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Impact of Covid-19 on farming systems in Europe through the lens of resilience thinking

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Abstract

CONTEXT

Resilience is the ability to deal with shocks and stresses, including the unknown and previously unimaginable, such as the Covid-19 crisis.

OBJECTIVE

This paper assesses (i) how different farming systems were exposed to the crisis, (ii) which resilience capacities were revealed and (iii) how resilience was enabled or constrained by the farming systems' social and institutional environment.

METHODS

The 11 farming systems included have been analysed since 2017. This allows a comparison of pre-Covid-19 findings and the Covid-19 crisis. Pre-Covid findings are from the SURE-Farm systematic sustainability and resilience assessment. For Covid-19 a special data collection was carried out during the early stage of lockdowns.

RESULTS AND CONCLUSIONS

Our case studies found limited impact of Covid-19 on the production and delivery of food and other agricultural products. This was due to either little exposure or the agile activation of robustness capacities of the farming systems in combination with an enabling institutional environment. Revealed capacities were mainly based on already existing connectedness among farmers and more broadly in value chains. Across cases, the experience of the crisis triggered reflexivity about the operation of the farming systems. Recurring topics were the need for shorter chains, more fairness towards farmers, and less dependence on migrant workers. However, actors in the farming systems and the enabling environment generally focused on the immediate issues and gave little real consideration to long-term implications and challenges. Hence, adaptive or transformative capacities were much less on display than coping capacities. The comparison with pre-Covid findings mostly showed similarities. If challenges, such as shortage of labour, already played before the crisis, they persisted during the crisis. Also, the eminent role of resilience attributes was confirmed. In cases with high connectedness and diversity we found that these system characteristics importantly contributed to dealing with the crisis. Also the focus on coping capacities was already visible before the crisis. We are not sure yet whether the focus on short-term robustness just reflects the higher visibility and urgency of shocks compared to slow processes that undermine or threaten important system functions, or whether they betray an imbalance in resilience capacities at the expense of adaptability and transformability.

SIGNIFICANCE

Our analysis indicates that if transformations are required, e.g. to respond to concerns about transnational value chains and future pandemics from zoonosis, the transformative capacity of many farming systems needs to be actively enhanced through an enabling environment.

Keywords: anticipating, coping, responsive, enabling environment, system characteristics

Highlights

- Comparison of pre-Covid-19 findings and Covid-19 crisis
- All systems displayed adequate agility to activate coping capacities
- The crisis triggered reflexivity about the operation of the farming systems
- Transformative capacities were not observed
- The systematic resilience assessment revealed system vulnerabilities

Graphical abstract

1. Introduction

Many farming systems in Europe are struggling with substantial challenges resulting from fundamental changes in their economic, technological, demographic, ecological and social environment (Meuwissen et al., 2020). The resilience of farming systems, i.e. their ability to cope with and respond to shocks and stresses, has therefore become a major concern (EC, 2020). The Covid-19 pandemic and the measures for its containment – e.g. lockdowns, travel restrictions and border closings – were expected to add another shock to farming systems. Using 11 in-depth case studies, this paper investigates the extent to which different farming systems across Europe were affected by the crisis, which resilience strategies they adopted, and which characteristics enabled or constrained their resilience abilities.

This paper contributes to a fast-growing literature on impacts of the Covid-19 pandemic on different parts of agricultural and food systems, e.g. food value chains, marketing channels, trade patterns and food security (e.g. Chang et al., 2020; Barichello, 2020; Hobbs, 2020; Mahajan and Tomar, 2020; Deaton 2020). Impacts on different farming sectors, e.g. due to production and demand distortions, have also been discussed (e.g. McEwan et al., 2020; Weersink et al., 2020; Brewin, 2020). Others have reflected on the resilience of food systems at large in the light of Covid-19 (e.g. Orden, 2020; Béné, 2020). However, a systematic assessment how characteristics of farming systems have enabled or constrained their responses to the Covid-19 crisis is missing. By using an elaborate framework (Meuwissen et al., 2019) to assess and compare the resilience of farming systems before and during the pandemic, this paper aims to enhance our understanding (i) how different farming systems were exposed to the crisis, (ii) which resilience capacities were revealed and (iii) how resilience was enabled or constrained by the farming systems' social and institutional environment.

Section 2 explains the SURE-Farm framework to assess the resilience of farming systems and the special data collection on Covid-19. Results are presented in Section 3, followed by discussion and conclusions in Section 4.

2. Approach

2.1 Resilience of farming systems

Following the social-ecological tradition of resilience thinking (Holling et al., 2002; Walker and Salt, 2006; Folke, 2016), we define the resilience of a farming system as its ability to ensure the provision of its desired functions in the face of often complex and accumulating economic, social, environmental and institutional shocks and stresses, through anticipating, coping and responsive capacities (Meuwissen et al., 2019). The resilience of a farming system is affected

by specific system characteristics (resilience attributes), and by the enabling or constraining environment, in particular institutional arrangements and resource availability (Termeer et al., 2019; Mathijs and Wauters, 2020). The resilience capacities define the possible range of actions to maintain the desired functions of the farming system, i.e. the provision of private and public goods at desirable levels. The selected courses of action in turn also affect the actors, institutions and resources of the farming system and its enabling environment, constituting a feedback loop.

2.2 Special data collection during early-stage of lockdowns as part of systematic resilience assessment

Resilience is a latent property of a system. The concept denotes a potential which is activated – and can be observed – only when a system is hit by stress or shocks (Meuwissen et al., 2020). It can thus be understood by learning from past trajectories and discussing future scenarios, and from assessing how actual shocks are dealt with (Figure 1). The first approach was used in a systematic assessment of sustainability and resilience over the course of 2017-2020. This provided insight into the multiple factors contributing to resilience. We used the second approach when Covid-19 hit European food and agricultural systems. This allowed us to compare the resilience attributes of the system and the resources and institutional support from the enabling environment that were activated to respond to challenges before and during the Covid-19 crisis. The 11 farming systems (Annex 1) have been analysed since 2017 in the SURE-Farm project, which has been funded under the EU research program Horizon 2020 and aims to understand and systematically assess the sustainability and resilience of farming systems.

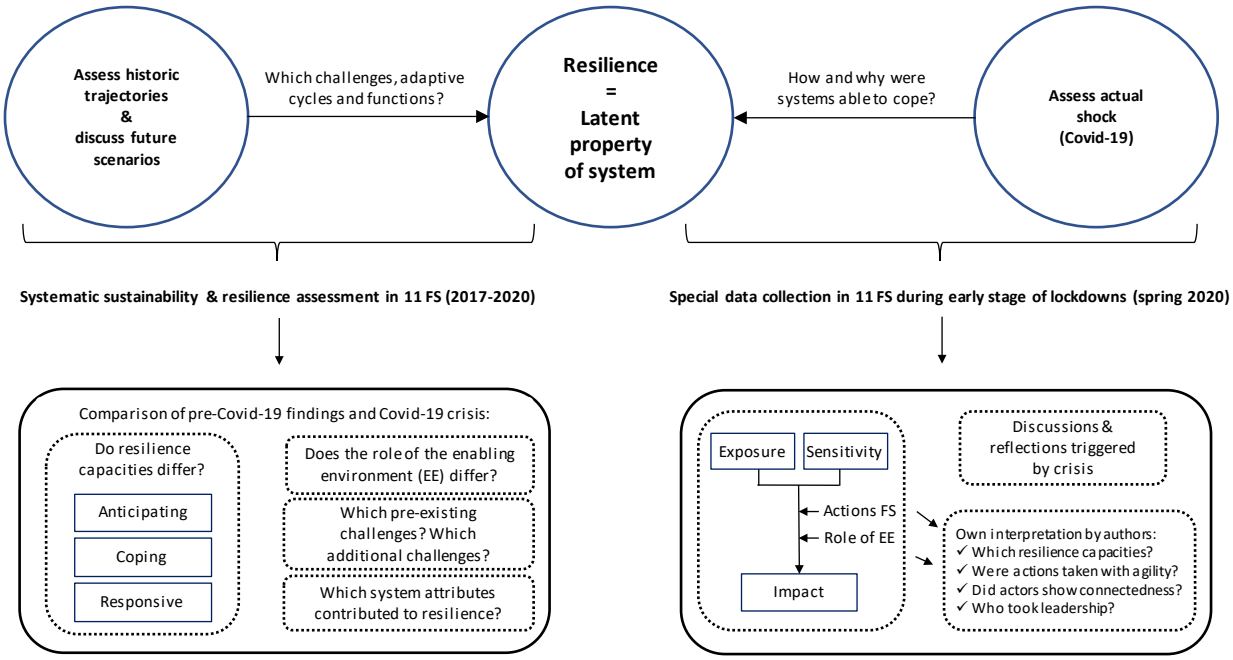

Figure 1: Combination of different approaches to assess resilience of farming systems (FS) and to understand Covid-19 impacts.

Qualitative data on the farming systems during the Covid-19 crisis were collected by members of the SURE-Farm consortium in their respective countries in spring 2020, focussing on exposure to restrictions and sensitivity of the farming system, actions taken by farming system actors in response to restrictions, the role of the enabling environment (resource availability and institutional environment), and discussions and reflections triggered by the crisis (Figure 1). Due to the short time-frame to plan data collection, different methods were used depending on availability and feasibility in each case study. In most case studies, interviews were complemented with a review of media and policy documents (Table 1). Each case study team interpreted the data with a focus on (i) the anticipating, coping and responsive capacities displayed by the actors in the farming systems, (ii) the agility of the actions (i.e. the speed with which actors accepted the situation as a crisis and shifted to crisis mode), (iii) the degree of fragmentation or connectedness across actors and (iv) the display of leadership, i.e. which actors shaped the interpretation of the situation, and provided guidance and coordination (Figure 1).

Table 1: Special data collection in 11 farming systems (FS) during early-stage of lockdowns due to Covid-19.

Farming systems	**Interviews (farmers; other FS actors)**	**Other methods**
Intensive dairy farming in Flanders, Belgium (*Dairy in Flanders*)	0; 25	Online farmer survey (n=191)

Large-scale arable farming in Northeast Bulgaria (*Arable in Northeast Bulgaria*)	2; 3	Media
Extensive beef cattle systems in the Massif Central, France (*Beef in Massif Central*)	-	Media, interactions with stakeholders and experts through value chain platform
Large-scale corporate arable farming with additional livestock activities in the Altmark in East Germany (*Arable in the Altmark*)	3	-
Small-scale hazelnut production in Lazio, central Italy (*Hazelnut in Lazio*)	4; 5	-
Intensive arable farming in Veenkoloniën, the Netherlands (*Arable in Veenkoloniën*)	2; 5	Review of media and policy documents
Fruit and vegetable farming in the Mazovian region, Poland (*Fruit & veg in Mazovian*)	14; 13	Comments on Facebook of Ukrainian forums devoted to work in Poland
Small-scale mixed farming in Northeast Romania (*Mixed in Northeast Romania*)	4; 9	Media, review of policy documents
Extensive sheep grazing in Northeast Spain (*Sheep in Northeast Spain*)	2; 7	Review of newspaper articles and reports
High-value egg and broiler systems in South Sweden (*Egg & broiler in South Sweden*)	-	Seminar with food system actors, review of newspaper articles, reports and policy documents
Arable farming in the East of England, UK (*Arable in the East of England*)	3; 9	-

The findings on the Covid-19 crisis were then compared to previous insights for each farming system, using selected findings from the systematic resilience assessment. These included findings on resilience capacities, the role of the enabling environment, prevailing challenges, and systems' performance of resilience attributes such as diversity, profitability and openness (Figure 1).

3. Results

3.1 Short-term impacts of lockdowns

Exposure and sensitivity differed across farming systems (Table 2). Major exposure and sensitivity were observed in the *extensive sheep farming system in Northeast Spain* and in the *small-scale mixed farming system in Northeast Romania*, mainly due to severely interrupted sales to restaurants and peasant markets, respectively. In the small-scale mixed system in Northeast Romania also milk collection was interrupted. A medium level of exposure and sensitivity was observed in *the fruit & vegetable system in Mazovian*. Here the travel limitations for foreign workers created problems. The other farming systems were exposed only to minor degrees. For instance, the *dairy system in Flanders* faced lower prices, but could continue production and delivery, and in other farming systems the timing of the lockdowns was

relatively fortunate, i.e. not affecting harvests but during tillage season (*small-scale hazelnut production in Lazio*) or after seeding and planting (*large-scale arable farming in Northeast Bulgaria*, *arable farming in the East of England*). In *the intensive arable system in Veenkoloniën* and *the extensive cattle grazing system in the Massif Central* important markets (starch potatoes and exports to Italy respectively) were barely affected.

Despite only minor exposure and sensitivity in most farming systems, a wide variety of actions was undertaken across all farming systems (Table 2). Similarities were financial support programs from governments and attempts to set up online-sales channels and home delivery services. Also, in many farming systems, cooperatives became active. For instance, in *the extensive sheep grazing system in Northeast Spain* cooperatives kept farm-gate prices at a reasonable level through stimulating national consumption and by developing new markets. In trying to solve shortages of foreign workers, farmers' associations in *the fruit & vegetables system in Mazovian* successfully anticipated and started to contact Ukrainian workers directly via Facebook platforms, while the German Farmers' Association (Deutscher Bauernverband) organised flights for migrant workers, among others from Romania and Bulgaria. The Spanish government ensured availability of shearers from Uruguay. In contrast, in the UK the government tried to mobilise local workers, such as through the 'Pick for Britain' and 'Student Land Army' initiatives, and in *the egg & broiler system in South Sweden* unavailability of migrant workers was coped with by hiring furloughed labour from companies in the region.

Impacts were overall minor (Table 2). For instance, in *the fruit & vegetables system in Mazovian* the speed of arranging availability of Ukrainian workers and the switch to less labour-intensive crops (e.g., pumpkin instead of cauliflower) reduced the system's medium exposure and sensitivity to a minor overall impact. The early signalling of the upcoming labour shortage by the farmers' organisation seemed a pivotal anticipating capacity. Some actions also reduced a system's exposure and sensitivity. For instance, the agile efforts of Belgian dairy processors to cooperate in order to ensure continuation of milk collection (despite reduced opportunities for valorisation) has been an important factor leading to relatively minor consequences in the *Flanders dairy system*. A somewhat more nuanced view on impacts came from some farming systems which recognised that impacts were unevenly distributed across actors, depending on membership of a cooperative (e.g. in *the extensive sheep system in Northeast Spain*) and entrepreneurship (in *the arable system in the East of England*). Also, despite minor impacts on the short-term, some actors in arable systems expressed concerns about long-term consequences on price levels (*Veenkoloniën* and *Northeast Bulgaria*).

Table 2: Overview of exposure and sensitivity, resilience actions, role of the enabling environment and impact in 11 farming systems (FS).

	Exposure and sensitivity[1]	Actions by FS actors	Actions by enabling environment[2]	Impact
Dairy in Flanders	**Minor**: farmers could continue their production; collection of milk was not interrupted. Negative: reduced opportunities to promote international trade (export is important); some logistical struggles in supply chain; reduced milk prices. Positive: increased sales of fresh milk in supermarkets (as this is the most important supply channel for organic milk products, the organic dairy sector was particularly positively impacted).	Anticipating. **Processors**: implemented crisis protocols and safety measures before the government imposed them. Coping. **Farmers**: employed cost saving strategies; used own buffer capacity to cover financial consequences. **Processors**: built private stocks and bought storage capacity to avoid waste; mobilised personnel to continue production. **Nat. federation of processors**: organised dialogue and cooperation between processors to prevent interruptions of milk collection and a collapse of milk processing and packaging activities. Responsive*. **Processors**: managed to restructure valorisation streams.	Coping. **Government**: declared the food industry as an essential sector, which motivated personnel at the processing plants to keep on working; implemented several subsidies to relief financial consequences, e.g. 'bridging loans' (applicable to farmers and intermediaries).	Overall **minor** impact at farming system level, although there was an uneven distribution, i.e. farmers who produce for the world market were more impacted than those (partly) selling to consumers. Also, processors focussing on restaurants were more impacted than processors delivering to supermarkets.
Arable in Northeast Bulgaria	**Minor**: production-related operations were only hindered for a short time as lockdown occurred after seeding. Negative: land owners asked for pre-payments due to financial distress. Positive: increased interest into diversification and better planning of financial flows.	Coping. **Farmers' associations**: managed to increase markets share at EU markets. Responsive*. **Processors**: developed new products (alcohol from corn, disinfectants). **Farmers, other value chain actors**: transferred to online communication (meetings, negotiations, orders etc.).	Coping. **Government**: created special rules for farmers, e.g. permission to travel outside towns, transport workers etc.; restructured CAP support; provided additional financial aid for farmers; provided flexibility to local offices with regard to visiting hours, accepting online applications etc. **Bank**: agreed on delayed repayments.	**Minor** for short-term period, but possibly medium for long-term period depending on global economic crisis in combination with more severe weather conditions.
Beef in Massif Central	**Minor**: export to Italy continued after initial hesitation. Negative: reduced carcass quality of calves due to longer period on farms; changed consumption patterns (more frozen and minced meat) led to unbalanced use of the carcass (less consumption	Coping. **Processors**: used veal for production of minced beef. Responsive*. **Private companies, cooperatives**: organised forms of home delivery, 'ready-to-work', and drive-take-aways.	Coping. **Government**: provided financial aids (in the form of daily allowance) for farmers who could not go to the farm (because of positive Covid-19 test, isolation, or care-taking responsibilities). **Beef association**: organised campaigns	**Minor**.

	Exposure and sensitivity[1]	Actions by FS actors	Actions by enabling environment[2]	Impact
	of the most "noble" parts). Positive: less commercial visits to the farm.		for consuming excess of beef produced (Pentecost veal).	
Arable in the Altmark	**Minor**: lockdown occurred after seeding; last year's grain harvest had already been sold. Negative: mental stress (what happens to my farm if I get ill); some fertilizers & pesticides were not available for a short period. Positive: public awareness about importance of agriculture (although some politicians argued industrial agriculture would be a cause of the pandemic').	Anticipating. **Farmers**: some purchased seeds, fertilizer, pesticides earlier. Coping. **Employees**: revealed high level of solidarity (helping each other, working more). Responsive*. **Farmers**: established new online communication and online seminars for farmers.	Coping. **Government**: provided financial support for severely affected farms. German **Farmers' Association**: organised flights for migrant workers, e.g. from Romania and Bulgaria, to work on farms.	**Minor**. Critical sectors facing unavailability of migrant labour, e.g. fruits & vegetables and livestock (particularly pork due to reduced slaughtering capacities) are not very important in this region.
Hazelnut in Lazio	**Minor**: lockdown occurred during tillage (not harvest). Negative: some delay in field activities due to interrupted supplies, e.g. of machinery spare parts; changed product demand (less through restaurants, more to retail); collapse of agritourism; cancellation of holy communion feasts; parents needed extra time to take care of their children at home.	Coping. **Farmers, processors**: started processing activities with regard to unsold vegetables. **Agritourism**: organised training activities for employees to learn anti-Covid-19 measures; rearranged open spaces for hosts. Responsive*. **Farmers, processors**: improved ICT to enhance order management and e-commerce; organised home delivery of farm products (e.g. fresh vegetables, processed products usually sold at the farm).	Coping. **Government:** initiated 'job-in-country' database for unemployed people (little response); attempted to set-up European corridors for foreign labour; provided cash-grant scheme up to 2.5 kEuro per farm with agritourism. Responsive*. **Government:** reduced red tape costs related to CAP, e.g. by using georeferencing instead of field controls.	Overall **minor**. Agritourism activities were heavily impacted, but these are only a small part of the overall system.
Arable in Veenkolonië n	**Minor**: lockdown was established before seeding and planting but there was no shortage of materials; main cash crop is starch potato (this market was hardly affected). Negative: some delay in availability of machinery supplies, e.g. spare parts for irrigation equipment; less opportunities for shared learning; some delays in international logistics and payments for processing	Coping. **Processing cooperative**: delayed sustainability goals of growers due to changed priorities; organised multi-functional crisis team. Responsive*. **Processing cooperative**: led quick transition to online communication with member farmers, including vlogs in demo-fields to update on new developments.	Coping. **Government:** provided financial support for severely affected farms. **Banks**: offered opportunity for delayed redemption.	**Minor** during early stage of lockdown. (There may be a medium impact on the longer-term due to lower commodity prices.)

	Exposure and sensitivity[1]	Actions by FS actors	Actions by enabling environment[2]	Impact
	cooperative. Positive: increased appreciation for countryside.			
Fruit & veg in Mazovian	**Medium.** Negative: higher prices for fertilisers and pesticides; temporary closing of shops (after re-opening: extra sanitary costs and problems with import); foreign workers were limited in travelling (when travelling was allowed, farmers had to facilitate quarantine and pay for Covid-test); difficulties to implement changing Covid-regulations. Positive: higher prices for vegetables and fruits (especially in short-term for apples); increased understanding of need for more elastic work permits for foreigners.	Anticipating: **Farmers' organization**: signalled upcoming labour shortage. Coping. **Farmers:** ignored to some extent restrictions to sell in crowded places. **Retailers**: quickly introduced obligatory protection measures to protect buyers and sellers. **Foreign workers**: intensified communication with intermediaries and among each other (through social media groups created by intermediaries on Facebook and Viber). Responsive*. **Farmers:** started online buying of inputs, and online sales; replaced human labour by machines; switched to less labour-intensive vegetables (beans and pumpkin instead of cauliflowers and broccoli).	Coping. **Government**: offered "anti-crisis shield" granting suspension of taxes for 3 months for self-employed retailers and other firms who agreed not to fire employees[3]; no special aid for horticulture but after mid-May reimbursed farmers for costs of Covid-tests for employees; lifted travel ban for seasonal workers from Ukraine with a guarantee for field work during the 14-d. quarantine. **Labour intermediaries (Polish, Ukrainian)**: spread information about possibilities to work in Poland; organised cross-border travel for employees; established contacts between Polish farmers and Ukrainian workers.	**Minor** as increased prices were temporary and farmers managed with available labour.
Mixed in Northeast Romania	**Major**. Negative: lower sales, e.g. lambs for Easter and fresh early spring vegetables; lower sales in peasant markets due to lack of customers' mobility; lower sales due to abandoned school programs (bread, milk, apples); interrupted deliveries of products to restaurants; lower mobility of commuting workers; reduced off-farm income if family members lost off-farm jobs; collapse of agritourism due to cancellations including those linked to peak periods such as Easter and 1-st of May holidays. Positive:	Coping. **Agritourism**: owners who faced closing of agritourism activities (occasionally) begun with meal deliveries. **Processors:** reduced buying of milk from farmers due to reduced demand. **Peasant markets, retailers:** established compulsory protection measures for sellers and customers. Responsive*. **Farmers**: started online and local direct sales of fresh vegetables, fruit, eggs and dairy. **Supermarkets, fast-food**: increased home delivery in urban areas.	Coping. **Government**: launched a platform for online sales of vegetables; extended period for direct payment applications; increased state aid; re-allocated funds from rural development programmes; introduced payments for "technical unemployment" if enterprises were forced to close or scale down until June 1 (75% of salary paid by state). **Banks**: increased finance opportunities for working capital or investments (available for all SMEs, 90% guaranteed by state); postponed credit instalments up to 9 months.	Overall **medium** for farmers, although there was an uneven distribution at farming system level, i.e. farmers selling large quantities of products in peasant markets and to restaurants were impacted more. Farmers who shifted sales directly to customers and/or Internet sales coped better.

	Exposure and sensitivity[1]	Actions by FS actors	Actions by enabling environment[2]	Impact
	increased appreciation for local products.			
Sheep in Northeast Spain	**Major**. Negative: interrupted sales to restaurants; sharp drop in prices. Positive: increased public awareness and appreciation of extensive sheep sector.	Coping. **Farmers**: kept animals longer on farm to deal with market oversupply. S**laughterhouses, feedlots**: regulated supplies to markets. Responsive*. **Farmers**: started online sales to consumers. **Cooperatives**: tried to keep farm-gate prices at reasonable level, e.g. through stimulating national consumption of lamb meat and opening new international markets; developed new products (processed, easy to cook).	Coping. **Government**: provided financial aid programs and storage of meat; ensured availability of skilled workers (shearers) coming from foreign countries (Uruguay). Responsive*. **Government**: established trade agreements for export of living animals with new countries, e.g. Jordania and Saudi Arabia.	Overall **medium** impact although there was an uneven distribution, i.e. those farmers who belong to cooperatives (instead of individually dealing with distributors) were better able to ensure sales at fair prices. Also farmers who diversified their activities and distribution channels were better able to cope.
Egg & broiler in South Sweden	**Minor**. Low export orientation. Domestic markets were not severely affected. Negative: some difficulties in fodder imports and access to migration labour. Positive: less competition from import.	Coping. **Farmers, processors**: hiried labour from companies in region that had shortage of work. Responsive*. **Farmers, processors**: increased use of ICT to find markets and link with consumers.	Coping. **Government**: offered financial support for severely affected farms and processors.	Overall **minor**, with few imbalances among actors.
Arable in the East of England	**Minor**. Lockdown occurred after seeding and planting. Negative: reduced demand for malting barley and potatoes; issues with packaging for flour for retail caused shortages in retail (it took time to redirect bulk supply to retail); slight delay with machinery parts; less activities on diversified farms, e.g. tourism, cafes, weddings. Positive: the image of British farming got a boost as people were looking to buy more local food and appreciated the work done by British farmers to keep the nation fed. They also realised that farmers	Coping. **Farmers' organisation:** launched a portal to match up supply and demand of potatoes; provided advice and represented farmers to government. Responsive*. **Potato growers**: shifted from chipping to bulk bags for consumers, where possible. (This was not possible for all growers as stored potatoes treated with CIPC cannot be sold as fresh potatoes if more than 2 applications have been applied. Also, some varieties used for chipping are not suitable for retail.)	Coping. **Government**: provided Coronavirus Business Interruption Loan Scheme; introduced job retention scheme; offered business rates relief; set up 'Pick for Britain' initiative, and 'Student Land Army' (worked for farms located nearer to urban centres - those in more rural locations have struggled as it is difficult for employees to travel to the farm, and potential issues of accommodation).	Overall **minor**, although there was an uneven distribution, i.e. those who were entrepreneurial were able to switch quickly to capitalise on the increased retail demand. Also, those who maintained diversity in their markets were better able to adapt.

	Exposure and sensitivity[1]	Actions by FS actors	Actions by enabling environment[2]	Impact
	provide important public goods, such as places for recreation.			

[1]Scope of lockdowns slightly varied across EU member states but largely included lockdowns of schools, (partial) closure of hotels, restaurant and cafes, travel restrictions, and cancellation of large events.
[2]The role of the EU is not specified here as they had a role in each FS, e.g. through aids for private storage and implementation of 'green corridors' to warrant food security and supply of machinery.
[3]Only limited relevance for farmers as they mostly work with family labour and seasonal employees.
*Responsive capacities are subdivided into adaptability (*) and transformability (**). The latter was not observed.

Most of the long list of actions undertaken by farming system actors and the enabling environment suggests coping capacities. This is especially pronounced for the actions undertaken by the enabling environment; only in *the hazelnut system in Lazio* and *the extensive sheep grazing in Northeast Spain* the government was partly responsive though changing physical field inspections to georeferencing and by actively engaging in identifying new export markets respectively. We observed more responsive actions at the level of farming systems; in *the large-scale arable system in Northeast Bulgaria* and in *the extensive sheep system in Northeast Spain* even the majority of actions by farming system actors were responsive (adaptive). Anticipation was quite rare and was observed only in *the dairy system in Flanders* where processors anticipated through crisis protocols, in *the arable system in the Altmark* where some farmers anticipated and responded by early buying of inputs, and in *the fruit & vegetables system in Mazovian* in relation to the availability of foreign workers.

Although few actions could be classified as responsive behaviour, the discussions and reflections triggered by the crisis dealt with a range of topics which would require fundamental changes in farming systems or food and agricultural sectors in general. Discussions related among others to calls for more self-sufficiency, shorter value chains, reduced dependence on migrant labour, improved fairness and inclusiveness in value chains, more cooperation among farmers, and more innovations (details are in Annex 2, including whether discussions related to the farming system level or food and agricultural sectors in general).

Not much variation in agility could be observed; where needed, actions were taken swiftly (Table 3). Only in *the Hazelnut system in Lazio* it was reported that decisions were taken promptly, but that the actual implementation of related actions was slow. Regarding leadership, more differences were observed across farming systems (Table 3). In the three farming systems with the highest exposure and sensitivity, leadership was taken by actors from the enabling environment in *the fruit & vegetable system in Mazovia* and in *the mixed system in Northeast Romania*, while in the *extensive sheep system in Northeast Spain* actors from the farming system itself led important actions. In other farming systems, leadership was jointly taken by actors from the farming system and the enabling environment. Connectedness was mostly apparent at the level of processing cooperatives (*dairy system in Flanders*, *sheep system in Northeast Spain*) or farmers' associations (*the fruit & vegetables system in Mazovia*). Little connectedness was found in *the large-scale arable system in Northeast Bulgaria*, *the extensive beef system in Massif Central*, and in *the small-scale mixed system in Northeast Romania*. In the latter, lack of cooperation along the value chain and between farmers was seen as rooted in the communist history and considered a major problem in developing solutions during the

lockdown. In Romania the lack of cooperation was also among the discussion topics (Annex 2).

Table 3: Interpretation of actions during lockdowns: leadership, agility and connectedness[1].

	Were actions taken with agility?[2]	**Who took leadership?[2]**	**Did FS actors show connectedness?[2]**
Dairy in Flanders	Yes	$FS^{2a,c}$	Yes ($FS^{2a,b,c}$)
Arable in Northeast Bulgaria	Yes (EE^{4})	FS^{1b}, EE^{4}	No
Beef in Massif Central	Yes	$FS^{2a,b,c}$, EE^{4}	No
Arable in the Altmark	Yes	-	-
Hazelnut in Lazio	Prompt decisions (EE^{4}) but slow implementation	FS^{1a}, EE^{4}	Negligible
Arable in Veenkoloniën	Yes, but only few actions	-	-
Fruit & veg in Mazovian	Yes (FS^{3}, $EE^{1c,4}$)	$EE^{1c,4}$	Yes (FS^{1b}), no (FS^{1a})
Mixed in Northeast Romania	Yes	$EE^{3,4}$	No
Sheep in Northeast Spain	Yes ($FS^{2b,}$ EE^{4})	FS^{2b}	Yes (FS^{2b})
Egg & broiler in South Sweden	-	-	-
Arable in the East of England	Yes where needed	Mix of FS and EE	-

[1]An '-' refers to limited agency, agility etc. because it was not needed.
[2]We distinguish between actors from the farming system (FS) and the enabling environment (EE). FS^{1a}: farmers, FS^{1b}: farmers' associations, FS^{2a}: private processors, FS^{2b}: processing cooperatives, FS^{2c}: association of processors, FS^{3}: foreign workers, EE^{1a}: farmers' organisations, EE^{1b}: associations of processors, EE^{1c}: labour organisations, EE^{2a}: private processors, EE^{2b}: cooperative processors, EE^{3}: banks, EE^{4}: national government. EU actions are not specified as they apply for each FS.

3.2 Comparison of pre-Covid-19 findings and Covid-19 crisis

Revealed resilience capacities during Covid-19 largely coincided with the resilience capacities from the pre-Covid assessment, i.e. also before Covid-19 there was a focus on short-term robustness (coping) as indicated by the multiple times 'b' in Table 4. However, there were a few exceptions. For instance, in *the arable system in Northeast Bulgaria* and *the arable farming system in the East of England* the pre-Covid-19 focus of farming systems was on coping capacities while the Covid-19 situation revealed mainly responsive capacities. With regard to actions taken by the enabling environment, the opposite was true in among others *the mixed system in Northeast Romania* and *the egg & broiler system in South Sweden*, i.e. there was more focus on supporting coping capacities during Covid-19 than before.

Table 4: Comparison of pre-Covid-19 and Covid-19 farming systems' (FS) resilience capacities, farm-level capacities and the role of enabling environment (EE)[1].

	Pre-Covid-19[2]			**Covid-19**		
	Perceived FS capacities	Revealed farm level resilience[3]	Role of EE	FS capacities	Farm-level capacities	Role of EE
Dairy in Flanders	**b**		**b**	a, **b**, c1	**b**	**b**
Arable in Northeast Bulgaria	**b**	c1	**b**	b, **c1**	**c1**	**b**
Beef in Massif Central	**b**, c1	c2	**b**	b, c1	-	**b**
Arable in the Altmark	**c1**, c2		**b**, c1	a, b, c1	a, c1	**b**
Hazelnut in Lazio	**b**	b, c1	**c1**	**b**, c1	b, **c1**	**b**, c1
Arable in Veenkoloniën	**b,** c1	b	**b**, c1	**b**	-	**b**
Fruit & veg in Mazovian	**b**	c2	**b**	a, **b**, c1	b, **c1**	**b**
Mixed in Northeast Romania	**c1, c2**	c1, c2	**c1**	**b**, c1	**c1**	**b**
Sheep in Northeast Spain	**c1**	c1	**c1**	b, **c1**	b, c1	**b**, c1
Egg & broiler in South Sweden	**c1**	c1	**c1**, c2	b, c1	**b**	**b**
Arable in the East of England	**b**	b	**b**[4]	**b**, c1	**c1**	**b**

[1]Letters refer to resilience capacities, i.e. a: anticipating, b: coping, and c: responsive. The latter is subdivided into c1: adaptability, and c2: transformability. Focal capacities are in bold.
[2]During the systematic assessment we did not consider the anticipating capacity.
[3]The table shows in which FS farms revealed relatively high coping (b) and responsive (c1, c2) capacities. Details are in Annex 3.
[4]Focus has been on maintaining the status quo, though agricultural policy could be about to undergo a fundamental change in a post-Brexit UK.

A comparison of pre-Covid-19 challenges and those observed during lockdowns shows that a number of challenges persisted during the lockdowns (Table 5). (Covid-19 challenges were extracted from exposure and sensitivity (Table 2), observations reported in Table 3 and discussion topics summarised in Annex 2.) For instance, each farming system in which labour shortage was already identified as a top-5 challenge in the pre-Covid-19 assessment (Annex 4) also reported labour issues during the lockdowns (*arable system in the Altmark*, *the fruit & vegetables in Mazovian*, *the mixed system in Northeast Romania*, and *the egg & broilers system in South Sweden*). Interestingly, in three farming systems respondents reiterated their worries about climate change, i.e. in the *arable system in Northeast Bulgaria*, *the arable system in Veenkoloniën*, and *the fruit & vegetables system in Mazovian*, as they feared that exposure, sensitivity and impact of climate change would be much larger than from Covid-19. The Covid-19 crisis also revealed a number of additional challenges (Table 5). These related to financial distress in *the arable system in Northeast Bulgaria* and mental stress in *the arable system in the Altmark*. Actors in three systems also reported problems due to collapse of agritourism activities (*the hazelnut system in Lazio*, *the mixed system in Northeast Romania*, and *the arable system in the East of England*), while such diversified activities were usually assumed to be less

vulnerable to external shocks than agricultural production activities. For *the mixed system in Northeast Romania* and *the extensive sheep system in Northeast Spain* also the interrupted sales were an additional challenge.

Table 5: Persistent and additional challenges during Covid-19.

	Pre-Covid-19 challenges which persisted during Covid-19	**Additional challenges**
Dairy in Flanders	Price drops	-
Arable in Northeast Bulgaria	Climate change[1]	Financial distress
Beef in Massif Central	-	-
Arable in the Altmark	Lack of skilled labour	Mental stress
Hazelnut in Lazio	Bureaucratic issues causing sluggishness	Collapse of agritourism
Arable in Veenkoloniën	Droughts[1]	-
Fruit & veg in Mazovian	Overregulation and bureaucracy; low cooperation among farmers; labour shortage; droughts[1]	-
Mixed in Northeast Romania	Poor integration in agri-food chains; lack of available labour	Interrupted sales; collapse of agritourism
Sheep in Northeast Spain	-	Interrupted sales; sharp drop in prices
Egg & broiler in South Sweden	Lack of qualified labour	-
Arable in the East of England	-	Less activities on diversified farms

[1]Fear that impacts of climate change outweigh those of Covid-19.

With regard to system characteristics (attributes) that enhance resilience, connectedness stood out (Table 6). Vice versa, lack of connectedness constrained resilience actions. The latter was illustrated by *the small-scale mixed system in Northeast Romania* in which low connectedness of small farms with value chains hindered small farms to access retail chains when peasant markets closed or were no longer visited by consumers (Table 6, 3rd column). System characteristics however did not explain all patterns of Covid-19 resilience actions (not in table). In two farming systems we observed that pre-Covid-19 connectedness among farmers was high, but this did not play a role during Covid-19. In *the hazelnut system in Lazio* individual farmers took actions, not the cooperative. Also, in *the beef system in Massif Central* processors took leadership. The opposite was observed in *the fruit & vegetable system in Mazovia* where pre-Covid-19 connectedness was low, but the Covid-19 crisis revealed that farmers' and labour organisations were well able to take joint actions to quickly ensure the availability of Ukrainian workers.

Table 6: System attributes contributing or hindering resilience[1].

	High-performing attributes contributing to resilience	Low-performing attributes hindering resilience
Dairy in Flanders	**High connectedness** among processors ensured continuation of milk collection at farm level, and valorisation.	**Low modularity** due to asset specificity led to dependence on processors.
Arable in Northeast Bulgaria	-	-
Beef in Massif Central	**Diversity of buyers** incl. local and export markets was pivotal because export markets remained open.	
Arable in the Altmark	-	-
Hazelnut in Lazio	-	-
Arable in Veenkoloniën	**High connectedness** across value chain reduced sensitivity due to temporarily delayed sustainability goals.	-
Fruit & veg in Mazovian	**Increasing openness** to knowledge enabled quick change to less labour intensive crops.	-
Mixed in Northeast Romania	-	**Low connectedness** and inclusiveness in value chains impeded small farms to shift markets.
Sheep in Northeast Spain	**High connectedness** with cooperatives was useful as they managed to keep farm prices at a reasonable level due to investing in consumer campaigns and new markets.	**Low exposure** to market disturbances caused a lack of alternative sales channels.
Egg & broiler in South Sweden	**High coupling** to national needs, i.e. low export orientation, led to minimal exposure and sensitivity to international trade disruptions. Also, being relatively well **socially self-organised** enabled hiring of furloughed labour from other companies. **High levels of social learning** enabled quick change to online sales.	-
Arable in the East of England	-	**Low functional and responsive diversity** hampered potato farmers who could not switch from bulk to retail.

[1]Pre-Covid-19 performance of attributes was described in Reidsma et al. (2019; 2020).

4. Discussion and conclusions

In this paper we assessed how and why farming systems in Europe were able to cope with Covid-19. We did so by assessing exposure and sensitivity of farming systems, actions undertaken by farming system actors and their enabling environment, leadership, connectedness, agility of actions and overall impact. We also assessed discussions triggered by the crisis in media and among stakeholders. Short-term impacts were then compared with pre-Covid knowledge about the farming systems, including prevailing systems' resilience capacities, the role of the enabling environment with regard to resilience, the range of pre-existing challenges and the performance of resilience attributes.

In most cases, few anticipatory capacities were observed, even when the impending pandemic became plainly visible through media reports in early 2020. All systems then displayed adequate agility to activate coping capacities. Related actions were led by farming system actors or the enabling environment, or both. Agility was mainly based on already existing connectedness among farmers and more broadly in value chains. Across cases, the experience of the crisis triggered reflexivity about the operation of the farming systems. Recurring topics were the need for shorter chains, more fairness towards farmers, and less dependence on migrant workers. However, we observed limited adaptive and no transformative responses. This might betray a general orientation towards robustness and attempts to avoid larger changes to the modes of operation.

Similar to the results of other studies (Laborde et al., 2020), our case studies found limited impact on the production and delivery of food and other agricultural products. This was due to either little exposure or the agile activation of robustness capacities of the farming systems in combination with an enabling institutional environment. While this constitutes a significant achievement, considerations during the crisis were almost exclusively limited to the productive functions of the system. Impacts on public goods and services barely received attention. Moreover, actors in the farming systems and the enabling environment generally focused on the immediate issues and gave little consideration to long-term implications and challenges. Hence, adaptive or transformative capacities were much less on display than coping capacities.

The comparison of pre-Covid findings and the Covid-19 crisis mostly showed similarities. For instance, if challenges already played before the crisis, they persisted during the crisis, sometimes even to a larger extent. Also, the focus on coping capacities was already visible before the crisis. In addition, the comparison confirmed the eminent role of resilience attributes. For instance, in cases with high connectedness and diversity we found that these system characteristics importantly contributed to dealing with the crisis. However, the comparison also revealed that the crisis did not entirely copy pre-Covid findings, i.e. some cases experienced other challenges, were able to mobilise more responsive capacities than expected, or showed that already existing connectedness did not lead to adequate actions during the crisis. This illustrates the latent, multi-faceted and dynamic nature of resilience.

The data only capture short-term responses to the immediate shock of the pandemic and the ensuing restrictions. For instance, we did not assess whether online platforms were sustained. Experiences from later (more partial) lockdowns during the second wave of the Covid-19 pandemic indicate that ‘many had to invent the wheel again’. This resonates with the observation that despite a long list of discussed topics, farming system actors did not use the

crisis as a window to trigger more structural change. The only exception in our sample – the prohibition of subcontracting in German slaughterhouses – was forced upon the industry by the Ministry of Labour Affairs, which enabled a change that most observers felt was long due. One year into the crisis it becomes clear that the short-term shock evolves into long-term stresses, in particular at the macro-economic level of unemployment, public and private debt and reduced purchasing power. Sectors that are particularly affected also lose valuable resources, from skilled labour to missing investments and interrupted social and economic network connections. It is plausible that the experience of labour shortages and the importance of digital platforms in developing coping strategies will accelerate trends towards automation and digitalization in the food and agricultural sector as in the general economy.

The findings have important implications for policy making. First, the analysis demonstrates a need to strengthen anticipatory capacities at all levels, in particular the ability to recognise signals of impending threats, whether they are short-term (Covid-19 pandemic) or long-term (climate change, biodiversity loss). Second, the actors' reflections in our case studies mostly betrayed a questioning of transnational value chains. Policy makers need to discuss openly whether regional and short value chains are indeed generally more resilient and should therefore become a policy priority. Third, the importance of resilience attributes iterates that system design matters and, thus, that being impacted by a crisis is not 'just a matter of bad luck'. It needs to be discussed how resilience attributes, such as connectedness in value chains and diversity, can become a more integral part of policy design. Fourth, the convergence of pre-Covid and crisis findings demonstrates that the systematic resilience assessment of farming systems points at system vulnerabilities. This knowledge can directly feed into stress tests of food systems. Fifth, the Covid-19 crisis is likely to reinforce concerns about future pandemics from zoonosis and to raise awareness of the interdependence of animal, plant, environmental and human health. From a resilience perspective, such public health issues create system vulnerabilities that might require a transformation, in particular of animal-based farming systems. At the same time, our analysis indicates that the transformative capacity of many farming systems needs to be actively enhanced and stimulated through an enabling environment. This includes (i) the provision of specific resources for a desired transition (e.g. innovative knowledge) and (ii) formal and informal institutional arrangements that provide a clear sense of direction and that enable rather than impede transformations that are necessary to maintain public goods and services.

An important question for future research is whether the focus on short-term robustness just reflects the higher visibility and urgency of shocks compared to slow processes that

undermine or threaten important system functions, or whether they betray an imbalance in resilience capacities at the expense of adaptability and transformability. Another task for research is the development of a systematic understanding how short-term crisis interventions to secure the provision of private goods can synergetically support transformations that are needed to address the broad range of challenges to public goods (public health, climate change, biodiversity, farm demographics, etc.).

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Annexes

ANNEX 1 A brief description of the farming systems in the SURE-Farm project.

	Description
Dairy in Flanders	Dairy farming is an important agricultural sector in Flanders, the northern part of Belgium. Flemish milk production has increased substantially over the last decade, and this is largely because of the structural intensification the sector has gone through, as the number of specialized dairy farms today is similar to 2012 while both the total number of dairy cows and average production efficiencies have increased. Since the announcement of the abolishment of the quota, which was in 2015, scale enlargement has been a dominant trend. But recently also organic dairy farming gained popularity, although it remains a niche.
Arable in Northeast Bulgaria	North-East Bulgaria is considered as highly important for crop production. The arable farming capacity in the region results from the natural conditions (fertile soils, varied landscape with semi-mountainous areas, river valleys and lowlands, and a continental type of climate) and is defined by the historical developments and transformations which have taken place during the last decades. Productivity of specialized farms is close to the EU average.
Beef in Massif Central	The Bourbonnais farming system is located in the Charolais basin in the centre of France (Massif Central). It is characterized by extensive beef-cattle systems based on grasslands. A large number of weanlings are exported abroad (mainly Italy) where they are fattened. The landscape is characterized by high aesthetic quality (grassland intermingled with a reticulate of hedges).
Arable in the Altmark	The farming system in the Altmark is dominated by large corporate farms as well as larger family and partnership farms. The farms rely mainly on hired labour and rented land. The fertility of the soils and annual rainfall are rather low. Livestock density is rather low and farms focus mainly on crop production. Despite of the high technical efficiency of the farms their profitability is weak. The region has a rather low population density and poor general infrastructure.
Hazelnut in Lazio	Italy is the world's second producer of hazelnuts. The farming system, that includes a portion of Viterbo province in Lazio region, produces one third of the Italian production and hosts about 6,000 hazelnut farms. Small farms (2-10 ha) dominate (89%), 10% have 10-50 ha and 1% runs more than 50 ha. Hazelnut orchards, due to their profitability, are growing and spreading in less suitable areas where soils, water availability and climate conditions are less favourable. This is generating some opposition from civil society that fears monoculture. However, the quality of the local production is recognized as high (proved by the recognition of PDO "Nocciola Romana"). Most production is supplied through producer organisations to the international confectionery industry, where few players largely dominate.
Arable in Veenkoloniën	The Veenkoloniën is located in two Northern provinces of the Netherlands — Drenthe and Groningen. Poor quality of sandy soils makes cultivation of many crops and vegetables impossible, and the farming system hence largely relies on starch potato production in a 1:2-1:3 rotation with sugar beet and wheat.
Fruit & veg in Mazovian	The farming system is located in the Mazovian region in the central-east part of Poland. It is traditionally dominated by horticulture and therefore has a diversified landscape. There are also other types of farms, especially medium-size arable, milk and poultry farms, supplying manure supply or facilitating crop rotation.
Mixed in Northeast Romania	The North-East of Romania is dominated by small mixed farms (arable and livestock), generally family run. In terms of size, 98% of the farms in the region have less than 10 ha, 95% less than 5 ha, and 56% less than 1 ha. The main crops grown in the region are cereals (maize and wheat), oilseeds (sunflower), and fodder crops, while the livestock is composed of bovines (mostly dairy cows), poultry, sheep, pigs, bee families and horses for transport purposes. The on-farm consumption is very high (more than 50%) in this region. There are quite few producers' associations and cooperatives (due to the historical background), and consequently there is poor inclusion in the value chains.

	Description
Sheep in Northeast Spain	The extensive sheep farming system in Huesca (Aragón), North-eastern Spain has a long history of ovine production. The number of farms and sheep have been more than halved in the last 20 years. Nowadays, the province has around 521,500 sheep heads and 930 farms dedicated to lamb meat production. Farms are mainly medium-size family business (200-1,000 sheep) diversified with almond orchards, olive trees, cereal crops and vineyard.
Egg & broiler in South Sweden	Swedish egg and broiler farms produce high-value products, and production is located in the southern part of Sweden, which is recognised for its fertile plain districts and agricultural activities which allow farms to have access to and/or to grow fodder. Swedish egg and broiler farms produce mainly for the domestic market.
Arable in the East of England	The East of England is considered the "bread basket" of the UK thanks to its extensive flat and fertile land. The region is highly productive in arable crops and contributes more to the UK's agricultural gross value than any other region. Production includes a wide variety of crops, but cereals (especially wheat and barley) are the most important, accounting for one third of the UK's entire cereal crop. The farms are large-scale, capital-intensive corporate and family farms.

ANNEX 2: Discussions and reflections triggered by the Covid-19 crisis about the farming systems (FS) and the national food & agricultural system (F&A).

	Topics
Dairy in Flanders	- FS. Discussions on need for more vertical communication & coordination. - FS. Reflections about risk management, e.g. increased awareness that sector should not depend on government interventions. Also, increased awareness about inflexibility of farmers to adapt production to changing circumstances. This led to debates about among others price contracts. There was also reflection on the limitation of specialising on one market channel, i.e. although highly efficient, it is more safe to spread risk through diversification. - F&A. Questions raised by some stakeholders about whether the Belgian dairy sector should focus more on the national market. - F&A. Discussions about the opportunity of short supply chains as an alternative business model. - F&A. Reflections in society about importance of agriculture and food self-sufficiency. However, the debate was temporary.
Arable in Northeast Bulgaria	- FS. Consideration of adaptation and, sometimes, transformation, e.g. towards construction of irrigation systems and other technological innovations, such as more autonomous machineries and transport vehicles, switch to bio-stimulation of soil health, and digitalisation of administrative services. - FS. Reflection on further restructuring of land market as crisis is expected to push mal-functioning farms out of business. This will increase trust in the system. - FS. Discussions about the need to develop strategies which better target the major national specificities including labour scarcity and climate change. - F&A. more societal appreciation for role and importance of agriculture.
Beef in Massif Central	- FS. Press releases from the Ministry of Agriculture highlighting the resilience of the beef value chain in France, but also calling for the need to restructure the chain towards fairer farm-gate prices and a more balanced structure. - F&A. Reflections in French society about importance of agriculture and food self-sufficiency. Society also showed feelings of gratitude for the agricultural sector and to employees of the food value chain. - F&A. Project calls about reducing the vulnerability of the French food system.
Arable in the Altmark	- F&A. Reflection in society about food production and self-sufficiency. The debate was however short-lived. - F&A. Concerns about the general problem of labour shortage intensified, especially among farmers who rely on labour force from other European countries like Poland (German-Polish border was temporarily closed), Romania and Bulgaria. - F&A. Attempts and discussions about whether Germans could replace migrant labour in certain sectors such as harvesting asparagus. - F&A. Discussions throughout Germany on the bottleneck of slaughterhouse capacities. As a consequence, subcontracting will be prohibited in the slaughterhouse business.
Hazelnut in Lazio	- FS. Discussions about the vulnerability of agritourism activities, which were usually assumed to be less vulnerable for external shocks compared to agricultural production activities. - FS, F&A. Wider reflection has grown at national level on the importance of having more proximity farming, as well as short food chains that better connect agricultural produce with consumers on a local or regional dimension.
Arable in Veenkoloniën	- FS. Local innovation centre notified the lack of discussions about fundamental problems.

	- F&A. Scenario thinking about the Post-covid-19 food system in the Netherlands including a scenario on adaptation ('together in the region') and transformation ('rethinking the country side'). - F&A. Letter from Ministry of Agriculture to parliament about need to reduce vulnerability of Dutch agro-food system, e.g, through more diversity, cooperation within EU markets, and entrepreneurship, and less dependence on labour migrants. - F&A. Discussions in media about the strength of short supply chains and the opportunity to further develop these in order to co-exist next to the longer and more complex chains. The crisis was eventually not used to start moving into the suggested directions.
Fruit & veg in Mazovian	- FS. Discussions about (irrational) hope among fruit and vegetable growers that high prices would prolong and will return in future extreme events. - FS. Discussions about importance of better planning, management and coordination among fruit and vegetable farmers, triggered by shortages of pesticides due to stockpiling by some farmers. - F&A. Reflections on the need to accelerate IT developments, among others at governmental level (e.g. Paying Agency and National Agricultural Support Center) to ease implementation of CAP, and at farm level to enable more use of IT systems in the field. - F&A. Recurring discussions on shortening food chains to enhance stability and food safety. - F&A. Reflections on importance of domestic production due to restricted imports in the initial period of the pandemic, and related need to further expand storage systems for vegetables and fruit. - F&A. Increased concerns about effects of climate change as impacts are expected to be more severe compared to Covid-19.
Mixed in Northeast Romania	- FS, F&A. Ongoing discussions about the vulnerability of Romanian agriculture due to lack of cooperation and poor inclusion of small farms in value chains. The rejection of cooperation is grounded in the Communist history and especially affects small-scale farms, i.e. their production volumes are quite large but due to lack of cooperation produce does not reach supermarkets. Instead, the latter prefer to import milk, dairy products, meat, vegetables and fruit. (The Covid-19 crisis was yet another occasion highlighting some negative consequences of the lack of cooperation.)
Sheep in Northeast Spain	- FS. Discussions by farmers' organizations and cooperatives about the need to improve value chain contracts to avoid price speculation and imbalances in the FS. - FS. Reflections by farmers' organizations about relatively low connectedness among farmers which hinders sectoral agreements to control production in situations of oversupply. - F&A. Public awareness about the importance of the agri-food systems and the need to support local/national producers.
Egg & broiler in South Sweden	- F&A. Public awareness about the importance of the Swedish food system in general. - F&A. Discussions about vulnerable aspects of the Swedish food system in general. This included discussions about how a full lockdown would impact the Swedish food system in general.
Arable in the East of England	- FS. Reflections about FS' weak capacity to adapt, because of its specialised nature across the supply chain and little flexibility due to long-term contracts. - F&A. Discussions and debate about the overall resilience of the food system re food security, combined with the future impact of Brexit, alongside very significant food insecurity for low income households combined with new vulnerable groups impacted by the virus. This has included discussion about the need to shorten and re-localise food chains. Part One of the National Food Strategy was rewritten to reflect Covid-19 (and Brexit). So the general discourse is very much reflective on how UK food chains need to be resilient.

ANNEX 3: Statistical analyses on revealed farm resilience (2007-2013).

	Sample			Composite indicator scores on revealed farm resilience[3]				
	NUTS 1/2/3 regions[1]	TF8/TF14 classifier[2]	Farms	Robustness (mean)	Adaptation on arable, crop & perennial farms (mean)	Adaptation on livestock farms (mean)	Adaptation on mixed farms (mean)	Transformation (proportion of transformed farms)
Dairy in Flanders	BE2	TF8 = 5	94	0.827		*0.258*		0.085
Arable in Northeast Bulgaria	BG33, BG32	TF8 = 1	104	*0.756*	**0.301**			0.067
Beef in Massif Central	FRK11	TF14 = 49	26	0.852		*0.249*		*0.000*
Arable in the Altmark	DEE0	TF14 = 80	27	0.790			*0.286*	**0.222**
Hazelnut in Lazio	ITI4	TF14 = 36	12	**0.879**	**0.428**			0.083
Arable in Veenkoloniën	NL111 , NL113, NL131, NL132	TF8 = 1	40	**0.878**	*0.286*			*0.050*
Fruit & veg in Mazovian	PL81, PL92	TF14 = 20, TF14 = 36	166	0.811	0.291			0.193
Mixed in Northeast Romania	RO2	TF8 = 8	6	*0.734*			**0.400**	**0.500**
Sheep in Northeast Spain	ES241	TF14 = 48	33	0.781		**0.367**		0.121
Egg & broiler in South Sweden	SE11, SE12, SE21, SE22, SE23	TF14= 50	57	*0.692*		**0.334**		0.123
Arable in the East of England	UKH	TF8 = 1	56	**0.910**	*0.279*			*0.036*

[1]Nomenclature of Territorial Units for Statistics (NUTS) refers to a subdivision of economic territory at 3 different levels. NUTS-regions range from NUTS1 (largest regions), over to NUTS2-regions (regions regional policies apply) to NUTS3 (smallest regions) (European Commission, 2018).
[2]TF8 classifiers refer to: 1 = field crops, 2 = horticulture, 3 = wine, 4 = other permanent crops, 5 = milk, 6 = other grazing livestock, 7 = granivores, 8 = mixed (FADN 2018). Selected TF14 classifiers refer to: 20 = specialist horticulture, 36 = specialist orchards - fruits, 48 = specialist sheep and goats, 49 = specialist cattle, 50 = specialist granivores.
[3]Following method described by Slijper et al. (2021). Scores can be compared across farming systems (not within a farming system). Top-three in bold, bottom-three in italics. For adaptation this is the top-two and bottom-two (for mixed farms: top-one, bottom-one).

ANNEX 4: Top-5 challenges identified during systematic resilience assessment[1]

Dairy in Flanders	Volatile milk prices and price drops; low availability and high price of land; extreme adverse weather events; severe and often changing regulations; changing consumer demand to less animal-based food.
Arable in Northeast Bulgaria	Constantly changing policies and legal framework; fragmented land ownership and related regulations; low soil fertility; price volatility; climate change[2]; depopulation of rural areas (ageing).
Beef in Massif Central	Increasing frequency of droughts; low profitability; difficulty to find successors; public distrust of farming practices; low quality of life and work.
Arable in the Altmark	Poor soils; increasing effects of droughts; high degree of bureaucracy; very low level of regional infrastructure (marginalized region); lack of skilled labour.
Hazelnut in Lazio	Rising social conflicts regarding impact on the environment; growing concern over downstream market power; increasing quality standards requested by the confectionary industry; bureaucratic issues causing sluggishness of Pillar 2 payments to farmers; droughts and water scarcity.
Arable in Veenkoloniën	Constantly changing policies and regulations; extreme weather events; plant diseases and plant parasitic nematodes; low economic margins.
Fruit & veg in Mazovian	Overregulation and bureaucracy; lack of long-term vision; low cooperation among farmers due to distrust; low attractiveness of rural area; labour shortage; price fluctuations; droughts.
Mixed in Northeast Romania	Poor integration in agri-food chains; dependence on off-farm income; increased frequency of extreme weather events; lack of available labour due to emigration of young people; constantly changing policies and regulations; social aid system too permissive (disincentive to work).
Sheep in Northeast Spain	Decreasing lamb meat consumption; low attractiveness of sector; low & unequal aid systems; limited access to and availability of pasture lands; lack of social services in rural areas.
Egg & broiler in South Sweden	Strict regulations; changing consumer preferences; power imbalances along value chain; lack of qualified labour; obstructing farm succession.
Arable in the East of England	Brexit and the uncertainty surrounding the UK's future market; fluctuating prices (market and input); regulation of plant protection products; labour supply; succession.

[1]Listed in random order (Reidsma et al., 2019).