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Canadian Agri-Food Resilience: A Toolbox for Managing Crises

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Research Report

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Note from CAPI

Following years of disruption, driven by a pandemic, climate change and extreme weather, geopolitics and more, there is increasing concern about the reliability of supply chains. Rather than the historic focus on lean, just-in-time, high-efficiency and low-cost supply chains, there is an emphasis in the public and private sectors about understanding threats, monitoring resilience, and striking a balance between efficiency and resilience.

Agriculture and food supply chains have not escaped recent disruptions, with entire value chains – from input suppliers to farmers, processors, retailers, and food service – all suffering.

It was with these dynamics in mind that CAPI commissioned this study, with the support of Agriculture and Agri-Food Canada's AgriRisk Initiative. The authors' analysis leads to the prospect of converging crises, leading to greater risks than any one crisis or peril. The authors take steps to develop a toolbox to help navigate and mitigate these risks. Moreover, the report underscores the need for agri-food policy that can confront sudden, highly disruptive events to ensure that supply chains can continue to fulfill their primary objective of ensuring food gets from the farmers and processors who produce it to the consumers who need it.

Key Takeaways

- The lack of a long-term vision for the Canadian agri-food sector constrains effective research, strategy, and analysis. A long-term vision must recognize supply chain vulnerabilities including climate/trade disasters, new/emerging diseases and pathogens, international trade conflicts, sharp inflation in input costs, and cyber security.
- Pork and greenhouse vegetable supply chains confront broad forces of instability – focused upon here as climate change, geopolitical instability, and global disease pandemics – as well as local disruptors.
- The crisis management toolbox developed in this study highlights the functional interconnections between vulnerabilities, and illustrates the distributional effects of converging crises throughout the supply chain.
- Ensuring the resilience of Canada's agri-food supply chain includes grappling with broad-based economic issues, environmental and social health, industry planning, a lack of coordination and concern over government intervention, the increasing impact of climate change, and the need for adaptation and water access and availability.
- Agri-food policy in Canada has typically seen supply chain vulnerabilities as transactional events that can be contained and managed within the impacted value chain. This is inconsistent with the risks of converging crises and the unique role of the food supply chain, and there is an opportunity, and need, to move beyond existing approaches.

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Introduction

Anyone who works in or knows the agriculture and agri-food sector would recognize that there are many challenges and risks but also opportunities and rewards. Although agriculture has always been characterized by wide-ranging uncontrollable risks – weather, pests, diseases, competitors, and markets – the growing commercialization and sophistication of production, processing, and marketing have created an evolving and complex environment for decision making.

The past three years introduced significantly increased risk pressures on the Canadian agri-food industry and its supply chains, with the multi-year impacts of COVID, the war in Ukraine, and increasingly more difficult supply chain issues (such as the availability of ships and containers, the blockage of the Suez Canal, damaged or destroyed transportation infrastructure, and labour shortages or strikes).

For a healthy and resilient Canadian agri-food ecosystem to thrive, it is critical that the industry's complex and dynamic supply chains function effectively and efficiently both inside and outside of Canada. It is critical that these supply chains be resilient and adaptable in a world of increasing risk. Stakeholders need to be willing and able to navigate the agri-food risk landscape and develop the appropriate responses to changing conditions. Responsive policies, programs, actions, and strategies built through consultation and collaboration are required to create and maintain a thriving agri-food sector. As we will see, a new level of shared situational awareness — sophisticated comprehension of what is going on, what is important, as well as future implications — will support and maintain Canada's enviable position in this sector.

Industry stakeholders are familiar with defining agri-food system health through vitality and stability, but most generally understand risk through the lens of single, discrete crises. Awareness of the impacts and effects of issues such as geopolitical tensions, human-induced climate change, and pandemics tends to be considered in isolation. However, we have entered an era of ***converging crises*** with combinations of three or more crises becoming common. These crises can result from a multitude of sources, including physical, geopolitical, cultural, human and animal health, and economic policies. The convergence of multiple crises – sometimes compounding, sometimes interrelated, and sometimes both – can result in synergistic impacts in which the total disruptive power is greater than the sum of the parts. All stakeholders in the agri-food eco-system – producers, governments, suppliers and marketers, financial services, academics – would benefit from information on how to recognize, analyze, and respond to this new era.

The objective of this report is to present an approach to enhance overall agri-food and supply chain resilience, an approach that adopts the principles of structured decision making (SDM). To develop this approach, pork and greenhouse vegetables were chosen as commodities to be representative of agri-food commodities in Canada which would serve to reveal issues, concerns, and opportunities generally experienced in other agri-food commodities.

Representatives were consulted from other commodities including beef, row crops, landscape and horticultural sectors.

The report presents the first phase of the development of a crisis management toolbox (CMT) for the Canadian agri-food sector. The toolbox is an innovative integration of six tools that build upon one another sequentially, and in the aggregate, deliver a powerful decision support process/product. The purpose of the various tools that comprise the CMT is to enhance agri-food industry resilience while providing a platform for increased supply chain efficiencies. This report presents the first phase in the development and application of an SDM process. The CMT provides a solid foundation for developing options and recommendations. Building upon participatory consultations and case studies, these tools aid in the identification and visualization of system-level disruptive forces, their dynamic relationships, their scales of operation, and quantitative impacts on the system. The tools in our CMT are:

(1) participatory consultations;
(2) case studies;
(3) vulnerability mapping (VM);

(4) force-disruptor-vulnerability mapping (FDVM);
(5) risk topography visualization (RTV); and
(6) foresight analysis.

All these tools operate within a structured decision making framework. These tools aid in the identification and visualization of system-level disruptive forces, their dynamic relationships, their scales of operation and quantitative impacts on the system allowing for effective adaptation opportunities and optimization of resource allocation critical to successful long-term planning and policy making.

Most importantly, the CMT provides farmers and other stakeholders with the roadmap to build informed, forward-looking, and insightful short-, medium-, and long-term plans for their operations, including farm succession and transition plans, which are critical for the stability and resilience of the Canadian agri-food ecosystem.

By using the tools presented here along with the SDM principles, agri-food system stakeholders can bring their concerns or insights into developing new policies as well as reviewing and revising existing policies using qualitative and quantitative data collected across the specific commodity's supply chain. Likewise, public sector policy makers and private sector decision makers will have deeper insights to better inform appropriate response strategies and actions to current and emerging risks, roles, and responsibilities. This will enable better performance monitoring of response actions. The approach presented in this report helps to create informed resilience strategies.

Notes from the Project Team

The topic of climate change is politically-charged in Canada as elsewhere. The range of views and responses is great and a consensus on its relevance, importance, and urgency is absent. That said, this report presents climate change as a disruptive force to the Canadian agri-food industry. The authors do not intend to alarm or prescribe any positions to anyone. Instead, the authors, through this report, intend to intrigue and inform the reader, and to invite consideration and discussion.

Several stakeholder comments are included in this report, either as unedited quotations (or have been paraphrased. By agreement with the consulted stakeholders, no attribution has been provided for the comments.

The figures provided in this report and the Appendix are for illustrative purposes. They represent snapshots of one step of progressive sequence of visuals that would be produced in the documentation resulting from a vulnerability mapping or force-disruptor-vulnerability mapping process (and not the totality of the information from that process).

1 Participatory Consultations and Case Studies: What Keeps Agri-Food Stakeholders Up at Night

1.1 Introduction

Participatory consultations and case studies provided Canadian agri-food stakeholders the means to discuss the broader context of the ecosystem, to know what is going on within that ecosystem, and what is important. We also discussed the capacity of individuals, companies, and industry advocacy groups to project into the future, to move beyond accepting the past as a proxy for the future. The insights and resultant knowledge acquired from the participatory consultations and case studies define the boundary conditions, criteria, and assumptions critical for the successful utilization of the crisis management toolbox (CMT). These sessions also helped to identify several pertinent disruptive forces and vulnerabilities that would need to be addressed to enhance agri-food resilience and supply chain efficiencies.

The participatory process for this report included discussions with more than 100 Canadian agri-food stakeholders, through individual conversations and six virtual regional meetings. Pork and greenhouse vegetables were chosen as commodities representative of agri-food in Canada which would serve to reveal issues, concerns, and opportunities generally experienced by other agri-food commodities. Other commodities consulted included beef, row crops, landscape, and horticultural sectors. The consultations primarily focused on the combined implications of geopolitical instability, pandemics, and climate change on the agri-food system in Canada. The participants included a broad representation of stakeholders: producers, trusted advisors, for-profit and not-for-profit organizations (e.g., financial services, general farm organizations), governments, and academic organizations. The participants cut across age demographics and represented the full range of operational scope from local and regional operations to those that are multinational and global.

Several disruptive forces/vulnerabilities were identified during the consultation process. These included: access to a skilled workforce, economic viability of farms (for example, labour, profitability and operational costs, and succession), processing and transportation infrastructure, market access and volatility, international trade rules, disease (animal, plant, and people), cybersecurity, extreme weather events, weather trends (for example, shifting seasons), consolidation, input costs, energy crises, population growth, and the disconnect between industry and policy. Other areas of interest mentioned during the consultative process included interest rates, land values, and biodiversity.

"We have 20 people working in our organization and labour is the biggest issue… no doubt."
– Comment from consultation session(s)

1.2 Case Study One: Pork Sector Supply Chains

"We farmers are not prepared for disruption, not even close. We cannot freeze our mortgage payments, and with the uncertainty in pricing of all commodities and inputs needed to produce a product, it makes it really hard to develop our cash flows and rely on them. As farmers, it seems we have the lowest status, and yet we are all holding everyone up.

–Comment from consultation session(s)

1.2.1 Pressing Issues Today

The pork industry in Canada supports 31,000 farm jobs and contributes to 103,000 direct, indirect, and induced jobs across the country for a total economic impact of $23.8 billion (Canadian Pork Council, 2023). Depending on the reference year, approximately two thirds of Canadian pork production is exported to three countries: the US, China, and Japan (Hein, 2022).

The consultations highlighted grave concerns about African Swine Fever (ASF), alongside issues amplified by the COVID pandemic: access to labour, input and operating costs, disease (endemic, production and reproduction limiting), industry consolidation, supply chains within Canada and across borders, consumer sentiment, and regulatory and public policy. In ways that are unprecedented, issues such as cybersecurity and potential weaponization of agriculture by "rogue" states or state-sponsored actors add to the pork industry's complex risk calculus. Excessive export dependence with one country or region is an issue that's been recognized by industry stakeholders, as are the systemic risks posed by the converging crises of geopolitical instability, climate change, and pandemic diseases.

- **Labour-related issues.** Securing reliable and consistent labour is a challenge on the farm, in processing facilities, and livestock transport. The recent pandemic exacerbated the issue as workers contracted COVID and could not work, public health officials closed processing facilities, border restrictions limited the flow of migrant workers, and as other opportunities for employment post-pandemic pulled workers to other sectors.

> *"We as farmers are faced with uncertainty daily, with input costs, power/utilities, and oil and gas constantly increasing. The market is so volatile that you might not get that return on your final product sold." – Comment from consultation session(s)*

- **Input and operating costs.** Some stakeholders felt that if production and processing cannot remain profitable, there will be a significant exit from the industry. Rising input and operating costs are of major concern to pork producers (and others in the supply chain) including the rising cost of energy, insurance, feed grains, and transportation. One stakeholder noted that the pork industry "was built on abundant low-cost feed grains but that is no longer the case." While Canada still enjoys lower feed and other input costs relative to other parts of the world, this advantage erodes as costs increase due to geopolitical instability and other disruptions. For example, in 2022, the war in Ukraine and extreme weather in the major grain-producing regions of Canada put upward pressure on feed grain prices.

> *"The Canadian pork sector will not come back from ASF [African Swine Fever]." – Comment from consultation session(s)*

- **Disease.** Aside from the very real concern of African Swine Fever (ASF), livestock stakeholders are already challenged by production and reproduction limiting diseases (for example, Porcine Epidemic Diarrhea – PED, and Porcine Reproductive and Respiratory Syndrome – PRRS). Producers are very concerned about border closures and limited market access due to surplus production and disposal, and how to maintain operational viability during and after a disease /outbreak.

- **Industry concentration in production and processing.** The pork industry is highly concentrated with fewer but larger farms, and just a few processors handling most animals. According to one stakeholder, "perhaps 40 or 50 of the largest pig owners in Ontario account for about 80% of the production." Other stakeholders noted that the processing situation turns "farmers into price takers" because the power of the relationship strongly favours processor/packers (slaughterhouses), further processors, and retailers. Others stated that inadequate processing capacity in various jurisdictions forces producers to transport animals across internal or national

borders, adding to cost and disruption risks. Labour strikes or energy system failures can cut product supply for an entire province. A single procurement decision by a large player can send shockwaves throughout the industry.

- **Cybersecurity.** In the context of geopolitical instability, the pork industry faces increased vulnerabilities from cybersecurity. One stakeholder pointed to the recent Maple Leaf Foods ransomware attack.
- **Weaponization of agriculture.** From the consultations we noted increasing concern with the potential weaponization of agriculture. Extensive reliance on international trade opens the industry up to disruption as trade is used to leverage the acceptance of agreements in other areas. One stakeholder was concerned that "we are very dependent upon the USA for major segments of our inputs and markets." It appears that with increased polarization within the political system there, support for "the fair treatment" of Canada's interests may decrease even more now (comment, paraphrased, from consultation session).
- **Regulation and public policy.** Pork producers worry about consumer trends and misinformation that could drive changes to regulation and public policy. Producers are challenged by, for example, the regulatory requirement for group sow housing, especially given the recent inflationary costs of raw materials and the subsequent cost to retrofit sow barns. The movement of urban populations to rural areas continues to present challenges for producers who are being pressured to control odours from manure, noise, and other farm operations.

1.3 Case Study Two: Greenhouse Vegetable Supply Chains

> *"The sector has experienced enough disruptions across a range of threats (pests, diseases, labour, costs) that the industry as a whole is seeing the value in rigorous risk management. However, there are many aspects of the business that rely on 'business as usual' such as temporary foreign workers, reliance on natural gas, municipal water, and cheap tipping costs that limit the sector's future ability to withstand the issues that will inevitably come to the forefront in the next few years. Cybersecurity is only starting to be acknowledged as a major potential threat."*
> *– Comment from consultation session(s)*

1.3.1 Pressing Issues Today

Greenhouse vegetable production is the largest and fastest growing segment of Canadian horticulture with sales over $2.7 billion in 2021. More than 15,000 people are employed by this sector, with approximately 40% being temporary foreign workers (Agriculture and Agri-Food Canada, 2022). Peppers, cucumbers, and tomatoes are the main vegetables currently grown for the fresh retail market. Canadian greenhouses are tightly controlled environments with many using highly automated systems to manage heat, water, nutrients, and light. The industry exports approximately 70% of its production, with 99% of that going to the United States (Agriculture and Agri-Food Canada, 2022). Most of Ontario's production, almost 87%, is exported, while the figures are around 11% for British Columbia and 2% for Quebec and Alberta (Agriculture and Agri-Food Canada, 2022). Given the greenhouse vegetable industry's increasingly binational significance, consultations highlighted grave concerns about disease and insect pest issues, alongside those amplified by the COVID pandemic (labour-related issues, input and operating costs, invasive species, export-related border issues/regulations, and vulnerability of infrastructure to extreme weather).

- **Labour-related issues.** The Canadian greenhouse industry relies significantly on temporary foreign workers and the governmental foreign worker programs that support them. During recent outbreaks of the pepper weevil, growers needed to increase their highly trained workforce for effective surveillance, control and/or elimination, a considerable logistical and cost challenge.

As one stakeholder said:

> *"Our labour force is heavily reliant on our government and on foreign governments. Many farms are not large corporate entities, and our increasingly limited profit margins reduce our ability to manage these things through redundancy and contingency planning." – Comment from consultation session*

- **Input and operating costs.** The greenhouse vegetable industry is capital intensive, operates on thin margins, and is locked into wholesale markets. One of the biggest concerns among greenhouse growers is the rising cost of natural gas. During the consultation process we heard repeatedly that the rising cost of fuel was a major concern. One stakeholder mentioned they pay a premium for gas contracts to protect themselves from wild swings in gas prices. Many growers find it difficult to manage significant increases in heating costs. Growers also use electricity as a backup energy source and for supplemental lighting. Lighting is also being used in new and innovative ways to increase the number of growing cycles; however, access to supply is an emerging issue. Other stakeholders cited rising input costs related to shortages in biocontrol agents, growing media, cardboard packaging, and glass, exacerbated during COVID.

"At almost $2 million per acre to build a greenhouse, we cannot risk not having inputs."

–Comment from consultation session(s)

- **Emerging diseases.** The global nature of seed and transplant production and materials distribution enables the movement of insect and disease pests across borders. The tomato brown rugose fruit virus (ToBRFV, or rugose) is a major threat to Ontario growers and mainly affects tomatoes and peppers. It was first detected in Canada in 2019 (Horti Daily, 2023). Rugose was first identified in Israel in 2014 and reported in multiple countries over the past few years, including Mexico, United States, and the EU (Chiu, 2021). According to one greenhouse vegetable integrated pest management (IPM) specialist at one of Canada's provincial agricultural ministries, the virus is persistent in the environment, highly transmissible, and mechanically spread (Agriculture and Agri-Food Canada, 2022). Mechanical spreading can include tools, equipment, hands, clothes, soil, infected plants, and seeds (Agriculture and Agri-Food Canada, 2022).

"[Eliminating] rugose is the number one priority among greenhouse growers today."

–Comment from consultation session(s)

- **Export-related border issues.** With more than 70% of product exported and the vast majority to the United States, trucking is the primary means of transport. During COVID, when borders were closed, the flow of exports was severely limited as was the free flow of transport capacity back and forth across the border. Requirements concerning the vaccination status of truckers and truckers' fears of contracting COVID also became an issue which further reduced cross-border shipping. Industry stakeholders also raised concerns that some shipments from Canada have been unfairly targeted by U.S. border agents that were using plant disease controls (for example, ToBRFV) as a restrictive trade issue. For example, the United Statesrecently imposed import protocols requiring all seeds lots, plants, and fruit to be inspected and tested free of rugose disease and symptoms prior to entering the country. U.S. Customs and Border Protection has increased inspections of tomato and pepper seed, plant, and fruit imports entering from Canada (and other countries) (USDA, 2023; Vegetable Growers News, 2019). This has the impact of reducing the timely delivery of Canadian products, thereby threatening the industry's reputation as a dependable supplier, and increasing the export costs to Canadian shippers.

- **Vulnerability of infrastructure to extreme weather.** Most participants recognized the potential impacts of changing and more extreme weather events with respect to the industry's physical infrastructure. Currently, greenhouses are built for expected weather rather than extreme weather driven by climate change. It is common for greenhouses to face extensive damage from wind and hail. Newer greenhouses use more resilient tempered glass that can still be shattered by the larger hailstones that result from more extreme storms. The frequency and severity of theses weather events is increasing the risk profile faced by greenhouse operators. Hurricanes can lead to full greenhouse collapse. Currently, structural damage to greenhouses caused by storms is insurable, but some growers are concerned that future insurance costs may be prohibitive or that property and casualty insurers may completely pull out of some markets.

- **Climate trends**. Significant changes in climate conditions are leading to more frequent and intense heating- and cooling-related weather patterns. For example, greenhouses in Leamington are experiencing issues related to heat stress, with potential to decrease the length of the growing season, as well as potential production decreases as much as 25%. As well, one stakeholder mentioned how heat stress decreases the immunity of plants, making them more susceptible to disease. Stakeholders mentioned that extreme heat and cooling trends will increase the cost of environmental control within greenhouses across Canada.

- **Regulation and public policy.** Farmers and industry representatives are feeling the increasing pressure of the regulatory environment. Some Ontario municipalities are looking to change local planning laws to deter development of large-scale greenhouses. Residents are concerned about light pollution, increased traffic, and the impact on wildlife and migratory bird populations. Smaller municipalities are also concerned about the investment required to provide large scale greenhouses with adequate infrastructure (electricity and gas) and access to land.

- **Greenhouse vegetable farm succession.** The next generation has voiced a hesitation to take over family operations, and family farm leaders have mixed feelings about asking them to do so. "It's a very under-appreciated business and seems like the farmer is a price-taker that regularly gets the short end of the stick. The risk often feels hard to bear and weighs you down from a mental health standpoint" (comment from consultation session).

1.4 Four Major Themes

More than 100 stakeholder-participants were consulted across the six regional consultations and individual conversations. These consultations cited four major themes:

1.4.1 Talk-Action Gap

Stakeholders noted that there is a growing list of supply-chain vulnerabilities and a noticeable gap between talk and action in addressing them. In Canada, there is a deep understanding of existing and emerging risks and threats to agri-food supply chains. However, the action commensurate with today's best state of understanding of these risks is uneven and fragmented. This gap is decreasing agri-food system resilience at a time when it needs to be supported and strengthened by appropriate levels of research and investment. The talk-action gap has grown for another reason: Emerging risks identified years ago are being experienced now, and the actions to mitigate those risks – actions that were not taken – has resulted in an environment where a shared understanding of where to take action and invest is extremely difficult and "politically charged."

1.4.2 No Long-Term Strategy

Producers and processing stakeholders expressed concern that strategic planning in the agri-food industry generally does not extend past five years. Many stakeholders felt some entity or authority needs to invest in research, analysis, and strategies to 2030 and beyond, and that producers and other stakeholders should be consistently involved.

1.4.3 Supply Chain Vulnerabilities

Stakeholders listed a growing number of agri-food supply chain vulnerabilities that have the potential to keep them up at night. These include farm-processor-retailer tensions; international trade conflicts; input costs; new/emerging diseases and pathogens; labour costs and retention; immigration to meet labour needs; industry concentration; climate/trade disasters; and regulatory and policy minefields.

1.4.4 Cybersecurity & Technology

According to the greenhouse industry stakeholders, cyber threats are proliferating. These can affect the entire supply chain including food safety, distribution, and more. Ransomware is a growing issue and too few agri-food stakeholders have enough cybersecurity or cyber resilience to face and/or recover from cyberattacks. Stakeholders talked about the lack of inclusive and responsible governance of data and technologies that have challenged transparency across supply chains and equal access to data. Producer stakeholders note that they do not have the ability or the industry leverage to benefit from aggregating and analyzing their own large datasets and capitalizing on them commercially.

In combination, these four key themes reveal that the greenhouse vegetable industry faces the inevitability of multiple shocks. This is because any one of the given forces of geopolitical instability, climate change, or pandemic/zoonotic diseases alone could yield disasters or catastrophes. Combined with a talk-action gap, no long-term strategy, and the addition of cybersecurity and technology-related risks, catastrophic events are certain while their timing is not. Associated impacts and effects would be impossible to mitigate, or adapt to, unless the four major themes are addressed with investment and resources commensurate with the implications of accurate and actionable multivariate risk analysis.

1.5 Converging Crises

Pork and greenhouse vegetable producers are already challenged with day-to-day economic, financial, and operational activities and stressors. Producers state they do not have the financial resources, time, or support to address the issue of converging crises such as climate change. Regardless, the need for resources is critical as these converging crises and the resulting destructive synergies will have significant impact on pork and greenhouse vegetable producers, the Canadian agri-food industry, and the countries to which we export our agricultural products.

"The industry needs to join forces, no matter how big or small, to ensure the survivability of everyone." – Comment from consultation session(s)

One of the immediate challenges of moving the Canadian agri-food sector towards resilience is that a divergence of views of the future sets the stage for intra-industry conflict among multiple stakeholders. In terms of resilience building, some pork industry stakeholders believe that industry consolidation adds to pork industry and agri-food system resilience, while others argue the opposite, that industry consolidation decreases opportunities for farmers and farming, and for land and ecosystem stewardship. On one hand, consolidation is thought to offer a more sufficient means to monitor and implement disease control measures as well as provide economy of scale. On the other hand, some see greater disease resilience with a diverse farming community that provides redundancy and the ability to control disease through local quarantine measures. Additionally, stakeholders are very concerned with the ability of farmers to remain profitable under a model of increasing consolidation of the processing sector, with examples in other sectors showing mixed results.

The greenhouse vegetable industry, meanwhile, sees overlapping issues related to increased disease and pest pressures, growing adverse climate impacts, pandemic-related labour and health issues, and ongoing and increasing cross-border trade-related tensions that could affect the industry's long-term viability and prosperity. They are worried about heat stress on greenhouse-produced plants, extreme weather impacts on greenhouse

infrastructure, and impacts of extreme heat on labour. One stakeholder raised the risk from sea level rise to greenhouse production in parts of the Fraser River delta in British Columbia:

> *"Climate change impacts will routinely destroy facilities and drive the cost of products to unaffordable levels." – Comment from consultation session*

The greenhouse vegetable industry also recognized that there was some hope in new technologies to address heat and ventilation issues: **"**New technologies are coming that can help, but they are early in development and expensive" (comment from consultation session).

In addition, growing competition from greenhouse vegetable industry players in the United States and Mexico poses stressors, as does the increasing size, complexity, and cost of greenhouse vegetable production facilities that are increasingly risky to operate unless producers take considerable and costly climate adaptation and resilience actions.

The consultations revealed that the reality of converging crises has meant that both pork and greenhouse industries face tipping points associated with an unprecedented risk environment. The author Malcolm Gladwell described a tipping point as "the moment at which some slow change in a system becomes irreversible, triggering a dramatic change in state of the system" (Gladwell, 2006).

These sectors identified the need for a new approach to stakeholder engagement that can help them find solutions to the challenges they face and that sometimes overwhelm them, some of which are completely out of their control.

> *"Get the industry to work collaboratively, rather than jockey to out-position neighbours and colleagues. Big problems don't get solved without collaboration." – Comment from consultation session(s)*

The following sections will help to bring clarity to this unique and very challenging context.

2 Forces: Drivers of Change

The short- and long-term security of the agri-food sector, as well as its respective supply chains, currently face some very high-risk challenges. Yet, at the same time, they are the focal points of very significant opportunities as well. The challenges are a combination of physical, economic, and even social forces that can manifest as a series of consequential impacts and effects, which we will discuss in more detail in sections 3 and 4.

It is these impacts that we refer to as ***forces***: *the highest level of disruptor, generally characterized by rapid change (e.g., exponential growth or decay, predominantly displaying nonlinear behaviour) that affects geographic areas (e.g., borders) across an array of different living or non-living system communities (e.g., multiple species or supply chains), causing some degree of physical, social and/or economic response, and associated hardship*. In their least imposing form, forces can hinder the efficiency of relevant ag-related supply chains, and at worst, can thoroughly disrupt these same supply chains, bringing agri-food security to a complete standstill, thus threatening the health and well-being of any exposed communities.

More localized forces are called ***disruptors***: a series of physical, economic, and social impedances that trigger a series of subsequent (cascading) impacts and effects. As with forces, disruptors can be in the form of physical, social, or economic events. Regardless of origin, disruptors play a significant role in generating minor to major impacts on the health of numerous agri-food commodities produced within Canada for local and international sale.

Disruptors come in many different types and forms, and cause impacts and effects that transcend physical forms, such as floods and droughts, to include impacts and effects that are best characterized as being impactful (usually in a negative context) to the economic and societal welfare of Canadian citizens and their overall quality of life. In subsequent sections, we illustrate examples of what are called “tiered” disruptors: events that are each related to a force-level disruption. We also show interconnections that describe the progressive decrease in disruption events from the largest (force-level, classified as tier 1) to the smallest and most localized or least impactful events (tier 5).

Disruptors have the added dimension of causing a wide range of impacts upon the condition of existing supply chains and related. Canada must rely upon these chains and networks to provide efficient allocation of food within its borders and into a wide array of international markets. Canada’s reliance on sustaining efficient, well-run supply chain networks, as well as the high-quality of commodities produced in this country, create significant demands on maintaining a well-run and effectively maintained supply chain network. Failure to do so threatens Canada’s revenue-generating export strategy and could affect the health and welfare of Canadian citizens.

Recognition of tiered events is crucial for understanding the continuum nature of what otherwise would be labelled as unrelated events and overarching teleconnections between the earliest and typically largest disruptions, and those that are the most recent and most localized.

This section identifies and describes three of the force-level (tier 1) agri-food disruption events (the primary focus of this study and observable worldwide): climate change, geopolitical instability, and pandemic as seen through the lens of COVID during the timeframe of late 2019 to the onset of 2023.

2.1 Climate Change Forces

Since the scientific community concluded that climate change is a legitimate existential threat to 21st century civilization, civilian and military scientific communities have conducted comprehensive studies of climate change across all scales of time and space including past, present, and future states, and from the sub-meter to a global scale. Given its destructive implications, the study of climate change has been the largest, most intensive, most expensive, most thorough, and most cooperative endeavour in human history.

Unfortunately, most studies to date have been produced by and for an exclusive, technically well-trained audience, one that considers itself the principal owner and beneficiary of the science-based outcomes. Yet, the strong cause and effect association between observed physical, biological, chemical, and socioeconomic

impacts (the real perpetrators of disruption at all scales) place climate change front and centre as the primary force behind global food insecurity, agricultural production variability, and supply chain disruptions. Yet, it is crucial to consider that the actual disruptions are themselves consequences of climate change, itself the consequence of human activities such as the emission of large quantities of greenhouse gases such as CO_2, methane, and nitrous oxides. It is these consumptive use practices that are the overarching cause of global climate change well beyond the concentration range of natural greenhouse gas emitting processes. Prior to the era of human activities emitting large amounts of greenhouse gases (starting in the 1750s and intensifying with the industrial revolution), climate change occurred within a delicate equilibrium with other ecosystem-related processes.

Since the true disruptions to the health of the agri-food system are the impacts and effects triggered by global climate change, the first goal in identifying the relevant disruptor roles is to observe and map out the cause-effect relationships that are driven by climate change and which are manifested as specific effects of the climate change processes themselves. Many of these cause-and-effect relationships have been observed, described, and written about over many decades and over many scales of authoritative and highly reliable assessments (including scientific assessments of the Intergovernmental Panel on Climate Change, the U.S. National Climate Assessment, and the 2017 Montana Climate Assessment: see (IPCC, 2014a, 2014b, 2014c; Melilllo et al., 2014; Stocker et al., 2013; Whitlock et al., 2017). The 2017 Arctic Assessments assessed the Canadian climate to be the third most sensitive (and therefore most likely to hit key tipping points; see Gladwell, 2006) across northern latitudes and the Arctic circle region.

Key documented climate change-related impacts and effects for across Canada include increased intensity and frequency of:

- floods;
- drought;
- proliferation of invasive species (animals, plants, and insects);
- human health issues;
- imperiled aquatic species (food web-based, recreational species);
- degraded agricultural lands and related commodities;
- species migration and catastrophic community failures (species collapse); and
- loss of natural resources (living and non-living).

2.2 Geopolitical Instability Forces

The forces of geopolitical instability are defining the ever-evolving world order, which includes considerable fluidity in nation-state alliances, some of which is destabilizing. Witness today's diplomatic and trade-related challenges between among Canada, the United States, and the EU on the one hand, and China, Russia, Brazil, and South Africa. The countries of the latter group are trying to establish new alliances and blocs, and questioning the value of previous alignments and relationships.

A world with more geopolitical instability and more climate change is one that tilts the odds towards more regional conflict as countries strive to secure water supplies for food production, mineral exploitation, manufacturing, and human consumption. For example, Russia's war on Ukraine has resulted in oil and gas shortages resulting in significant increases in fuel and fertilizer prices affecting Canadian farmers. Recent tensions in Canada's relations with China were accompanied by trade actions affecting Canadian agricultural commodities such as canola being imported into China. Pork industry stakeholders identified their concerns that this deteriorating trade relationship could devastate their pork markets in China. Targeting new markets elsewhere in Asia would be extremely challenging with both economic and political risks.

Geopolitics and climate change are inextricable links in other Asian markets and will pose significant supply chain risks at the levels of ocean transport, port infrastructure, and cyber security attacks from adversaries that might wish to disrupt the smooth functioning of Canada's agri-food sector.

Farmers are particularly vulnerable to systemic disruptions because they already experience a high level of risk stemming from challenges such as emerging diseases of livestock and plants, changing weather patterns, growing global competition, competitive access to capital investment and debt financing, risks to continued funding of insurance and agricultural stabilization programs, fluctuating foreign exchange and interest rates, and inflation-related production costs.

Pork and greenhouse industry representatives admitted in the consultations that their understanding of geopolitical instability is not as advanced as it needs to be for these industries to work effectively with trade and political representatives from Global Affairs Canada and other experts in international market access.

2.3 Pandemic-Related Forces

Pandemics have undeniably impacted human history. Visualizing the history of pandemics (LePan, 2020) takes us through history's major recorded pandemics beginning with the Antonine Plague in the year 165, to the Plague of Justinian in the year 541, through to the current 2019 SARS-CoV-2 (coronavirus) disease (COVID). It is equally true that human history has been impacted by plant and animal pathogens. For example, in the nineteenth century, Rinderpest caused massive livestock mortality that resulted in the starvation and death of almost two-thirds of the East African Maasai population (African Union Inter-African Bureau for Animal Resources, 2011). The Irish potato famine (1845-52) caused by potato blight reduced the Irish population by 25% through starvation or migration (Fraser, 2003). Many pandemics are zoonotic, where transmission occurs between species, either human to animal or animal to human.

On March 11, 2020, COVID was officially declared a pandemic by the World Health Organization (WHO). In the ensuing years, scientists identified an overwhelming number of animal species susceptible to infection. As of October 2022, there had been 675 natural outbreaks occurring in 58 different species including humans. As a result, COVID may be considered the first real-time documented case of a true pandemic zoonotic outbreak (Agnelli & Capua, 2022).

The impacts of disease are often reported alongside mortality rates but the impact extends far beyond mortality. Disease outbreaks have sparked riots, propelled innovations in public-health, prefigured revolutions, and redrawn maps: "just as there are many ways for microbes to infect a body, there are many ways for epidemics to play out in the body politic" (Kolbert, 2020).

To fully evaluate the economic and societal impact of epidemic disease, it is important to consider not only mortality and morbidity, but measures such as disability adjusted life years (DALY), cost of illness for the public health sector, and the economic losses to the tourism, industrial, and agricultural sectors.

Canada is comparatively well positioned to deal with human, plant, and animal disease outbreaks relative to other countries. However, COVID as an ongoing panzootic outbreak provided a rich opportunity for experiential learnings within the Canadian agri-food community, and an opportunity to explore disease-related vulnerabilities, impacts, and synergies with the disruptive forces of climate change and geopolitical instability.

Through the consultation process, several highly disruptive agri-food/COVID-related impacts and effects were identified:

- rapidly declining workforce and labour availability;
- decreased access to critical foreign labour;
- decline of public health and wellness of agri-food workforce;
- overall long-term loss of market services and related volatility;
- reduced agri-food and related support services;
- concomitant agri-food market volatility; and
- decreased export and import market access.

3 Forces, Disruptions, Vulnerabilities, and Impacts

The purpose of the various tools that comprise the crisis management toolbox (CMT) is to enhance agri-food resilience while providing a platform for increased supply chain efficiencies. This report presents the first phase in the development and application of a CMT, the result of integrating tools that build sequentially to deliver a powerful decision process. The CMT provides a solid foundation for decision making and developing solutions. Building upon participatory consultations and case studies, these tools aid in the identification and visualization of system-level disruptive forces, their dynamic relationships, their scales of operation, and quantitative impacts on the system. These tools include:

- participatory consultations and case studies with requisite stakeholder groups and leaders;
- vulnerability mapping (VM) using initial vulnerability values collected during the participatory consultative sessions;
- force-disruptor-vulnerability mapping (FDVM);
- risk typography visualization (RTV); and
- foresight analysis (FA).

By using the tools presented here along with the principles of structured decision making (SDM), agri-food system stakeholders can bring their concerns or insights into developing new policies as well as reviewing and revising existing policies using qualitative and quantitative data collected across the specific commodity's supply chain. Likewise, public sector policy makers and private sector decision makers will have deeper insights to better inform appropriate response strategies and actions to current and emerging risks, roles, and responsibilities. This will enable better performance monitoring of response actions and iterating where necessary. The approach presented in this report helps to create informed resilience strategies.

Most importantly, CMT provides individual farmers and their stakeholders with the roadmap to build flexible, forward-looking, and insightful farm succession and transition plans, critical for the entire Canadian agri-food ecosystem.

It is important to note the work completed in this report provides a solid basis for next steps but does require greater refinement through further engagement with industry and subject matter experts.

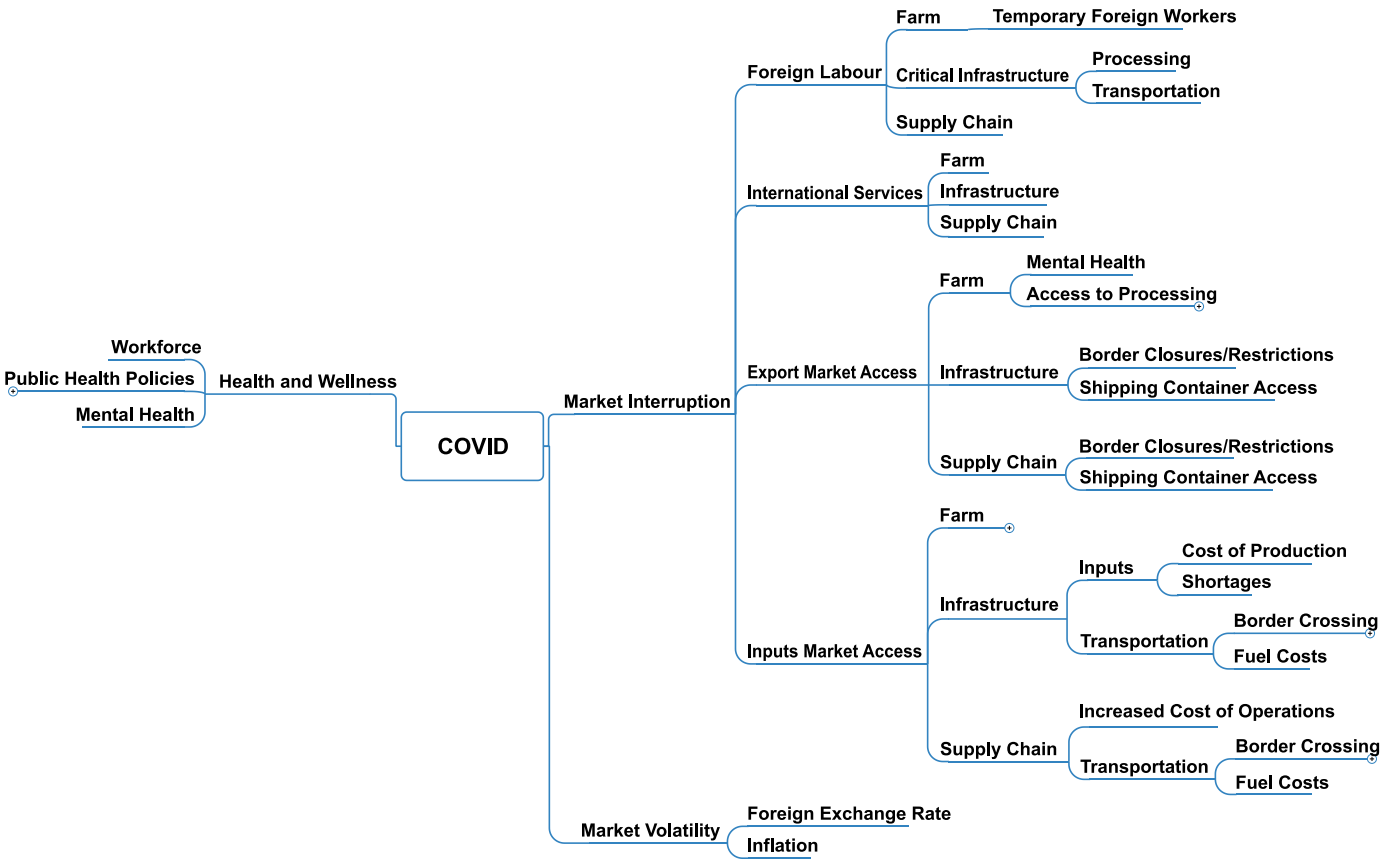
3.1 Vulnerability Mapping

Vulnerability mapping (VM) is a visualization tool for situational awareness. Participatory consultations with diverse representatives in pork and greenhouse commodities across Canada were extremely informative in describing what keeps stakeholders "up at night," providing critical insight into current concerns, challenges, and vulnerabilities. However, translating what keeps stakeholders up at night to system-level vulnerabilities requires a step beyond listening. What is required is to visually map and validate their concerns and challenges to make sense of the important themes, patterns, and clusters that arise.

"Decisions are made in a vacuum, [with] little understanding of all implications." – Comment from consultation session(s)

The process of VM is illustrated in Figure 3.1 using COVID-related learnings from the participatory consultations.

Figure 3.1. Simplified vulnerability map of COVID-related agri-food vulnerabilities based on consultative findings



A full-page slide of this figure is available in the appendix.

In examining Figure 3.1, it is easy to identify the major and sub-major vulnerabilities identified during the consultative process related to COVID: commodities are vulnerable to market interruptions, volatility, and health and wellness concerns related to the physical and mental health of the workforce. When and how public health policies are enacted and enforced during a pandemic was another important concern for stakeholders. For example, stakeholders in Nova Scotia talked about the closure of the Eden Valley chicken processing facility due to public health orders. There was no communication path between the agri-food community and public health to discuss this order's timing, significance, and implications.

> *"Nova Scotia had issue with isoweans – no nursery space in Nova Scotia for them during labour disruptions due to COVID in Quebec." – Comment from consultation session(s)*

Vulnerability mapping helps bring these and other concerns forward for discussion, analysis, and planning among stakeholders.

The process of vulnerability mapping requires extensive engagement with stakeholders across the ecosystem, commodity, or supply chain of interest and a clear statement of boundary conditions and assumptions. For example, the COVID vulnerability map (Figure 3.1) was completed as a retrospective exercise with stakeholders in the Canadian swine and greenhouse commodity sectors within a five-month interval of time (October 2022 to March 2023). Furthermore, one can assume similar vulnerabilities would arise in future pandemics similar in nature to COVID in terms of transmissibility and severity as well as number of species affected.

It is important to note the process of VM is time- and engagement-intensive. It requires numerous iterations and refinements throughout. There is no one "correct" map, as VMs change with time, space, and perspective. However, vulnerability mapping is foundational to the entire process to ensure derivation of the correct boundary conditions, criteria, and assumptions. Once the VM is done, force-disruptor-vulnerability mapping (FDVM) and risk topography visualization (RTV) can be undertaken with the best available information.

In summary, VM requires:

- participatory consultations and case studies;
- a clear statement of boundary conditions and assumptions; and
- inclusive stakeholder discourse and iteration.

Vulnerability mapping (VM) is a situational awareness visualization tool and an important part of the Canadian agri-food risk management framework (RMF). VM allows for the identification of key vulnerabilities within the complex and dynamic supply chains that comprise the Canadian agri-food ecosystem.

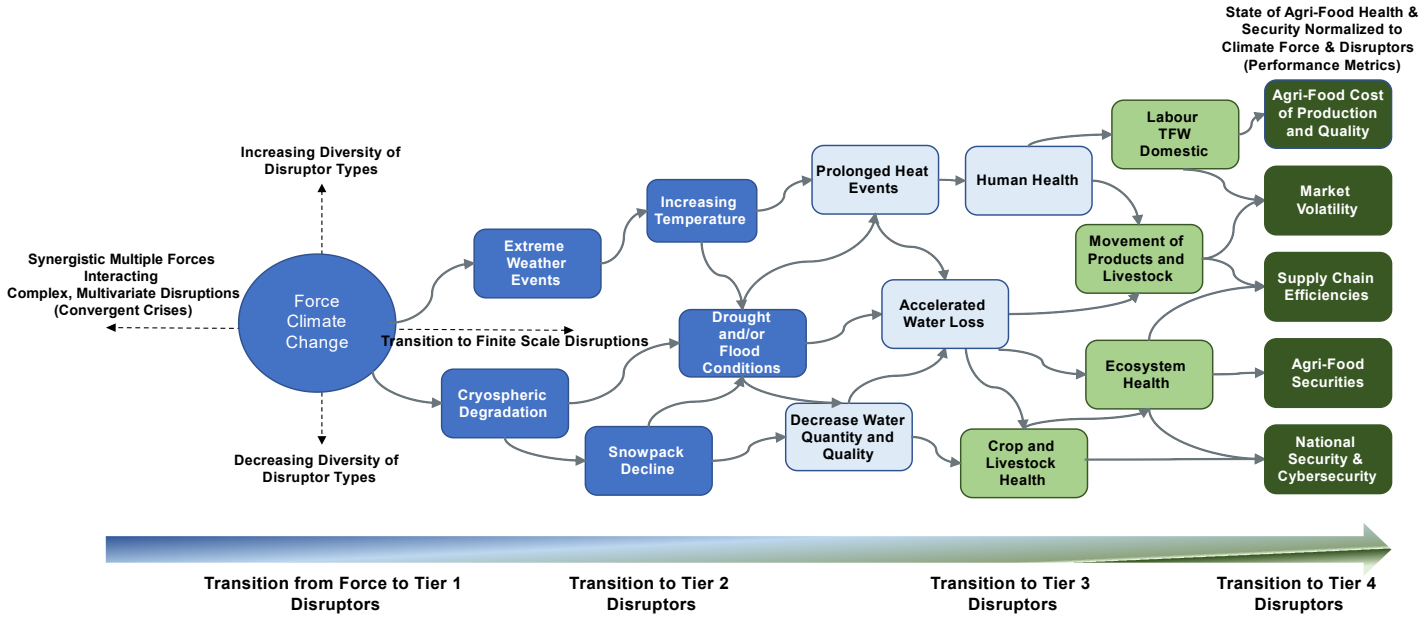
3.2 Force-Disruptor-Vulnerability Mapping

> *"We are involved in a number of associations... as I see it producers see climate change as an umbrella and don't understand what it means to them." – Comment from consultation session(s)*

Force-disruptor-vulnerability mapping (FDVM) is a visualization tool that illustrates and describes the cause-and-effect relationship between disruptors and identified vulnerabilities. FDVM requires a transdisciplinary working group that includes relative discipline experts. Insights and outcomes from the process of FDVM in the CMT requires inputs related to the participatory consultations and vulnerability mapping.

The FDVM example presented in Figure 3.2 is a simplified way of capturing and illustrating the integrated, and in many cases, the synergistic behaviour of disruptive forces within systems. The impacts due to the multivariate and synergistic behaviours of disruptive forces can now be effectively identified, prioritized, and described.

Figure 3.2. Interoperations between force and/or multi-scale disruptions



A full-page slide of this figure is available in the appendix.

As a simplified example of the disruptive force of climate change on key agri-food vulnerabilities, Figure 3.2 illustrates the interconnections and downscale movement of climate change disruption from global to local, ending with the disruption of agri-food vulnerabilities.

"Heat stress is now an issue in greenhouses in Leamington... strange, given that Leamington was chosen because of climate conditions there then." – Comment from consultation session(s)

The process of mapping the relationships, synergies, and amplifications between disruptive forces and system vulnerabilities builds upon the findings of the VM and an iterative consultation process.

In summary, FDVM requires:

- participatory consultations and case studies that deduce the specific forces and disruptions occurring within the ecosystem of study (the entire architecture of Figure 3.2);
- the listing of key vulnerabilities (first identified by VM);
- knowledge of the system and the force-disruptor vulnerabilities dynamics; and
- inclusive stakeholder discourse and iteration.

The FDVM provides the context to appropriately quantify the impacts on vulnerabilities due to disruptive forces and their interactions. Impact quantification is also critical in determining system resilience, the primary goal of the methodology proposed in this report. Risk topography visualization (RTV), the next tool in the CMT, leverages the findings of the FDVM.

3.3 Risk Topography Visualization

"We need to measure whether we actually need to be concerned." – Comment from consultation session(s)

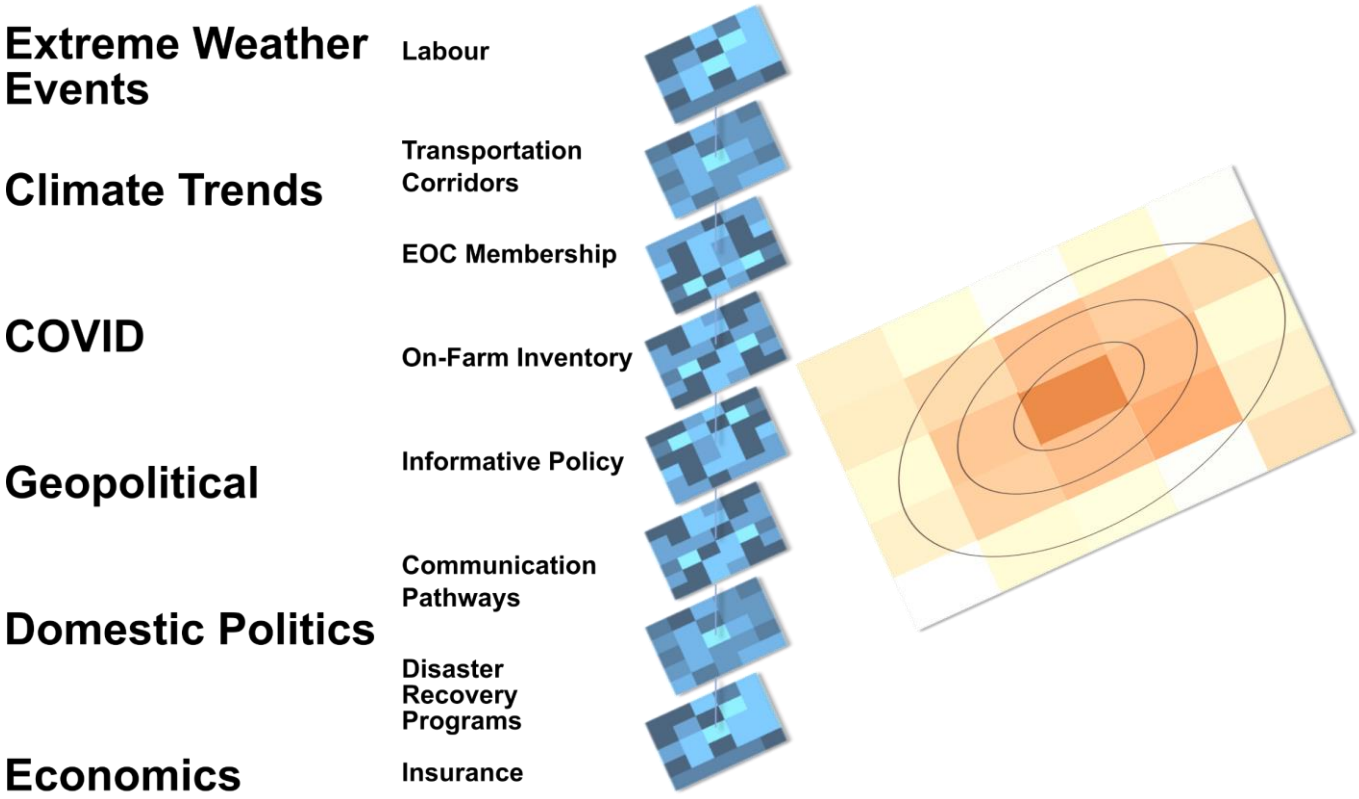
Risk topography visualization (RTV) is a tool that quantifies the impacts of disruptive forces and related synergies on the system. The quantitative results are summarized in data layers and overlaid to create a visual image: the risk topography. The process of RTV requires a clear statement of boundary conditions and assumptions that have been developed iteratively starting with the participatory consultations and ending with FDVM.

"We did not imagine how tragic was the flood, how impactful... corridors were all cut off, rail, highways." – Comment from consultation session(s)

Figure 3.3 is a simplified example illustrating how RTV can be used to capture and summarize the findings of the consultative process as they relate to two extreme weather events: Hurricane Fiona that made landfall on the coast of Nova Scotia on September 24, 2022 (an exceptionally strong cyclonic storm; see Pasch et al., 2023), and the British Columbia floods in November 2022 (significant rainfalls resulting in extreme stream flows; see Senate of Canada, 2022). Both events occurred during the COVID pandemic, with different levels of government response, provincially, regionally, and locally.

"Government closed roads, decided quickly… only let through those with farm (license) plates transporting livestock... but was needed also for other needs without farm plates." – Comment from consultation session(s)

Figure 3.3. A simulated risk topography based on the consultative findings related to extreme weather events.



A full-page slide of this figure is available in the appendix.

"EOC [Emergency Operations Centre] was activated late, given impact on ag, didn't have a seat… need someone from ag on EOC." – Comment from consultation session(s)

The higher order disruptive forces in Figure 3.3 (extreme weather events, climate trends, COVID pandemic, geopolitical, domestic politics and economics) were identified in the consultation sessions. Specific examples of the higher order disruptive forces were used to define the data layers for the risk topography including labour, transportation corridors, emergency operations centre (EOC) membership, on-farm inventory (such as animal feed), informative policy (for example, the impact of government policy actions on the agri-food community), communication pathways to decision makers, and coherent integrated access to disaster recovery and insurance programs. For the RTV in Figure 3.3, the data layers and related metrics, when fully integrated, defined the topography of the RTV. In this example, contour lines were added to demonstrate the full potential of using RTV.

The quantification of the risk landscape needs to be undertaken with great care to ensure the boundary conditions and assumptions are clearly understood and all the requirements are met. In addition to the requirements for VM and FDVM (including clear boundary conditions and underlying assumptions), the process of RTV requires:

- participatory consultations and case studies;
- vulnerability mapping (VM);
- force-disruptor-vulnerability mapping (FDVM);
- a clear statement of boundary conditions and assumptions;
- identification of appropriate vulnerabilities (i.e., data layers);
- identification and clear definitions of metrics related to system impacts and synergies; and
- discourse and iteration.

Risk topography visualization (RTV) is a visualization tool that assesses the overall stability and/or disequilibrium of a system acted upon by numerous disruptive forces. It is a critical component of the crisis management toolbox (CMT) given the complex and dynamic landscape of converging crises in the Canadian agri-food ecosystem.

4 Implications

Canadian society relies on the agri-food system for its stability even more so in this "era of converging crises." The discipline of strategic planning is aiming to adapt in real time to the growth in risks and decline in opportunities that an expanding risk landscape implies. Exactly how quickly, iteratively, and holistically the planning discipline can be integrated into the strategic and operational activities of agri-food stakeholders is part of the effort to build agri-food system resilience. Individual producers — and multiple stakeholders collectively — need to consider learning and adopting new planning practices even as they deal with immediate and short-term challenges and crises. This may feel overwhelming and time consuming, but shifts in circumstances demand the effort. Next, they need to make requisite investments in planning and in tangible resilience building for their own operations.

Given an accumulation of potentially catastrophic risks in the Canadian agri-food system and its associated supply chains regionally, nationally, continentally, and globally, a strategic planning reset is needed among agri-food stakeholders across the producer-processor continuum (Ramírez et al., 2023). Mastering how to work with the CMT as a "resilience toolkit" described in this study can help dedicated agri-food stakeholders to plan more effectively and strategically for today's and tomorrow's radically uncertain contextual environments.

4.1 Foresight Analysis: 2030 and Beyond

This section highlights supply chain vulnerabilities that multiple stakeholders face as they evaluate plausible futures of supply chain disruptions and determine if and how to address them most effectively. Such disruptions are inextricably linked with the selected converging crises (also: forces) (Khanna & Coon, 2020) chosen for this pilot study: geopolitical instability, climate change, pandemics, and panzootic diseases (Agnelli & Capua, 2022). The crises, individually and in aggregate, can trigger cascading and compounding impacts and effects that could perpetually undermine the stability of Canada's agri-food system and national security (Bronskill, 2023), as well as the health and well-being of millions of people within its borders and beyond. Given the vital importance of its agri-food products in a world beset by unequal access to nutrition, and periodic yet significant instability, Canada's agri-food system contributes to societal stability at home and abroad in nations that rely on Canadian food exports for core nutritional values derived only from a secure agri-food system.

As documented in section 2, stakeholders shared concerns that keep them up at night, highlighted challenges, and described gaps in knowledge, expertise, or resources that, if overcome, could help them to identify and even to prioritize plausible future agri-food supply chain vulnerabilities with greater precision. Filling these gaps can support the development of timely strategic insights that contribute to Canada's agri-food resilience and national security strategy. Building on the identified supply chain vulnerabilities of geopolitical instability, pandemics, and climate change, this section's approach to foresight analysis aims to inform strategic conversations, strategic planning, operational assessments, and investments. To do so, the section puts a wider range of present and future supply chain vulnerabilities into relief, making it possible to improve decision making among multiple stakeholders in critical areas necessary for agri-food supply chain resilience. These include, but are not limited to:

- input costs;
- transportation costs;
- water-food-energy nexus;
- novel viruses and disease vectors;
- labour-related health and productivity;
- climate resilience and ecosystem services;
- industry consolidation within and across sectors;
- capital and innovation;
- labour-related disputes, from wages and benefits to human rights; and
- supply chain and international trade vulnerabilities at national, regional, binational (Canada-U.S.), trinational (Canada-U.S.-Mexico), and international levels.

4.2 Foresight Analysis: What It Is

Foresight analysis involves reviewing contributions gathered in the participatory consultations and determining where gaps may exist in stakeholders' risk perception (underestimation or overestimation of a particular risk or issue), buttressing those gaps with additional research, and determining relevant new elements of planning, investment, and regulatory and compliance positions that could help to reduce risks or increase the chances of capitalizing on opportunities.

Foresight analysis can also contribute to scenario planning: the development of multiple plausible, memorable, useful, and distinct scenarios for a conceptual future that is one, three, or ten years out, or even 50 years out (Wilkinson, 2017). Scenario planning provides narratives for multiple plausible futures that engage stakeholders and allow strategy teams to identify how the organization might:

- navigate a radically uncertain contextual environment with relevant disruptive forces including, but not limited to, geopolitical instability, pandemic diseases, climate change, and cyberattacks including ransomware;
- interact in the transactional environment with regulators, competitors, policy makers, customers, suppliers, investors, employees, lobbies, NGOs, et cetera;
- inform strategy in the "here and now"; and
- make the organization resilient to plausible futures.

The purpose of foresight analysis and scenario planning is not to predict the future. Rather, it is to establish well-informed opinions about the future via a set of plausible futures that can be discussed and turned over by participants using a common language.

Here, organizations can clarify and absorb risks and opportunities, and use strategic insights from the scenario planning process to inform strategic and operational planning, thereby building greater resilience to, and preparedness for, plausible future scenarios (Orlando et al., 2022).

As the last method in the integrated "resilience toolbox," foresight analysis draws upon learnings from each prior effort — participatory consultations, case studies, vulnerability mapping (VM), force-disruptor-vulnerability mapping (FDVM), and risk topography visualization (RTV) — identifying gaps so that a more complete picture informs decision support for an agri-food interest or organization using the toolbox.

4.3 The How: Scenario Planning

Once gaps are identified looking across the outputs of the "resilience toolbox," one useful scenario planning method, the Oxford Scenario Planning Approach (OSPA) (Ramírez & Wilkinson, 2016), can be used to increase comprehension and understanding of the multiple domains of risk identified in a contextual environment of converging crises.

The use of narrative and storytelling is essential because narratives distill the issues into a digestible form. Narratives that are plausible can be discussed among key stakeholders in terms of implications and counterintuitive insights how others in the transactional environment might respond to each of the scenarios, ultimately leading to an understanding of the gaps in the "here and now" that organizations engaging in scenario planning encounter today.

The OSPA's objective is to help organizations make sense of a conceptual future set one to ten or more years out in a turbulent, uncertain, novel, and ambiguous world by improving the quality and relevance of strategic conversations. To do so, two or three memorable, plausible, and distinct narratives set in that world are developed for a "user" that has strategic questions to answer. These scenarios are designed to be useful for the user (company, industry body, farm operation, regulator, etc.), and their development harnesses evidence-based information gleaned from each of the other tools in the CMT.

There are at least five important crises (domains) to research as the scenario planning process unfolds. These include:

- geopolitical instability;
- socioeconomic reordering;
- physical and mental health declines;
- technological acceleration; and
- global change and climate change.

4.4 The When: Supply Chain Vulnerabilities and Time

Faced with the reality of an increasingly crisis-prone context for decision making, decision makers often freeze, overwhelmed by future risks greater than today's. They simultaneously face urgent present-day business and policy issues that demand immediate attention. It is common for them to ask internal experts and outside risk consultants to predict "when" they will face such contingencies, and how to justify potentially eye-popping investments in resilience building that increasingly crisis-prone environments demand.

Unfortunately, contextual environments that are radically uncertain do not lend themselves to the typical investment justifications that decision makers would like to see made. This is because risks and opportunities in a radically uncertain contextual environment are *inherently unpredictable*. Even so, a contextual backdrop of radical uncertainty does make it important to consider time horizons and other contextual issues that scenario planning helps to incorporate into strategic conversations. This typically yields valuable strategic insights that can help strategy become more resilient amidst radical uncertainty — and its associated unpredictability.

The OSPA uses the concept of "the three arrows of time" (Ramírez & Wilkinson, 2016, pp. 40–41) to help scenario learners make sense of the context of radical uncertainty.

4.4.1 Future Coming Towards Us

Future supply chain vulnerability-related issues can be described as unpredictable issues, trends, and events coming towards us. In this case, the "us" of a specific agri-food system is a stakeholder as well as the entire agri-food system within which they operate. According to multiple Canadian agri-food system stakeholders and supported by research, such issues include, but are not limited to:

- increased conditions of climate change;
- new infectious diseases;
- pestilence and forever pandemic;
- more international conflict;
- more cyber attacks;
- more sophisticated mis- and disinformation;
- more input cost uncertainty;
- additional cross-border interruptions to trade flow;
- greater food and nutritional insecurity;
- more social vulnerability among populations in Canada and abroad;
- more worker skills challenges; and
- more difficulty in securing farm succession.

4.4.2 Going Forward from the Present

From the point of view of the present, stepping into a changing world highlights stakeholders' current worries about issues that are challenging, and that may be spiralling beyond their control, such as:

- inflation;
- producer debt;
- industry consolidation;
- supply chain bottlenecks;
- foreign exchange arbitrage;

- labour costs;
- international trade with China (pork) – overreliance on export markets;
- continental trade with U.S. and Mexico (pork and greenhouse);
- government relations;
- producer-processor power asymmetry;
- transport supply chain oligopolies and regulatory responses;
- diseases such as African Swine Fever (pork), tomato brown rugose fruit virus, and pepper weevil (greenhouse); and
- increasing rate of extreme weather and climate impacts for which the industry does not see itself as prepared (Têtu, 2021).

4.4.3 The Past Catching Up with Us

The concept of the past catching up with us relates to the consequence(s) of not having invested earlier in preventing harmful things from occurring today, despite evidence that this would have paid off. Examples include:

- inadequate investment in robust and modern transport infrastructure;
- regulatory permissiveness of transport consolidation in rail;
- regulations that restrict and limit activities of provincial processing facilities;
- general lack of on-farm animal feed inventory to ensure adequate supply in the event of sudden supply chain disruptions (e.g., BC flood);
- inadequate preparation for extremes in weather and climate; and
- little to no long-term planning informed by foresight, as well as negative accrued impacts of farming methods borne of a different agricultural era (Prager & Wiebe, 2021), all of which create cultural norms and barriers to action in the "here and now" to mitigate risks, adapt to change, and identify and capitalize on opportunities.

4.5 Expanding Awareness of Supply Chain Vulnerabilities

Addressing the totality of risk and opportunity in a holistic manner is critical. This requires having a total risk-opportunity framework that can simultaneously incorporate risks and opportunities associated with multiple relevant crises (Mora et al., 2018). After reviewing the outputs of participatory consultative engagement, case studies, vulnerability mapping (VM), force-disruptor-vulnerability mapping (FDVM), and risk topography visualization (RTV; sections 2 and 4), this pilot study used foresight analysis to expand awareness of supply chain vulnerabilities beyond those already identified through the "resilience toolkit" and through the study's initial focus on geopolitical instability, pandemics and panzootic diseases, and climate change.

Additional areas identified by foresight analysis applied to the agri-food system in Canada include:

- **Health.** All aspects of health need to be addressed to preserve the capacity to think well and act effectively in an environment of converging crises (Watts et al., 2021).
    - **Physical health.** Long COVID and other chronic health conditions disproportionately threaten farmers, farm labour, and managers and management across the agri-food system. Most of the key knowledge holders in these areas are in their fifties and sixties and thus are more at risk of adverse outcomes. The evidence-based medical and public health literature researching long COVID impacts and effects identifies increased cardiovascular disease and brain ageing as concerns (Capua & Piccolo, 2023).
    - **Mental health.** As noted above, maintaining mental health during the pandemic and in times of increasing uncertainty for the pork and greenhouse sectors is proving challenging, and mental health needs to be incorporated into foresight analysis and scenario planning, including the potential implications for farmers, workers, managers, senior executives, and all consumer-citizen demographics (Barchielli et al., 2022).

    - **Organizational health.** The mental and physical health of entire organizations will remain an important factor shaping decision making across organizations. The more suboptimal health is, the more suboptimal decision making will be in narrow operational situations and at the level of strategy.
    - **Cultural flexibility.** The ability of an organizational culture to adapt to new risks and threats, which were not given adequate attention at earlier moments, is a key aspect of organizational health and associated effectiveness.

- **Intergenerational succession and diversity across the agri-food system** (Richard, 2023). This issue is an obvious one, according to the participatory consultations, at the farmgate. It is not as obvious, but is critically important, across the agri-food system for an orderly talent transition. Factoring this into foresight analysis and scenario planning activities is part of a holistic approach to strategic planning.
- **Opposition to regulations that contribute to systemic resilience.** Participatory consultations revealed stakeholder frustration with, and opposition to, some environmental and other regulations that, while costly in the short term, could help to build systemic resilience in the short, medium, and longer terms. Industry associations can use foresight analysis and scenario planning to wargame their lobbying aims and objectives and explore whether these are useful or potentially detrimental to the agri-food system, the agri-food sector, or their own organization.
- **Consideration of average temperature rise of 1.5 degrees Celsius to 6 degrees Celsius (or more) by 2100.** There is a much wider range of plausible temperature change and yet-to-be-quantified sensitivities to these changes. Canada, its trading partners, and export markets will all be made more unstable in the current, emerging, and long-term global change environment.
- **Analysis of water availability at national and continental scales.** There will need to be a much more sophisticated, data-driven, and foresight-informed approach to understanding water availability issues and prediction (Erler et al., 2019) at national and continental scales for Canada's agri-food system stakeholders to plan for water-related crises in dialogue with potential water allies and water competitors within Canada and in the United States.
- **Addressing climate adaptation gap(s).** Decarbonization is capturing the spotlight in government policy. Governments, industry associations, and private sector companies are making what seem to be bold decarbonization pledges. Unfortunately, Earth system instability means that climate adaptation must move to the fore and do so aggressively. There is no getting around the fact that adapting to the climate crisis will require significant and frequent financial and human capital expenditures, including public sector incentives and subsidies now and for any foreseeable future(s). The failure of public-private partnerships such as the Canada Infrastructure Bank to motivate private sector co-investment reflects systemic private sector risk aversion to building national scale infrastructure that would strengthen the resilience of vulnerable supply chains. New approaches need to be taken to fund the planning (Guyadeen et al., 2019), design, development, and building of climate-adaptive and resilient infrastructures (Hay, 2021). Incorporating the climate-adaptation gap into foresight analysis and scenario planning is important here (Goldstein et al., 2019).

Appendix 3 provides a wider range of supply chain vulnerabilities relevant to expanded (and more complete) risk perception.

4.6 Examples of Where Scenario Planning Is Useful

Here are three examples that show in what contexts scenario planning can be helpful to multiple pork and greenhouse stakeholders.

4.6.1 Example One: Climate Change (Greenhouse Sector)

Climate-related extreme weather events, such as those involving heat waves, ice storms, or extreme snowfall, place stresses on greenhouse infrastructure that the infrastructure is not designed to withstand. Greenhouses can collapse because of extreme cold-related events and can overheat because of prolonged heat intensity, placing pressure on the electricity grid in both cases, with producers under financial pressure because of increased energy costs they do not have the profit margins to absorb.

Extreme weather and all manner of climate-driven phenomena also create issues for property and casualty insurance policies, which are becoming more expensive, sometimes prohibitively so, while yielding more potential exclusions to claims settlement. Participatory consultations with members of the greenhouse sector reveal that greenhouse infrastructure used in central and eastern Canada is not designed to withstand extreme weather events: extreme cold and ice storms in winter and extreme heat and drought in the summer.

Greenhouses were mostly developed in the Netherlands for the more temperate climate there. It is essential, then, to develop greenhouse infrastructure for Canada that can cope with more weather extremes, for electricity grids to be more resilient, and for water availability and hydrogeology-related issues to be addressed. This may be an opportunity for the greenhouse vegetable industry or various entities within the industry to use the CMT to explore scenarios to address extreme weather of all kinds in the context of climate change; the role of geopolitical instability in affecting agricultural trade relations between Canada and the international community; and pandemic and panzootic events affecting labour and crop viability, energy resilience, and water availability.

4.6.2 Example Two: Geopolitical Instability (Pork Sector)

An industry association identified a lack of sophisticated geopolitical understanding of markets and trade as a key vulnerability of its membership. This gap in understanding led the industry association's members to express frustration with the federal government about geopolitical instability and the implications of more antagonistic diplomatic relations on pork exports to China, which is consistently in the Canadian pork industry's top three export markets.

As an outcome, potential geopolitical and international trade risks with China have led the pork industry to pivot to alternate markets as export hedges. That said, they have not yet considered how China might retaliate against these customers for accepting more Canadian pork, or how the international shipping industry and alternate markets for pork are very ill prepared for volatile climate-driven oceanic conditions that, in the years to come, will test the resilience of current ship designs, shipping routes, and port infrastructure.

Here, scenario planning can be used by the industry association or its individual members to gain clarity about what needs to be done in the "here and now" to address the confluence of geopolitical, pandemic, and climate risks.

4.6.3 Example Three: Pandemic and Panzootic Disease (Pork Sector)

African Swine Fever (ASF) is the biggest concern among pork producers as the introduction of the disease into swine populations leads to crippling restrictions on exports and is considered an extinction-level event by the Canadian pork industry. Given the existential risk of ASF and the critical issue of continually investing in efforts to keep it out of swine populations, the pork industry finds it challenging to simultaneously address the ongoing, underlying, and esoteric risks associated with climate change and the changing market landscape resulting from geopolitical instability.

Climate change needs to be considered in all pork industry scenarios as a threat multiplier that can increase the risks of ASF entering the swine population. That is, a warming climate introduces and amplifies ASF risks. Here, the role of contextualizing ASF amidst an expanding risk landscape will be important as extreme weather has the potential, in certain circumstances, to bring the industry to its knees.

The assumptions underlying the viability of China, alternate markets for Canadian pork, all of which are affected by the climate crisis, by a potential decline of middle-class buyers of animal-based proteins, and by impacts of

environmental and climate change on shipping and port infrastructure scenarios. These complex interrelated issues create an opportunity for multiple stakeholders within the pork sector to use scenario planning as part of the CMT in order to develop clarity about how to inform key strategic, operational, and regulatory domains.

4.7 Mindset, Skills, Experience

A core challenge for all stakeholders concerned with future supply chain vulnerabilities is that groupthink is sometimes embedded in a particular industry consensus that informs each stakeholder's asks of federal, provincial, and municipal levels of government. While rational in terms of addressing immediate business and industry needs, some asks can create supply chain vulnerabilities that weaken agri-food resilience at a systems level. As an example, it may prove unwise for industry associations to lobby against increasing food safety and climate resilience-related compliance legislation. Although it is counterintuitive from the perspective of competitiveness and efficiency, as risks to agri-food system supply chains grow, industry associations, private companies, and civil society groups may need to find compromises that aid in building the short-, medium-, and long-term resilience of the Canadian agri-food system.

Another related challenge is that Canada lacks foresight experts with the requisite knowledge, skills, expertise, and experience to inform strategy and support from within organizations to support development of a robust foresight function (Banfield, 2016). Equally challenging is identifying experts who can translate foresight-related learnings to the mindsets and needs of executive management and boards of directors. In fact, there may not be enough qualified foresight experts anywhere in the world with the ability to credibly address issues related to a convergence of crises across industry sectors and society. At present, and as the COVID-19 pandemic demonstrated, federal, provincial, and municipal governments find it difficult to incorporate foresight and scenario thinking into policy planning cycles and into preparedness strategies.

5 Conclusion

The objective of this study was to present an approach to enhance overall agri-food and supply chain resilience that adopts the principles of structured decision making (SDM). Pork and greenhouse vegetables were chosen as commodities representative of agri-food in Canada which would serve to reveal issues, concerns, and opportunities as representative of other agri-food commodities.

Disruptive forces studied in this report include climate change, geopolitical instability, and pandemic. These disruptive forces cover a broad range of impacts, are readily observable, and will continue to have disruptive impacts across the Canadian agri-food system into the future.

Participatory consultations identified the following key vulnerabilities:

- access to a skilled workforce;
- precarious economic viability of farms (for example, labour, profitability and operational costs, and succession); and
- vulnerable processing and transportation infrastructure.

In addition, challenges were identified with market access and volatility, international trade rules, disease (animal, plant, and people), cybersecurity, extreme weather events, weather trends (for example, shifting seasons), consolidation, input costs, the energy crises, population growth, and the disconnect between industry and policy. Generally, representatives interviewed from other commodities indicated their agreement with these concerns.

The report develops the first phase of the crisis management toolbox (CMT) for Canadian agri-food resilience that encompasses six innovative tools. These tools build on one another sequentially and in aggregate to deliver powerful decision support. These tools include participatory consultations, case studies, vulnerability mapping (VM), force-disruptor-vulnerability mapping (FDVM), risk topography visualization (RTV), and foresight analysis, all operating within a structured decision making environment.

Vulnerability mapping (VM) is a mechanism that translates concerns, worries and “what keeps me up at night” identified in the consultative sessions into key vulnerabilities. These key vulnerabilities provide a solid foundation for determining system resilience in a rapidly changing world.

Force-disruptor-vulnerability mapping (FDVM) is a tool that builds upon the findings of vulnerability mapping. FDVM connects the identified vulnerabilities to the disruptive forces and provides a simplified way to illustrate the synergistic behavior of disruptive forces within the system.

Risk topography visualization (RTV) was described as a tool that quantifies the impacts of disruptive forces and related synergies on the system. The quantitative results are summarized in data layers and overlayed to create a risk topography visual.

Lastly, foresight analysis is a tool that draws upon learnings from participatory consultations, case studies, vulnerability mapping (VM), force-disruptor-vulnerability mapping (FDVM), and risk topography visualization (RTV) to identifying gaps and enable decision support to enhance resilience within the agri-food system.

Scenario planning, or the development of multiple plausible scenarios for a conceptual future over a given time horizon, was described as a tool and/or approach that provides decision makers with the ability to inform strategic planning that improves agri-food resilience for multiple plausible futures.

By using the crisis management toolbox (CMT) developed for this project, effective adaptation opportunities and optimization of resource allocation critical to successful long-term planning and policy making are achievable. Importantly, the CMT provides farmers and their stakeholders with the roadmap to build informed, forward-looking, and insightful farm succession and transition plans, critical for the entire Canadian agri-food ecosystem.

It is important to reinforce the tenet of discourse and iteration. In moving forward with the findings of this report, one must fully recognize the need for continuous industry engagement to fully realize the potential of the crisis management toolbox to strengthen the resilience of the Canadian agri-food system.

The structured decision making approach and use of the tools in the CMT have not formed the basis for agri-food policy in Canada, either in business risk management, or at industry levels. The focus has rather been to treat risks to individual businesses – farms, processors, et cetera – as well as systemic risks at essentially a transactional level. This approach, informed by experience, essentially assumes that the perils acting upon Canadian agri-food are independent, contained within the agricultural sector, and will revert back toward initial equilibrium through market forces and facilitating government policy/programming. In some cases, this is quite explicit: for example, in establishing reference margins, AgriStability assumes that adverse deviations in farm returns will correct back within a three-year time period. For the most part – and with some notable exceptions, such as hogs in 1998, and BSE in 2003-05 – this approach has been adequate, and ad hoc emergency programming has been invoked to deal with the larger industry-level calamities.

The analysis here should lead us to question how this approach to agri-food policy will address the problem of converging crises, in which perils build upon one another (perils are not independent), the perils are subject to tipping points (non-reversion to initial equilibrium), and/or the perils extend to/from outside of agriculture. A world of converging crisis creates new demands on agri-food policy; the CMT developed here contributes a platform from which to draw.

Appendix 1

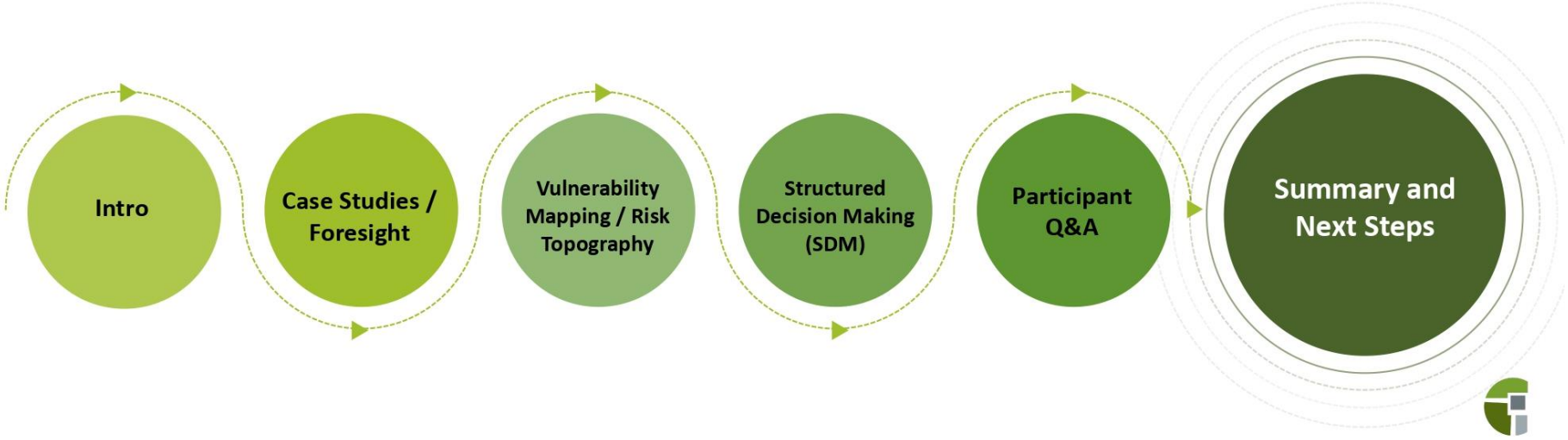
CAPI Project Presentation, March 27, 2023 (Elora, Ontario)

CAPI
THE CANADIAN AGRI-FOOD POLICY INSTITUTE

Supply Chain Resilience: Towards Understanding Forces and Disruptors

Wrap Up Session

Our goals are to share some of what we've heard during the past five workshops across Canada, and to share some of the tools we are including in the final report. Then we will listen carefully to your insights and perspectives.



CAPI Pilot Project Team

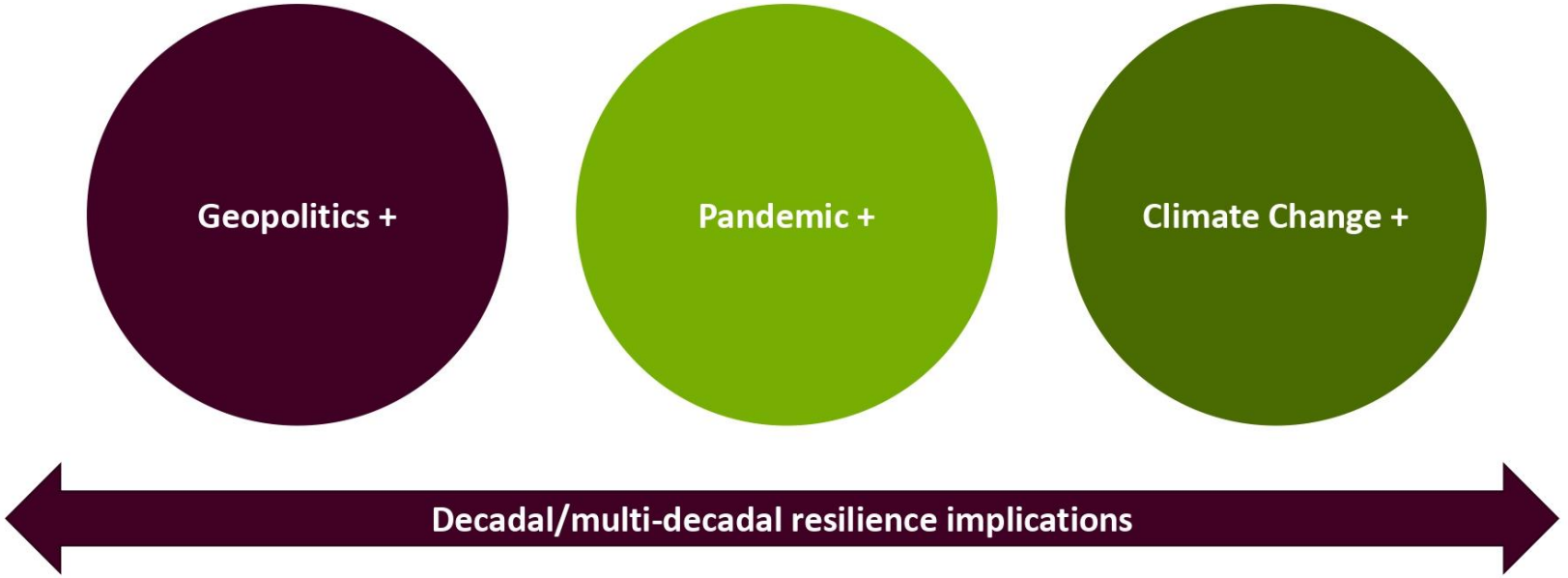
Sanjay Khanna
Foresight Analysis

Karen Hand
Digital Strategy

Tom Armstrong
Global Change

John Fisk
Food Systems

Supply Chain Resilience: Agri-Food/Agriculture



Producer and processing stakeholders expressed concern that agri-food strategy does not extend past 5 years. Stakeholders believe **some entity** needs to invest in horizons from 10 years to 30 years out—and beyond.

More agri-food vulnerabilities: Farm-processor-retailer tension, trade conflict, input costs, new/emerging diseases, pestilence, labour cost/retention, immigration, industry concentration, climate/trade disasters, regulatory & policy minefields.

Agri-food industry understanding of key risks and threats is unevenly distributed. Action is not commensurate with today's best state of understanding. "Talk-action gap" needs bridging at significant cost and effort.

Cyber threats are proliferating. These can affect the entire supply chain including food safety. distribution and more. Ransomware is a growing issue. Too few agri-food stakeholders have enough cybersecurity/ resilience for various kinds of cyberattacks.

Supply Chain Resilience: Agri-Food/Agriculture

Geopolitics +	Pandemic +	Climate Change +
Russia/Ukraine war; increased China-Canada, U.S.-China, China-West, China-India-Pakistan tensions; global conflicts and growing tensions associated with need to secure agri-food inputs and supply chains.	Implications of COVID-19 and emerging Sars-Cov-2 viruses on health conditions of labour, management, citizen-consumers; farming, processing industries; short-, mid-, long-term cost management and industry viability.	Underlying acceleration of climate change affecting farming and processing, including underlying crop varieties, animal breeding, nutrition, disease spread, supply chains, disaster preparedness, and much more.

Decadal/multi-decadal resilience implications

Unique Future(s) Orientation

Geopolitics +	Pandemic +	Climate Change +
How does—and how will—geopolitics shape the future of Canada's agri-food system? How can Canadian agri-food system players adapt to supply chain-related geopolitical risks and threats that can be anticipated?	What risks and threats are related to COVID-19's Year Four and beyond? How long will COVID-19 risks and threats (incl. long Covid) affect labour, management, ops, and decision making in agri-food? How can multi-year effects on supply chains be mitigated?	How fast is climate change happening? How widespread will impacts/effects become? How might animal husbandry, crop yields, processing, transport, human health, agri-food supply-chain resiliency be affected? How might small vs. large producers be affected? Consolidation?

Decadal/multi-decadal resilience implications

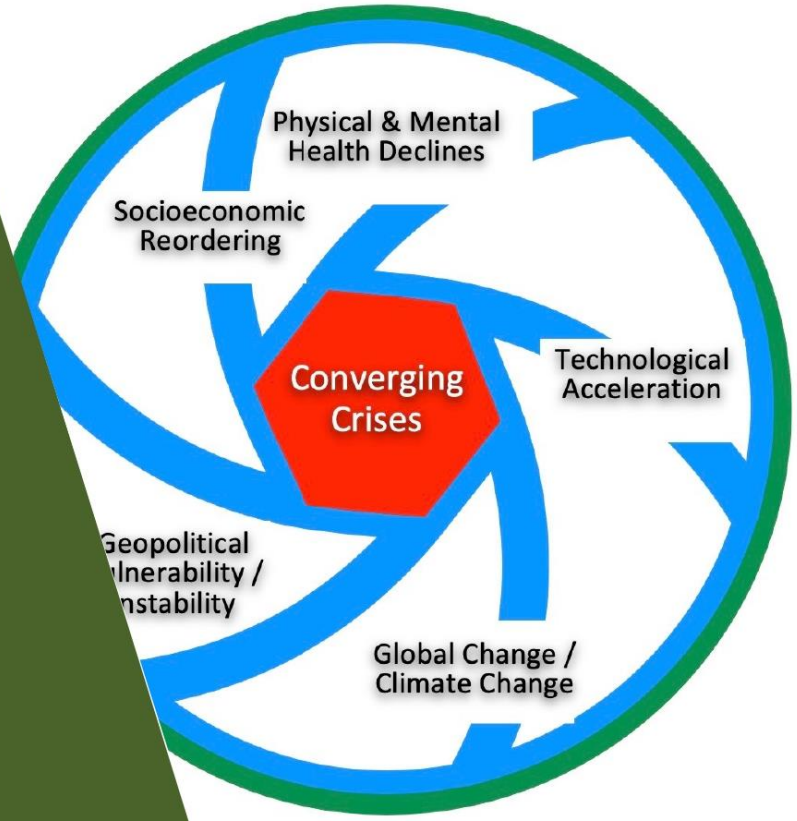
Converging Crises

Converging Crises and Supply-Chain Vulnerability

How do the converging crises of Geopolitics + Pandemic + Climate Change lead to cascading and compounding impacts within the Canadian agri-food supply-chain?

What resilience-related strategies and solutions can address supply-chain vulnerabilities as the threat landscape expands?

What can be done in the "here and now" of strategy development to build resilience in agri-food supply chains?



Case Studies / Foresight Analysis

John Fisk, PhD & Sanjay Khanna, MFA, BEd

Lived Experience

- **Farm Level.** Farmers aware of climate disruptions and yet challenged financially to address them. With input costs and inflation rising dramatically, financial risks have grown in tandem. Mental health issues are commensurate with growing uncertainty.
- **Processing Level.** Infrastructure consolidation can drive efficiencies, but also puts farmers at risk. Closure of just one plant can significantly reduce food supply. Labor an issue at all scales of the industry and supply chains.
- **Transportation Level.** Heavily reliant on export markets and subject to transport disruption from COVID-19 and climate impacts globally. Rail and truck transportation key issues. Disease a major concern across borders. Reliance on inputs from abroad (hogs to fertilizer to pest control).
- **Policy Level.** Strategic need for competent leadership at this level is critical. Politics and bandwidth remain dangerous obstacles.

Case Study Benefits: Pork & Greenhouse

Contribute to describing & prioritizing systemic vulnerabilities within agri-food supply chains

- Document relevant lessons learned
- Provide data and insights for plausible future scenarios
- Use pork and greenhouse vegetable production to understand and illustrate vulnerabilities
- Summarize existing information on these supply chains including vulnerabilities identified

Case Study: Pork

Overview

- Canada is third largest exporter of pork and live pigs
- Approximately 7,600 farms producing over 14 million animals
- Roughly 2/3 total production exported pork valued at approximately $5 billion
- Export US, China, Japan, Mexico, Philippines, South Korea, Vietnam, and more
- Production is largest in Quebec, Ontario, Manitoba
- Production and processing and marketing operate on a tight “just in time” schedule

Case Study: Pork Challenges

Now/Short Term

- ASF – African Swine Fever (viral)
- Labor – on farm, in processing,truckers, etc.
- Input and operating costs
- Processing capacity and concentration
- Cybersecurity and weaponization of Ag trade

Longer Term

- ASF – impact on trade, borders, climate impact
- Weather driven disruptions: transportation, feed grain production, infrastructure
- Increased opportunity for zoonotic disease
- Market loss and other dynamics due to geopolitics and growing global divisions
- Changing climate adding risk and cost will impact farm succession

Case Study: Greenhouse Vegetables

Overview

- Largest and fastest growing segment of Canadian horticulture
- Self-contained “controlled environments” with automated systems for heat, water, and nutrients, artificial lighting
- Peppers, cucumbers and tomatoes, diversification trend
- Ontario largest - 71% of production, also BC, Quebec, Alberta
- $2.7 billion in sales in 2021
- Export 70%, primarily to USA
- Over 15,000 people employed, about 40% temporary foreign workers

Case Study: Greenhouse Veg Challenges

Now/Short Term

- Labor
- Cost of energy: gas and electric
- Invasive Species – globalization major factor
- Border issues impact on exports
- Infrastructure vulnerability to extreme weather

Longer Term

- Changing and extreme climate:
  - ➢ Heat stress on plants can reduce production by 25%, effectiveness of biocontrol agents
  - ➢ Infrastructure vulnerability
  - ➢ Rising sea levels in BC and hurricanes in NS
- Disruption to supply of inputs
- Growing competition and increasing costs
- Succession and farm transition

Case Studies

Overarching Learnings

- Export market reliance makes sectors vulnerable to disruption
- Increasing food insecurity – Growing global food needs combined with slowing production, geopolitical impacts, extreme climate and weather impacts, labor disruptions. May develop in Canada
- Farms are particularly vulnerable to disruptions as they are already under pressures from multiple angles
- Immediate threats such as ASF are critical to address in a coordinated and planned way. Similarly, planning and investments are needed to avoid or minimize converging disruptions
- Industry is focused on operations and hard to shift focus to plan for future shared threats across sectors

Planning – What We Heard

"The industry needs to join forces, no matter how big or small, to ensure the survivability of everyone."

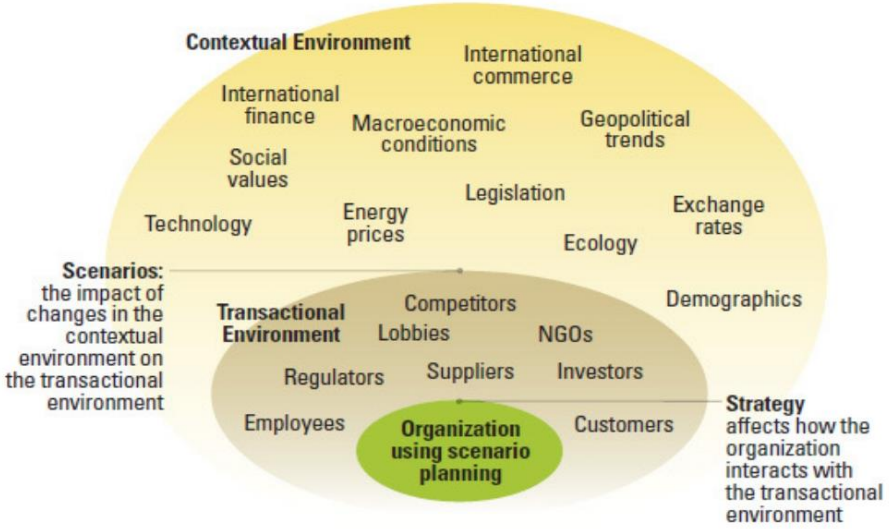
"There has to be practical conversations involving processors, industry associations, CFIA and government officials to agree in principal and specifically on fast, flexible support to processors and producers in crisis situations."

"Processors and producers need to know that the support will be there in times of crisis and that we can continue to provide food for Canadians."

"Simulations can be very helpful in drawing attention to specific disruptions and, if well-organized have some entertainment value for the participants…."

"Get the industry to work collaboratively, figure out what is in everyone's best interest and share experiences and data to move the sector forward rather than jockey to out-position neighbors and colleagues. Big problems don't get solved without collaboration."

Foresight Analysis: Scenario Planning



Oxford Scenario Planning Approach (OSPA)

Ramirez, R., Churchhouse, S, and Hoffman, J. (2017).
Using scenarios to reshape strategy. MIT Sloan Management Review, 58(4).

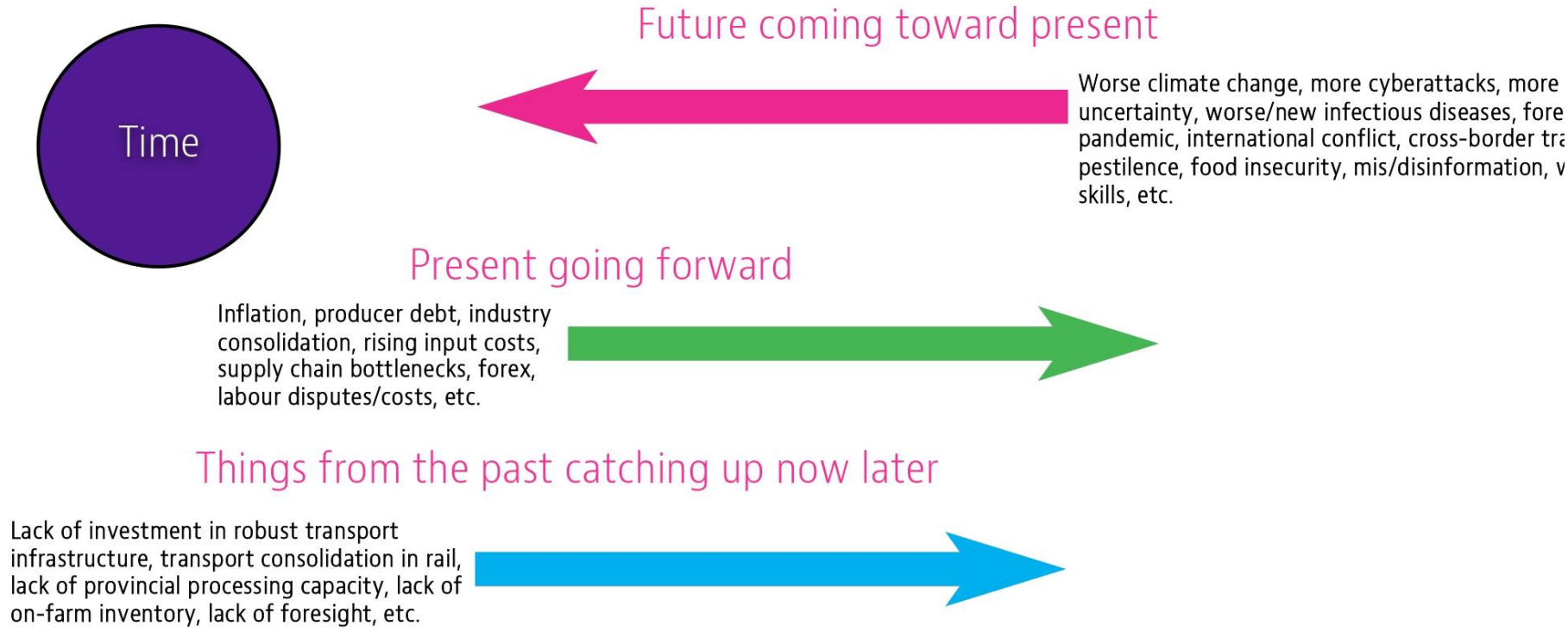


Figure 2.2. Three arrows of time from Oxford Scenario Planning Approach (OSPA)

Scenarios

Scenario 1 | Scenario 2 | Scenario 3

Hypothetical Scenario Set

Stance

**"Well-structured…
Well-researched…
…opinions."**

Dr. Rafael Ramirez
Oxford University

Learner-Centred

**Plausible
Challenging
Memorable
Useful**

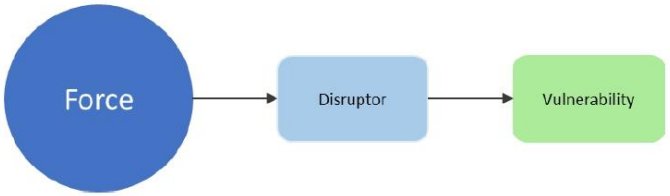
Framework for Resiliency in Canadian Agri-Food

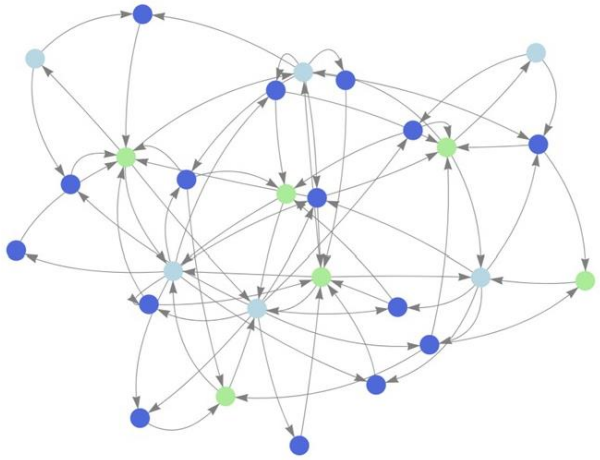
Thomas Armstrong, PhD & Karen Hand, PhD

From Disruptor to Vulnerability: A Dynamic System

The resiliency of the Canadian Agri-Food ecosystem and related supply chain elements requires a new level of situational awareness that demands:

- Identification of vulnerabilities
- An understanding of the disruptor-impact dynamics
- Assessment of system risk tolerance
- Response with appropriate action taken by appropriate actors
- Iteration and monitoring





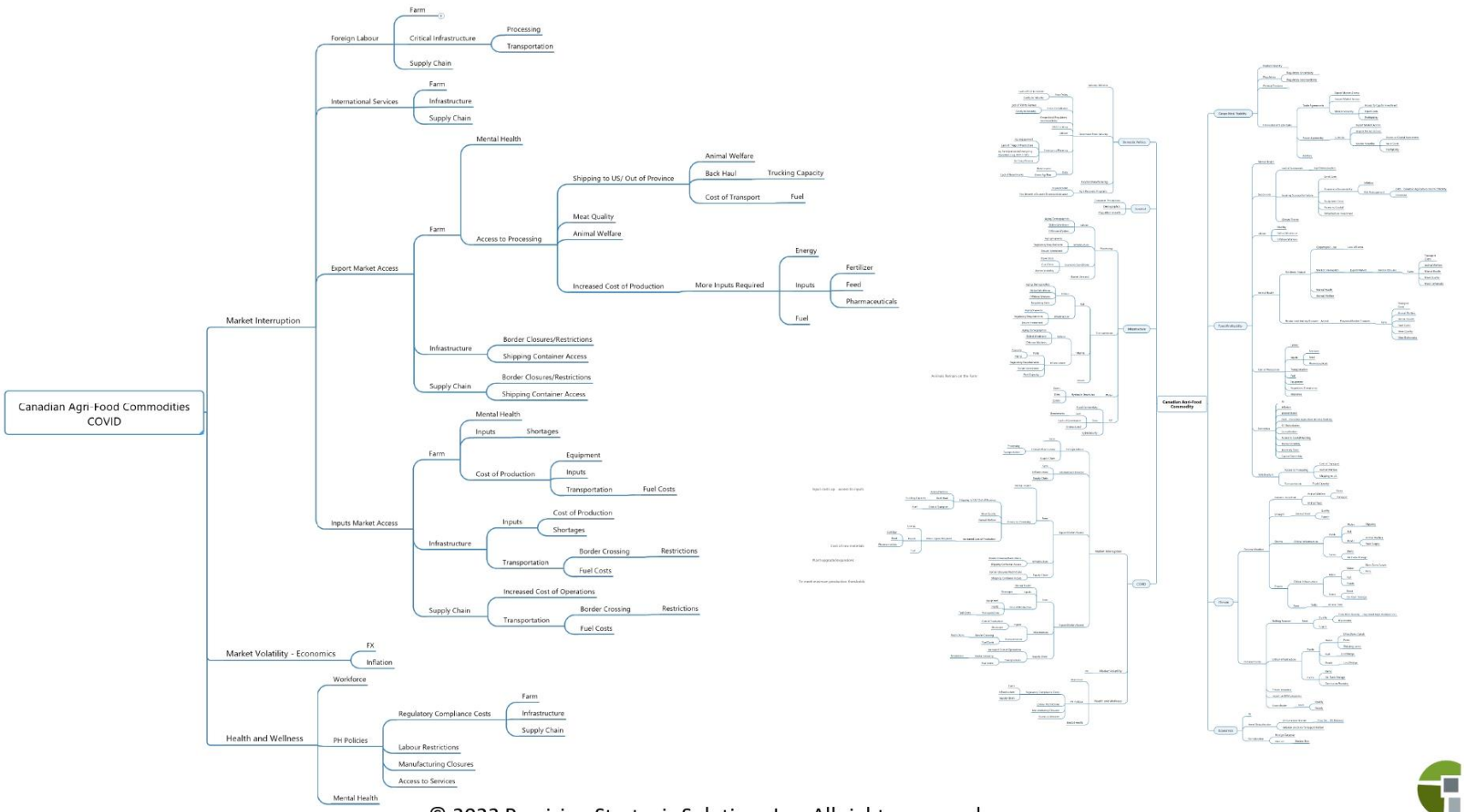
Vulnerability Mapping (VM)

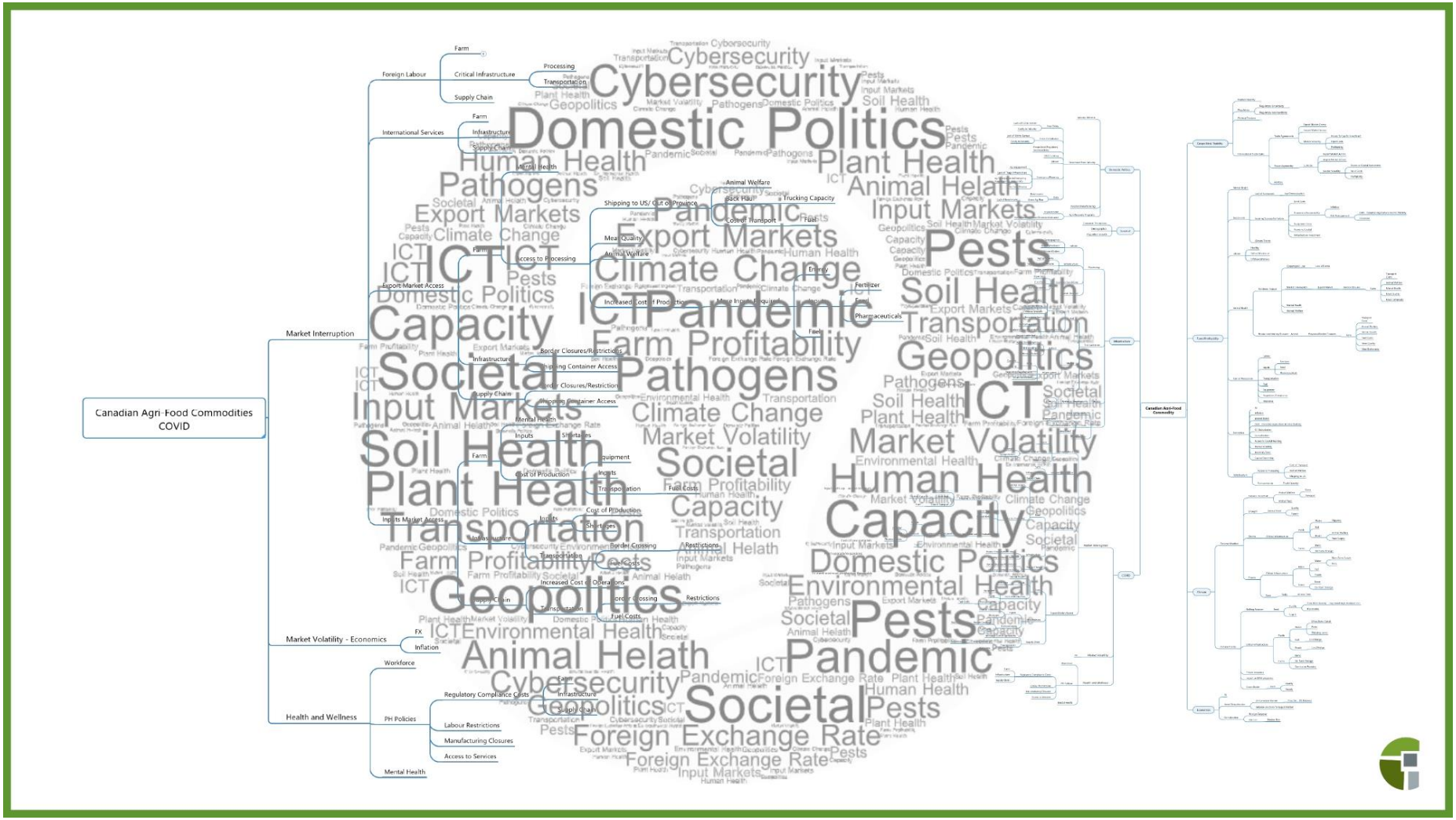
Situational Awareness

First step in process is to map the vulnerability landscape in order to better visualize what can be accomplished and appropriate actions.

Vulnerability Mapping (VM) requires:

- Participation from all ecosystem stakeholders
- Identification of common themes – disruptors and vulnerabilities
- Clear statement of boundary conditions and assumptions
- Discourse and iteration




Canadian Agri-Food Commodities COVID
Market Interruption
Market Volatility - Economics
Health and Wellness
Cybersecurity
Domestic Politics
Human Health
Plant Health
Pathogens
Export Markets
Climate Change
ICT
Pests
Capacity
Pandemic
Farm Profitability
Societal
Input Markets
Soil Health
Transportation
Geopolitics
Animal Helath
Foreign Exchange Rate
Market Volatility
Environmental Health
Domestic Politics
Human Health
Capacity
Pests
Pandemic
Societal
Foreign Exchange Rate
Input Markets
Soil Health
Transportation
Geopolitics
ICT

Force-Disruptor-Vulnerability Mapping (FDVM)

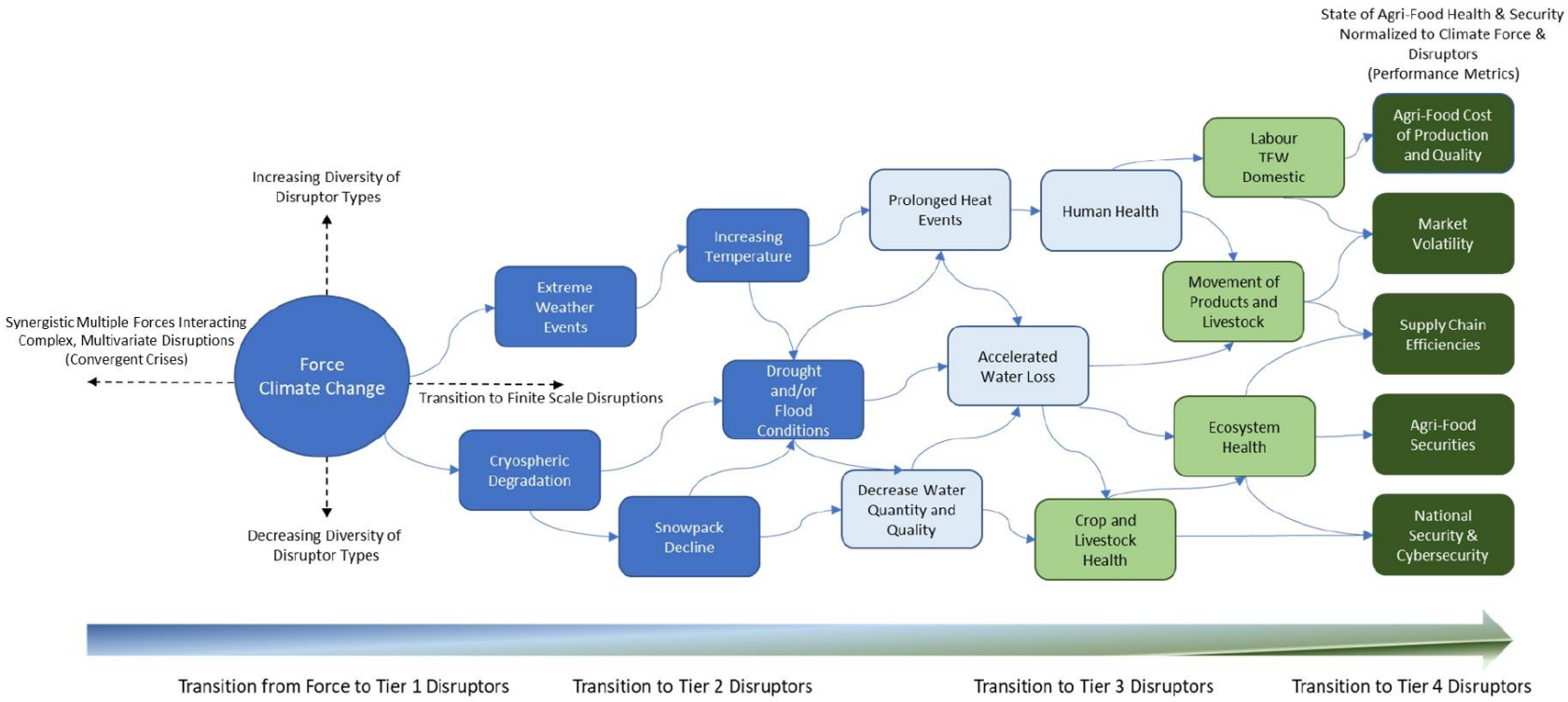
Relationships and Synergies

The second step in the process is to map the relationships and synergies to understand how vulnerabilities are dynamically impacted in order to enable the exploration of consequences and understand how actions may change system dynamics.

Force-Disruptor-Vulnerability Mapping (FDVM) requires:

- Knowledge of the system and the force-disruptor-impact dynamics
- A transdisciplinary team with subject matter experts within the Agri-Food ecosystem and the related force-disruptor disciplines
- Discourse and iteration

Mapping Climate Vulnerabilities Within Force – Disruption Space



Continuum Between Force and Multi-Scale Disruptors

Risk Topography Visualization (RTV)

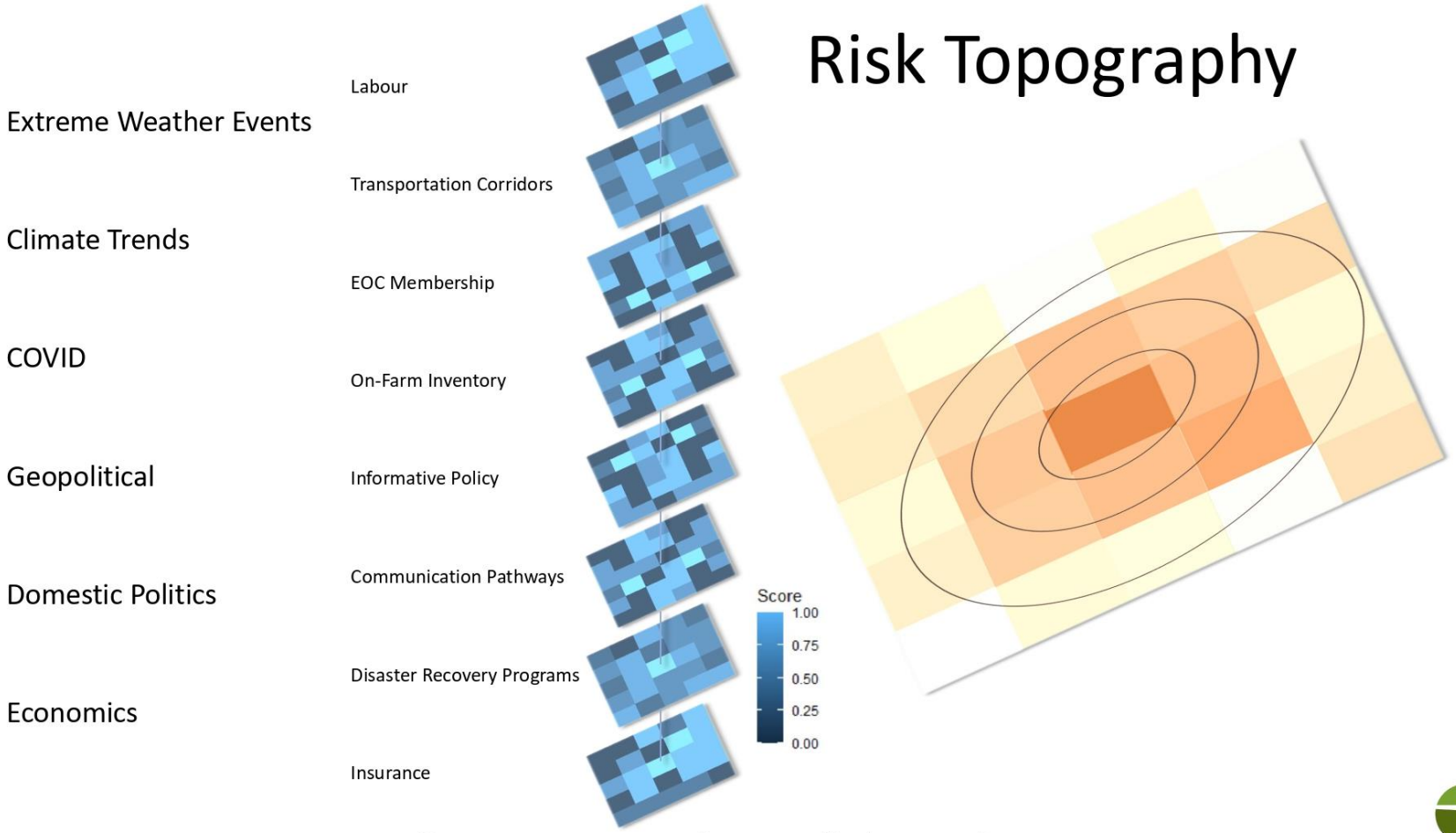
The Landscape

Third step in process is to map the topography of the risk landscape to visualize vulnerability impacts and the force-disruptor synergies in the system in a quantitative manner.

Risk Topography Visualization (RTV) requires:

- Vulnerability Mapping (VM)
- Force-Disruptor-Vulnerability Mapping (FDVM)
- Identification of appropriate knowledge layers
- Identification and clear definitions of metrics related to system impacts and synergies
- Discourse and iteration

Risk Topography



Structured Decision Making

- Foresight Analysis ☑
- Case Studies ☑
- Vulnerability Maps ☑
- Force-Disruptor-Vulnerability Maps ☑
- Risk Topography ☑
- Risk Tolerance Assessment ☑
- Response and Action Strategy ☑
- Iteration and Monitoring ☑

Moving Forward

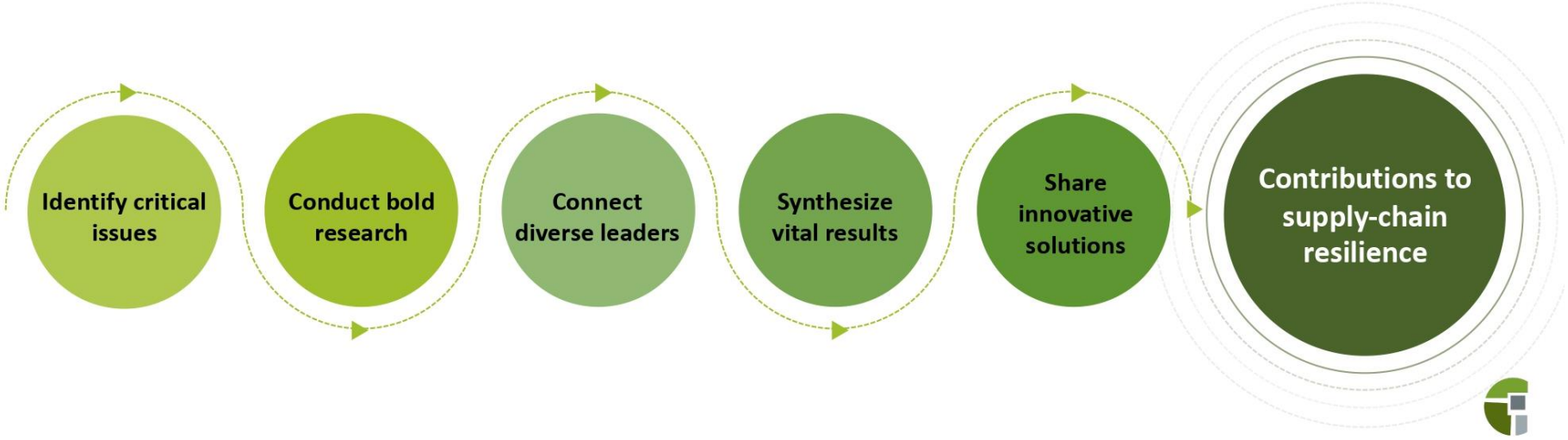
The resiliency of the Canadian Agri-Food ecosystem and related supply chain elements requires a new level of situational awareness that demands:

- Identification of vulnerabilities ☑
- An understanding of the disruptor-impact dynamics ☑

- Assessment of system risk tolerance ☑
- Response with appropriate action taken by appropriate actors ☑
- Iteration and monitoring ☑

Summary and Next Steps

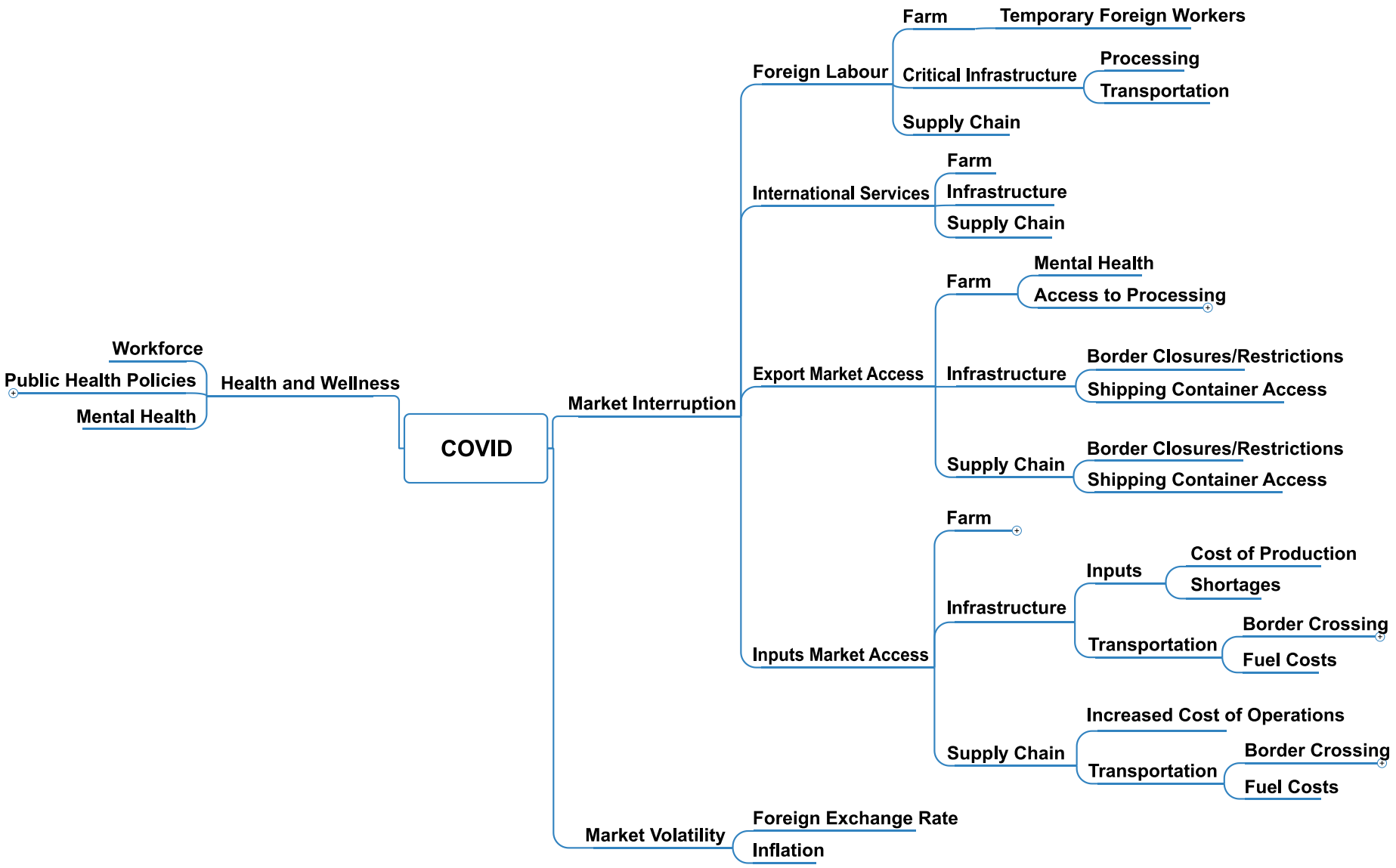
This is the final summary session preceding the publication of a report and accompanying pilot resilience toolbox to be released by CAPI.



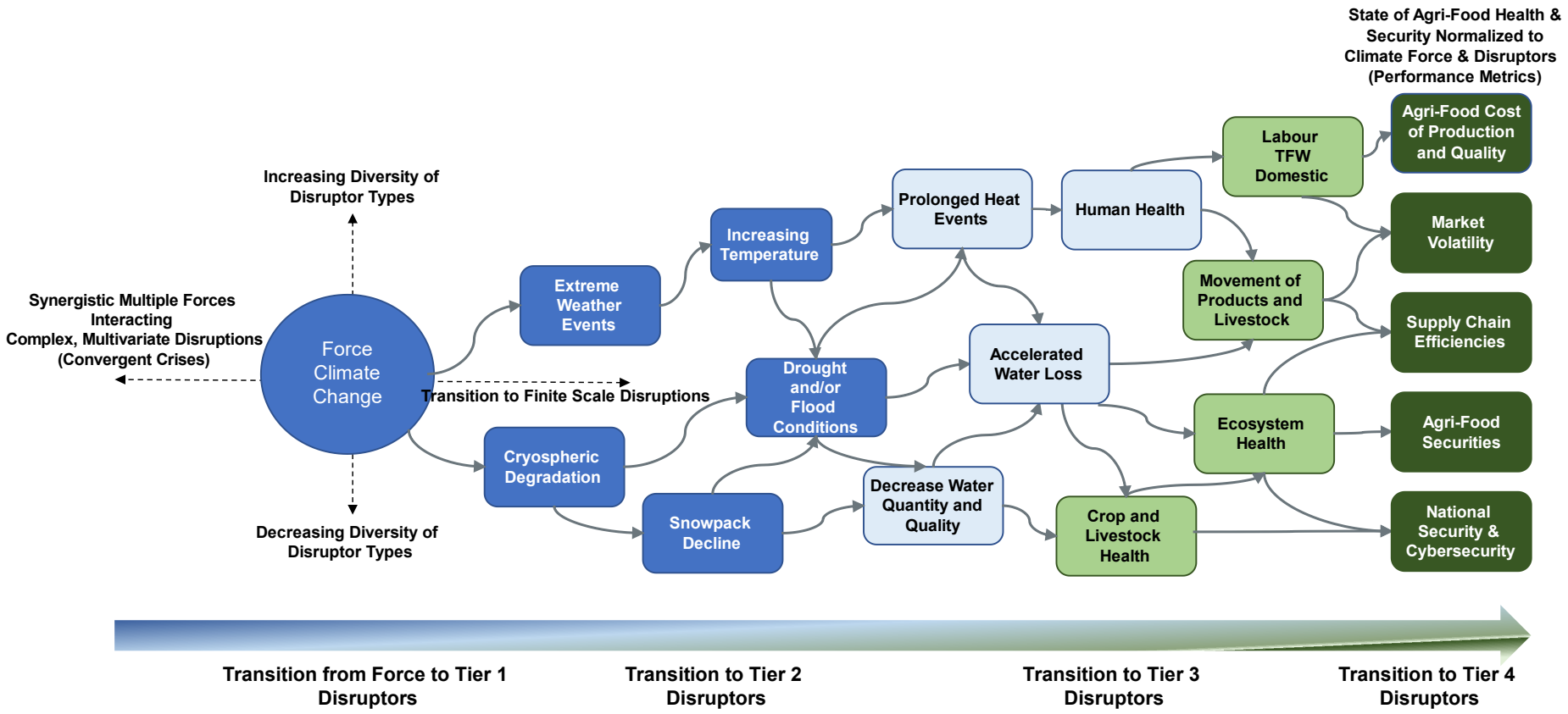
Thank You

Appendix 2: Figures

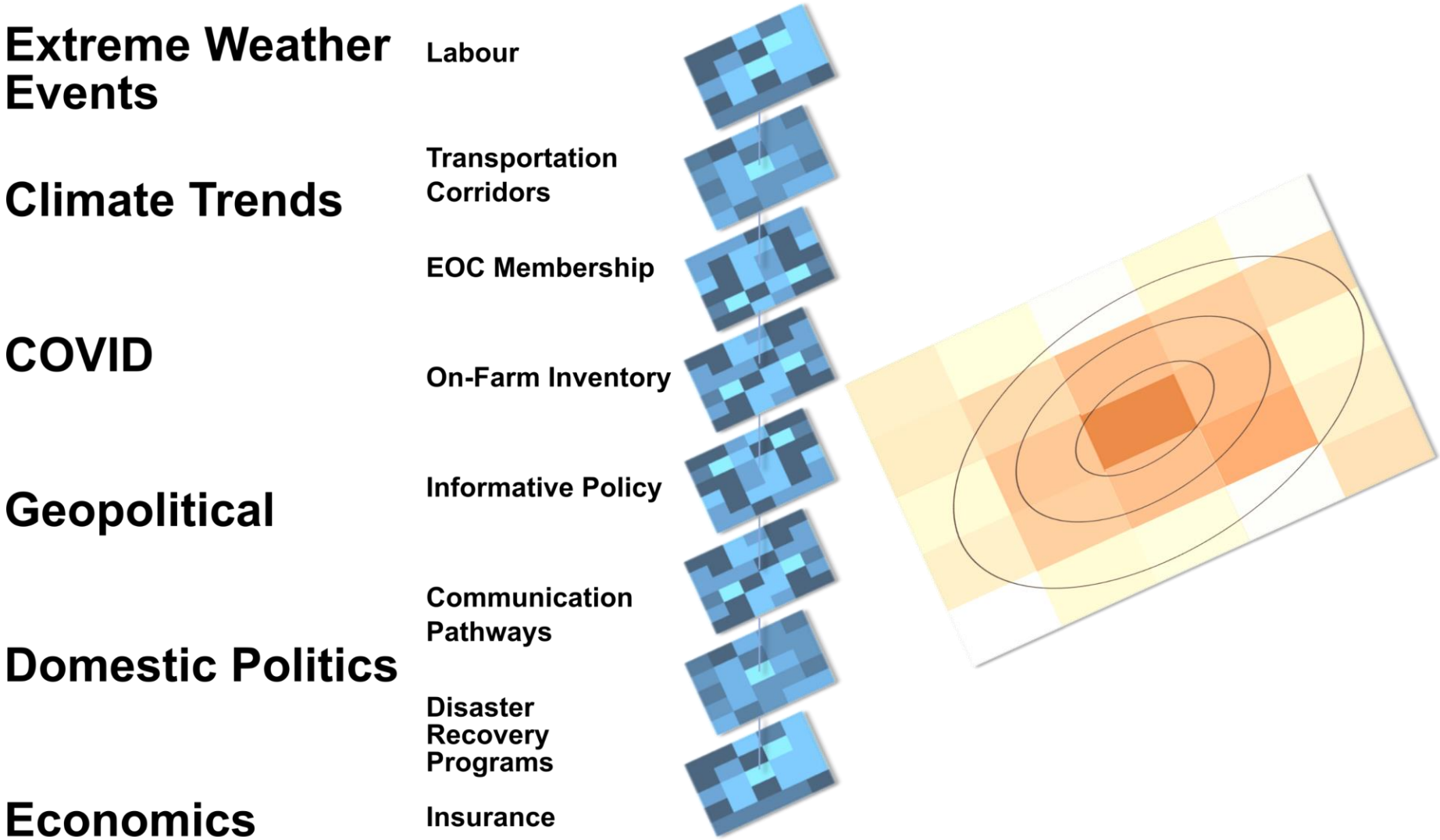
Simplified vulnerability map of COVID related agri-food vulnerabilities based on consultative findings



Interoperations between force and/or multi-scale disruptions



A simulated risk topography based on the consultative findings related to extreme weather events



Appendix 3

Expanding awareness of supply chain vulnerabilities

Geopolitical Instability

- **Geopolitical risks and international trade related impacts.** These are increasingly multi-faceted and require a converging crises lens since climate change, pandemic and panzootic diseases, war between Russia and Ukraine, and other factors co-influence the context within which agri-food systems are evolving.

Socioeconomic Reordering

- **Economic and financial systemic risks and related impacts including market volatility.** This is out of the control of many agri-food system stakeholders and so it needs to be explored so that stakeholders can explore these risks on the contextual environment for agri-food over a given time horizon.

- **Social protest driven by food insecurity, food hyperinflation, or both.** Some who took part in the participatory consultations view a future of food insecurity with trepidation, but also believe that such a future is not only plausible, but likely. Others disagree, believing that Canada's water resources, new agri-food innovations, and so on, will stave off the threat of such risks. Either way, these kinds of issues need to be part of foresight analysis and scenario planning initiatives as agri-food system players coalesce around what it might mean to build systemic resilience now, and in the years to come. Issues related to children's rights to a liveable and secure future play into this research theme.

- **Developing supply chains in new rural and remote agri-food outposts.** There is considerable interest in moving north to grow crops, raise animals, and build new greenhouse infrastructure. Despite the massive land base in Canada and the misplaced notion that temperature extremes in southern Canada that will affect agriculture there can be addressed by moving north (Banfield, 2016), the challenge of northern agri-food expansion is non-trivial. Land in northern Canada is more sensitive to average temperature rise and Indigenous peoples are being made more vulnerable to environmental and climate shocks, affecting food availability and security (Banfield, 2016). Moving agriculture north requires building the right relationships with Indigenous land stewards and their growing practices (Banfield, 2016), planning and building local infrastructure, and enabling supply chains. This will be costly and complex, given considerations related to participatory sociocultural engagement and infrastructure design and development in environments that face unprecedented climate-related disruptions.

- **Environmental and climate litigation in relation to environmental, social, and governance (ESG) issues or even new legal theories such as "ecocide."** The fossil fuel industry is facing litigation from various plaintiffs for impacts and effects of climate change on municipal infrastructure, the futures of young people, health-related impacts and effects, destruction of Earth's life support systems (Banfield, 2016), and more. As of today, agri-food plaintiffs suing for damages from fossil fuel interests have yet to emerge, but it is conceivable that some might sue for crop losses, future earnings losses, and other material impacts and effects. These kinds of issues represent gaps that may influence how the agri-food industry and governments view the expanding risk landscape.

Physical and Mental Health Declines

- **Human capacity building.** The capacity to build psychological resilience in the face of converging crises was not brought up in the participatory consultations although mental health concerns among producers were raised repeatedly. It must be emphasized that as crises continue to converge, it will become harder to make good decisions under the pressures of the chronic stress that a background of long-term converges crises may impose on decision makers and the agri-food system in Canada as a whole.

- **Decision making.** As noted above, the health of individuals and organizations are inextricably linked, and are manifested in management cultures, business decisions, strategy development, and operational approaches:

- **Foresight** (Banfield, 2016). Far too few agri-food system stakeholders harness the necessary foresight to protect their short-, mid-, and long-term interests. The approach is to look at costs without adequately entertaining the even worse implications of not building resilience. This creates deficits in proactive decision-making that then lead to a buildup of risks that then threaten to become catastrophic at a systems level for agri-food.

- **Patience.** A background context of turbulent, uncertain, complex, and ambiguous (TUNA) conditions creates a decision-making environment that sometimes precipitates anxiety-driven decisions that can be counterproductive. Maintaining patience while addressing urgent strategic issues is necessary to improve the quality of decisions.

- **Wisdom.** Drawing on the precautionary principle more often as the era of converging crises adds to risk complexity and the synergistic impact of multiple risks together requires wisdom as well as smarts. Smarts alone will not be enough.

- **Psychological and cognitive flexibility.** The ability to reframe thinking as crises converge will require both psychological and cognitive flexibility among policymakers (Banfield, 2016), business leaders, teams, and workers, no matter which agri-food system stakeholder group they are part of. This will also aid in building collaborative partnerships borne of the necessity of resilience-building as the agri-food system becomes more shock-prone.

Technological Acceleration

- **Cyber-related disruptions to supply chains.** From ransomware to crippling offensive cyberattacks on energy grids, precision agriculture, agricultural processing, transport and critical infrastructure, Canada's agri-food system needs to incorporate cyber risks (Banfield, 2016) and responses into its foresight analysis.

- **Large language models (LLMs) as an exponential accelerator of mis- and disinformation.** In an already dangerous infosphere for mis- and disinformation, new technologies that dramatically amplify dangerous mistruths will further delay policymakers, industry associations, farmers, and processors in addressing polarizing issues that are subject to mis- and disinformation related to the agri-food system. Without appropriate mitigations, this will make it even harder to reduce converging crises-related risks, and to take advantage of important opportunities that need to be targeted and captured quickly amid polarization in professional decision-making environments.

- **Technology-driven opportunities.** Incorporating promising and realistic technologies — and their potential unintended consequences — is crucial for foresight analysis and scenario planning efforts. Precision agriculture, climate-resilient genetic modification, animal disease monitoring, precision livestock feeding and health, agri-food product innovations, pest resistance improvements, and more, show promise. The adoption and use of innovative, privacy-respecting data architectures governed by ecosystem members would enable greater use of advanced data analytics, for example: proactive disease and pest management; validation and verification of best management practices to Canadians and global markets; benchmarking and optimization of key supply chain attributes; and adoption and advancements in robotics and automation designed for the Canadian environment to alleviate labour-related challenges and cost of production.

Global Change and Climate Change

- **New and emerging pandemics and panzootic diseases.** This requires expertise from fields such as epidemiology, virology, and animal and human health, as well as conceptual frameworks that make clearer the relationships between animal health, biodiversity, and human health. Such frameworks include One Health, Planetary Health, and Circular Health.

- **Intensifying climate and ecological impacts.** These twinned issues will not improve at scale in any foreseeable future, meaning that the multiple future societies that the Canadian agri-food system may face all involve many more existing and new risks.
    - ***Oceanic and terrestrial supply chain vulnerabilities.*** Oceanic wave (Banfield, 2016) and storm-related behaviour in a climate-changed world is changing significantly and will pose additional risks to shipping as most of the existing global shipping fleet is not designed for new, more turbulent oceanic conditions. So, too, with existing port infrastructures worldwide (Banfield, 2016). Additionally, terrestrial supply chains will experience new vulnerabilities as roads, highways, railways, bridges, ports, airports, and other infrastructure were designed for much less challenging environmental and climatic conditions. Simultaneously, labour-related issues, transport industry concentration, and social and political tensions remain flashpoints.
- **Transportation supply-chain mix.** Transportation supply chain challenges include: industry consolidation in rail transport; extreme weather and climate-related risks to road and highway infrastructure; trucking issues ranging from labour-related matters to animal welfare issues in transit amidst greater extreme heat or cold; electrification of trucking fleets; and streamlining of cross-border verifications of crop and livestock shipments. These issues raise questions about how Canada's next transportation supply chain mix might need to evolve to ensure supply chain continuity and reduce more frequent disruptions.

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