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Research

Codesigning a resilient food system

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ABSTRACT. Global changes, especially the progression of climate change, create a plethora of adaptation needs for social-ecological systems. With increasing uncertainty, more resilient food systems that are able to adapt and shape their operations in response to emerging challenges are required. Most of the research on this subject has been focused on developing countries; however, developed countries also face increasing environmental, economic, and social pressures. Because food systems are complex and involve multiple actors, using codesign might be the most productive way to develop desirable system characteristics. For this study, we engaged food system actors in a scenario-planning exercise to identify means of building more resilient food systems. In particular, the actors focused on determinants of adaptive capacity in developed countries, with Finland as a case study. The brainstorming session followed by a two-round Delphi study raised three main characteristics for effective food system resilience, namely, energy and nutrient sovereignty, transparency and dialogue in the food chain, and continuous innovativeness and evidence-based learning. In addition, policy interventions were found instrumental for supporting such food system resilience. The main actor-specific determinants of adaptive capacity identified included the farmers' utilization of agri-technology and expertise; energy and logistic efficiency of the input and processing industry; and for retail, communication to build consumer trust and environmental awareness, and effective use of information and communication technology. Of the food system actors, farmers and the processing industry were perceived to be the closest to reaching the limits of their adaptive capacities. The use of adaptive capacity as a proxy seemed to concretize food system resilience effectively. Our study suggests that the resilience approach generates new perspectives that can guide actors in developing food systems that are adaptive in uncertainty.

Key Words: *adaptive capacity; Delphi method; food system; participatory approach; resilience; uncertainty*

INTRODUCTION

Global environmental changes, population growth, and the need for increased but sustainable production of food, goods, services, and energy are shaping the way that social-ecological systems maintain and adapt their functions (Walker and Salt 2006). Food production and distribution systems are examples of human-driven dynamic systems that depend on the environment, ecosystems, and social institutions (Ericksen 2008*a*). Food is an essential part of our daily lives and food security, which refers to the availability, access to, and utilization of food, connects to our welfare. Food system actors, i.e., the farmers, processing, distribution, retail industries, and consumers, make choices that induce feedback on what kind of food is produced, processed, and made available, as well as how these components of the food chain are undertaken. The complex dynamics of food systems need to be observed and understood because they have an impact on both global environmental sustainability and food security (Ericksen 2008*b*). In light of global warming and limited natural resources, it is imperative to build resilient food systems that deliver food security.

Resilience relates to the ability of a system to maintain its structure and functions and reorganize in the face of disturbance (Holling 1973). Although it is based in ecology, the theoretical constructs of resilience are assistive in understanding the dynamics and functions of many types of social-ecological systems, which include food systems (e.g., Babu and Blom 2014, Darnhofer 2014). Some critics have noted resilience being used as popular policy jargon that has no clear conceptual meaning (Brand and Jax 2007). Darnhofer et al. (2010*a*) acknowledged that developing sets of indicators seems to be more useful than direct attempts to measure the resilience of complex systems, such as farms, industries, and agri-food systems. We suggest that identifying the determinants of adaptive capacity that actors can shape for their own use might be most helpful in building resilience in practice. Our approach follows this thought: to improve food system resilience, we attempted to gain recognition for key capacities of food system actors and the food system as a whole, to reveal how to enhance resilience in practice. Thus, we used adaptive capacity as a proxy for resilience, in terms of "coping with uncertainty in all ways" (Folke et al. 2010).

In developing countries, climate change and population growth have an impact on the food-energy-water security nexus directly. This has led to the development of resilience approaches that aim to recognize and support lacking capacities, such as social capital that allows actors to face challenges, adapt, and rebuild food systems for the improvement of their future food security (Pingali et al. 2005, Babu and Blom 2014, Wood et al. 2014). Contrastingly, in developed countries, the dominant challenge concerns the methods for supplying food in a stable and sustainable manner, while facilitating the promotion of global and local social and economic well-being. Resilience studies conducted to date in developed countries have mostly concentrated on managing uncertainty, unexpected changes, and disruptions, such as issues caused by food crises and climate change (Ericksen 2008*a*, Benton et al. 2012, Hodbod and Eakin 2015). Proactive preparation of resilient food systems that draw on the cooperative effort of actors acknowledging that understanding the functioning of each component is not adequate for explaining the functioning of the food system as a whole is a step toward concrete resilience building (Babu and Blom 2014, Tendall et al. 2015). An integrated view

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incorporates the analysis and design of supporting institutions and policies as well. However, to our knowledge, there is a dearth of studies that involve food system actors in the identification of the contribution they can make to food system resilience in developed countries. Our study gathered the views of actors on food system resilience from all main levels of the food system. Finland was selected as a case study because it represents a typical open and globally integrated food system. Because it is also one of the most northern countries that practices agriculture and is dependent on global trade, Finland faces both rapidly advancing climate change and strong volatility in the markets.

Comprehensively including actors and processing information in an iterative manner can assist in dealing with complicated multiactor issues, such as food system development. For example, scenario-based modeling of food security under climate change has been supported by involving relevant actors (Vervoort et al. 2014). Multiactor dialogue is beneficial for recognizing potential synergies and avoiding trade-offs or the amplification of risks (Tendall et al. 2015). It might also be easier to collectively recognize indications of reaching the limits of the ability to adapt in a food system, and factors that may attract or distance system collapse (Dow et al. 2013). In addition, participatory platforms can create equity-supporting, cost-effective, and innovative ways of system transformations (Walker et al. 2002, Aldunce et al. 2015). Thus, by engaging actors within an iterative process of codesigning a more resilient food system, the dynamics within the entire food system become more visible to all actors. Optimally, the expertise of all actors is utilized to benefit the whole food system. Our study exemplifies the creation of such a platform for codesigning a resilient food system.

The aim of this study was to identify key determinants of adaptive capacity for food system actors and for the food system as a whole. The study utilized the operating environment of industrial European countries, by drawing on Finland as a case study. Contrasting future scenarios, which mirrored the high uncertainty presented by potential changes, were used to allow actors to envision the determinants of adaptive capacity that improve resilience in all these situations. In addition, we investigated the opinions of actors regarding the often-mentioned determinant of adaptive capacity, i.e., diversity, for resilience (Norberg et al. 2008, Lin 2011, Kahiluoto et al. 2014, Hodbod and Eakin 2015), and the limits to adaptation that determine the need for transformation of the system (Dow et al. 2013). A resilient food system was defined as a system that is able to persist, adapt, and transform under conditions of uncertainty (Folke et al. 2010).

METHODS

The study approach consisted of three steps (Table 1). The first step operationalized the concepts of adaptive capacity and resilience in food systems during a brainstorming workshop, which included food system actors as participants, to aid planning for the next two steps of the research process. The second step examined the determinants of adaptive capacity of the actors and the entire food system, and the third step linked these characteristics to practical means required for enhancing food system resilience.

Finland's food system is representative of the systems found in other European industrial countries and the United States in terms of the consolidation of the food and retail industries. The two leading retailers had shares of 46% and 33% of total national Finnish retail sales in 2014 (Niemi and Ahlstedt 2015). Finland represents the Common Agricultural Policy (CAP) of the European Union (EU) countries in terms of regulation of primary production. Primary agricultural production has undergone rapid farm consolidation, from there being 95,000 farms with an average cropping area of ca. 23 hectares in 1994 to 56,000 farms with ca. 41 hectares in 2014 (Niemi and Ahlstedt 2015). Finnish farms are smaller than those in main agricultural EU member countries but larger than those in many of the new member states, such as Poland (Eurostat 2015). The agrochemical input industry mostly comprises of transnational actors. Large amounts of protein fodder and its raw material is imported, constituting a 42% share of inputs used for producing animal feed (Knuuttila and Vatanen 2015). The two main processing industries in Finland are milk production and meat product processing. The raw materials for Finnish food manufacturers are mostly domestic in origin, with a 22% import share found in milk product processing as well as in bakery products, and 21% in meat processing (Knuuttila and Vatanen 2015).

The Delphi method, which is widely used in futures studies, was selected to be used in the study to allow various actors' views to be shared and for feedback to be given, which could lead to the enrichment of the actors' perspectives. Linstone and Turoff (1975) characterized Delphi as a method for structuring a group communication process that is effective in allowing a group of individuals as a whole to address a complex problem. Two irreducible elements of the Delphi technique are: (1) anonymity and (2) feedback and iterative rounds. The Delphi technique has been used in studies of policy-related research questions (Rikkonen and Tapio 2009, Frewer et al. 2011, Tapio et al. 2011). These are often multifaceted, create divergence in opinions on the best means to solve a problem, and suggest multiple alternative or integrated solutions. Current applications of Delphi utilize online tools to maximize a range of expert opinions and generate knowledge and insights efficiently (Steinert 2009, Varho et al. 2016). Consequently, the Delphi technique is well suited for studying the resilience of food systems, because during the process, one can easily engage multiple actors, familiar with and possessing varying interests on food system dynamics, in dialogue.

We included actors from all levels of the food system, from primary production to the input and processing industry, retail, and consumption, as well as support systems, such as research, governance, and policy making, as the target group of our study. A food system was defined as food supply and demand, including all the supporting networks.

Step 1: Brainstorming workshop to unpack meaning of resilience and set the stage for the study

A brainstorming workshop (Step 1 in Table 1), which assisted in the design of the following Delphi process, took place for three hours on 29 August 2011. The research team identified persons who possessed exceptionally wide knowledge and acted in key positions in the Finnish food system (farming, processing, retail, consumers, and global food security perspectives included). Of the 12 people invited to participate, 7 ultimately attended the brainstorming session. The group consisted of representatives from the Finnish farmers' union, a member of a retail union, two

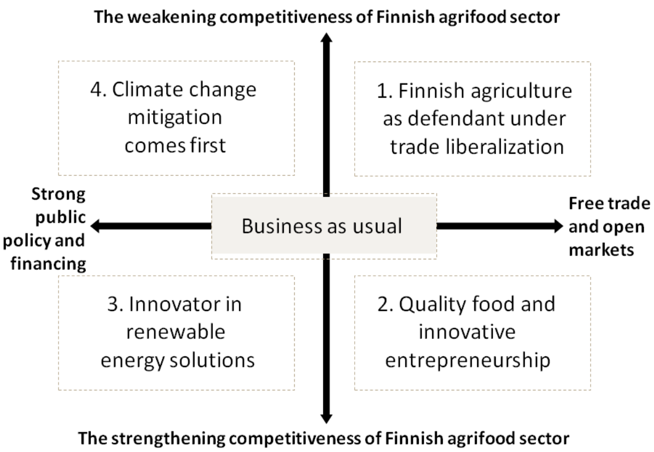
Table 1. Outline of the study.

Main objective	Data collection method	Analysis of data	Outcomes
Step 1: Testing the concepts of adaptive capacity and resilience as perceived by actors: relating theory to practice	Brainstorming workshop for invited food-system actors with two "what if" cases and three contrasting future scenarios presented	Qualitative content analysis of lists written by the actors and transcription of conversations	Knowledge on how actors perceive the concepts of adaptive capacity and resilience, used as background information for the Delphi process
	Brainstorm participants individually listing and discussing together: what determines the adaptive capacity of the actors and of the food system in such situations? Who should act and how, to enhance resilience?	As above.	Listing of the determinants of adaptive capacity actor-wise and for the whole food system, and means for enhancing food-system resilience, used as input for steps 2 and 3
Step 2: Seeking the determinants of adaptive capacity in food systems	Delphi questionnaire, round 1: Evaluation of brainstorm-originating determinants of adaptive capacity	Quantitative ranking of the listed determinants of adaptive capacity actor-wise and for the whole food system	Ordinal listing of the most important determinants of adaptive capacity actor-wise and for the whole food system
	Delphi questionnaire, round 2: Reevaluation of the ranking of adaptive capacity determinants	Qualitative analysis on the feedback	Main determinants for the adaptive capacity of food-system actors
	Delphi questionnaire, round 1: Identification of the determinants of adaptive capacity of the food system under different scenarios (Niemi and Rikkonen 2010)	Qualitative analysis on the adaptations and determinants	Characterization of the scenario-specific adaptation strategies
	Delphi questionnaire, round 1: Open-ended questions on the role of diversity for adaptive capacity and the limits of adaptive capacity	Qualitative analysis of actors' views on the role of diversity and the limits of actor adaptive capacity	Arguments on the role of diversity and the limits of actor adaptive capacity, used as input for step 3
Step 3: Linking food system adaptive capacity and means for enhancing resilience	Delphi questionnaire, round 1: Identification of the determinants of adaptive capacity of the food system irrespective of the scenarios (under a turbulent and hard-to-predict future)	Qualitative analysis of the determinants	Thematization of system-wide characteristics of a resilient food system: eight themes
	Delphi questionnaire, round 2: Evaluation of Delphi round 1 arguments on the role of the eight themes for determining food-system resilience	Quantitative assessment on the unity of opinions and importance of the characteristics for food-system resilience	Thematization of system-wide characteristics of a resilient food system: three main themes
	Delphi questionnaire, round 2: Evaluation of the role of diversity for resilience of food systems and the limits of actor adaptive capacity	Quantitative assessment on the unity of opinions	Outline of the role of diversity for resilience and recognized limits of actor adaptive capacity
	Delphi questionnaire, round 2: Evaluation of the means for enhancing resilience	Ranking of the means for enhancing resilience and listing of new suggestions	A codesigned plan to support resilience

business representatives who held core positions within industry and retail, and three participants with agro-ecological and socioeconomic scientific expertise about food systems.

The workshop was organized under the title of "Food and resilience: what would help food system maintain function in a turbulent future?" The researcher facilitating the workshop presented the concept and theory behind building resilience and how adaptive capacity, being easier to operationalize than resilience, is used as a proxy for resilience. Two "what-if" cases of unexpected, abrupt events (a shock either on the supply or the demand side of the food chain) were then presented as follows: (1) how would we respond if energy prices increased 10-fold, and (2) how would we respond if Finland suddenly received 500,000 immigrants from an area struck by catastrophe. The situations helped to illustrate the challenge of the unpredicted from the viewpoints of different actors. The second part of the workshop utilized an earlier foresight study conducted by Niemi and Rikkonen (2010) for contrasting scenarios, to widen the perspective of the actors on alternative driving forces that could plausibly create uncertainty in food systems. In these scenarios, two key dimensions were varied, namely, (1) the strength of public policy versus market orientation, and (2) the competitiveness of the Finnish agri-food system (Fig. 1). Climate change and the scarcity of fossil fuels were described as decisive driving forces. Three scenarios (1, 2, and scenarios 3 and 4 combined) were presented by the facilitator. Key determinants of the adaptive capacity of actors and the entire food system were listed, by each participant, first in the what-if cases, second in each scenario, and third as an unknown future consideration, irrespective of the scenarios, and then jointly discussed in the workshop. Lastly, the means for supporting food system resilience, namely, who should act and how, were discussed. The lists of determinants written by participants and transcribed conversations were used in designing the Delphi process.

Fig. 1. The alternative scenarios introduced to the Delphi panelists (based on Niemi and Rikkonen 2010).

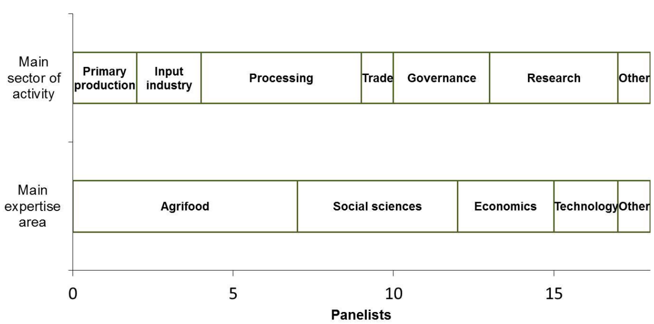


Step 2: Recognizing determinants of adaptive capacity

The actors' expert panel

Two rounds of the Delphi process were performed via the Internet using Webropol 1.0 software (Webropol Oy 2002) in December 2011. In the first Delphi round, 76 representatives of the Finnish food system (including participants of the brainstorming session) were invited to take part in the panel via e-mail. The aim was to comprehensively and inclusively reach all the sectors that actors operated in and important areas of expertise. The resulting panel consisted of 18 people (representing a 24% response rate), as shown in Figure 2. Twelve of the panelists were male and six were female. The second round questionnaire was sent to the first round panelists, of which eight people responded (42%).

Fig. 2. Main sectors of activity and expertise areas of the Delphi panelists (n = 18).



In the first round of the Delphi, the suggestions collected during the brainstorming session for the determinants of adaptive capacity for primary production, input industry, processing industry, and for the retail sector, as well as for the food system as a whole, were ranked for importance, with the opportunity offered to rationalize the opinions (the full lists are shown in Appendix 1 Table A1.1). The average importance values were calculated for each determinant, and 10 actor-specific and food system-wide determinants of adaptive capacity with highest means were reevaluated in the second round of the Delphi. The panelists were able to comment on any need for reorganization or supplementation of the listings.

In the first Delphi round, open-ended questions were used to characterize food systems, which would be able to function well in the four contrasting scenarios in Niemi and Rikkonen (2010), with the "business as usual" scenario omitted (Table 2). Scenario-specific adaptations were listed. Open-ended questions were also used for gathering the panelists' perspectives on the role of diversity for the adaptive capacity of food systems. Diversity has been suggested as one major influence of adaptive capacity and resilience for farming (Lin 2011), food systems (Hodbod and Eakin 2015), adaptive networks in social-ecological systems (Norberg et al. 2008), and general resilience (Carpenter et al. 2012). Therefore, we asked panelists about (1) the positive and negative aspects of diversity at different levels and operations within the food system, (2) the level at which diversity has the largest and smallest roles (if any role at all), (3) what type of diversity is the most meaningful when thinking of adaptive capacity, and (4) the impacts of concentration and effective coordination versus diversification and the specific actions that these are important for in food systems. Because the connection between diversity and resilience builds on earlier literature, this part of the study followed a more theory-based approach. Opinions with the highest consensus, as well as those with the greatest divergence from the consensus, were reevaluated in the second Delphi round.

The first round questionnaire also aimed to investigate what changes would have the potential to induce exceeding the adaptive capacity of the food system and would therefore force the whole food system to transform. Finally, panelists were able to give their opinions on which actor levels within the Finnish food system are nearest to reaching the limits of their adaptive capacity and why. These were reevaluated in the second Delphi round.

Step 3: Means for enhancing resilience

In the first round of the Delphi questionnaire, an open-ended question was used to characterize food systems that would be able to continue functioning well when faced with a turbulent and unpredictable future, irrespective of the scenarios listed in the earlier questions. The characteristics suggested by respondents were analyzed using qualitative content analysis, by examining all the data, cutting and sorting arguments related to a shared theme, and labeled as the main theme with potential subthemes presented in the arguments. Eight main themes, which were identified as being important for the resilience of food systems, were then reassessed in the second round of the Delphi by including the arguments with the greatest consensus or divergence in opinions among the panel members in these themes. The responses were quantified for opinion consensus and on their relative importance for resilience. Finally, three main themes, which showed the greatest convergence of opinions within the panel and were considered as important for food system resilience on the basis of both Delphi rounds, were identified. The suggestions that had originated in the brainstorming session and the first round of the Delphi on the means to support the resilience of the food system were also quantitatively assessed for their usefulness in the second round of the Delphi, along with an opportunity being offered to suggest additional alternatives.

Table 2. Delphi panel views on potential adaptations of food systems to various future scenarios in Finland (Niemi and Rikkonen 2010), and the actors and actions having a key role in each scenario.

Scenario	1: Finnish agriculture as defendant under trade liberalization	2: Quality food and innovative entrepreneurship	3: Innovator in renewable energy solutions	4: Climate change mitigation comes first
Description	The liberalization of agricultural products, centralization increases, markets the decisive driver for action	Decentralized local learning based development, multisectoral entrepreneurship, local food a marketing asset	Renewables and energy innovations strengthen agriculture, consumers value eco-efficiency	Mitigation and adaptation to climate change a priority in society solutions sought from nuclear energy
Key adaptations envisioned	Polarizing food systems: enlarging units and niche production combined Economy of scale, e.g., cooperation Large and efficient farms Specialization for niche markets Local food systems Innovative domestic food products When no imported protein feed, animal production reduced Food sovereignty of households	Shorter production chains Transparency increases High-value food Strict quality regulations Local food efficiently produced, marketed, and distributed Logistical challenges Innovative marketing channels Novel local cooperations Information and communication technology connects producers and consumers Food price increase Direct sales Novel small enterprises in all food-system levels	Bio-economy via research and added value Renewable energy sources: wind, solar, bioenergy Less dependency on imported energy Energy production becomes integral part of farming Countryside as carbon sink Less food waste Nutrient cycling across food system Environmental footprints emphasized Payments for ecosystem services Research-based food systems Export of water-intensive milk and meat products	Regulated cropping and seasonal diets. Climate change increases production and risks Carbon-neutral food systems Large, energy-sovereign units Field cropping replaces animal husbandry Permanent field crops cover the soil year round Agricultural area remains stable Effective logistics Shorter transport distances Strict policy regulations
Key actors and actions	Research and product development is central Import secures the processing industry Retail supports domestic agriculture and processing Policies and regulations ensure competitiveness	Farmers need to learn and innovate Transition from large-scale processing to local processing Transition from hypermarkets to local groceries More consumer communication Communal decision makers support local food	More research focus on developing bio-economy Novel business opportunities via networks around biomaterials	Primary production affected foremost Retail aims to minimize food transport

Statistical analysis

As outlined in Table 1, both qualitative content analysis and basic quantitative analyses (rating of importance) were used to describe the data. Mean values and standard deviations were calculated using IBM SPSS Statistics for Windows 20.0 (IBM Corporation 2011).

RESULTS

Making sense of resilience

Global changes and the resilience of food systems

Global population growth and developing countries' increasing purchasing power were identified by participants of the brainstorming session as potential external key drivers that could affect developed countries' food systems in the future. When food shortages appear, prices change and volatility occurs, which in turn could lead to local political crises and security issues. Economic and natural resource reserves, as well as stable institutional structures, were found to be assets in dealing with unexpected sudden events or conditions for Finland because it is vulnerable given the distant northern location of the nation and its dependence on overseas imports. In a global crisis, local agricultural production and management of logistics were considered imperative, and global trade and trust can also counteract the negative impacts of such crises. It was suggested that the worst conditions would stem from total international isolation. In this case, the national sovereignty of protein crops, nutrient cycling, and the availability of energy were raised as the most important considerations for food system functioning.

The participants of the brainstorming session discussed how all food system actors influence the functioning of the system in crisis situations, and it is difficult to predict which actors play the largest role in each crisis. Both the challenges for preserving food system operations and the ability to take on novel opportunities in response to unexpected events were discussed by the group, and rapid adaptations and agility to changing direction (if required) were noted as being key for building resilience in times of uncertainty.

Food system actors meet changes differently

In the brainstorming session, the what-if case on energy prices increasing 10-fold was perceived to impact food systems both bottom-up and top-down: the farmers and the consumers were recognized as key actors. Owning and selling energy would create a major opportunity for farming, contrary to the options for other food system actors. Biomass in all forms and agricultural land were perceived to increase in value. Renewable energy from domestic sources and energy sovereignty of farmers (for example, seen in the use of biogas or combined heat and power production) were recognized for bringing about adaptive advantages. The use of energy-intensive fertilizers would drop, and closed cycles of nutrients would increase. The rising production costs should lead to increased producer prices for the farm; if not, only innovative, energy-efficient production (crop production that is less affected than energy-intensive animal husbandry), and farms with large capital would survive and be able to compete with imported food. Another key actor is the consumer who decides whether to buy based on the origin or price. The consumer also influences how the product selection and distribution channels would be maintained or transformed (e.g., if energy-consuming cooling can be replaced by dried products, or if market selection was to be transformed toward the most energy-efficiently produced products). Other living costs were considered likely to be reduced before food would be, but diets might also shift toward the most economical options.

The second what-if situation (large-scale immigration to Finland) was found to mostly have an impact on the retail and processing industries that have regional or global operations. Adaptations included widened selections of food through imports or an increase in groceries with affordable prices. The retail industry would meet an increase in the demand for food, as well as have better access to a working force offered by the immigrants in a situation with a shortage on available workforce. The processing industry would also be able to adapt by developing novel products for the increasing and changed markets. The availability of raw materials and production capacity were not perceived to be bottlenecks because there is currently a surplus of capacity in this regard. As more food would be consumed in Finland, import and export relations would change, and all food system actors might be affected by this. Participants of the brainstorming session discussed how producers and consumers are mostly locally bound actors, whereas processing and retail industries are more closely linked to regional or global operations, and thus their adaptation dynamics would follow different routes and emphasize differential adaptive capacities.

Determinants of the adaptive capacity of food system actors in the context of uncertainty

The views of the Delphi panel on adaptations needed in food systems in the four alternative scenarios ranged from economies of scale to building systems based on quality food, and from renewable energy to being carbon neutral (Table 2). The actors in key roles varied from food system actors to stakeholders, such as policymakers and researchers. Although interesting for describing the differential adaptation strategies, these scenario-specific adaptations served in our study to help recognize adaptive capacity indicators more generally, as important in times of uncertainty, irrespective of the scenario and changes. Proceeding from envisioning adaptations to various scenarios, to considering general adaptive capacity irrespective of the scenario, the concept of resilience also became more concrete and enhanced the views of the actors in terms of the importance of a systems approach.

The determinants of adaptive capacity recognized as central to managing uncertainty, included numerous biophysical, economic, and social characteristics (top 10 in Fig. 3, with full list available in Appendix 1 Table A1). For primary production, advanced agri-technology, good expertise in main production line, soil quality, and economic profitability were found most important in the first Delphi round ranking. The second round feedback further emphasized knowledge, soil as a resource, and energy efficiency. For the production input industry, efficiency in energy use and logistics, environmental awareness, and cooperation with research were ranked as being most important. The second round feedback expanded these factors to include the quality of production inputs and emphasized more dialogue with other food system actors. The processing industry was considered to be the most reliant on product development skills, energy and logistical efficiency, and communication to build consumer trust. In this case, the second round feedback raised market research and future foresight, quality of products, and dialogue with other food system actors as being additionally important. The retail sector was perceived to build adaptive capacity based on consumer communication, environmental awareness, information and communication technology, and market research and foresight, with the feedback further emphasizing flexibility in supply channels and dialogue with other food system actors. Regarding food system-wide adaptive capacity, dialogue with consumers, agri-food research, and transparency were found to be important, with the feedback extending this list to include dialogue within the food system, legitimate and transparent policy, and high share of domestic production. Overall, the determinants were found to be difficult to rank for their comparative importance and thus, the determinants that were identified were perceived to describe jointly (rather than individually) important adaptive capacity building factors.

Characteristics of a resilient food system

As envisioned by the panel, a food system that is well prepared for an uncertain future had the following characteristics: diversity and flexibility; equality and open discussion; preparedness and agility; consumer acknowledgement; sustainability, and nutrient and energy sovereignty; locally based actions; skills and continuous learning; and profitability (as shown in Table 3). Taking into account both Delphi rounds, the following three themes were found to be the most important to develop in an effort to increase the resilience of the food system: (1) energy and nutrient sovereignty via the use of domestic, renewable energy sources, such as biogas, the recycling of nutrients, and energy efficiency; (2) transparency, dialogue, and equity in the food chain; and (3) innovativeness and learning, utilizing technology, developing expertise, and research-based know-how.

Means to enhance food system resilience

Although the ability to recognize the main determinants of adaptive capacity is important, the knowledge itself does not yet yield system change, nor does this recognition drive actor adaptations. Policy interventions to support energy and nutrient sovereignty and eco-taxation, as well as strengthened agricultural

Table 3. Thematic analysis of the main characteristics of a resilient food system for Finland, based on answers given by the Delphi panelists (n = 12-18). The mean values (on a scale from total disagreement (1) to total agreement with the argument (5)) show the degree of convergence of opinions regarding representative and selected arguments raised by the panelists in Delphi round 1, which were reassessed in round 2. The characteristics are not exclusive of each other, but rather provide multiple approaches to enhancing resilience.

Characteristics of a resilient food system and arguments raised by panelists	Mean
1: Diversity, modularity, and flexibility	
"A resilient food system has multiple different-sized actors in joint interactions"	4.38
"A multiscale production system with local, regional, national, and international producers."	
"Diversity is a central feature for flexibility; lack of diversity is a serious threat."	3.75
"Diverse is important in the sense that when one direction fails, another one will work."	
"Retail needs to have diverse suppliers."	3.88
"Diversity is most important for primary production; it secures yields."	3.75
"Pluriactivity is an advantage."	3.63
2: Equal, responsible, open, discussing, takes system-wide benefit into consideration	
"Food systems should be open and transparent so that actors' roles, meanings, and revenue logics are open to other actors and consumers."	4.63
"Discussing so that needs and wishes by all actors become heard."	
"Communication and appreciation within food-system actors improves flexibility."	4.13
"Good internal relations and communication within the food system improve adaptive capacity."	
"Actors should acknowledge their own role in the system and support its functioning taking into account societal total benefit."	3.50
"The actors should take responsibility so that money is not the sole criterion."	
3: Preparing, plans ahead, perseverant, supported by proactive policy actions, able to observe changes, and react quickly	
"Long-term planning brings stability to survive sudden changes."	4.50
"One should be able to recognize and avoid large risks beforehand."	
"Adaptation requires being a forerunner and innovative."	4.25
"Governmental support on research and development should be based on a long-term vision."	4.13
"National view on food system and its future, supported by coherent policy actions would improve system functioning."	
"High level of national emergency supply benefits adaptation."	4.00
"One should react to changes as rapidly as possible to maintain competitiveness and take benefit of opportunities."	3.75
"Food system should observe silent signals and react in time to changes in demand and the operational environment."	3.25
"One should take into account the possibility for transformation prior to investing; one cannot rely on the same operations to succeed over decades."	
4: Acknowledging consumers	
"Traceability is important for food systems."	4.63
"Constant enlightenment of consumers on strengths and knowledge that the actors have in our food system."	4.25
"Acknowledging consumer actions guiding the operations."	
"Development of specialized niche production for national and international markets."	3.88
"People should maintain contact with food production."	
5: Sustainable, nutrient, and energy sovereign	
"Everything possible has to be made in regard to saving energy."	4.38
"Nutrient cycling nearly closed in food systems. Only the nutrients in food would leave the cycle."	3.88
"Food systems should be more or totally independent on fossil and foreign energy sources."	3.75
"Low carbon, nutrient, and water footprints."	
"Minimizing negative environmental impacts."	
"Food should be produced with low inputs, such as in organic production."	
6: Local- and domestic-based actions	
"Retail should prioritize domestic production when possible."	4.38
"Degree of domestic origin high, close to 80%."	
"Locality of food production is an asset in sudden crisis situations."	4.25
"Loyal customers using local products provide more stability under difficult times."	
7: Skilled, technology-based, continuous learning and development, innovative	
"Food system should be transnational, to the degree that international innovations and developments are known and learned from."	4.50
"More professional farming, increasing knowledge of farmers, and effective advisory services are important for adaptive capacity."	4.38
"High-quality knowledge creates the ability to transform challenges into opportunities."	
"Technological know-how and innovative research improve adaptive capacity."	4.25
"One needs ability to use most novel technologies without prejudices."	
"Innovative for collaborations, logistics solutions, sales, and marketing means."	
8: Profitable	
"Business know-how improves adaptation."	4.50
"One should save in good times to be able to balance in bad times."	4.25
"Competition should function at all levels of food systems."	4.00
"When profitability throughout the food system is good, adaptive capacity is good as adaptation needs investments in all actor levels."	3.88

Fig. 3. Determinants of adaptive capacity ranked as most significant for primary production (farm), the input industry, the food-processing industry, the retail, and the whole food system, according to the Delphi panel. A list of potential determinants to rank for significance was presented to the panel based on the brainstorming conversations. The scale was from 1 (no significance) to 5 (very high significance). ICT refers to information and communication technology. n = 11-18.

Primary production	Mean
1. Advanced agritechnology	4.64
2. Expertise in the main production line	4.57
3. Soil quality	4.47
4. Current profitability	4.40
5. Longevity and trust in client relations	4.38
6. Energy efficiency	4.35
7. Surveillance of profitability in the long run	4.33
8. Level of education and knowledge	4.33
9. Quality of production: animal material, crop yield, etc.	4.25
10. Exploitation of ICT	4.21

Input industry	Mean
1. Energy efficiency	4.57
2. Efficiency of logistics	4.31
3. Environmental awareness in processes	4.29
4. Cooperation with research	4.15
5. Longevity and trust in client relations	4.08
6. Market research and future foresight	4.08
7. Public image and societal responsibility	3.93
8. Willingness and capability for risk taking	3.93
9. Current profitability	3.92
10. Dialogue with other food system actors	3.77

Food system	Mean
1. Dialogue of food system actors and consumers	4.50
2. Quality of food research	4.41
3. Quality of agricultural research	4.35
4. Transparency of the food system	4.33
5. Exploitation of ICT	4.28
6. Legitimacy and transparency of policy	4.22
7. Infrastructure	4.17
8. Dialogue among food system actors	4.17
9. Share of domestic production	4.11
10. Communication within each actor level	4.06

Processing industry	Mean
1. Skills in research and product development	4.60
2. Efficiency of logistics	4.50
3. Energy efficiency	4.50
4. Communication to build consumer trust	4.50
5. Market research and future foresight	4.47
6. Environmental awareness in processes	4.47
7. Cooperation with research	4.40
8. Willingness and capability for risk taking	4.20
9. Current profitability	4.13
10. Dialogue with other food system actors	4.07

Retail	Mean
1. Communication to consumers	4.47
2. Environmental awareness in processes	4.47
3. Exploitation of ICT	4.47
4. Market research and future foresight	4.33
5. Flexibility in supply channels	4.20
6. Dialogue with other food system actors	4.13
7. Share of locally produced food from sales	4.00
8. International cooperation	4.00
9. Willingness and capability for risk taking	4.00
10. Current profitability	3.93

and food research were ranked as the most useful means for enhancing food system resilience (Table 4). Additional means suggested by the panelists included improvements in the foresight abilities of actors and access to information; food system-wide communication toward common goals; the reduction of food waste; local food-based diets; taxation of animal products; the monitoring of system-wide bottlenecks and public actions to solve these issues undertaken by the authorities; and policy coherence for effective food system coordination.

Diversity in building resilience

Regarding the role of diversity in supporting resilience, the panelists mostly found there to be a positive effect from diversification in terms of the safeguarding and flexibility of food system operations. A lack of diversity was considered to be a threat to the resilience of food systems because diversity was perceived as being important for securing the system against many types of risks and ensuring agility in reacting to varying needs and opportunities. However, the positions of the respondents varied, and according to some, diversity should not be perceived as an overwhelmingly positive characteristic. In certain operations, the importance of efficiency was considered to

Table 4. Delphi panel views on the usefulness of different means, suggested in the brainstorming session and by Delphi round 1 participants, for supporting food-system resilience in Finland. The mean values and standard deviations are based on Delphi round 2 rankings on a scale from 1 (total disagreement) to 5 (total agreement) by the panelists on the usefulness of the means. n = 7-8.

Means	Mean rating	SD of rating
Policies for energy and nutrient self-sufficiency, eco-taxation	3.88	0.99
Investment support for technology and infrastructure	3.43	1.13
Strengthening agricultural research	3.38	1.19
Strengthening food research	3.29	0.76
Policies for enhancing the equity and profitability of all food-system actors	3.00	1.07
Policies allowing free competition	3.00	1.07
Supporting the formation of actor-led associations	2.63	1.41

override diversity, and the assumption of a trade-off between diversity and efficiency was expressed. For instance, diversity might hinder the optimization of transportation logistics. The usefulness of diversity in agricultural production, product selection, and supplier contacts by retail were agreed upon by the panel, whereas the benefit of diversity for the processing industry in terms of suppliers of raw materials or one actor, such as a farm alone pursuing multiple activities, generated diverging opinions.

Views were raised regarding the different positioning of farm production lines in terms of the importance of diversity because it is easier to diversify crop production actions for increased resilience, but the farm management of capital- and work-intensive animal production are less easily buffered with more diverse farm actions. Although, at a regional level, there might be possibilities and advantages that are gained from diversification. Diversity in input providers at every actor level and the importance of modularity for the food system in terms of multiple and different-sized actors interacting to build food system-wide resilience were emphasized. In particular, it was suggested that there was a greater need for more modularity in trade. Diversity was not considered to undermine the importance of coordination. Rather the opposite was found to be true: more diverse food systems also benefit from the planning of operations and of the safeguarding structures. However, according to the respondents, coordination should allow all actors to equally find their space in the system, support efficiency at all actor levels, and acknowledge that markets constantly shape food system dynamics.

Limits to the adaptive capacity of a food system: identifying and distancing them

The panel found that the current low profitability of farming has driven farmers and the processing industry, which depends on domestic raw material, closest to the limits of their adaptive capacity. In contrast, retail was considered to be the safest of the actors, mostly because of good profitability, current overproduction leading to a strong position in pricing negotiations, and well-developed transnational contacts that provide imported products. Potential situations that could lead to a large-scale collapse or major transformation of the food system were envisioned to be related to the availability and pricing of energy as well as nutrient and protein inputs for agriculture, the continuance of negative profitability development of farms, and sudden catastrophes, such as a nuclear deposit, extreme weather, or an animal disease epidemic. On the other hand, the infrastructure, economic assets, human capital, and natural resources in Finland were considered to secure many food system actors and operations and to act as a buffer for the whole food system in facing many types of changes.

DISCUSSION

Knowledge, system understanding, and foresight can contribute to the capacity of people to manage the resilience of various social-ecological systems. We utilized the concepts of adaptive capacity and resilience in a future envisioning exercise. Finnish food system actors were engaged in the process of codesigning a food system that could be resilient within the context of uncertainty present in the European climate, market, and policy environment. Food system resilience was linked to the ability to maintain both national food security and to manage food system operations sustainably in the face of global challenges. As evidenced by our findings, pursuing resilience via a systems approach adds value to adaptation planning and is of interest to food system actors. Food systems are networks of complex material, economic, social, and institutional interactions, which yield multilevel actor dynamics and encompass various actor goals. Thus, the use of the practice-oriented concept of adaptive capacity that actors are able to shape themselves may help build resilience in such multilevel networks. Considering food systems under variable future scenarios further aided to identify key capacities and practical means of developing resilience.

Adaptive capacity of food system actors

The recognized biophysical, social, and economic determinants of actor-wise adaptive capacity mirrored both the main operations and the position of the actor in the food system. The environmental awareness in processes, and market research and foresight, seemed to be important for most actors. Finnish farms' adaptive capacity was characterized by independence regarding resources and availability of technology and expertise, whereas end-of-the chain actors seemed to rely more on communication and social capital for building adaptive capacity. Similarly, Darnhofer (2014) identified resourcefulness, the reallocation of resources, flexibility, and continuity as factors having an impact on farm resilience. The resources available and the personal ability to make use of them under changing socioeconomic conditions determine how adaptive capacity is realized by farmers (Fleming et al. 2015). The resourcefulness can be gained either through a self-controlled resource base or through connectedness to shared resources via social capital (Darnhofer 2014). Thus, the adaptive capacity of farms relies on a combination of social and material resources. Farmers are usually site-bound actors and balance between short-term efficiency and long-term adaptability. This can lead to certain limits being placed on adaptation capacity and trade-offs, because investments in specialized technology and competences might encompass later adaptations if assets are not easily liquidated, for example (Darnhofer et al. 2010*b*).

The product development skills and consumer trust were raised as being important for adaptive capacity in the processing and retail industries, and this reflects how consumers, at the end of the chain, guide many of the actions related to food processing and distribution. There is also competitive pressure created by retail on products from domestic processors and imports, which shapes the markets (Niemi and Ahlstedt 2015). Retail builds on consumer communication, technology, and flexibility, and this connects to their position as a regulator of product availability, as well as at the food chain to the consumer interface.

System-wide assessment allowed for the recognition of how research and policy actors may play a major role in supporting resilience building of national food systems, in addition to the practitioners themselves. The importance of dialogue and transparency, as well as the physical infrastructure supporting the adaptive capacity of the food system, was recognized through this study. Concrete, resource-based determinants of adaptive capacity, which allow actors to take action, were identified within all actor levels. Thus, the use of adaptive capacity as a proxy seemed to concretize food system resilience effectively.

Resilience of food systems

Making sense of resilience by food system actors

Food system resilience is a multifaceted concept that contains the potential to be assistive in the face of climate and other global changes, but actor awareness and employment of resilience approaches in practice are still in their infancy (Tendall et al. 2015). In our Delphi process, the actors realized how considering resilience might offer added value under the conditions of global volatility relative to conventional streamlining of food systems for economic profit and efficiency (Thompson and Scoones 2009). The current turbulent operating environment of food systems, which will likely only worsen in years to come, pursues constant learning and adaptations as manifestations of adaptive capacity (Smit and Wandel 2006). This was also reflected in the actors learning, during the study process, to make sense of and discuss both actor-specific and the general resilience of food systems, although most of the actors were not familiar with the concepts or how they had been utilized in research. Thus, such processes may themselves critically contribute to the adaptive capacity of national food systems.

The importance of the multiple ways that each actor shapes, while adapting, the adaptive capacity of the national food system was revealed by the identified system-wide determinants, following the collection of different actors' views via a multiround study process. Resilience thinking thus seemed to provide a conceptual lens, which was new to the actors, and brought added value to understanding the development needs of the food system, from the viewpoints of multiple actors.

What defines food system resilience?

In general, the eight main characteristics for food system resilience identified by the research, fit well with the indicators for adaptive capacity and resilience requirements identified by earlier work (e.g., Casti and Ilmola 2012, Babu and Blom 2014, Tendall et al. 2015). These include biophysical resources, such as infrastructure and technology (Brooks et al. 2005, Smit and Wandel 2006), resource-use efficiency (Lipper et al. 2014), taking into account the sustainable use of natural resources (Cabell and Oelofse 2012, Dearing et al. 2014), and reasonable profitability (Cabell and Oelofse 2012). Social networks (Wood et al. 2014), dialogue, transparency and trust (Carpenter et al. 2012, Casti and Ilmola 2012), and supporting policy (Darnhofer 2014) have also often been found to support resilience. Human capital has been identified as being important for resilience, for example, via the use of research-based knowledge combined with grassroots practical experiences and farm advisors' knowledge (Williams et al. 2015), the capability for actor foresight and adaptation planning (Vervoort et al. 2014), and the building of human capital through shared learning (Cabell and Oelofse 2012). Characteristics less emphasized by earlier studies, which were identified as being important in our case study, were better acknowledgement of the role of the consumer and the importance of strengthening domestic and locally based actions.

Resilience determinant 1: energy and nutrient sovereignty and energy efficiency improved

The sustainability goal of food systems was raised by actors through the views shared on increasing energy and nutrient sovereignty, nutrient cycling, the use of renewable energy, and energy efficiency. Energy is vital for numerous food system operations, in terms of both supply and cost (DEFRA 2009). Thus, investing in energy efficiency and renewable energy can be perceived as adaptations toward sustainability and resilience in the long term. Energy efficiency also emerged as a key determinant of adaptive capacity for several food system actors, which serves as evidence of the major impact it has throughout the system. Finland's northern location, resembling the situation of other northern countries and island locations, such as the UK, and long transport distances further emphasize this aspect. Energy and food security, and the need for sufficient sovereignty and storage capital need to be proactively considered (DEFRA 2009). In addition, diversity in supply sources and supply reliability are important for safeguarding the functioning of the food system. In terms of the role of nutrient sovereignty and cycling, environmental concerns are combined with reduced input dependence, with the goals of increasing self-sustained farming (Darnhofer et al. 2010*b*), sustainable use of limited natural resources (Rockström et al. 2009), and ecological self-regulation (Cabell and Oelofse 2012). The key inputs for farming (aside from energy) such as seeds, fertilizers, plant protection products, and feedstuff are mostly imported to Finland and have fluctuating prices (Knuuttila and Vatanen, 2015). Thus, increasing nutrient and other key input sovereignty could help with adaptation to price shocks and sudden profitability risks. In addition, diversification of production risk and developed logistics for large, stable volume products can be regarded as European-scale risk buffers.

Resilience determinant 2: enhancement of dialogue and transparency of the food system

The most important social dimensions for resilience included transparency, dialogue, and equity throughout the food system. These mirrored the food system dynamics, policies, and power relations, and emphasized how the pursuit of resilience is not a static property, but rather a dynamic state that is based on connections between actors. Farmers have reportedly struggled with profitability in Finland, and the processing industry is dependent on domestic primary production (Niemi and Ahlstedt 2015). Lately, retail has been criticized by some for potentially contributing to the decreased profitability of primary production by increasing its own profit margin. The consolidation of one actor level in a food system might indeed create inequality in power relations. In a study report on German retailing, increasing concentration in retailing did not affect consumers negatively, but oligopsony market power was found to have an impact on producers and processors of certain products such as meat (Hermann et al. 2009). The notion that more transparency is needed is shared within European agriculture: the current CAP has included the promotion of interests of the producers in its targets and desires to increase their negotiating power for pricing (Niemi and Ahlstedt 2015).

Resilience determinant 3: utilizing human capital

Innovativeness, collective learning, expertise, and research-based competence reflect human capital as a resource of adaptive capacity and resilience. Knowledge empowers adaptation both by creating options and by providing predictive power (Williams et al. 2015). The panel recognized that research in the agricultural and food sectors, as well as in product development and consumer behavior, can advance the collaborative development of food systems. In addition, researchers have an advancing role for adaptation and a supporting role for decision makers; they also have the ethical responsibility to consider how their recommendations have an impact on different actors (Lacey et al. 2015). Codesigning solutions via joint processes and making use of research data, such as future scenarios, have already proven to be useful for food security within climate change issues in East Africa, for instance, (Vervoort et al. 2014). Such methods could be more widely employed to empower evidence-based practices in developed countries as well.

The role of diversity for resilience

Diversity, in certain forms, was considered to be important for resilience by our Delphi panel, in accordance with previous research (e.g., Carpenter et al. 2012, Hodbod and Eakin 2015). Modularity, namely diverse connectedness, has been suggested earlier as being an effective buffer from economic crises (May et al. 2008). In this study, it was mentioned as a buffering mechanism that provides alternative routes and back-up for food system operations. Agroecosystem and farm diversification have been noted to contribute to farm resilience (Darnhofer et al. 2010*b*, Lin 2011, Cabell and Oelofse 2012), and our panel also saw benefits in diversification at the farm level. However, potential trade-offs between gaining efficiency and allowing transformability, and practical constraints on the desire to diversify (for example, on livestock farms with large investments) might complicate this aim in practice.

It was also stated that not all types of diversity were beneficial, and a more detailed identification and analysis on the types of diversity that effectively enhance the resilience of specific operations is needed. Diversity can take the form of functional diversity (diversity within actors contributing to the same function), which enables food system operations in a complimentary manner (Hodbod and Eakin 2015). For example, the panel found that the consolidation of trade, leading to erosion in functional diversity, carried potential risks. If one large actor were to fail, this would have an impact on all food system actors, including consumers. Desired diversity can also be response diversity (diversity in the responses of the actors to changes), which can buffer the food system against different types of changes (Kahiluoto et al. 2014, Hodbod and Eakin 2015).

Implications of the study: how actors, policy, and research can support food system resilience

There was unanimity that research and society have a responsibility to support food system structures to achieve resilience and the global change adaptation of national food production and distribution. This connects to the limits of actor adaptation, which determine system performance and transformation: farmers and the processing industry were identified to currently be the closest to reaching their limits. In the farmers' opinion, even larger transformational change might be beneficial for diverging from the reported negative profitability development (Niemi and Ahlstedt 2015). The need for actors to consider their actions and adaptation strategies from the perspective of the whole-food system and its resilience is central for distancing undesirable system collapse. Approaches involving codesigning and knowledge sharing, as exemplified by our case study, can reveal weak links from a seemingly well-functioning system as key targets for further society- and research-supported actions (Wise et al. 2014). Because building resilience often poses financial constraints, selecting certain key focuses based on system vulnerabilities and key adaptive capacities, can benefit adaptive comanagement in economic terms as well (Darnhofer et al. 2010*b*).

In Finland, policy is based on democratic decision-making processes that have major connections to European policies, whereas research is largely driven by competitive funding, with governmental, international, and entrepreneurial sources having an impact on the volume and targeting of research. The CAP of the EU buffers and also potentially restricts European farmers in their adaptation capacities. The EU spent circa 55 billion € per year on agricultural policy during the period of 2010-2014, of which circa 40 billion € was spent on direct subsidies (Niemi and Ahlstedt 2015). In addition, the close dependences of agriculture with EU policy as well as national food systems on global trade suggest that large scale socioeconomic changes are met at the European and global level, rather than at the national level. The main means being used by national policy to enhance food system resilience, as recognized by our panel, relates to national investment support for renewable energy, which is a topical political issue across Europe. The distribution of power between the food system actors, which affects the profitability of food system operations, is also somewhat a national policy issue because it is related to national food security. Policy toward equity and profitability for all levels of food system actors, as suggested, could serve as a securing buffer. However, this might not be a straightforward task because free competition was also deemed to be important for resilience.

The quality of agricultural and food research is important for developing national food systems and their resilience. Our study also indicates a need for research efforts targeted nationally toward multidisciplinary research that aims to gain a systemic view, look into the future, and thus support innovative systems solutions and adaptation pathways. In general, policy and science were rated in our study to support resilience more effectively than actor-initiated or market-led means.

Limitations on defining adaptive capacity and resilience of food systems

The actors of food systems include a variety of different sized enterprises and interconnections that have an impact on their adaptation potential. This presents a major challenge for characterizing adaptive capacities in such a diverse group of actors. As Darnhofer (2010*a*) indicated, even a single farm is a highly complicated system to analyze in terms of its resilience, let alone an entire food system. Food systems also differ from other social-ecological systems with their multifunctional, normative nature, with food security being a major policy objective, and the multifaceted economic structures they hold (Hodbod and Eakin 2015). Determining who can and how to support the resilience of national food systems in practice requires knowledge of the operations and tradeoffs at different scales: from individual to local, regional, national, and international levels (Ericksen 2008*a*, Tendall et al. 2015). What makes this even more difficult is that institutions and policy are often slow to change and the actors need to adapt fast and continuously, while balancing between maximizing profitability and being resilient in the long term. Therefore, creating neutral platforms for food system actors to engage into continuous dialogue with each other, research, and policy appear to be an effective and potent strategy to advance in practice.

Our study used the concept resilience and its proxy (adaptive capacity) as tools for analyzing and guiding food system development. Our approach drew from a qualitative examination of actor perceptions, which were then concluded once data saturation had been reached. Insights were developed while familiarizing participants with a new perspective that contributed added value to their perspectives. It serves as an experimental example of a step-by-step approach to create a multiperspective view on a resilient, modern food system. Methodologically, the outcome of a Delphi process is always only as valid as the perspectives of the panel experts. Iterations, however, improve the validity. Feedback and reevaluation based on accumulating knowledge should be assistive in codesigning solutions toward developing food system resilience.

CONCLUSION

It is a challenging task to recognize and support the adaptive capacities needed to make national (but globally integrated) food systems more resilient to uncertainty. Foresight methods in applying the resilience approach can offer food system actors novel perspectives to be considered in their decision making and capital building, and to make their roles and that of other actors involved in the whole food system more visible. Our research showed how science and policy are also perceived as instrumental to resilient food systems. The three major ingredients of resilient food systems recognized are (1) sovereignty in terms of core resources, such as nutrients and energy also linked to Earth system functions; (2) social capital enabling entire food systems to reorganize; and (3) human capital to create novelty. The transformation of developed food systems to embrace these capacities can take different pathways and codesigning offers one means to mediate the change. This research provided starting points for the food system actors themselves and to the policymakers and researchers that are facilitating system changes. Codesigning is central to offering a more integrated view for building actor and food system resilience.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/8878

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Appendix 1

Table A1.1. Suggestions from the brainstorming session of the determinants of adaptive capacity in terms of actors and for the food system as a whole. Determinants are classified based on their predicted central role in strengthening biological and physical resources, social and human capital, or economic resilience.

	Biological and physical resources	Social and human capital	Economic resilience
Primary production (farmers)	Farm size Age of the farmer Amount of land area Soil quality Diversity of crops grown Diversity of crop rotation Diversity of crop cultivars grown Advanced agri-technology Livestock housing at use Quality of production: livestock material, crop yields etc. Water resources available for use Transport and other public infrastructure Self-sufficiency in production inputs Self-sufficiency in energy Own storages for production goods Energy efficiency Efficiency of logistics Exploitation of information and communication technology Closeness to markets Direct sales from farm Diversity in purchasing production inputs Diversity in marketing channels	Level of education and knowledge Expertise in the main production line Knowledge on continuing of a family farm by the next generation Communication with co-farmers Farmer co-operation in using machinery Farmer co-operation in manure distribution and producing feed Farmer co-operation in marketing Dialogue with other food system actors Co-operation with advising Co-operation with research Co-operation with administration Direct international contacts and efforts towards export Longevity and trust in client relations Activity in interest organizations Societal activity Possibility for land trading	Current profitability Surveillance of profitability in the long run Current capital Ratio of debt Earlier investments Availability of investment support Availability of loan capital Willingness and capability for risk taking Pluriactivity Amount of contract-based production Length of contracts Share of forestry Additional incomes by working outside farm Voluntary insurances
Production input industry	Size of enterprise Environmental awareness in processes Energy efficiency Efficiency of logistics Diversity of suppliers Diversity of sales channels Closeness to customers Reserve supplies Dependence from import Market research and future foresight	Longevity and trust in client relations Diversity of international contacts Longevity of international contacts Public image and societal responsibility Communication with co-producers Dialogue with other food system actors Co-operation with research Co-operation with	Current profitability Willingness and capability for risk taking

		administration	
Processing industry	Size of enterprise Production capacity Environmental awareness in processes Energy efficiency Efficiency of logistics Closeness to suppliers of processing material Diversity of suppliers Share of domestic processing material Closeness to markets Dependence from import Efforts towards export Skills in research and product development Market research and future foresight	Communication to build consumer trust Communication with co-processors Dialogue with other food system actors Co-operation with research Co-operation with administration International co-operation	Current profitability Willingness and capability for risk taking
Retail	Size of enterprise Environmental awareness in processes Amount of suppliers Diversity of suppliers Capacity of suppliers Flexibility in supply channels Direct contacts to producers Centralization of logistics Exploitation of information and communication technology Share of fresh products from sales Share of locally produced food from sales Share of "private label" products from sales Share of imported products from sales Closeness to markets Market research and future foresight	Communication to consumers Communication with co-retailers Dialogue with other food system actors Co-operation with research Co-operation with administration International co-operation	Current profitability Willingness and capability for risk taking
Food system as a whole	Infrastructure National emergency supplies Quality of agricultural research Quality of food research Quality of economic and policy research Exploitation of information and communication technology Diversity of the food system Development of local food production Share of domestic production	Transparency of the food system Legitimacy and transparency of policy Communication within each actor level of the food system Dialogue among food system actors Dialogue of food system actors and consumers Equability International co-operation	Omission of sub-optimization