editors and editorial board, we solicited eight team papers designed to summarize as many global regions as possible: Africa, Latin America (Tittonell et al., 2021), Central America (Lopez-Ridaura et al., 2021), Canada and the United States (Weersink et al., 2021), Antilles and Caribbean Island states (Blazy et al., 2021), Asia (Dixon et al., 2021), Europe (Meuwissen et al., 2021), and the Pacific region (Snow et al., 2021). We are enormously grateful for the efforts of the 191 members of these teams for working on these comprehensive and rich regional summaries, under pandemic conditions, to bring this information to the Special Issue and to the research community at large. Second, we launched an open call for submissions to the Special Issue in May 2020 (Stephens et al., 2020). In total across the open call submissions and the regional team summaries, 38 submissions are part of this Special Issue. All the papers (solicited and volunteered) were fully peer-reviewed so we are also enormously grateful for all the reviewers that assisted in improving the quality of the papers.

The contributions and key themes that emerge from them will be summarized in the next section.

3. Contributions to the special issue

Table 1 summarises the range of topics, regions and systems covered in the special issue. As can be seen, this Special Issue has wide geographic coverage and a breadth of topics and analytical approaches assessing the impacts of the first waves of the pandemic.

4. Regional summaries and articles

4.1. Africa

Four papers in the Special Issue covered analysis of the pandemic first waves across several countries in Sub-Saharan Africa. A team began to work on an African regional paper but was not able to complete it due to several complications. Nonetheless, preliminary analysis from this team, substantiated by the subsequent research paper contributions to

Table 1
Topics, regions and approaches covered in the COVID-19 Special Issue.

Authors	Topic	Region	Countries covered	Analytical approach
Acosta et al	Global dairy sector	International/ comparative		key informants
Adhikari et al	Agriculture and food systems, resilience	Asia	Nepal	key informants
Alvi et al	Women's access to agricultural extension services	Asia	India, Nepal	surveys
Andrieu et al	Covid19 mitigation and greenhouse gas emissions	International/ comparative	Burkina Faso, Colombia, France	surveys/modelling
Balwinder-Singh et al	Labor, food security and air quality and COVID19 mitigation	Asia	India	modelling
Blazy et al	Agriculture and food system responses	REGIONAL	Caribbean region	surveys/key informants
Boughton et al	Covid19 mitigation and agri-food system resilience	SUMMARY		
Coopmans et al	Food value chains, agri-food system resilience	Asia	Myanmar	surveys
Darnhofer	Agricultural system resilience	Europe	Belgium	surveys/key informants
Davila et al	Food systems, resilience, sustainable development	Conceptual/ theoretical		conceptual
de Boef et al	Seed value chains	Pacific/Oceania	Papua New Guinea, Timor-Leste, Fiji, Kiribati, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu	surveys
Dixon et al	Response and resilience of agrifood systems	International/ comparative	Ethiopia, Myanmar, Nigeria, Uganda	surveys/key informants
Fang et al	Chicken and egg farming systems	REGIONAL		conceptual model/ surveys/key informants
Goswami et al	Fuzzy Cognitive mapping, resilience	Asia	Asia	surveys
Graham et al	Shocks and livestock greenhouse gas emissions	Asia	India	surveys/modelling
Hammond et al	Covid19 mitigation policy and food security	Africa	Kenya	conceptual model/surveys
Haqiqi and Horeh	Shocks and short run agricultural production response, labor productivity shocks	International/ comparative	Burundi, Kenya, Rwanda, Tanzania, Uganda, Vietnam, Zambia	surveys
Iese et al	COVID19 and agriculture and food systems	Americas	United States	modelling
Jha et al.	COVID19 and Cereal crop yield impacts	Pacific/Oceania	Fiji, Solomon Islands	surveys/focus groups/key informants
Kumar et al	COVID19 mitigation and farming systems in Uttar Pradesh	Africa	Senegal, Burkina Faso	modelling
Lioutas and Charatsari	COVID19, agriculture and managing major crises	Asia	India	surveys/key informants
Lopez-Ridaura et al	Farming systems and COVID19 impacts	Conceptual/ theoretical		conceptual
Magar et al.	COVID19 mitigation and agri-food system resilience	REGIONAL	Central America and Mexico	key informants/public reports
Marusak et al.	Resilient regional food supply chains	SUMMARY		conceptual/pathway analysis
Meuwissen et al	Farm system resilience	Asia	Nepal	case studies
Middendorf et al	Farmer perceptions of COVID19	Americas	United States	surveys/key informants/ case studies
Nchanji et al	Bean value chains	REGIONAL	Europe	surveys
Perrin and Martin	Organic dairy farms	Africa	Kenya, Uganda, Tanzania, DR Congo, Burundi, Zambia, Zimbabwe, Mozambique, Cameroon	surveys/key informants
Prosser et al	Local food and drink producers and markets in Wales	Europe	France	surveys/key informants
Rivera-Ferre et al	Two-way relationships between COVID19 and food systems	Conceptual/ theoretical	UK	case studies
Snow et al	Agri-food system resilience	REGIONAL		conceptual
Song et al	Urban food supply chains	SUMMARY	Pacific/Oceania	surveys/key informants
Tittonell et al	Family farms and agroecology movement responses to COVID19	Asia	Singapore	modelling
Tougeron and Hance	Apple orchards	REGIONAL	Latin America	surveys/key informants/ case studies
Vargas et al	COVID19 mitigation and coffee and potato producers	SUMMARY		conceptual
Varshney et al.	Social assistance and agricultural sector impacts	Europe	EU	surveys/key informants
Weersink et al	Agri-food system response	Americas	Peru	surveys/key informants
Zhan and Chen	Food system resilience	Asia	India	surveys
		SUMMARY	Canada and the United States	
		Asia	China	

the Special Issue, indicated that the pandemic has exacerbated existing agri-food system vulnerabilities. These vulnerabilities include: relatively low levels of mechanization and commercialization; high reliance on imports of capital goods related to farming; and the prevalence of food insecurity, particularly for rural small-scale subsistence agricultural

producers. In the initial call, authors were asked to consider how the pandemic might impact achievement of the Sustainable Development Goals (SDGs), and the papers focusing on Africa indicate that several of the SDGs will move further out of reach, particularly SDG2 (zero hunger).

Other papers in the Special Issue focused on different parts of the African continent considered pandemic-induced shocks with respect to impact on primary agricultural production of cereals and livestock, livestock greenhouse gas (GHG) emissions, and comparative analysis of the full value chain of an important commodity (beans).

Graham et al. (2021) outlined a framework to rapidly assess whether pandemic shocks have impacted GHG emissions from the livestock sector in Kenya. They described different pathways between the pandemic and emissions, including changes in herd sizes, feed availability and decreased animal movements due to COVID-19 mitigation measures and market closures. They identified a reduction in GHG emissions mostly due to reductions in herd sizes as documented in the proxy data used in the framework. They hypothesized that this is due to more informal market transactions and shutdowns of larger more formal markets during pandemic mitigation measures. Satellite data used in the analysis also showed that concurrent to the pandemic, feed production was improved, which is associated with greater GHG emissions and potentially less movement of animals due to greater local feed availability. They highlighted the importance of comprehensively tracing shocks like the pandemic, along with other more common shocks in the region like drought, through multiple pathways to assess implications for GHG emissions.

Jha et al. (2021) used crop simulation models to project the impact of the first waves of the pandemic on major cereal crops in Burkina Faso and Senegal. They hypothesized that pandemic related shocks to supply chains, labour supply and input availability will translate into shocks to both planting area and yield. Using the DSSAT suite of models, they simulated crop production in the two countries under a range of scenarios on areas planted and yields. They estimated that the pandemic, in a worst-case scenario, could cost both countries between 7 and 8% of agricultural GDP. The same research team, led in a contribution by Middendorf et al. (2021), then drilled down to farmer-reported perceptions of potential impacts of the pandemic in Senegal. They documented significant farmer-reported concerns on the negative impact of pandemic related disruptions to inputs and agricultural markets, and to their food security. These farmer-identified vulnerabilities can help to highlight where to provide support to increase resilience to the shocks of the pandemic.

Finally, Nchanji et al. (2021) presented results of a highly detailed and comprehensive bean value chain survey from nine African countries. They showed some variation in the severity of impacts, but overall, they highlighted that the shocks from the pandemic have the potential to set back the establishment of resilient bean value chains in the continent by years, as many were still emergent and not fully resilient to an encompassing shock like the COVID-19 pandemic. Disruptions to seed production systems due to the pandemic are likely to impact future growing seasons and may continue to ripple through the continent's agri-food systems for many years. They estimated that bean production for the current season is expected to decline due to problems accessing critical agricultural inputs and labour. Aggregators and traders have also been negatively impacted by COVID-19 mitigation strategies that have limited personal movements and access to markets, particularly for those who operate on a small and independent and more informal scale, which is common across the continent as well. International trade in food commodities has also been subject to COVID-19 mitigation measures, to maintain domestic food supplies for food security reasons, so the value chain disruptions do not end at national boundaries. They concluded that all of this has led to an increase in short-term food insecurity via instability in the full value chain and trading network of a major staple food commodity like beans. With the pandemic still ongoing, if pandemic mitigation strategies remain in place, these documented short-term shocks will continue. They also identified a longer-term vulnerability if shocks to a staple commodity value chain spillover into future years by reversing progress made to developing a more robust system of markets to secure bean production inputs and access to trade networks and output markets. They concluded that this is

cause for great concern on the current and future resilience of agri-food systems in the African continent.

4.2. The Americas

Four regional teams assessed the initial impacts of the first waves of the pandemic on different regions in the Americas, using a wide variety of frameworks to assess COVID-19's impact on the diverse agricultural systems within the Americas. Tiftonell et al. (2021) used a combination of key informant and farmer surveys as well as case studies to investigate the role of local agri-food systems and the agroecology movement across several countries in Latin America as sources of resilience during the pandemic. They found that local agri-food systems were able to provide social safety nets and fill in gaps in COVID-19 supports from other sectors, like public social safety net programs. Solidarity networks, built within the agroecology movement, also proved to be important in shifting quickly to providing food security and social support to urban food consumers and small producers suddenly coping with COVID-19 mitigation shocks. Lopez-Ridaura et al. (2021) examined the pandemic's impact across the principal farming systems in operation in Central America and Mexico through analyzing available academic and media reports and conducting key informant interviews. They found all farming systems from smallholders up to corporate farms were impacted to varying degrees. Both large corporate systems and small subsistence systems were less impacted than medium scale enterprises. Large systems were protected by control of their operation via vertical integration. Smallholders were protected due to limited interactions with markets and a focus on subsistence consumption, which can buffer the effects of COVID-19 mitigation policies that disrupt agricultural markets. Medium enterprises had protection from neither of these and thus were exposed to the greatest degree to policies designed to manage the public health crisis.

Weersink et al. (2021) focused on the highly integrated agri-food systems between Canada and the United States and compared the pandemic impact across major six commodity groups or sectors (cattle, hogs, poultry, dairy, grains and oilseeds, and fruits and vegetables). They observed large shocks and bottlenecks at the beginning of the pandemic but that the different sectors had largely recovered to pre-pandemic levels by the end of 2020. This demonstrates a great deal of flexibility and adaptive capacity within commodity value chains in the Canada-US region. One unanticipated vulnerability was the impact of the collapse of the 'Hotel, Restaurant and Café' (HORECA) marketing channels, and the inability of value chains to easily divert produce destined for restaurants and institutional food settings to the grocery outlets, despite the increase in grocery demand due to more home consumption. Whether commodity value chains will invest more permanently in more flexible marketing channels remains to be seen, but the pandemic highlights a previously undocumented vulnerability in the Canadian-US integrated agri-food system.

Blazy et al. (2021) summarized impacts of the first waves of the pandemic on the Caribbean region, using combined farmer, household, and key informant surveys to flesh out effects across different parts of the region's agri-food system. The pandemic weakened already vulnerable agri-food systems, noting that the small island states were heavily import-dependent for food and had limited agricultural production resources. The pandemic threatened food security in the region due to its impact on both food imports as well as restricting the farm incomes and valuable foreign exchange earned from high value agricultural exports that dominate the sector. The pandemic will likely exacerbate pre-existing agri-food system challenges, like coping with high vulnerability to climate change and multiple nutritional health challenges like undernourishment and high obesity rates for the population. Similar to the summary from Tiftonell et al., Blazy et al. also found an increase in prevalence of mutual aid systems for food security to help cope with pandemic related shocks.

Additional submissions from the Americas include Haqiqi and Horeh

(2021), who developed an innovative model to assess immediate impacts of both labour and demand shocks from the pandemic on agricultural production across counties in the United States. They estimated an 1–8% drop in agricultural production attributed to agricultural labour shortages in the first stages of pandemic, but with significant heterogeneity across counties. Counties with the highest numbers of small-scale farms were most vulnerable to the pandemic, which had on average a larger impact on the more heavily represented non-white and female-run operations at this scale. Marusak et al. (2021) presented seven case studies on smaller-scale, regionalized food supply chains (RFSCs) in Texas and Iowa to compare their relative resilience to the pandemic in contrast to nationalized and global food supply chains. They highlighted that RFSCs were able to quickly adjust their logistics and distribution strategies to cope with COVID-19 mitigation strategies and pivot to COVID-19-safe access strategies to food for consumers (e.g., home deliveries) as well as avoid supply disruptions that impacted larger food supply chains in the early days of the pandemic. They hypothesized that experiences of these RFSCs will likely help improve their ability to provide food and support their network of producers and distributors into the future after the end of the pandemic and may in the end be strengthened by the experience of adjusting to the pandemic.

Vargas et al. (2021) contrasted initial pandemic impacts between potato and coffee producers in Peru, documenting different experiences due to value chain structure differences. On average, coffee producers in the study were more insulated from COVID-19 related shocks than potato producers due to less pandemic-induced uncertainty in the more commercialized and highly integrated coffee value chains. Potato producers were much less certain on being able to market their output in local markets that were more strongly impacted by Peru's COVID-19 quarantine measures. Potato producers were also more likely to use savings to cope with pandemic related shocks. Both groups indicated concerns about reduced food security, although through different channels. Coffee producers indicated they were considering diversifying into more food crops to cope with more limited food accessibility in local markets and a lack of home production of a major staple like potato. Potato producers can consume their own output to manage food security concerns but were worried about reduced incomes from more uncertain potato revenues, which will increase food insecurity for other important consumption goods.

4.3. Asia

Thirteen papers in the Special Issue studied the effects of COVID-19 on agricultural and food systems in Asia. The first is a detailed Asia-wide regional paper, Dixon et al. (2021), co-authored by forty-five researchers studying the effects in 25 Asian countries. The remaining papers are based on individual countries or comparison of two or more countries. Four papers are from India, two each from Nepal and Myanmar, and one each from China and Singapore. One paper compared the effects in India and Nepal while one other included Myanmar in a comparison with other three countries in sub-Saharan Africa.

Asian farms are typically managed by smallholder households as integrated production-consumption systems within local communal, landscape and institutional settings. Land uses and farming and food systems (FFSs) in Asia vary greatly among the five sub-regions (East, Southeast, South, Central and West). Each FFS is characterized by contrasting patterns of resource availability, production mixes, provisioning services, food marketing arrangements, rural consumption patterns, off-farm income and livelihoods, and development trajectories. Many food system chains are in transition and comprise both traditional and modern technologies and institutional arrangements.

As the pandemic initially spread in Asia, various local surveys, focus group discussions, and mini reviews and perspective studies based on grey literature, blogs and media reports had been published from some countries in Asia, but a major gap remained in knowledge about the nature and magnitude of COVID-19 effects on agri-food systems at the

regional scale. Dixon et al. addressed this gap by assessing the initial responses of four principal Asian FFSs (viz, lowland rice based; irrigated wheat based; hill mixed; and dryland mixed systems) to COVID-19 in 25 countries, using key informants' surveys that included policy makers, researchers and university staff, extension workers and farmers in each of those countries. For each country, they compared the effects on each FFS through effects on labour and gender, market and policy, food and nutrition security, and resilience and sustainability. A conceptual framework was developed and applied by including key pathways linking the direct and indirect effects of COVID-19 to the resilience and performance of the FFSs.

Dixon et al. found that across the four FFSs and all the countries, rural livelihoods and food security were affected primarily because of disruptions to local labour markets, farm produce markets, and input supply chains. The overall effects on system performance were most severe in the irrigated wheat-based system and least severe in the hill-mixed system, associated in the latter case with greater resilience because of diversification and less dependence on external inputs and long market chains. They suggested that the FFSs' resilience and sustainability should be critical considerations for recovery policies and programs by governments and development workers, especially in relation to economic performance that initially recovered more slowly than productivity, natural resources status, and social capital. They concluded that overall, the resilience of Asian FFSs were strong because of inherent systems characteristics reinforced by public policies that prioritized staple food production and distribution as well as complementary welfare programs.

Using a quasi-experimental method and phone survey data from 1789 smallholder households in Rajasthan, Madhya Pradesh, and Uttar Pradesh States, Varshney et al. (2021) examined the impact of the Indian government's assistance package (some households received assistance from more than one mechanism) and/or cash transfers on the procurement of agricultural inputs for the 2020 Kharif (monsoon) farming season. Their findings showed that both mechanisms had a positive and significant impact on the procurement of agricultural inputs. The farmers who received benefits from the social assistance scheme however spent significantly more on the procurement of seeds, fertilizers, and pesticides than farmers benefiting from the cash transfer scheme. A plausible reason could be that when farmers received multiple benefits under the overall package, they had additional benefits (such as cash transfer for women, conditional cash transfer for buying cooking gas, and free food rations). As a result, they could afford to shift their additional spending on purchasing agricultural inputs. The study contributed towards improving government support in mitigating the potential productivity shock in the agricultural sector amid the COVID-19 pandemic.

Based on the published and unpublished sources of information and expert judgments, Kumar et al. (2021) reported the various consequences of the lockdown in four phases from March 24 to May 31, 2020 on overall national economy, farming and food systems, and economic challenges faced by farmers in India. They analysed different factors that contributed to the severe disruption of farming systems and the entire agricultural sector following the initial lockdown in March in Uttar Pradesh. Some of the most important consequences of the lockdowns that have affected farming systems and their value chains in the Uttar Pradesh include (i) surpluses and deficits in agricultural labour depending on location that resulted in wage decreases and increases; (ii) insufficient storage facilities; (iii) difficulties in transporting and distributing goods and produce; (iv) no or limited access to rural markets; and (v) insufficient availability of agricultural produce to meet rural and urban demand, resulting in inflated prices for agricultural produce. The authors argued that the lessons learned from the experience of the COVID-19 crisis within the agricultural sector, if taken into account by policy makers, could fuel the development of new sustainable agro-policies and decision-making in response not only to future pandemics but also to the sustainable development of agricultural

systems in India and in developing countries in general.

More than 95% of rice establishment in India is dependent on manual labour. In Punjab and Haryana states in NW India, COVID-19 induced lockdowns triggered reverse labour migration from these states. This resulted in labour shortages and delays in rice transplanting which would have huge effect on its productivity as delayed rice production delayed sowing of the subsequent wheat crop which then suffered from heat stress. [Balwinder-Singh et al. \(2020\)](#) evaluated four scenarios (considering labour-induced rice transplanting time delays and rice area transplanted) representing labour constraints on the timing of rice transplanting. Simulations suggested that rice productivity losses under all delayed transplanting scenarios would be lower than that of wheat with total rice-wheat system productivity (24%) and economic (US\$ 1.5 billion) losses due to labour shortages. Late rice transplanting and harvesting could increase and prolong residue burning period and aggravate winter air pollution and concomitant health risks. The available technological options to tackle labour shortage included: direct-seeded rice using seed drills, staggered nursery transplanting and mechanised rice transplanting, wheat sowing under residues with Happy Seeder, and crop diversification with maize instead of rice. However, government policy interventions and strategic planning would be required to implement such interventions by the farmers.

Smallholder farmers in Asia live under complex socio-economic and cultural environments and operate complex and diverse farming systems. These require many instant decisions by farmers who continually adapt to local environments and often seem to be resilient to unexpected changes or events. An understanding of how these complex systems function and how farmers adapt to unexpected events such as COVID-19 is necessary for planning and interventions. [Goswami et al. \(2021\)](#) used qualitative analysis using stakeholders (farmers, NGOs workers, etc.) interviews followed by fuzzy cognitive mapping and mental modelling with farmers and other stakeholders affected by COVID-19 and the named Amphan cyclone that hit southern West Bengal in eastern India in May 2020 right after the start of the pandemic. They conducted scenario analyses that were developed based on the shared mental model of stakeholders that suggested a varied technological and policy options to handle the simultaneous COVID-19 and Amphan cyclone crises. The study identified the immediate adaptation strategies used by the farmers and analysis suggested a combination of both short-term coping and long-term resilience strategies to handle the post-COVID-19 and post cyclone crises in agriculture. Scenario analysis with multiple stakeholders suggested enhanced market access and current household income, sustained investment in farming, rapid improvement in affected soil, irrigation water and livestock as the most effective strategies to enhance the resilience of farm families during and after the pandemic.

Except in some peri-urban areas and in the Terai plains where semi-commercial or commercial farming is practised, Nepal's agriculture is predominantly subsistence in nature, particularly in the hills and mountains. It was expected that the COVID-19 pandemic would result in differential impacts on subsistence and commercial farming systems. [Adhikari et al. \(2021\)](#) assessed the effectiveness of government measures to deal with the crisis in Nepal. They found that the lockdown and transport restrictions had severe consequences, adversely affecting all four pillars of food security (productivity, stability, availability and accessibility) and achieving the SDGs 1 and 2. Traditional subsistence farming systems were more resilient to the pandemic than the commercial systems due to their lesser reliance on external inputs for production, and greater stability of food production and accessibility to food. The findings have implications for policies to improve both subsistence and commercial farming systems. The experiences from the pandemic revealed the importance of identifying, collecting, conserving, and researching the indigenous species of crops, animals and other useful plants and promote the resilience aspects of subsistence farming especially in the hills and mountains to achieve resiliency at the time of future shocks while also promoting commercial or semi-commercial farming to achieve food sufficiency. The study identified four

innovations required during such crisis: scale-appropriate mechanization, cash support for bringing fallow lands into cultivation, digital marketing connecting local producers and consumers for up-scaling of activities, and good institutional infrastructures, governance structures and multi-sector coordination.

[Magar et al. \(2021\)](#) presented major pathways and priority actions to rebuild and revitalize the growth of the agricultural sector in Nepal while addressing the challenges posed by the pandemic to generate employment and income-earning opportunities. They emphasized the need for scale-appropriate strategies, programs and plans to build resilience of production, supply chains, and agribusiness systems. They suggested that the government initially focus on targeted priority interventions to the pandemic-affected farmers and agro-entrepreneurs, and strengthen their productive, competitive, and adaptive capacities. Together with these short-term strategies, long-term strategies such as development of agricultural infrastructure, innovative policies, legal instruments, and institutional arrangements, including strengthening of the recently established local governments in line with the federal structure, need to be developed.

Using phone surveys during different stages of lockdowns in Gujrat (Western State in India) and Dang (mid-western district in Nepal), [Alvi et al. \(2021\)](#) identified that women's access to agricultural extension was impacted by the lockdowns which then affected agricultural productivity. The impacts were heterogenous and varied by caste and education, crop type and region. In both countries, women's already low access to formal extension was reduced further, leading to an increased reliance on informal social networks. They suggested various means and tools (e.g., ICT-based tools such as smartphones, computers, and internet) by which inclusive and more gender-sensitive and resilient agricultural systems could be provided to adapt to future crises and pandemics. Use of innovative IVR (interactive voice response) technology to reach illiterate farmers and with different caste and gender, farmers' field schools aimed at inclusivity and local context specific, employing female extension workers and training and promoting women farmers in communities, group-based extension, and training and deployment of community frontline workers could be used to provide agricultural extension services and adapt to any pandemics.

China was the first country in the world hit by COVID-19. China adopted a series of stringent policies to contain the spread of virus, leading to food system disruptions due to restrictions on labour and interruption of transport, processing, retailing, and input distribution. [Zhan and Chen \(2021\)](#) studied COVID-19's initial impacts and the resilience of China's food system to the pandemic and discussed government's policy responses from the early stage of pandemic that promoted a resilient food system. Prompt policy responses and long-term strategies resulted in little panic in the food system with largely sufficient supplies and stable prices and returning the agriculture and livestock growth to normal and stabilizing the food prices that had increased initially. The study showed that other countries could learn from China's experience to tackle COVID-19 and build resilient food systems during such pandemic.

[Boughton et al. \(2021\)](#) documented the initial impacts of COVID-19 on Myanmar's agri-food system (crop production, farm inputs, mechanization services, marketing, retail, and household income effects). They showed pervasive negative effects. A household survey after the first lockdown in April 2020 showed that ~18% households were struggling to eat sufficient food, which increased to ~29% after the second lockdown in September 2020, suggesting that income losses and extreme poverty due to pandemic have been pervasive across Myanmar. They also showed that almost 50% households took loans or made purchase on credits, raising the risk of long-term indebtedness. Urban households were more dramatically affected by the pandemic than the rural farm households. They identified some key lessons to enhance the resilience of Myanmar's agri-food system in the face of any similar future pandemics, including recommendations on pandemic policy flexibility for agricultural goods and services, as well as types of government support

policies that are most helpful for the agricultural sector during a crisis such as the COVID-19 pandemic.

Fang et al. (2021) studied the responsiveness and resilience of different types of farming systems in Myanmar and evaluated the implications of the performance of the important poultry sector for the SDGs. They found that (i) the COVID-19 resulted in closure of more than 30% of broiler farms and 10% of layer farms closed and 42% of farmworkers were laid off by June, (ii) the sector experienced a V-shaped recovery until September 2020 when a second wave of COVID-19 hit the country, (iii) broiler farms were able to rapidly adjust operational status by closing or reopening due to their shorter production cycle, (iv) impact of pandemic varies by farming system since integrated layer-fish farms were more resilient to the COVID-19 shock than the other three types of farms, and (v) higher egg prices for consumers due to the slow supply response of layer farms affected the nutritional intakes by low-income consumers. These results have far-reaching implications as low egg intakes and loss of farmworkers' jobs made it difficult for Myanmar to achieve the SDG 2 (zero hunger; Target 2.1 – Universal access to safe and nutritious food) and SDG 8 (Decent work and economic growth; Target 8.3 - Promote policies to support job creation and growing enterprises) by 2030.

Pandemics can disrupt cities and urban areas, along the food supply chain, and hence they can be more vulnerable than rural areas, because cities generally rely more heavily on both domestic and international imports to meet their daily food demands. Thus, during pandemics, city dwellers and consumers have the tendency of hoarding food items including perishable vegetables and fruits which can result in shortage as well as wastage, especially of vegetables. Song et al. (2021) used the system dynamics approach for a hypothetical pandemic to 1) understand the potential impacts of the pandemic on local vegetable production and their shortage or wastage, and consumer hoarding behaviour, and 2) identify leverage points in the supply chain to improve vegetables availability during pandemics or other catastrophes such as COVID-19 in Singapore. The study conducted the scenario analysis by simulating the multiple pandemic waves with changing maximum infectivity, their effects on consumer hoarding behaviour, changes in external supply and the subsequent feedback in the entire supply chain and identified factors that could cause vegetable shortage and wastage during a pandemic. The scenarios suggested that hoarding behaviour of the consumers was more important than the reduction of the vegetable imports in causing food shortages during a pandemic. Their results suggested that during pandemics or similar catastrophes, more effort should be made on reducing consumer hoarding behaviour rather than increasing vegetable inventories among suppliers. Such study could provide directions for future pandemic planning to improve cities' food resilience without causing excess wastage.

4.4. Europe

The regional team summary for Europe (Meuwissen et al., 2021) adopted a resilience framework and took advantage of long-term farming systems data via the SURE-farm network. Following a framework (Meuwissen et al., 2019), they assessed aspects of farming system resilience across 11 case studies. Broadly they identified relatively few immediate impacts and attributed this to several resilience characteristics. First, in all but three systems, exposure and sensitivity to pandemic shocks and mitigation efforts were deemed to be minor. In many cases, this was due to the relatively fortunate timing of the pandemic. Second, they found several successful short-run coping strategies for farming system actors and in the broader enabling environment, like making use of buffer stock savings, quickly implementing pandemic health protocols, farmer solidarity and mutual aid, pivots to online direct to consumer sales, and government support for agriculture across the case study sites. However, they found little evidence of longer-term, adaptive, or transformative resilience capacities mobilized by the shocks of the pandemic. Therefore, it is difficult to see broader

farming system transformation emerging from these initial experiences of the COVID-19 pandemic in the European systems studied by the regional team, despite expressed concerns in the data collection process about these underlying, more systemic vulnerabilities in the agri-food systems in Europe, like exposure to long value chains or a heavy reliance on migrant labour. This assessment could change after a longer time frame has passed under continued pandemic conditions.

The other contributions to the Special Issue that focused on the European region found similar limited impacts of the pandemic, via strong resilience capacities at the farm level as well as at the institutional and public policy level. Coopmans et al. (2021) looked at the pandemic's impact within the broader agri-food system in Belgium, assessing resilience in terms of primary agricultural production as well as the downstream agri-food supply chain. They documented several short-term disruptions to primary producer revenue and the collapse of the HORECA marketing channels observed in many of the regions covered by this Special Issue. But they also noted significant resilience capacity within the supply chain to cope with these unanticipated shocks. Farmers in relatively exposed sectors, such as dairy with highly perishable output susceptible, responded that the financial consequences of these shocks were large, with less market power within the broader agri-food system than food processors and retailers to shield them from the large demand-side shocks. Processors were able to partially offset the loss of demand from hospitality market chains through reallocation to other market channels as well as strategic, temporary collaboration between traditional competitors for the broader objective of minimizing COVID-19 related losses.

Perrin and Martin (2021) similarly found evidence of significant resilience at both the farm level as well as the supply chain level for organic dairy production in France. Many of the farmers were family farms and engaged in production of their own livestock feed. Thus, they were largely shielded from labour and input supply disruptions that have negatively impacted farms in other regions. Active management of the pandemic at the supply chain and government level was also important in minimizing the effects of the pandemic. Supply chains were able to shift to producing a narrower mix of dairy products to simplify work. Farmers were asked to reduce production by 5%, smaller dairies more actively coordinated production and processing to minimize shocks, and other supply chain logistics problems were resolved relatively quickly with flexible management. Farmers in this study thus did not experience large effects and remained more concerned about other kinds of shocks, including climate change.

Prosser et al. (2021) examined case studies from the Welsh agri-food system in the United Kingdom to explore the impact of the pandemic on food and drink producers and affordable food access. They emphasized the positive role of the 'alternative food systems' set up because of the pandemic, which worked to connect small and medium sized local producers with food processing and market access channels. They described a quick shift to online direct marketing to consumers, with one specifically designed to maintain food delivery access to food insecure individuals and families by using excess farm produce supply to match up with program recipients. They compared these new models to conventional agri-food value chain structures in the context of the pandemic and explored potential for longer term viability once the pandemic is over.

Finally, Tougeron and Hance (2021) reported on impacts on apple orchard value chains, as well as research programs on orchard production systems, in the European Union. Difficulties in accessing seasonal labour was the first identified concern for apple orchards, due to COVID-19 mitigation measures limiting movements of workers. Additional disruptions to important input supply chains were also found. Household demand for apples increased during the pandemic, both because of more home consumption overall and because of disruptions to imports of potential substitute tropical fruits. This increase has somewhat offset the restrictions on other foodservice marketing channels like restaurants and institutions. They identified other complex shocks and offsets that

have been observed for apples, such as the benefits of the ability to store apples over the long term, in contrast with the shutdown of apple picking and farmers markets which are important particularly to smaller scale orchard operations. Additionally, exports have been restricted, but this is in conjunction with consumers looking more for 'eat local' options. Finally, they noted that there may be unintended and long-term implications of labour shortages and physical movement restrictions that should be further considered. On-farm labour is essential in the early detection of pests and phytosanitary risks which may have been missed during the start of the pandemic, with on-going ramifications into future production years. Free movement of researchers and communication with producers is also critical to the conduct of scientific research on apple production and relies heavily on both farm and field access, as well as access to research facilities, all of which have been severely curtailed during the pandemic.

4.5. Pacific Region

Snow et al. (2021) focused on Australia and New Zealand applying a framework to identify sources of resilience. They compared agricultural sectors with distinct characteristics that condition their ability to respond to disruption caused by pandemic mitigation strategies. Following their analysis, the authors emphasized the role of *plasticity* in understanding and contextualizing pandemic impacts. Some sectors with ability to store output along different stages of the value chain (like increased dried grain storage) are more plastic and can use this resilience attribute to smooth out disruptions. Others however have limited capacity to store or adjust production and processing in the face of sudden shocks (e.g., the pork and chicken value chains) and were characterized by relatively low plasticity. Despite this variation, both high and low plasticity sectors were observed to be relatively resilient, but utilized different strategies to achieve this, including relatively more reliance on government and institutional and social support for low plasticity sectors with fewer risk mitigation options within the value chain itself. They note also that many questions remain about longer term changes to agricultural value chains that may emerge or are unresolved at the time of writing during mid-2020. These included questions about rebounds in high-value export markets and transportation systems on which both countries rely, as well as the return of seasonal and migrant labour important to many agricultural sectors. Permanent shifts in the relative importance of exports or seasonal labour would have large structural consequences for the agricultural sectors, but as of late-2020, it remained to be seen whether these shocks were simply transitory in nature and production systems will remain fundamentally unchanged.

To complement Snow et al. (2021), two other research submissions from the Pacific region contributed to our understanding of the pandemic and agricultural systems.

Davila et al. (2021) presented evidence from Papua New Guinea, Timor-Leste and seven Pacific Island Countries on food systems in these countries through to July 2020. Using a systems-based analytical framework to assess food system resilience, they divided their analysis across impacts on smallholder livelihoods, supply chains, governance responses, vulnerable populations, and employment and income. The largest impacts were in the steep losses of employment and income due to both COVID-19 shocks and mitigation efforts. Social safety nets across the countries were insufficient to fully cushion the blow to incomes, particularly for vulnerable populations such as the urban poor and women (who were more exposed to market shutdowns as well as being tasked with increased care-taking responsibilities during the pandemic). There was substantial evidence of reduced food access, which threatened food security most severely among more marginalized populations. Existing connections in these Small Island Developing States (SIDS) to global food value chains were a source of resilience that offset local food system disruptions. The authors concluded with three proposed recovery pathways:

- focusing on assessment and possible restructuring of food value chains,
- leveraging longer standing investments in climate change adaptation to integrate these efforts with improved food system resilience, and emphasis on food security, and
- addressing serious issues in food system inequality and vulnerability for groups that the pandemic exposed in particular relief.

Iese et al. (2021) offered detailed agri-food system evidence from Fiji and the Solomon Islands using a combination of focus group meetings and household interviews with peri-urban and rural households. They examined pandemic-related impacts on: primary agricultural production; agricultural markets; value chains; incomes; government and non-governmental organization strategies; household food systems and production practices; and dietary diversity. Households in these countries have responded to COVID-19 shocks in a variety of ways including: shifting more to home production of staple goods to overcome issues associated with market access, loss of income, and changes in food prices. There has been out-migration from cities to rural areas, leading to increased agricultural production in rural areas. This out-migration has also increased food access issues in peri-urban and rural areas. The researchers noted that, given the impact on a range of components of the entire agri-food system, continued monitoring and research was needed to better understand the longer-term implications of these shifts, particularly with respect to food security shocks and consequences.

5. Comparative/theoretical pieces

Seven research teams contributed pieces that were more theoretical or comparative in nature, highlighting cross-cutting themes and issues across agricultural systems subjected to pandemic shocks and changes.

Acosta et al. (2021) highlighted pandemic impacts on the global dairy sector. They were able to gather information both near the beginning of the pandemic and then one year into the pandemic, and so offer valuable longitudinal insights. The episodic nature of the pandemic caused waves of shocks to both demand and supply, with shifts in demand away from commercial/hospitality outlets towards home-based consumption which required adjustments in processing. They also examined shocks to international trade in dairy commodities, and foreign exchange considerations. Most informants indicated that, by the second round of surveys, many of the episodic waves had subsided but overall costs of the pandemic to the global dairy sector have likely exacerbated longer-term structural changes in the industry. These include greater concentration and consolidation in the sector with the exit of smaller dairy producers.

Andrieu et al. (2021) bridged three continents and compared the impact of the pandemic and mitigation strategies with longer term agricultural sector objectives on climate change in Burkina Faso, Colombia, and France. Using the Cool Farm Tool, they assess the impact of the pandemic and mitigation measures on GHGs emissions from a diverse set of agricultural systems in the three countries. They found that most COVID-19 mitigation strategies were aimed at short-term stabilization of the agricultural sectors. However, larger scale reductions in agricultural commodity exports and a general reduction in production caused temporary reductions in agricultural GHGs in each study area. They highlight that there was little coordination between pandemic mitigation and possible prevention of unintended consequences for other agricultural policy objectives like climate change mitigation and adaptation, and the risks that may pose in the future in terms of pandemic policies working at cross purposes to the achievement of other agricultural sector priorities.

de Boef et al. (2021) provided a rapid, comparative assessment of the impact of the pandemic on seed production value chains in Ethiopia, Myanmar, Nigeria, and Uganda. Relative impacts varied across countries depending on the stage of the cropping season, however they identified human mobility restrictions and decreased sales of higher

quality seed in formal markets as the main immediate consequences of COVID-19 mitigation measures to deal with the pandemic. They developed a rapid formal seed system alert assessment to compare different COVID-19 pandemic measures and their impact on different stages of formal seed systems. Looking in detail at an important input market like seeds gives a glimpse into how the costs and fallout from the pandemic may potentially stretch across multiple cropping seasons. They concluded that effects would stretch into future threats to food, nutrition and income security. They also highlighted that the pandemic has weakened the seed sector overall by exacerbating existing structural weaknesses, further strengthening the need for already-identified reforms.

Darnhofer (2021) contributed a Perspectives article, reflecting more broadly on resilience in the context of unexpected agricultural system shocks. Darnhofer notes that unexpected events are ‘ubiquitous’ but are an insufficiently studied focus of agricultural system research. We should put more attention on how to ‘bounce forth’ from the unexpected rather than the more common assumption that resilience is equivalent to ‘bouncing back’ to the status quo. Adaptive systems and an emphasis on research that illuminates future pathways and co-learning were presented to contrast to methodological approaches that focus more directly on efficiency and one-off optimization approaches. These latter studies do not usually incorporate more flexible resilience choices. In a similar vein, Lioutas and Charatsari (2021) discussed what the COVID-19 pandemic can teach us about coping with disasters and crises in agricultural systems. They offered a useful definition of a crisis as low-probability, high risk and highly unpredictable, then analysed the implications of the COVID-19 pandemic as a crisis event on global agricultural systems. One feature that stood out was that COVID-19 mitigation strategies often work, as a side effect, to damage the functioning of our agri-food systems.

Hammond et al. (2022) analysed a large collection of smallholder farmer surveys from seven countries in Sub-Saharan Africa and Southeast Asia to assess their self-reported impacts of pandemic mitigation policies and their consequent coping strategies. They found consistent reporting from smallholders across these disparate countries on negative livelihood and food security consequences of pandemic mitigation measures like restricted movements of individuals and disruptions to agricultural markets. They used these first-hand accounts to flesh out the difficulties in finding a policy balance between pandemic mitigation and the overall well-being of particularly vulnerable smallholder populations reliant on the agricultural sector for both incomes and food security. They offered a number of different policy options, including agricultural commodity price and value-chain stabilization, tiered mobility restrictions that make allowances for economic hardships for smallholders and direct aid to these vulnerable populations.

Finally, Rivera-Ferre et al. (2021) examined the complex feedback relationships between food systems and the pandemic. They noted that our agri-food systems have clearly been severely affected by the pandemic and our mitigation strategies. But they also noted that our agri-food systems may also be driving emergent infectious diseases (EIDs) and zoonosis risks. They argue that a comprehensive food systems approach is necessary to sufficiently analyze the pandemic and facilitate our ability to avoid future crises that may emerge from our agri-food systems.

6. Emergent themes from the special issue

The Special Issue has fortunately been able to capture a breadth of initial observations on the pandemic, across multiple geographies, farming systems, rural and urban communities, from producers and consumers, and along key components of our local, regional, national, and international agri-food system structures. Despite this diversity of submissions and perspectives, some common themes emerged as summarized in Table 2.

In our initial editorial call for contributions to the Special Issue

(Stephens et al., 2020), we articulated several concerns about how the pandemic could impact our agricultural systems. Based on emerging, primarily anecdotal, accounts, we anticipated that the pandemic could lead to large-scale food security issues, labour shortages and human health concerns, negative consequences of COVID-19 mitigation strategies, supply chain issues and threats to agricultural system connectivity. We also had significant concerns about our agricultural systems resilience capabilities to these different shocks. Much of the evidence collected in this Special Issue strongly corroborates these initial hypotheses, at least over the initial short term. What remains to be seen, potentially in a follow up special issue, is whether these myriad disturbances to agricultural systems worldwide will result in permanent shifts and changes to the systems themselves.

One overarching observation on this Special Issue contributions is that they on balance contribute much more to our body of knowledge about the impact of COVID-19 mitigation measures and policies on agricultural systems than our understanding and information about the impact of the human and public health cost of the pandemic on agricultural systems. This is due partly to the fact that this Special Issue captured immediate impacts from the first waves of the pandemic, which for many stakeholders in agricultural systems worldwide were much more related to coping with mitigation strategies, many of which involved restrictions on human movement and interaction to curb the spread of COVID-19.

One picture that emerges from this is to highlight perhaps more forcefully how important physical human movement, market access and trade are to the functioning of our agricultural systems. This can be seen across the submissions, from papers documenting the effects of restricted movement of agricultural labour from source regions to agricultural systems in destinations worldwide that depend on this mobile workforce (the ‘Agricultural Labour Shortages’ pieces in Table 2), to the importance of physical access to spot markets, critical for the livelihoods of smallholder farmers worldwide (the ‘Local/Spot Agricultural Market Challenges’ pieces in Table 2), and also how shocks to different supply chains at a variety of scales have disrupted agricultural systems as well (the ‘COVID-19 Mitigation and Markets’ pieces in Table 2).

Changes in policies surrounding physical human movement and market access within the agricultural sector created agricultural labour shortages and agricultural production impacts in some regions (Balwinder-Singh et al., 2020; Kumar et al., 2021) and agricultural labour surpluses in other regions, in the case where there was an outflow of people from urban areas into rural areas as part of some COVID-19 mitigation efforts (c.f. Iese et al., 2021). Vargas et al. (2021) and Tintonell et al. (2021) and several other papers document the difficulties caused from restrictions on important staple agricultural commodity spot markets, particularly for marginalized groups, like rural women farmers. Tougeron and Hance (2021) describe potential costs to agricultural science, extension, and risk mitigation due to restricted access to agricultural operations, which may result in future costs to agriculture (e.g., reduced agricultural pest surveillance by research and extension personnel). Documenting these experiences can hopefully lead to improved pandemic mitigation strategies that are able to both manage public health risks as well as the costs of human movement restrictions (Hammond et al., 2022).

Multiple contributions to the Special Issue documented how COVID-19 mitigation has disrupted agricultural supply chains at all scales (local, regional, national and international), the shocks from which are still working their way through global supply chains at the time of writing in early 2022. Specialized value chains for commercial outlets (the ‘Challenges with loss of HORECA market channels’ papers in Table 2) were particularly vulnerable to COVID-19 mitigation measures that shuttered restaurants, hotels and institutional food service settings like schools, leading to losses and significant retooling of food value chain systems to redirect agricultural produce to meet increased demand from home consumption. At the largest spatial scales, disruptions to

Table 2
Emerging themes from contributions to the COVID-19 Special Issue.

Emergent theme	Regions present	Papers
COVID19 Mitigation and Labour: Agricultural Labour Shortages	Canada/US, Asia, Europe	Balwinder-Singh et al., Haqiqi and Horeh, Dixon et al., Kumar et al., Singh et al., Snow et al., Tougeron and Hance, Weersink et al
COVID19 Mitigation and Labour: Internal displacement of people due to job loss/movement restrictions	Latin America, Asia, Pacific/Oceania	Tittonell et al., Kumar et al., Iese et al.
COVID19 Mitigation and Labour: Local/Spot Agricultural Market Access Challenges	Africa, Latin America, Asia, Pacific/Oceania	Middendorf et al., Vargas et al., Dixon et al., Kumar et al., Hammond et al Tittonell et al., Marusak et al., Goswami et al., Adhikari et al., Zhan and Chen, Fang et al., Meuwissen et al., Coopmans et al., Perrin and Martin, Prosser et al., Snow et al., Iese et al., Darnhofer
Resilience: Resilience/alternative agri-food systems innovation	Latin America, Canada/US, Asia, Europe, Pacific/Oceania	Nchanji et al., Blazy et al., Boughton et al., Acosta et al
Resilience: Regional/International Supply Chain Agricultural Market Access Challenges	Africa, Caribbean, Asia	Lopez-Ridaura et al., Weersink et al., Vargas et al., Davila et al., Acosta et al
Resilience: Vertical integration/international value chain buffers	Central America/Mexico, Canada/US, Latin America, Pacific/Oceania	Weersink et al., Coopmans et al., Tougeron and Hance, Acosta et al
Resilience: Challenges with loss of HORECA (Hotel/Restaurant/Café) market channels	Canada/US, Europe	Jha et al., Nchanji et al., Blazy et al., Alvi et al., Davila et al., Acosta et al., De Boef et al., Rivera-Ferre et al
Long term costs: Long term costs/losses/vulnerabilities	Africa, Caribbean, Asia, Pacific/Oceania	Middendorf et al., Dixon et al., Boughton et al., Tougeron and Hance, Acosta et al., De Boef et al
Long term costs: Agricultural input market shocks and losses	Africa, Asia, Europe	Middendorf et al., Tittonell et al., Blazy et al., Vargas et al., Dixon et al., Adhikari et al., Boughton et al., Fang et al., Davila et al., Iese et al.
Long term costs: Food Insecurity/Household income shocks	Africa, Latin America, Caribbean, Asia, Pacific/Oceania	Blazy et al., Lopez-Ridaura et al., Boughton et al., Iese et al
Long term costs: Rural agricultural system stress	Africa, Central America/Mexico, Asia, Pacific/Oceania	Blazy et al., Graham et al., Hammond et al., Magar et al., Davila et al., Darnhofer, Varshney et al., Andrieu et al., Lioutas and Charatsari, Rivera-Ferre et al
Policy: ‘Build back better’: COVID19 policy opportunities, challenges and unintended consequences	all regions	

international shipping capacity for agricultural output caused the largest shocks to entire commodity value chains that had limited capacity to buffer these disruptions, due to low ‘plasticity’ and flexibility (the ‘Vertical integration/international value chain buffers’ papers).

There is also significant evidence presented in the Special Issue of long term, multiyear costs of the pandemic to our agricultural systems. As an example, Nchanji et al. (2021) and de Boef et al. (2021) both presented a detailed description of the disruptions in value chains across several countries. By looking at commodity supply chains as a whole, they documented the costs of the pandemic on current production and incomes but also looking into future seasons and anticipated that some emerging value chains may be fundamentally weakened. Acosta et al. (2021) documented similar long-term costs from the pandemic to the global dairy sector and speculated that the pandemic would accelerate the existing structural consolidation processes. Lopez-Ridaura et al. (2021) documented similar inequalities in costs and impacts for agricultural systems in Central America and Mexico. They found mid-sized agricultural systems were most at risk from pandemic-related costs and disruptions. Simultaneously, they do not have the overarching protection and insurance of very large, global producers connected to multi-national value chains (Weersink et al., 2021; Snow et al., 2021), but are also more exposed than very small subsistence producers who have limited connections to agricultural output and input markets (Adhikari et al., 2021; Dixon et al., 2021; Goswami et al., 2021).

Additional long-term costs have been observed in many papers in this Special Issue collection. These costs are expected to grow in size due to large income and employment losses, particularly for low-income and marginalized agricultural producers worldwide (as seen in Alvi et al., 2021, Middendorf et al., 2021, Boughton et al., 2021, Davila et al., 2021, Iese et al., 2021), for whom there is already very little in the way of social safety nets or any significant insurance mechanisms. Other submissions documented potential stresses on our agricultural systems due to urban to rural out-migration (Iese et al., 2021) or the superimposition of COVID-19 related shocks on already stressed agricultural systems contending with other long-term dynamics, like climate change (Blazy et al., 2021) and the potential for future pandemics (Rivera-Ferre et al., 2021).

A more positive cross-cutting theme in the Special Issue was *resilience*. Many contributions to the Special Issue documented evidence of sources of resilience within our agricultural and agri-food systems to the pandemic. Several papers document actions contributing to agricultural system resilience capacities, such as:

- rapid emergence of community-based mutual aid groups (Tittonell et al., 2021);
- COVID-19-sensitive agricultural and agri-food marketing innovations (Prosser et al., 2021; Meuwissen et al., 2021);
- adaptive commodity marketing within supply chains (Perrin and Martin, 2021; Snow et al., 2021; Marusak et al., 2021);
- problem solving following to the loss of HORECA marketing channels (Weersink et al., 2021; Coopmans et al., 2021; Snow et al., 2021); and
- successful agri-food system policy interventions (Zhan and Chen, 2021; Adhikari et al., 2021; Dixon et al., 2021).

Given the time frame for contributions to this Special Issue (primarily between April 2020 and June 2021), it remains to be seen if some of these adjustments will become permanent structural changes. Several authors from the Special Issue speculate that some innovations may outlast the pandemic, particularly in direct-to-consumer agricultural produce marketing, as this market channel has the potential to be viable even when agri-food systems are no longer contending with pandemic-related shocks and changes.

A final theme concerns both productive and counterproductive impacts of COVID-19 mitigation policy on other policy objectives. A desire to ‘Build Back Better’ can be observed in several submissions. Andrieu et al. (2021) and Graham et al. (2021) both estimated the impact of the pandemic on GHG emissions in agricultural systems. They showed both that the pandemic has impacted GHG emissions which are a significant agricultural policy target in many countries, but also that COVID-19 policy has the potential to undo progress made on climate mitigation policy for agriculture if the policy environment for agriculture is not examined more holistically. Hammond et al. (2022) also contrasted COVID-19 mitigation policies with food security policy objectives and

found significant contradictions in dual objectives to manage public health as well as agricultural livelihoods. Darnhofer (2021) offered an overview perspective on how the experience of the pandemic could help agricultural systems policy to think more about ‘bouncing forth’ from uncertainty and the unexpected with more investments in supporting complex adaptive agricultural systems, a point echoed by Lioutas and Charatsari (2021). These ideas are in line with thinking on system transition and transformation, where global crisis such as COVID-19 may trigger fundamental and transformative change, much alike other large-scale events or processes such as climate change (Gaitán-Cremaschi et al., 2019; Dinesh et al., 2021). The resilience of some agricultural systems (as mentioned above) may in this respect also be seen as ‘negative resilience’ as even large shocks as the COVID-19 have not created tipping points that induce transitions to fundamentally different systems (Oliver et al., 2018; Conti et al., 2021). ‘Build Back Better’ as a mission and the role of societal trust in resilience (Lenton et al., 2022) may hence need to be more central in policy and innovation support efforts for agri-food systems transformation (Klerkx and Begemann, 2020; Baudron and Liégeois, 2020), also to address long term costs and vulnerabilities of current systems.

7. Conclusions

This Special Issue resulted in a diverse set of perspectives on the immediate impacts of the pandemic on global agricultural systems, from the early onset of COVID-19 in early 2020 until early-mid 2021. Despite rapid development of vaccines for COVID-19, the pandemic continues to roll on as of the time of writing (early 2022). Only time will tell how the new variants of COVID-19 impact our, already weakened, agricultural systems and how the dynamics described in this Special Issue will play out in the coming years, which we will attempt to capture in a future follow up special issue. Evidence of resilience contained in this Special Issue provides some hopeful perspectives, but also can guide future strategies to boost these emergent agricultural value chains and more broadly, food systems transformation.

Evidence presented in this Special Issue of the significant and ongoing pandemic-related challenges to agricultural labour markets, trade, value chains and food security can guide our future actions as the pandemic continues. Although we uncovered several sources of agricultural system resilience, like direct marketing innovations, and the swift mobilisation of social network and community safety net systems in the face of COVID-19, they were not universally available. We therefore see particular need to shore up vulnerable agricultural systems and populations most negatively affected by the pandemic to date. A further need is to ensure that long term costs and unrecoverable losses from the pandemic are accounted for and mitigated to the extent possible to preserve other agricultural systems policy objectives, such as improving food security, or climate change mitigation and adaptation.

Finally, we thank the many contributors (authors and reviewers) to this Special Issue for offering up this wealth of knowledge and insights that can contribute to our collective recovery from the pandemic.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank all the authors and reviewers that contributed so willingly to this Special Issue for their efforts during times which were unsettled and stressful. We also gratefully acknowledge the assistance of Daniel Rodríguez, a former Editor of the journal, who agreed to handle the review of the manuscript for which all the current Editors were conflicted.

References

- Acosta, A., McCorriston, S., Nicolli, F., Venturelli, E., Wickramasinghe, U., ArceDiaz, Scudiero, E.L., Sammartino, A., Schneider, F., Steinfeld, H., 2021. Immediate effects of COVID-19 on the global dairy sector. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103177>, 192 (this VSI).
- Adhikari, J., Timsina, J., Khadka, S.R., Ghale, Y., Ojha, H., 2021. COVID-19 impacts on agriculture and food systems in Nepal: implications for SDGs. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.102990>, 186 (this VSI).
- Alvi, M., Barooah, P., Gupta, S., Saini, S., 2021. Women’s access to agriculture extension amidst COVID-19: insights from Gujarat, India and dang, Nepal. *Agric. Syst.* 188 (this VSI) <https://doi.org/10.1016/j.agsy.2020.103035>.
- Andrieu, N., Hossard, L., Graveline, N., Dugue, P., Guerra, P., Chirinda, N., 2021. Covid-19 management by farmers and policymakers in Burkina Faso, Colombia and France: lessons for climate action. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103092>, 190 (this VSI).
- Balwinder-Singh, Shirsath, P.B., Jat, M.L., McDonald, A.J., Srivastava, A.K., Craufurd, P., Rana, D.S., Singh, A.K., Chaudhari, S.K., Sharma, P.C., Singh, R., Jat, H.S., Sidhu, H. S., Gerard, B., Braun, H., 2020. Agricultural labour, COVID-19, and potential implications for food security and air quality in the breadbasket of India. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.102954>, 185 (this VSI).
- Baudron, F., Liégeois, F., 2020. Fixing our global agricultural system to prevent the next COVID-19. *Outlook Agric.* 49, 111–118.
- Blazy, J.M., Causseret, F., Guyader, S., 2021. Immediate impacts of COVID-19 crisis on agricultural and food systems in the Caribbean. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103106>, 190 (this VSI).
- Boughton, D., Goeb, J., Lambrecht, L., Headey, D., Takeshima, H., Mahrt, K., Masias, I., Goudet, S., Ragasa, C., Maredia, M.K., Minten, B., Diao, X., 2021. Impacts of COVID-19 on agricultural production and food systems in late transforming Southeast Asia: the case of Myanmar. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103026>, 188 (this VSI).
- Conti, C., Zanello, G., Hall, A., 2021. Why are agri-food systems resistant to new directions of change? A systematic review. *Global Food Security* 31, 100576.
- Coopmans, I., Bijttebier, J., Marchand, F., Mathijs, E., Messely, L., Rogge, E., Sanders, A., Wauters, E., 2021. COVID-19 impacts on Flemish food supply chains and lessons for Agri-food system resilience. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103136>, 190 (this VSI).
- Darnhofer, I., 2021. Resilience or how do we enable agricultural systems to ride the waves of unexpected change? *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.102997>, 187 (this VSI).
- Davila, F., Bourke, R.M., McWilliam, A., Crimp, S., Robins, L., van Wensveen, M., Alders, R.G., Butler, J.R.A., 2021. COVID-19 and food systems in Pacific Island Countries, Papua New Guinea, and Timor-Leste: Opportunities for actions towards the sustainable development goals. *Agric. Syst.* 191 (this VSI) <https://doi.org/10.1016/j.agsy.2021.103137>.
- de Boef, W.S., Borman, G.D., Gupta, A., Subedi, A., Thijssen, M.H., Aga, A.A., Beko, M.H., Thein, S.Z.M., Thein, W., Okelola, F., Olusegun, O., Ojo, O.P., Agbara, C., Otim, G., Semwogerere, C., Ntare, B., Oyee, P., 2021. Rapid assessments of the impact of COVID-19 on the availability of quality seed to farmers: advocating immediate practical, remedial and preventative action. *Agric. Syst.* 188 (this VSI) <https://doi.org/10.1016/j.agsy.2020.103037>.
- Dinesh, D., Hegger, D.L.T., Klerkx, L., Vervoort, J., Campbell, B.M., Driessen, P.P.J., 2021. Enacting theories of change for food systems transformation under climate change. *Global Food Security* 31, 100583.
- Dixon, J.M., Weerahewa, J., Hellin, J., Rola-Rubzen, M.F., Huang, J., Kumar, S., Das, A., Qureshi, M.E., Krupnik, T.J., Shideed, K., Jat, M.L., Prasad, P.V.V., Yadav, S., Irshad, A., Asanaliyev, A., Abugalieva, A., Karimov, A., Bhattarai, B., Balgos, C.Q., Benu, F., Ehara, H., Pant, J., Sarmiento, J.M.P., Newby, J.C., Pretty, J., Tokuda, H., Weyerhaeuser, H., Digal, L.N., Li, L., Sarkar, M.A.R., Abedin, M.Z., Schreinmachers, P., Grafton, Q., Sharma, R.C., Saizoda, S., Lopez-Ridaura, S., Coffey, S., Kam, S.P., Win, S.S., Praneetvatakul, S., Maraseni, T., Touch, V., Liang, W.-L., Saharawat, Y.S., Timsina, J., 2021. Response and resilience of Asian agrifood systems to COVID-19: an assessment across twenty-five countries and four regional farming and food systems. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103168>, 193 (this VSI).
- Fang, P., Belton, B., Zhang, X., Win, H.E., 2021. Impacts of COVID-19 on Myanmar’s chicken and egg sector, with implications for the sustainable development goals. *Agric. Syst.* 190 (this VSI) <https://doi.org/10.1016/j.agsy.2021.103094>.
- Gaitán-Cremaschi, D., Klerkx, L., Duncan, J., Trienekens, J.H., Huenchuleo, C., Dogliotti, S., Contesse, M.E., Rossing, W.A.H., 2019. Characterizing diversity of food systems in view of sustainability transitions. A review. *Agron. Sustain. Dev.* 39, 1.
- Goswami, R., Roy, K., Dutta, S., Ray, K., Sarkar, S., Brahmachari, K., Nanda, M.K., Mainuddin, M., Banerjee, H., Timsina, J., Majumdar, K., 2021. Multi-faceted impact and outcome of COVID-19 on smallholder agricultural systems: integrating qualitative research and fuzzy cognitive mapping to explore resilient strategies. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103051>, 189 (this VSI).
- Graham, M.W., Chelanga, P., Jensen, N.D., Leitner, S.M., Fava, F., Merbold, L., 2021. A framework for assessing the effects of shock events on livestock and environment in sub-Saharan Africa: The COVID-19 pandemic in Northern Kenya. *Agric. Syst.* 192 (this VSI) <https://doi.org/10.1016/j.agsy.2021.103203>.
- Hammond, J., Siegal, K., Milner, D., Elimu, E., Vail, T., Cathala, P., Gatera, A., Karim, A., Lee, J.-E., Douxchamps, S., Tu, M.T., Ouma, E., Lukuyu, B., Lutakome, P., Leitner, S., Wanyama, I., Thi, T.P., Phuc, P.T.H., Herrero, M., van Wijk, M., 2022. The impacts of COVID-19 restrictions on smallholder farmers: evidence from seven lower- and middle-income countries. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2022.103367>, 103367 (this VSI).

- Haqiqi, I., Horeh, M.B., 2021. Assessment of COVID-19 impacts on U.S. counties using the immediate impact model of local agricultural production (IMLAP). *Agric. Syst.* 190 (this VSI) <https://doi.org/10.1016/j.agsy.2021.103132>.
- Iese, V., Wairiu, M., Hickey, G.M., Ugalde, D., Salili, D.H., Walenenea, J., Tabe, T., Keremama, M., Teva, C., Navunicagi, O., Fesaitu, J., Tigona, R., Krishna, D., Sachan, H., Unwin, N., Guell, C., Haynes, E., Veisa, F., Vaike, L., Bird, Z., Ha'apio, M., Roko, N., Patolo, S., Dean, A.R., Kiran, S., Tikai, P., Tuiloma, J., Halavatau, S., Francis, J., Ward, A.C., 2021. Impacts of COVID-19 on agriculture and food systems in Pacific Island countries (PICs): Evidence from communities in Fiji and Solomon Islands. *Agric. Syst.* 190 (this VSI) <https://doi.org/10.1016/j.agsy.2021.103099>.
- Jha, P.K., Araya, A., Stewart, Z.P., Faye, A., Traore, H., Middendorf, B.J., Prasad, P.V.V., 2021. Projecting potential impact of COVID-19 on major cereal crops in Senegal and Burkina Faso using crop simulation models. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103107>, 190 (this VSI).
- Klerkx, L., Begemann, S., 2020. Supporting food systems transformation: the what, why, who, where and how of mission-oriented agricultural innovation systems. *Agric. Syst.* 184, 102901.
- Kumar, P., Singh, S.S., Pandey, A.K., Singh, R.K., Srivastava, P.K., Kumar, M., Dubey, S. K., Sah, U., Nandan, R., Singh, S.K., Agrawal, P., Kushwaha, A., Rani, M., Biswas, J. K., Drews, M., 2021. Multi-level impacts of the COVID-19 lockdown on agricultural systems in India: the case of Uttar Pradesh. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103027>, 187 (this VSI).
- Lenton, T.M., Boulton, C.A., Scheffer, M., 2022. Resilience of countries to COVID-19 correlated with trust. *Sci. Rep.* 12, 75. <https://doi.org/10.1038/s41598-021-03358-w>.
- Lioutas, E.D., Charatsari, C., 2021. Enhancing the ability of agriculture to cope with major crises or disasters: what the experience of COVID-19 teaches us. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103023>, 187 (this VSI).
- Lopez-Ridaura, S., Sanders, A., Barba-Escoto, L., Wiegel, J., Mayorga-Cortes, M., Gonzalez-Esquivel, C., Lopez-Ramirez, M.A., Escoto-Masis, R.M., Morales-Galindo, E., Garcia-Barcena, T.S., 2021. Immediate impact of COVID-19 pandemic on farming systems in Central America and Mexico. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103178>, 192 (this VSI).
- Magar, D.B.T., Pun, S., Pandit, R., Rola-Rubzen, M.F., 2021. Pathways for building resilience to COVID-19 pandemic and revitalizing the Nepalese agriculture sector. *Agric. Syst.* 187 (this VSI) <https://doi.org/10.1016/j.agsy.2020.103022>.
- Marusak, A., Sadeghiamirshahidi, N., Krejci, C.C., Mittal, A., Beckwith, S., Cantu, J., Morris, M., Grimm, J., 2021. Resilient regional food supply chains and rethinking the way forward: key takeaways from the COVID-19 pandemic. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103101>, 190 (this VSI).
- Meuwissen, M.P.M., Feindt, P.H., Spiegel, A., Termeer, C.J.A.M., Mathijs, E., de Mey, Y., Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vigan, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., Ciecchomska, A., Accatino, F., Kopainsky, B., Poortvliet, P.M., Candel, J. J.L., Maye, D., Severini, S., Senni, S., Soriano, B., Lagerkvist, C.-J., Peneva, M., Gavrilescu, C., Reidsma, P., 2019. A framework to assess the resilience of farming systems. *Agric. Syst.* 176 <https://doi.org/10.1016/j.agsy.2019.102656>.
- Meuwissen, M.P.M., Feindt, P.H., Slijper, T., Spiegel, A., Finger, R., de Mey, Y., Paas, W., Termeer, K.J.A.M., Poortvliet, P.M., Peneva, M., Urquhart, J., Vigan, M., Black, J.E., Nicholas-Davies, P., Maye, D., Appel, F., Heinrich, F., Balmann, A., Bijttebier, J., Coopmans, I., Wauters, E., Mathijs, E., Hansson, H., Lagerkvist, C.J., Rommel, J., Manevska-Tasevska, G., Accatino, F., Pineau, C., Soriano, B., Bardaji, I., Severini, S., Senni, S., Zinnanti, C., Gavrilescu, C., Bruma, I.S., Dobay, K.M., Matei, D., Tanasa, L., Voicilas, D.M., Zawalińska, K., Gradziuk, P., Krupin, V., Martikainen, A., Herrera, H., Reidsma, P., 2021. Impact of Covid-19 on farming systems in Europe through the lens of resilience thinking. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103152>, 191 (this VSI).
- Middendorf, B.J., Faye, A., Middendorf, G., Stewart, Z.P., Jha, P.K., Prasad, P.V.V., 2021. Smallholder farmer perceptions about the impact of COVID-19 on agriculture and livelihoods in Senegal. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103108>, 190 (this VSI).
- Nchanji, E.B., Lutomia, C.K., Chirwa, R., Templer, N., Rubyogo, J.C., Onyango, P., 2021. Immediate impacts of COVID-19 pandemic on bean value chain in selected countries in sub-Saharan Africa. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103034>, 188 (this VSI).
- Oliver, T.H., Boyd, E., Balcombe, K., Benton, T.G., Bullock, J.M., Donovan, D., Feola, G., Heard, M., Mace, G.M., Mortimer, S.R., Nunes, R.J., Pywell, R.F., Zaum, D., 2018. Overcoming undesirable resilience in the global food system. *Global Sustain.* 1, e9.
- Perrin, A., Martin, G., 2021. Resilience of French organic dairy cattle farms and supply chains to the Covid-19 pandemic. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103082>, 190 (this VSI).
- Prosser, L., Lane, E.T., Jones, R., 2021. Collaboration for innovative routes to market: COVID-19 and the food system. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103038>, 188 (this VSI).
- Rivera-Ferre, M.G., López-i-Gelats, F., Ravera, F., Oteros-Rozas, E., di Masso, M., Binimelis, R., El Bilali, H., 2021. The two-way relationship between food systems and the COVID19 pandemic: causes and consequences. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103134>, 191 (this VSI).
- Snow, V., Rodriguez, D., Dynes, R., Kaye-Blake, W., Mallawaarachchi, T., Zydenbos, S., Cong, L., Obadovic, I., Agnew, R., Amery, N., Bell, L., Benson, C., Clinton, P., Drecker, M.F., Dunningham, A., Gleeson, M., Harrison, M., Hayward, A., Holzworth, D., Johnstone, P., Meinke, H., Mitter, N., Muger, A., Pannell, D., Silva, L.F.P., Roura, E., Siddharth, P., Siddique, K.H.M., Stevens, D., 2021. Resilience achieved via multiple compensating subsystems: the immediate impacts of COVID-19 control measures on the Agri-food systems of Australia and New Zealand. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103025>, 187 (this VSI).
- Song, S., Goh, J.C.L., Tan, H.T.W., 2021. Is food security an illusion for cities? A system dynamics approach to assess disturbance in the urban food supply chain during pandemics. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103045>, 189 (this VSI).
- Stephens, E.C., Martin, G., van Wijk, M., Timsina, J., Snow, V., 2020. Editorial: impacts of COVID-19 on agricultural and food systems worldwide and on progress to the sustainable development goals. *Agric. Syst.* 183, 102873 <https://doi.org/10.1016/j.agsy.2020.102873>.
- Tittonell, P., Fernandez, M., El Mujtar, V.E., Preiss, P.V., Sarapura, S., Laborda, L., Mendonça, M.A., Alvarez, V.E., Fernandes, G.B., Petersen, P., Cardoso, I.M., Cardoso, A., Ocariz, P., da Silva, G.P., de Souza, J.C., Furlani, N.S., Caballero, L.F., Alvarez, A.A., de Freitas, A.F., Cruz, N.A.C., Cittadini, E., Sarandon, S., Baldini, C., Aristide, P., Giobellina, B., Felix, G., 2021. Emerging responses to the COVID-19 crisis from family farming and the agroecology movement in Latin America – A rediscovery of food, farmers and collective action. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103098>, 190 (this VSI).
- Tougeron, K., Hance, T., 2021. Impact of the COVID-19 pandemic on apple orchards in Europe. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103097>, 190 (this VSI).
- Vargas, R., Fonseca, C., Hareau, G., Ordinola, M., Pradel, W., Robiglio, V., Suarez, V., 2021. Health crisis and quarantine measures in Peru: effects on livelihoods of coffee and potato farmers. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2020.103033>, 187 (this VSI).
- Varshney, D., Kumar, A., Mishra, A.K., Rashid, S., Joshi, P.K., 2021. India's COVID-19 social assistance package and its impact on the agriculture sector. *Agric. Syst.* <https://doi.org/10.1016/j.agsy.2021.103049>, 189 (this VSI).
- Weersink, A., von Massow, M., Bannon, N., Ifft, J., Maples, J., McEwan, K., McKendree, M.G.S., Nicholson, C., Novakovic, A., Rangarajan, A., Richards, T., Rickard, B., Rude, J., Schipanski, M., Schnitkey, G., Schulz, L., Schuurman, D., Schwartzkopf-Genswein, K., Stephenson, M., Thompson, J., Wood, K., 2021. COVID-19 and the agri-food system in the United States and Canada. *Agric. Syst.* 188 (this VSI) <https://doi.org/10.1016/j.agsy.2020.103039>.
- Zhan, Y., Chen, K.Z., 2021. Building resilient food system amidst COVID-19: Responses and lessons from China. *Agric. Syst.* 190 (this VSI) <https://doi.org/10.1016/j.agsy.2021.103102>.