

COVID-19 impacts on Flemish food supply chains and lessons for agri-food system resilience

Isabeau Coopmans^{a,b,*}, Jo Bijttebier^a, Fleur Marchand^a, Erik Mathijs^b, Lies Messely^a, Elke Rogge^a, Arthur Sanders^a, Erwin Wauters^a

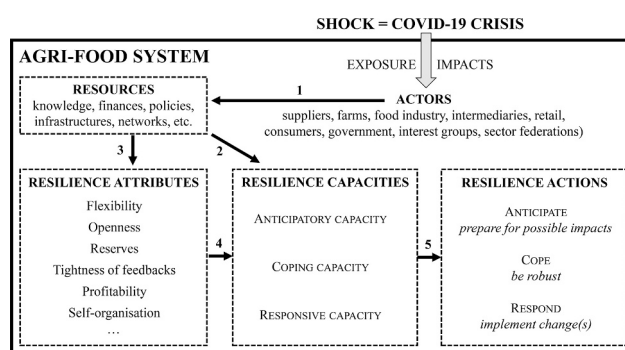
^a Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Belgium

^b Division of Bioeconomics, KU Leuven, Belgium

HIGHLIGHTS

- COVID-19 crisis imposed major challenge to agri-food systems' functioning and resilience
- We assess the resilience of Flemish food supply chain actors to COVID-19 by focussing on impacts and resilience actions
- Impacts of and resilience actions to COVID-19 varied extensively across different firms and agricultural sectors
- Overall, Flemish agri-food system's ability to provide food was not impaired by COVID-19
- Higher resilience capacities could be due to resilience attributes diversity, flexibility, openness, and self-organisation

GRAPHICAL ABSTRACT



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ABSTRACT

Context: Resilience represents the ability of systems to anticipate, withstand, or adapt to challenges. Times of great stress and disturbance offer opportunity to identify and confirm key contributors to agri-food system resilience. The COVID-19 pandemic and its related consequences constituted major shock, challenging the resilience of many agri-food systems worldwide.

Objective: This paper aimed to report the immediate effects of the COVID-19 crisis on various key actors from Flemish food supply chains. By analysing and assessing the observed impacts of and reactions to this crisis from a resilience perspective, it also aimed to gain empirical evidence on resilience-enhancing characteristics of agri-food systems to sudden shocks.

Methods: A first, quantitative step of our mixed method approach measured 718 farmers' experienced impacts and applied strategies following the crisis through an online survey. A second, qualitative step captured impacts and responses from other key actors downstream the food supply chain through 22 in-depth interviews and 18 on-line questionnaires. Data gathering and interpretation followed a conceptual framework for analysing resilience of agri-food systems to external challenges, that we developed based on the literature. The framework states that resilience actions stem from three types of resilience capacities: anticipatory, coping and responsive

* Corresponding author at: Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Belgium.

E-mail addresses: isabeau.coopmans@ilvo.vlaanderen.be, isabeau.coopmans@kuleuven.be (I. Coopmans).

capacities. These are determined by both resources allocated by system actors, as well as by resilience attributes from the system.

Results and conclusions: The COVID-19 crisis induced a simultaneous dropped demand for food products in the hospitality industry and risen demand in retail. This shifted demand significantly disturbed food production, processing and marketing processes in terms of labour organization, planning, operation, logistics, and economic returns. Perceived impacts varied extensively across actors from the agri-food system, mostly depending on their marketing strategy, customer base, and flexibility and diversity of their practices. Reported reactions to this crisis revealed that resilience capacities varied according to actors' abilities to negotiate prices, adjust production processes, and maintain or reorient sales. Some agri-food sectors showed higher responsive capacity because of a higher connectivity and self-organization within the system.

Significance: Our findings suggest that flexibility and diversity, despite their tendency to diminish price optimums, increase resilience capacities, which may be more beneficial to systems for thriving in turbulent and uncertain environments. A more tangible, operationalized understanding of resilience is necessary to effectively improve agri-food system resilience. Our conceptual framework proved a valuable tool for operationalizing resilience assessments to major shocks.

1. Introduction

In recent decades, agri-food systems are under increasing pressure due to complex interactions of multiple stresses and disruptions, which challenge the maintenance of qualitative and affordable food production while creating viable incomes for those working in the sector (Hodbold and Eakin, 2015; Bullock et al., 2017; Meuwissen et al., 2019; United Nations, 2020; European Commission, 2020; Tendall et al., 2015). On top of these existing challenges, the recent COVID-19 pandemic caused extensive consequences for many actors involved in the agri-food system, constituting another major challenge (European Commission, 2020). COVID-19 is an infectious respiratory disease which spreads through a so-called airborne transmission and causes high infection rates (Karia et al., 2020; Rothan and Byrareddy, 2020). Strategies for preventing transmission include minimising physical contacts, social distancing (i.e., keep physical distance of at least 1.5 m), quarantining infected individuals, wearing face masks, and ensuring proper hand hygiene. Mandatory lockdowns introduced for managing the COVID-19 crisis significantly impacted society worldwide (trade, social events, airline industry, etc.).

Amongst others, the COVID-19 measure to close restaurants and (food) markets in many countries changed demand for food products and caused other indirect effects, which drastically disrupted the global agri-food system (Stephens et al., 2020, this issue). Consequently, this

crisis further intensified the debate about the resilience of global and local agri-food systems. In the search for a transition towards resilient food supply chains that meet the United Nations' Sustainable Development Goals, learning from how agri-food systems have (not) been able to swiftly and appropriately react to shocks can generate helpful insights. In this paper, we study the case of Flanders (the northern part of Belgium) to complement the already existing literature on the impact of COVID-19 on agri-food system resilience, which has, at the time of writing, mainly focussed on developing countries (see e.g., Béné, 2020; Paganini et al., 2020; Sukhwani et al., 2020).

Resilience is a useful yet abstract concept. It has applications in various disciplines, such as psychology and ecology, and researchers have used various definitions to build their resilience-investigative framework (good overviews can be consulted in Bhamra et al., 2011 and Kamalahmadi and Parast, 2016). In this paper, we build on definitions used in literature on social-ecological systems (SES), wherein resilience consistently refers to a system's ability to either withstand, absorb, or appropriately respond to disruptions (Carpenter et al., 2001; Folke et al., 2010; Meuwissen et al., 2019). Despite having profound theoretical foundations, the literature generally lacks empirical research demonstrating how resilience could be improved (Bhamra et al., 2011). Evidence-based insights on what really contributes to resilience are needed; and times of great stress and disturbance offer an opportunity to better understand this latent construct. In this paper, we aim to assess

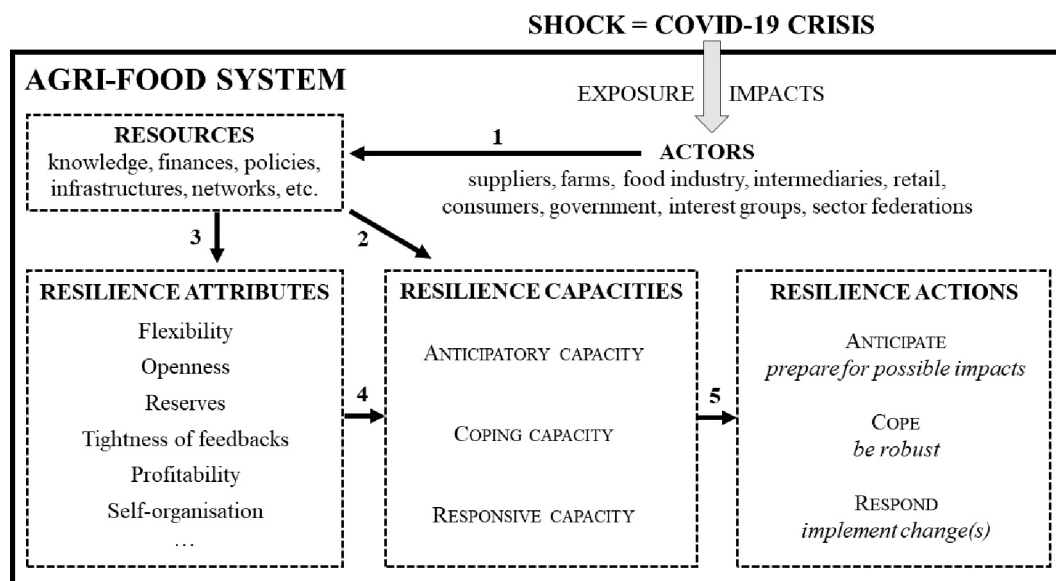


Fig. 1. Conceptual framework for assessing the resilience of the Flemish agri-food system to the COVID-19 shock (based on Mathijs and Wauters, 2020; and Meuwissen et al., 2019).

the resilience of the Flemish agri-food system in the light of the early unfolding of the COVID-19 pandemic, by studying the immediate impacts of and reactions to the COVID-19 crisis across various actors amongst the Flemish agri-food chain. The remaining of this section further specifies this research aim, by explaining the conceptual framework that guided our investigative approach and clarifying the timeframe of interest.

1.1. Assessing resilience by distinguishing its building blocks

The building blocks for our interpretation of the resilience of the Flemish agri-food system to the COVID-19 crisis were adapted from Mathijs and Wauters (2020), who proposed a framework for improving resilience of farming systems. We have used their fundamental deconstruction of resilience contributors as a source of inspiration to build an analytical lens for understanding demonstrated (non-)resilience of the Flemish agri-food system in the face of the COVID-19 shock. This analytical lens is presented in Fig. 1 and explained hereafter.

If exposed to (particular effects of) the COVID-19 crisis, actors from the agri-food system may experience certain *impacts*. These may urge them to perform certain *resilience actions*, which are determined by the *resources*, the *resilience attributes*, and *resilience capacities* of the system. We can distinguish three types of resilience actions: (1) *anticipation* to possible adverse consequences of the crisis, (2) *coping* with the impacts by exploiting available resources and existing capacities, but without needing to implement large changes, and (3) *responding* to impacts by implementing innovations or adapting former practices. We assume that for some specific effects of the crisis, a tailored resilience action suffices to appropriately attack the issue. For example, firms can work harder to deliver more output in case demand for a certain food product increases, which is coping. In other cases, more than one resilience action might be needed, for example to deal effectively with the COVID-19 crisis as a whole. Resilience actions can only be conducted if *resilience capacities* are present and mobilized within the system (arrow 5 in Fig. 1). In accordance with the resilience actions, we define three resilience capacities. First, *anticipatory capacity* refers to the ability to detect

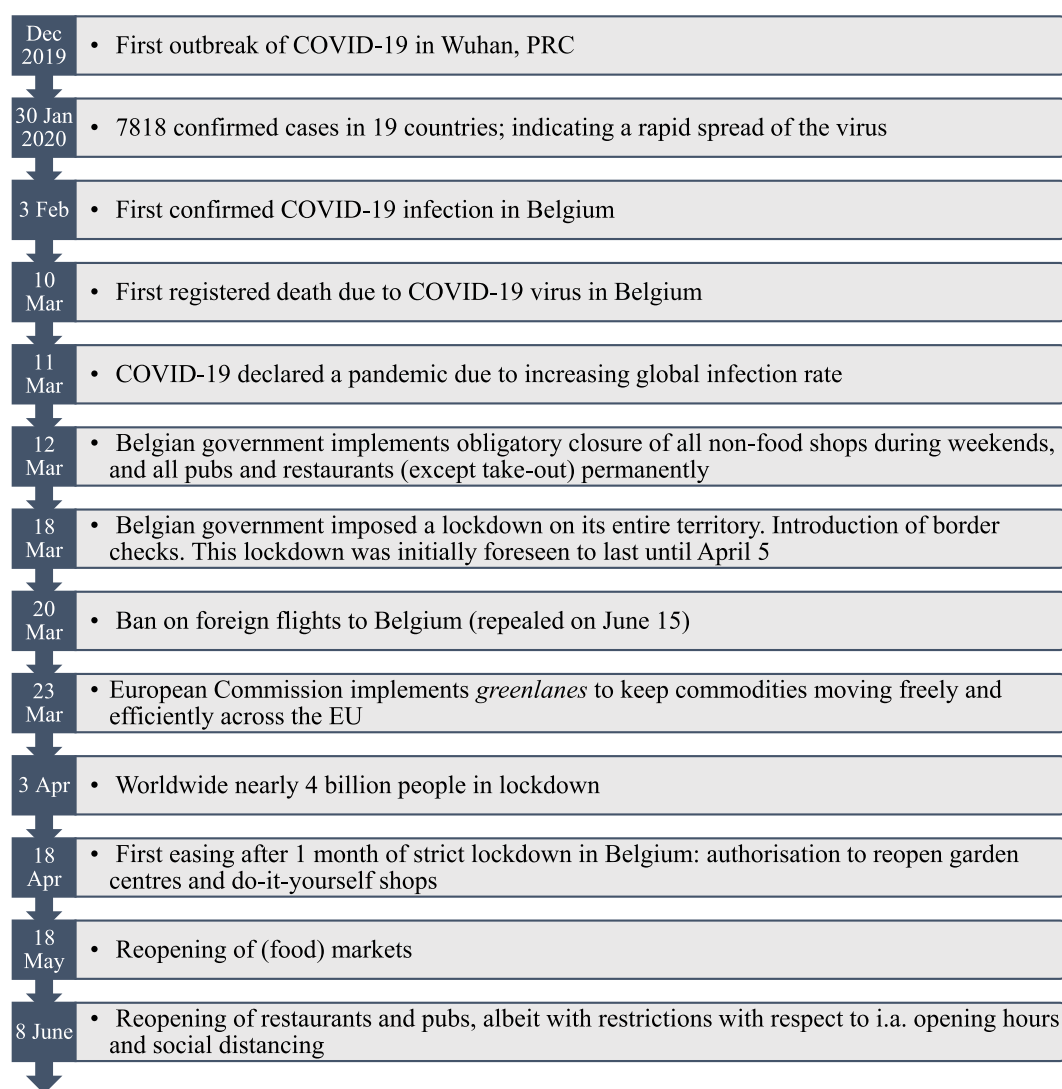


Fig. 2. Timeline of COVID-19 induced events and measures of relevance to the agri-food sector during end of January 2020 - half of June 2020 (EC, 2020; Euronews, 2020; Sun et al., 2020; WHO, 2020).

potential critical impacts from COVID-19 that might adversely affect actors' performances. Second, *coping capacity* indicates whether actors are able to cope with impacts, i.e., keep their functioning and produce of outputs at adequate levels, without having to change a lot. In other words, actors with high coping capacity are robust to (certain) consequences of the COVID-19 crisis. Third, *responsive capacity* reflects the ease with which actors can implement changes to keep performing well under changing circumstances, mostly when coping does not suffice. Such changes can be incremental (adaptions) or radical (transformations). The three resilience capacities can be reinforced by actors from the agri-food system, as they put resources into the system (arrow 1), which can be either a direct investment in the resilience capacities (arrow 2) or form an indirect contribution by strengthening resilience attributes (arrows 3 and 4). *Resources* can take on different forms. Financial resources allow firms to set aside a financial buffer to deal with unexpected events. But physical infrastructure and cognitive resources - such as knowledge, networks, and social capital - are equally important contributors to both resilience capacities and attributes. *Resilience attributes* are the system characteristics that affect the resilience capacities of the agri-food system (arrow 4). Resilience attributes can be inherent features of the system or its components, but they can also relate to certain dynamics within the system. For example, flexibility is a widely recognized resilience attribute, as it is associated with risk spreading and by definition increases coping and responsive capacities. More examples of resilience attributes can be found in the literature, see e.g. Cabell and Oelofse, 2012.

This conceptual framework guided our resilience assessment as follows. First of all, we evaluated to what extent different actors from the Flemish agri-food system were exposed to the consequences of the COVID-19 crisis, and, related to this *exposure*, we studied the different experienced *impacts*. Subsequently, we examined the *resources* used by, and, consequently, *resilience actions* performed by different actors of the agri-food system to deal with this crisis. Based on these findings, we then identified *resilience attributes* that enhanced or constrained the *resilience capacities* used. Overall, we investigated how these impacts of and reactions to the crisis affected the functioning of the agri-food system and the delivery of its outputs (i.e., the production of food and the processing and distribution of it to the consumer).

1.2. Time scope of the resilience assessment

We interpreted the COVID-19 crisis as a sudden and unforeseen shock, and were interested in the period just before and the first three months after the Belgian government imposed a national lockdown. The events and consequences triggered by the crisis of relevance to the agri-food system are chronologically summarized in Fig. 2. The lockdown entailed confinement for all: people were only allowed to leave their house for essential movements like buying food and medicines, or to commute if employed in an essential sector such as health care. All non-essential shops, schools, sports infrastructure, (food) markets (even in open air), and so forth, were closed. Working from home was obliged wherever possible. To mitigate the spreading of the virus, people were urged to comply with the safety measures (e.g. social distancing, maintaining hand hygiene, avoiding contact with people from outside the household as much as possible). Border checks on non-essential movements to and from Belgium, but also in other EU Member States, caused delays in transportation of (essential) goods. In response to this, the European Commission issued practical advice on the implementation of 'green lanes' to open border crossings to all freight vehicles carrying goods, stating that any checks or health screenings should not exceed 15 min. Member states were thus supposed to ensure the seamless free movement of goods across the Single Market (EC, 2020).

The remainder of this paper is structured as follows. The next section explains our mixed method approach, consisting of a large-scale farmers survey and in-depth interviews with other actors from the Flemish agri-food system. Then, the results section presents self-reported impacts

from the crisis and allocated resources as reactions to the crisis, first for farmers, then for the other key actors downstream the food supply chain. In the discussion, we develop a better understanding around these reported impacts and resources mobilized, by linking them to the conceptual framework while taking into account the specifics of this particular shock. Finally, implications and lessons learnt about agri-food system resilience are summarized in the conclusion.

2. Methods and materials

2.1. Overall procedure

A time-efficient approach was required to be able to capture the immediate impacts of the COVID-19 crisis. At the time, media coverages strongly suggested that both farmers and food processors were amongst the most impacted actors (VILT, 2020b; Landbouwleven, 2020b; Landbouwleven, 2020a). These actors were therefore prioritized to constitute a largest share in our total sample of informants. To achieve data able to provide a comprehensive view on the direct effects of the crisis in various links and sectors of the food supply chain, we conducted a mixed method approach. We started with collecting farmer's early experiences regarding impacts of and strategies in reaction to the crisis through an online survey, which was widely spread by different gatekeepers to reach as many Flemish farmers as possible. Then, this quantitative dataset was complemented with qualitative data from in-depth interviews with other key actors from the agri-food system.

Both the survey and the interviews were organized, performed, and analysed in a way that ensured targeted and appropriate information gathering to fulfil the research purpose, based on the conceptual framework presented in Section 1.1. As annexes 1 and 2 illustrate, this implied centralising four research aims (RAs). First, gaining an extensive insight in the *impacts* induced by the COVID-19 crisis, by also evaluating the degree of *exposure* to challenges caused by this shock (RA1). Second, assessing whether and how *resilience capacities* were available and utilized to deal with the crisis, by investigating what *resources* were used in crisis responses (RA2). Third, exploring the link between certain impacts of and reactions to the crisis on the one hand, and the presence or absence of certain *resilience attributes* on the other hand (RA3). In the formulations of the questions asked to respondents, attention was paid to different levels of analysis, i.e. individual firms, different farming or food sectors, different links of the value chain, and finally system level (RA4).

2.2. Data collection and analysis

2.2.1. Farmers' questionnaire

The aim of the survey was firstly to assess how the COVID-19 crisis impacted farmers from a business perspective, and secondly, to assess whether farmers resorted to available resilience capacities. The concepts of the conceptual framework were translated into concrete and rateable questions, presented in Annex 1, along with their respective format and scales. The survey consisted of three sections. The first section concerned general farm characteristics, such as agricultural specialization and main marketing channels and served as valuable input for solving RA3. The second section gauged farmers' perceived impacts of the crisis at the farm level, thus corresponding to RA1. Farmers were first asked to rate the overall impact of the COVID-19 crisis on a scale from 1 (very negative) to 5 (very positive). Thereafter, three questions aimed at capturing farmers' perceived impact on revenue (i.e., in general, on sales, and on prices), all answered on a scale from 1 (much lower than usual) to 5 (much higher than usual). Also the impact on overall management was measured with questions concerning the impacts on prices and availability of farm inputs, namely materials and permanent and seasonal labour, and the difficulty to comply with lockdown and safety regulations, again all on a 5 point Likert scale. The third section of the survey focussed on how farmers reacted to the crisis, i.e., through coping

Table 1

Summary statistics of the farmers survey sample (n = 718). If publically available, figures are also given for population level.

Characteristic	Sample*	Population**
Age (years)		
Average age (std.dev.)	49.90 (10.33)	54
≤40	18.80%	9.74%
41–50	28.55%	23.84%
51–60	39.83%	38.52%
>60	12.81%	27.90%
Sex		
Female	28.61%	11.64%
Male	71.39%	88.36%
Farm Type		
Organic farm	2.79%	2.20%
Farm with some degree of short supply chain marketing	17.55%	15.00%
Farm with some degree of processing activities	4.87%	
Farm with some degree of broadening activities	9.33%	
Farming sector		
Crop farming (arable, horticulture, perennials, or combinations)	22.84%	27.39%
Livestock farming	49.30%	49.51%
Dairy, beef, sheep, or goats	34.40%	33.71%
Pigs, poultry, or rabbits	9.75%	11.70%
Combinations of livestock	5.15%	4.10%
Mixed farming	27.02%	11.18%
Other farms	0.84%	
Business stage		
Starting up	4.32%	
Established and growing	25.77%	
Established and stable	49.72%	
Established and shrinking	5.43%	
Preparing takeover	7.24%	
Winding down for retirement	7.52%	

* Percentages are corrected to account for non-responses.

** Source: (Departement Landbouw en Visserij, 2020b).

or responsive strategies, thus corresponds to RA2 (anticipatory actions were not measured, since we assumed there could not have been a way for farmers to perform a targeted preparation for such an unforeseen, society-wide shock). Here, farmers had to indicate which concrete actions they did (or did not) implement. Some final questions probed how the crisis affected long-term intentions regarding farm management and continuity.

The online survey was administered in April–May 2020, almost entirely coinciding with the national lockdown period. Various gatekeepers, such as cooperatives, farmers' organizations, banks and advisors were asked to forward the survey amongst their networks of farmers. Additionally, the survey was announced through social media platforms, newsletters and websites. This resulted in an initial sample of 1095 responses, which was reduced to 718 after omitting incomplete or unreliable observations. The final sample thus covered about 3% of the total population of 23,318 Flemish farms (Statistiek Vlaanderen, 2019). As the total number of addressed farmers is unclear, an exact response rate could not be calculated. Some potential biases prevent claims for perfect representativeness, but were inevitable and stem from the different intensity (with or without incentive) with which the distributing organizations motivated their members to fill in a questionnaire. However, given the targeted distribution method and the resulting sample size and statistics (see Table 1), we consider the sample to be suitable for evaluating the impact of the COVID-19 crisis on professional agriculture in Flanders. Basic descriptive and inferential statistics were performed to analyse the survey data using STATA software.

2.2.2. In-depth interviews with key actors from the agri-food system

To interrogate targeted supply chain actors for obtaining additional insights into the various effects and reactions triggered by the COVID-19 crisis, an interview outline (Annex 2) was set up. This outline focussed

concrete points of attention related to the conceptual framework and also ensured consistency as the interviews were performed by different researchers. Its basic structure was organized in three sections: (1) requesting information about the potential and actual *impacts* of the crisis for individual companies and for the supply chain as a whole (RA1 and RA4); (2) asking for information on how the companies/sectors dealt with these experienced impacts and consequences, more specifically, to get insight into the *resources* available and used, for evaluating whether resilience capacities were present and executable (RA2); and (3) requesting information about *resilience attributes* (i.e., system features and dynamics) that enabled the resilience of (a specific segment of) the Flemish agri-food chain against this shock (RA3 and RA4).

Stakeholders from the agri-food chain were purposively and personally addressed by the researchers. An important criterion for selecting candidates was to obtain a sample of stakeholders who had knowledge of the supply chains of potatoes, pork, dairy, vegetables, and fruit, since these are important sectors in Flanders (Platteau et al., 2018) and initial media reports suggested they experienced severe immediate impacts (De Samber, 2021; Van Fleteren, 2020; VILT, 2020c; De Roo, 2020; Landbouwleven, 2020b). However, the content of the conversations was not limited to these sectors, as the aim of the study was to obtain an comprehensive view on the impact of and reactions to the COVID-19 crisis in the entire Flemish agri-food system. Between end of June – end of August 2020, 22 in-depth interviews were conducted by four researchers, each lasting 40 to 90 min. According to the preference of the interviewee, some face-to-face conversations took place, one telephone call, but online video calling was the most commonly used interview method since COVID-19 restrictions were still in place. In addition, 18 respondents took an online survey with the same open-ended questions. These written answers were of course less comprehensive, but it was an efficient way to achieve confirmations on the themes discussed during the interactive conversations. Data saturation was reached for all links in the agri-food chain, except for the retail sector. They showed little interest in participating and only two respondents were interviewed, hence data saturation for this group cannot be ensured. The resulting sample of 40 respondents mostly consisted of informants with key roles in the main sector federations and companies of the industries between the farmer and retailer.

All interviews were recorded and afterwards re-listened by four researchers, during which they made notes, summarized information, and transcribed the most important fragments. In this way, a list of main themes that arose from the data was obtained and discussed amongst these researchers. The written summaries of the interviews with sections of paraphrasing and of more strict transcripts were then manually coded and analysed in a structural way, following the conceptual framework presented in Section 1.1. and the RA's extracted from it.

3. Results

3.1. Farmers' survey

3.1.1. Sample description

The summary statistics of the final sample are presented in Table 1. Where possible, figures are given for the whole population of farmers in Flanders.

3.1.2. Flemish farmers' self-reported impacts of the COVID-19 crisis

Regarding the overall impact of the crisis, 61% of the surveyed farmers experienced a negative to very negative impact. Regarding economic impact, 71% indicated a moderate or severe loss in revenue. This seemed more because of a drop in price and less because of a drop in sales volume: 72% reported lower output prices, while 38% indicated a decreased sales volume. On top of that, one in two farmers indicated increased input prices. Consequently, more than one third (36%) reported liquidity problems, being unable to pay invoices and/or rent. In Table 2 we disaggregated these main (economic) impacts according to

Table 2

Farmers' perceived impact of COVID-19 in general, on revenue, on sales volumes, and on prices received. Rating was done on a 5-point Likert scale (1 = very negative/much lower than usual; 5 = very positive/much higher than usual). Results are shown for the entire sample and for three distinguishable groups in terms of marketing channels: (1) farmers selling all their produce to wholesalers; (2) farmers selling through both wholesale and (an) alternative sales channel(s); and (3) farmers only using (an) alternative sales channel(s). Kruskal-Wallis test results indicate whether there is a statistically significant difference in perceived impacts between the three groups of farmers.

		Whole sample (n = 718)		Only wholesale (n = 542)		Combination of wholesale and alternative sale channels (n = 66)		Only alternative sale channels (n = 101)		Kruskal-Wallis μ (mean rank impact scores) χ^2 (df) p
		Percent*	Cum. Percent	Percent*	Cum. Percent	Percent*	Cum. Percent	Percent*	Cum. Percent	
Overall impact	1	22.44	22.44	23.75	23.75	21.54	21.54	14.85	14.85	$\mu_1 = 334.38$
	2	38.15	60.59	41.37	65.12	32.31	53.85	24.75	39.60	$\mu_2 = 386.46$
	3	32.40	92.99	30.61	95.73	27.69	81.54	45.54	85.15	$\mu_3 = 430.83$
	4	5.33	98.32	2.60	98.33	15.38	96.92	13.86	99.01	23.370 (2)
	5	1.68	100.00	1.67	100.00	3.08	100.00	0.99	100.00	0.0001**
Revenue	1	37.34	37.34	40.71	40.71	36.51	36.51	19.39	19.39	$\mu_1 = 326.86$
	2	33.52	70.86	36.43	77.14	28.57	65.08	22.45	41.84	$\mu_2 = 370.13$
	3	19.52	90.38	16.91	94.05	17.46	82.54	32.65	74.49	$\mu_3 = 464.10$
	4	5.80	96.18	2.97	97.03	12.70	95.24	17.35	91.84	43.206 (2)
	5	1.70	97.88	1.30	98.33	3.17	98.41	3.06	94.90	0.0001**
Sales	NA	2.12	100.00	1.67	100.00	1.59	100.00	5.10	100.00	
	1	16.64	16.64	16.98	16.98	19.05	19.05	13.54	13.54	$\mu_1 = 343.56$
	2	21.38	38.02	20.57	37.55	25.40	44.44	21.88	35.42	$\mu_2 = 316.48$
	3	35.29	73.31	38.30	75.85	28.57	73.02	26.04	61.46	$\mu_3 = 371.65$
	4	7.03	80.34	3.77	79.62	20.63	93.65	16.67	78.13	3.254 (2)
Output prices	5	2.15	82.50	1.32	80.94	3.17	96.83	6.25	84.38	0.1965
	NA	17.50	100.00	19.06	100.00	3.17	100.00	15.63	100.00	
	1	45.48	45.48	52.04	52.04	28.57	28.57	19.39	19.39	$\mu_1 = 320.01$
	2	26.84	72.32	27.70	79.74	28.57	57.14	21.43	40.82	$\mu_2 = 414.32$
	3	18.79	91.10	12.64	92.38	34.92	92.06	42.86	83.67	$\mu_3 = 473.28$
	4	4.10	95.20	2.97	95.35	7.94	100.00	8.16	91.84	62.225 (2)
	5	1.27	96.47	1.67	97.03	00.00	100.00	0.00	91.84	0.0001**
	NA	3.53	100.00	2.97	100.00	00.00	100.00	8.16	100.00	

* Percentages are corrected to account for non-responses.

** Groups are significantly different ($p < 0.01$).

marketing channels used, distinguishing farmers selling all of their produce to wholesalers (type 1 = wholesale farmers), farmers combining sales in the wholesale trade with (an) alternative sale channel(s) in the short supply chain (SSC) (type 2 = wholesale+SSC farmers), and farmers solely marketing through (an) alternative sale channel(s) in the SSC (type 3 = SSC farmers). Alternative channels in the SSC can be, i.e., direct sales to local restaurants, through third parties, in on-farm shops, via web stores, or on food markets (see Annex 1).

Table 2 shows that type 2 and 3 farmers consequently report less negative economic effects, and this tendency of less negative impacts is stronger for type 3 (SSC farmers) than type 2 farmers (wholesale + SSC farmers), i.e., when only the alternative channels are used. Only for sales figures was this trend not so pronounced, and indeed the Kruskal-Wallis test confirmed a significant difference only for the overall impact and economic indicators revenue and output prices. Conversely, whereas wholesale farmers are very unlikely to report positive effects, substantial shares of SSC farmers, as well as wholesale + SSC farmers experienced an overall positive impact, probably resulting from increased sales and therefore revenue. In addition, farmers active in the SSC seemed better able to keep prices at normal levels: only 41% of SSC farmers reported lower prices, against 57% of wholesale+SSC farmers and 80% of wholesale farmers, respectively. Our data thus indicate that the success of short supply chains, which was at the time fiercely promoted in the media (e.g. [Renson, 2020](#); [Vander Gracht and Bernolet, 2020](#); [VILT, 2020a](#)), was mainly resulting from a better ability to control output prices, and in some cases combined with a sales spike. Relating to this media attention that also more broadly put the merits of farmers in the picture, we found that almost one third of the sampled farmers perceived a higher societal appreciation towards farming, which was also a recurring theme in answers on the open ended question at the end of the survey. Nonetheless, the self-reported situation was still relatively negative for type 2 and 3 farmers (e.g. shares of farmers reporting negative impacts fluctuate around 40% or more, depending on the economic indicator of interest). zA Analysing these figures in deeper

detail revealed a large heterogeneity in impacts experienced by SSC farmers, which can be explained by the diversity of marketing channels that type 2 and 3 farmers use, and the specific combination of several of these channels and also wholesale in the case of type 2 farmers – and the difference with which these were affected by the lockdown measures. To illustrate, while sales at the farms mostly increased, the farms mainly supplying to restaurants or industrial kitchens were thwarted by the lockdown.

It should be noted that one fifth of the wholesale farmers designated the 'not applicable' option to the sales impact, which probably has to do with their production cycle, for instance, apple and pear farmers were still months away from harvesting period when participating in the survey. The same holds for arable farmers, whose harvest from the previous year was sold while current crops were growing or just being sowed. Besides this, the variety of marketing systems in the most common supply chains explains why some farmers were unable at the time being to evaluate the impact of the crisis on their revenue.

Also the measured impact on labour was substantial, 35% of the farmers who rely on hired labour ($n = 158$) reported a lower attendance of their permanent employees, while 11% of them reported a higher attendance. Similarly, 55% of the farmers who rely on seasonal labour ($n = 141$) reported a lower availability of seasonal workers, while 10% of them reported an increased availability. By way of contrast, 26% of the farms where family members provide labour ($n = 412$) were more likely to report an increased availability of family labour.

Perceived impacts also varied according to the farm's business stage. Two types of farms can be distinguished: (1) developing farms, where farmers are supposed to (plan to) invest in farm development, i.e., farmers starting up, preparing farm take-over, or running growing farm businesses; and (2) stagnating farms, where farmers are assumed to have ceased intensive investments, i.e., farmers preparing to retire, or not foreseeing to increase farm size, or even actively diminishing farm size. From the farmers running developing farms, 65% indicated to worry more about the future of their farm since the COVID-19 crisis, compared

Table 3

Number (and relative shares) of farmers applying strategies in reaction to the COVID-19 crisis. The last column shows the Chi-square or Fisher's exact test results, which indicate whether farmers who reported a negative overall impact of the COVID-19 crisis were more likely to apply certain strategies compared to farmers who reported an overall neutral or positive impact.

Strategies	Full sample (n = 713)	Negative impact (n = 432)	Neutral or positive impact (n = 281)	$\chi^2(df; p)$
Governmental instruments				
Apply for temporary unemployment for my staff	17 (2.38)	10 (2.31)	7 (2.49)	0.0304(1); 0.862
Apply for bridging loans at the bank**	41 (5.71)	37 (8.56)	4 (1.42)	16.0208(1); 0.000
Apply for the one-off corona compensation premium which compensates loss in turnover*	33 (4.63)	26 (6.02)	7 (2.49)	4.7992(1); 0.028
Apply for the one-off nuisance premium which compensates the (partial) closure of a business	35 (4.91)	26 (6.02)	9 (3.20)	2.8917(1); 0.089
Apply for the emergency fund**	13 (1.82)	13 (3.01)	0 (0.00)	0.002***
Use the VLIF ¹ guarantee scheme for bridging loans	11 (1.54)	7 (1.62)	4 (1.42)	1.000***
Strategies relating to financial stress				
Request delay of repayment from bank**	76 (10.66)	59 (13.66)	17 (6.05)	10.3471(1); 0.001
Request delay of payment of invoices**	69 (9.68)	58 (13.43)	11 (3.91)	17.6209(1); 0.000
Tap into own financial reserves**	368 (51.61)	284 (65.74)	84 (29.89)	87.6053(1); 0.000
Save costs**	335 (46.98)	247 (57.18)	88 (31.32)	45.7060(1); 0.000
Search other marketing channels for (part of) my products	57 (7.99)	38 (8.80)	19 (6.76)	0.9583(1); 0.328
Strategies relating to managerial stress				
Adjust my cultivation plan	87 (12.20)	55 (12.73)	32 (11.39)	0.2869(1); 0.592
(Temporarily) cease certain activities*	73 (10.24)	53 (12.27)	20 (7.12)	4.9156(1); 0.027
Temporarily employ those who are in technical unemployment or (bridge) pension	9 (1.26)	6 (1.39)	3 (1.07)	1.000***
Use volunteers to help with the farm work	30 (4.21)	16 (3.70)	14 (4.98)	0.6905(1); 0.406
Work harder**	335 (46.98)	235 (54.40)	100 (35.59)	24.1860(1); 0.000
Change supplier(s)	21 (2.95)	13 (3.01)	8 (2.85)	0.0157(1); 0.900
No need to adjust or do anything**	184 (25.81)	62 (14.35)	122 (43.42)	75.1160(1); 0.000
Strategies affecting long-term farm management				
Postpone planned investments**	247 (34.64)	185 (42.82)	62 (22.06)	32.4080(1); 0.000
Considering to radically change farm management (e.g. other products or marketing channels)	39 (5.47)	22 (5.09)	17 (6.05)	0.3017(1); 0.583
Considering early termination of farm business**	53 (7.43)	43 (9.95)	10 (3.56)	10.1190(1); 0.001
This crisis has confirmed to me that my future plans for my farm are well founded**	123 (17.25)	53 (12.27)	70 (24.91)	19.0629(1); 0.000

* Groups are significantly different ($p < 0.05$).

** Groups are significantly different ($p < 0.01$).

*** When Chi-square test assumption of expected frequencies ≥ 5 is violated, Fisher's exact test is performed, which has no test statistic but only computes the p-value.

¹ Vlaams LandbouwInvesteringsFonds: The Flemish investment subsidy policy instrument.

to half of the farmers running stagnating farms. In line with this, 70% of the developing farmers reported a general negative impact, compared to 55% of the stagnating farms.

3.1.3. Flemish farmers' self-reported reactions to the COVID-19 crisis

Focussing on the full sample of farmers in Table 3, a large share of the strategies listed to the surveyed farmers as possible targeted methods to deal with aversive consequences were not abundantly applied. It is noteworthy that, at the time of completing the survey, governmental instruments to mitigate socio-economic impacts from the crisis were only applied by a small minority of farmers (always less than 6%). However, such seemingly low uptake does not necessarily reflect inadequate state intervention. Indeed, the aim of the government was to support those farms affected by this crisis, in a targeted way, which translated into such support measures made available for entire sectors (e.g. floriculture and potato growers) or for farms fulfilling certain conditions, such as running a farm terrace (VLAIO, 2020). Strategies to diminish financial damage could also relate farmers' own resources. One in ten farmers of the full sample requested postponement of repayment from the bank or asked their suppliers if they could agree on a deferment of payments. Against this, for each strategy of the list that might affect personal or even farm household wellbeing, i.e. working harder, saving costs, and drawing on own financial reserves, around half of the farmers gives an affirmative answer. Regarding operational farm management, one out of 10 indicated to have ceased or planning to (temporarily) cease certain activities, and a bit more adjusted their cultivation plan in reaction to the crisis. Almost 35% had to postpone planned investments, indicating that the crisis interrupted the development of many farms.

Table 3 also disentangles the self-reported coping/responsive strategies according to how farmers had rated the overall impact they experienced from the COVID-19 crisis. We distinguished farmers who reported a clearly negative impact and farmers who reported a neutral or

even positive impact. Chi-square test results indicate statistically significant differences between these two groups of farmers for seven strategies aiming at easing financial stresses (either through governmental support of by exploiting on-farm reserves), and for six strategies relating to operational and strategic management. Negatively impacted farmers were much more likely to rely upon governmental instruments and to adjust their own financial management, by drawing on private buffers or by implementing changes in payment arrangements. In addition, they were more likely to cease certain activities, which could have been the reason for their perceived negative impact. Similarly, a higher share of the negatively impacted farmers fears adverse long-term consequences for their farm or even early termination of their farm. In contrast, these farmers were significantly less likely to indicate that they did not have to adjust anything in reaction to the crisis, and to state the crisis confirmed their conviction of doing the right thing.

Additionally to applying strategies in reaction to the crisis, also other aspects of the crisis were examined. For example, not many farmers have struggled with implementing the sanitary measures on their farms. About 55% declared not to be hindered by them, while 17% experienced difficulties to stick to them. One third indicated to find solutions to their experienced problems resulting from the crisis, but an equally large group did not smoothly succeed herein. Irrespective of the fact whether they experienced major problems, the share of farmers who indicated to lack knowledge about where to find advice or help (about 40%) was larger than the share of farmers who declared to know where to turn (about 30%).

3.2. Interviews with actors from the agri-food chain

3.2.1. COVID-19 impacts throughout the Flemish food supply chain

There was a reported short term increased demand for certain food products due to hoarding behaviour of consumers at supermarkets from

the end of February to mid-March. This caused acute retail sales spikes in many food categories, especially for non-perishable foods. At some point, for some products empty shelves and temporary stock outs occurred due to logistical problems and lack of capacity of the suppliers and distribution centres. According to the interviewees, the main bottleneck to meet this sudden high demand and collective stockpiling (both by consumers and distributing agents throughout the chain) was the limited number of trucks and drivers. Most of these increased retail sales were acute and temporary, however, for highly perishable foods such as fruit and vegetables, they persisted during April–May.

Testimonies clearly indicated a simultaneous breakdown of demand for specific products used in hospitality industry. This sharp contrast for a lower general demand for (niche) products was explained by the fact that people typically consume such products (examples are veal, micro vegetables, and fried foods) in restaurants rather than at home. In few sectors, like fresh fruits and vegetables, the decreased demand in the hospitality industry was generally compensated by the increased demand in retail. However, in most sectors, it was indicated that the increased demand for retail items was largely undone by a national (and global) decreased demand in the food services and hospitality industry. It was reported that disturbed demand equilibrium also entailed a change in type of products demanded (e.g., more liquid milk versus less milk powder), and in type of packaging (e.g., more small-sized packages). For dairy, meat and potatoes, large volume shares are often destined for the hospitality industry, and moreover, these products typically generate higher added value compared to products going to retailers (e.g. cream vs. milk, pork tenderloin vs. minced meat, or bulk vs. French-fried potatoes).

As a result, firms seem to be impacted according to the ratio market share for retail versus market share for hospitality industry: the more specialized into the latter, the more negatively impacted. In the Flemish food industries there is a considerable amount of companies targeting hospitality industry as only customer type, while only few focus exclusively on retail. Nonetheless, respondents representing such companies with a significant amount of market share in the retail nuanced the positive effect of their customers' stockpiling because of two main reasons. First, some respondents explained that the increased demand especially occurred for store brands (retailers' private label), which are typically the lower cost alternative for the consumer, meaning the food processors get less added value from such products compared to the so-called A-brand product. Therefore, the increase in volumes sold did not coincide with an equivalent increase in revenue. Second, the sudden promotion ban imposed by the government was often detrimental to the food processors; because they had already sold to retailers at a promotional price, or because they had to throw away products already prepared in promotion packages.

In addition, border closures temporarily eliminated markets across the EU and beyond or caused logistical problems, resulting in a globally decreased availability of (and thus higher costs for) shipping containers. The reported effect of this was twofold. First, it caused a decreased demand for export related production. Firms were thus also impacted according to the ratio market share for the internal vs. export market. Dependence of export somewhat correlated with agri-food sector. For example, the Flemish pig and dairy sectors are very much export oriented, hence price evolutions depended on disturbances in the European and global market. Second, it disturbed the supply of input resources. Therefore, some companies experienced difficulties in obtaining the right type and amount of packaging materials, just as equipment for protection against the virus (e.g., face masks, disinfectants). This lack of production inputs was not limited to physical resources; it also related to labour availability. Companies were confronted with exceptionally high levels of increased absenteeism in the second half of March, which challenged feasibility of food processing. Some workers feared being infected in the workplace, while others took advantage of the situation according to our respondents, as it was very easy by that time to get a doctor's note because of the extreme precautionary attitude (no

infection test was required, only calling the doctor and declaring you showed symptoms). One respondent noted that the increased absenteeism mainly occurred amongst female workers, and related this to closure of schools. Firms relying on foreign labour (e.g. meat industry and slaughterhouses, as well as in the fruit and vegetable agricultural sector) were very much affected because their workers were either unwilling to travel to Belgium or experienced difficulties to cross borders due to administrative bottlenecks.

3.2.2. Resources and resilience actions to deal with the COVID-19 crisis

To diminish hoarding behaviour of consumers, the government imposed a temporary prohibition on promotions. To stimulate consumption of food products for which demand had dropped, the Flemish Center for Agricultural and Fisheries Marketing launched campaigns to trigger people to experiment with food items they usually do not use in their kitchen (VLAM, 2020). Still, the net effect of this was very marginal according to our respondents.

Still, the sudden drastic changed demand urged firms to renegotiate existing market relationships. Retailers, besides trying to obtain additional volumes from their existing suppliers, contacted other suppliers to meet shortages and prevent empty shelves. As a result, alternative brands, packaging and package sizes, that are not part of the usual assortment in supermarkets, appeared. Interviewees confirmed that these products were not bought anymore as soon as the customer's familiar product or brand was available again. Hence retailers were left behind with a stock of products difficult to sell. Food processing and distributing firms with a large share of export, like many slaughterhouses, potato processors, and dairies, experienced uncertain and very fast evolving changes in markets, depending on the moment when measures against the virus were introduced in various countries around the world. When one market disappeared, access to another was re-established. It was reported that these companies constantly had to monitor evolution at international level to adjust their production levels at these changing markets. Some firms had an advantage of better access to strategic international networks due to their history. Some industries with flexible processes could better regulate the production levels and for others, finding alternative markets was a possible solution. It was repeatedly mentioned that such substitute options were hard to find for the meat industry, as for many carcass parts destined for export world markets, an alternative Belgian or European market could hardly be found. Also, noble pieces of meat typically bought by restaurants and meat with specifications retailers impose for quality labels were difficult to market through other (retail) channels. Similarly, in highly automated sectors, like the potato and the frozen vegetable processing industry, shifting to other sales markets (e.g., to regions where, until then, COVID-19 had less of an impact) was only possible during the first weeks of the lockdown in Flanders. However, once the pandemic became a global phenomenon, this option largely disappeared. Market saturation was one of the main issues in these sector highly dependent on bulk production. To conclude, for many companies, altering market channels to different retailers was insufficient for many companies to compensate for the nearly complete loss of sales to the hospitality industry.

A frequently observed reaction following the imbalances between demand and supply, which occurred in all parts of the food supply chain, was temporarily storing products, preferably on site, but if necessary, by hiring external storage capacities. Storage was possible if products were not perishable in the short run or could be frozen, and if sufficient storage capacity existed. If storing was not possible anymore, and the exploration of new markets did not lead to a solution, some products were sold at very low prices ('dumping') or even were donated to charity organizations. Related to this, the government also allowed an extension of the collection period for fresh milk, which provided the system some more room for manoeuvre when the supply of milk was acutely too high, and processors were still reorganizing their production.

Respondents reported unusual forms of collaboration between competing companies of the food industry, which were possible due to

the severity and potentially far-reaching consequences of the crisis. This was primarily about strategic discussions on sector-level strategies for dealing with possible worse case scenarios, for example, agreeing on priority to the continuance of certain large plants which play a crucial role in preventing collapse of the entire system. According to our observations, such dialogues did not take place in all sectors, at least not with the same amount of collective spirit and openness to cooperation. In some sectors, like the dairy industry, multiple of such collaborations between companies had happened in the past, e.g. in case a crucial machine failed. Respondents from the dairy industry explained that the presence of such connections have prevented food waste when disaster stroke in the past, especially with highly perishable products like milk. For such collaboration to take place, mutual trust and openness to share knowledge and resources (e.g., processing and storage capacities) were mentioned as essential, however, not achieved overnight. In other sectors, such as the pork meat industry, respondents testified that because of tensions caused by extremely low margins and a nearly saturated market, they did not see a possibility to achieve cooperation at such a level. They added that external interventions, like government support, could provide a first step in mitigating “the cutthroat competition” and opening the way to reasonable negotiability.

During the first two weeks of March, similar safety measures were implemented in the food processing and packaging factories. Be it in a slaughterhouse, cutting plant, vegetable auction or dairy plant, recurring guidelines included, amongst others, circulation plans to regulate the movements of people, assigning employees to strictly fixed teams to prevent a company-wide outbreak, designating ‘back-up’ employees who needed to stay at home and standby to replace a colleague in case of absenteeism. As these measures were crucial for safeguarding continuance of production, a lot of manpower was allocated to awareness-raising and checking compliance. Posters and other designation material made employees aware of sanitary measures they had to respect. The sector federations took actions to support their members in decision-making and to equip them for the extensive consequences caused by the health hazards. They collected and disseminated knowledge on, i.a., globally recognized precautionary principles with regard to mitigating the rate and extent of COVID-19 infections. Based on these best practices and previous experiences (both from Flanders and abroad) semi-formal protocols were designed that contained concrete recommendations for handling the crisis. These guidelines provided by the sector organizations were often used by their members as a strict checklist. According to our respondents, industry federations also regulated collective purchases of e.g. hand disinfecting gels and face masks - even before the government made it mandatory. Many of these proactive measures were later echoed by the government, confirming their relevance.

For tackling liquidity problems, the government offered various aids, amongst which nuisance and compensation premiums, measures to bridge loans, to delay redemption or to enable postponing of payments, and juridical support for temporal closure and technical unemployment for companies in great distress. The Flemish Department of Agriculture and Fisheries also accelerated their planned compensation payment to farmers for production losses caused by the exceptional drought of 2019. To mitigate the high impacts in the floricultural and potato sector, the Flemish emergency fund allocated 35 million euros in total to these two sectors ([Departement Landbouw en Visserij, 2020a](#)). For certain dairy and meat products, the European Commission decided at the end of April to allocate aid through a private storage subsidy scheme. Demand for such aid in the pig sector was not met.

Solutions to tackle the lack of labour happened due to reactions at different system levels. Most absenteeism issues largely disappeared after the first two to three weeks of lockdown, partly because the government implemented relaxations and initiatives to facilitate enough labour capacities. In some companies, the initially increased absenteeism even dropped down to levels below what was normal for the time of the year. This was potentially the consequence of fear for the possible long term economic complications of the crisis, with staff members

fearing grounds for dismissal should the firm be forced to reorganize.

Many respondents emphasized the importance of the government issuing the official acknowledgement of the food industry as an essential sector. Managers of food processing plants also reported a remarkable commitment – one spoke of “*unprecedented collegiality*” – amongst the lion’s share of their staff. They sensed some kind of shared pride, dedication, and fierceness that kept a positive atmosphere at the work floor. Personnel cancelled their planned annual leave or volunteered for taking up the shifts of those in sick leave. Managers attributed this bottom-up support as one of the key factors that allowed the continuance of food production, and some of them related it to the campaign #FoodHeroes launched by the Federation of the Belgian Food Industry to explicitly thank all primary producers and everyone working in the agri-food system for their efforts that allowed the continued production of food products, as well as to raise the societal awareness on the vital importance of the agri-food industry. The campaign was successfully taken up in social media by different actors from within and outside the agri-food system, motivating those employed in the agri-food business. As a result, most absenteeism issues were reported to largely disappear after the first two to three lockdown weeks. In some companies, the initially increased absenteeism even dropped down to levels below what was normal for the time of the year. Some respondents said this was potentially the consequence of fear for the possible long term economic complications of the crisis, with staff members fearing grounds for dismissal should the firm be forced to reorganize. Next to that, some other companies had to deal with shortage of foreign labour due to closed borders of East-European countries. The sector federations took necessary actions to assure rapid solutions for such bureaucratic obstacles.

4. Discussion

The previous section firstly described the various *impacts* caused by the COVID-19 crisis, which varied greatly between different agri-food sectors, between different links in the food supply chain, and between individual actors. Yet they can be categorized as follows. On the one hand, there were impacts relating to mitigating direct health risks, namely the need to take precautionary sanitary measures. Literally everyone was exposed to this need, but Flemish farmers usually work in circumstances where it was easy to comply with these measures. Indeed, farmers indicated to experience relatively little hindrance from the sanitary measures. In sharp contrast, this required many food processing firms to implement extensive and *agile responsive actions* with regard to reorganizing labour conditions. This often led to delays and increased costs. On the other hand, there was the supply/demand imbalance following the lockdown, which disturbed the functioning of the market. The majority of farmers experienced decreased farm gate prices, which highlights the adverse position of many farmers as price-takers, especially those who market to the wholesale supply chain. At the same time, some respondents nuanced the recurring statement “the farmer is once again the victim”. After all, also many food processing companies suffered severe financial losses and liquidity problems, and in their case the crisis additionally demanded much more *coping and responsive behaviour*, e.g., reorganizing production processes and/or the marketing of products. When evaluating the impact of this crisis at the level of the people working in the agri-food system, it should be noted that, while people working in the food processing industry were affected by the crisis, e.g. by experiencing higher workloads, the impact of the crisis was not so directly and immediately reflected in their wages as was the case for most farmers’ incomes.

The *exposure* of different actors and sectors of the agri-food system to these impacts was largely determined by the timing of the crisis. Some sectors have not really been exposed to any consequences, while others suffered extreme economic losses, and these observations would probably have been totally different if the timing would have been different. For example, producers of ornamental plants and flowers saw their

entire spring season, during which they typically achieve the majority of their yearly revenue, collapse. The Belgian pig sector was just starting to recover from the impact of the African Swine Fever crisis. Here, both farmers and companies active in pork meat processing and trade suffered severe impacts following the combined and cumulative effects of both crises. The timing was also inconvenient in the dairy sector, as milk production in Flanders is cyclical every year, slowly rising to a peak in April–May, thus coinciding with the period wherein the dairy supply chain was affected by a lower demand for high-value products such as cream. Exposure to impacts and, related to this, accessible resilience capacities, could also vary from actor to actor. For example, arable farmers specialized in one crop and/or doing early cultivation were more affected than those with a higher diversity of crops or those planting a bit later, who could still make changes to their cultivation plan taking into account the effects of the COVID-19 crisis. Also, firms who had just implemented large investments, or were planning to do so, have reported more negative impacts compared to firms who were in a more secure financial phase.

Besides timing, exposure also depended on marketing channels used by actors, both for market channels in the wholesale and the ones in the SSC. Farmers and firms that have chosen for efficiency strategy, and thus focus on one (or few) marketing channel(s), were either slightly impacted or (only in few cases) experienced positive impact, or they were very much hampered to cope with this COVID-19 crisis. In the potato sector, farmers delivering through contracts were less affected compared to farmers selling on the free market, who often had to dispose their harvest as fermentation or animal feed at very low prices. Positive impacts were registered for example for farmers and food processing firms who mainly produce and process for a specific label (e.g., organic farming), or farmers who were able to maintain sales volumes and to set their prices (e.g., direct selling on the farm). In contrast, SSC farmers or food processing firms producing for the hospitality industry were very much impacted. So, we can conclude that diversity of production processes and marketing channels proved to increase both coping and responsive capacities in response to this crisis, both at the level of individual firms and of whole sectors. Many informants acknowledged the trade-off between efficiency and diversity, and stated that this crisis particularly has increased preferences towards spreading risks by building in diversity into a system rather than exploiting economies of scale.

An important part of our conceptual framework related to the three types of resilience capacities and actions that we have defined, for which we investigated how they were influenced by the observed *resources* mobilized to respond appropriately to the crisis, which were of various kinds. To start with, the government provided several subsidies to increase the *coping capacities* of affected firms. Still, our data indicated that many processing firms and farmers coped with this crisis by tapping into their own financial buffer, by saving costs, and/or by postponing planned investments. Some processing companies could use backward and forward price setting as coping mechanism, farmers could not. Companies with a greater financial buffer were better able to cope with financial implications from the crisis. These all relate to the resilience attribute *system reserves*. Further, non-monetary resources played an important role in successful crisis management, allocated by different key actors from the agri-food system. First, labour shortages were challenging and increased workload for those who remained in post, however, as far as we know, within the studied timeframe, Flemish food processing firms managed to avoid cease of business operations due to an outbreak of COVID-19 amongst the staff by a timely implementation of measures aimed at diminishing the risk of infection. This prevention of tipping points was largely allocated to the human and social capital at the firms' disposal, which was in turn enabled by the anticipatory actions at the level of the firms and of the sector federations, as well as by the declaration of food industry as an essential sector and by (publicly funded) campaigns. Second, products being temporarily in surplus were stored wherever possible, from using full own storage capacity (i.e.,

exploiting coping capacity) to investing in hired external ones (i.e., utilizing responsive capacity). Third, new markets were explored, as well as options to adapt production processes, which are determined by the resilience attribute flexibility. Some companies were relatively flexible in their effort and ability to find new markets and to try and make use of changed demands (mainly in vegetable industry and some dairies) by either shutting down specific production lines (often those directed to food service) or transforming to an alternative product that, for example, had a longer expiry date. However, redirecting bulk supply to those products and sales that gained in demand (eg. retail, consumption milk, fresh potatoes) had its limitations due to infrastructural restrictions, and because market saturation quickly emerged since nearly everyone in the food system was confronted with a surplus of processed and yet to be processed products.

Regarding *anticipatory actions*, not many of them have been observed. This is partly because we assumed farmers could not have taken targeted measures to prepare for this crisis, and therefore have not been included in the farmers questionnaire. In the first few months that this study has investigated, the COVID-19 shock differed from other shocks that have adversely affected the agri-food system in the past, which often impacted one or a few particular sectors. For example, the Russian embargo on EU products in 2014 largely affected Flemish apple and pear producers (Lievens et al., 2018). COVID-19 mainly caused logistical challenges for food processing and distribution, resulting from the sudden need to reorganize the delivery of primary food supply in the right form, right packaging and through the right marketing channel to the consumer. The need for such profound and far-reaching reorganizations was unseen in the agri-food sector, however, exposure to previous (animal) health crises that required sanitary measures, such as avian flu outbreaks or the 1999 dioxin crisis (Buzby and Chandran, 2003), has enabled the industry federations in swiftly and proactively setting-up guidelines to prepare for potential effects of COVID-19. Indeed, our study revealed that the Flemish agri-food industry has showcased some level of anticipatory capacity, as they were alarmed in time by the events in Asia. Both sector federations and individual companies took proactive measures (based on experience from previous agricultural and food crises) to prepare themselves for potential consequences. As such, these proactive actions have increased the *coping and responsive capacities* at the time the crisis actually hit Flanders. Moreover, hygienic standards, such as wearing face masks and regularly disinfecting the hands, were already common in this link of the agri-food chain, hence most COVID-19 measures were additional to already existing habits. We can relate the above characteristics to the resilience attributes *system openness* and *exposure to disturbances* from the literature. The fact that different sub-segments of the agri-food supply chains are well organized in industry federations substantially contributed to this agility and proactivity. We found that already existing networks and previous collaborations between different (often competing) actors of a food value chain contributed to a better and more coordinated response to the changed demand, as well as to take advantage of economies of scale in collaborative purchases for acute scarce products or services such as disinfectants and cargo containers. This illustrates how a system's *self-organization* can inherently improve its responsive capacity (Carpenter et al., 2001; Berkes, 2007; Olsson et al., 2015; Ostrom, 2009).

Finally, regarding *responsive capacities*, a great variety of possibilities for adaptation to this sudden shock was detected. Farmers generally had relatively little room to manoeuvre, because they could not adjust their production process in the short run. Farmers selling (part of) their produce in an on-farm shop were able to control selling prices, however, they needed to implement some adaptations to meet the safety rules and to respond to their customers' needs. By way of contrast, farmers who market their products via the wholesale supply chain did not need to implement concrete adaptations in response to the changed market demand, as their products kept being collected by e.g. their cooperative. Ironically, farmers selling their produce directly to, e.g. local restaurants or tourist groups which normally visit their (educational) farm, who

used to have a relatively stronger bargaining position, had few options to adapt, as market saturation for their products or their inability to reorient their specialized business model usually prevented proper responsive actions. Similarly, the sudden demand market disturbance induced a disastrous impact for food processors specialized into delivering to the hospitality industry. If possible, they tried to increase their sales volumes through those channels that were less affected. But in their search for good responsive actions, they were confronted with multiple limitations. Highly automated processes were difficult to reorient due to technical or machine inelasticity, hence production intended for large volume packaging for food service markets, could in most cases not be converted into smaller packaging. Other observed restrictions related to personnel limitations or logistical and time constraints hampering swift adaptations to production processes.

5. Conclusion

To understand the underlying contributors to resilient food supply chains, and consequently design trajectories to improve agri-food system resilience in a targeted way, researchers can learn the most from investigating those instances where the agri-food system was severely challenged. The COVID-19 pandemic constituted a major challenge to agri-food systems. This paper provided a detailed and comprehensive description of the events and consequences triggered by the COVID-19 crisis, and strategies applied as a reaction to these impacts, at different levels and sectors of the Flemish agri-food system. These observed impacts and reactions, as well as what system characteristics made them (im)possible, were then assessed in terms of how they enabled or undermined the resilience of food value chains in Flanders in the immediate aftermath of this unexpected shock. As such, the paper delivered empirical evidence to theoretic resilience concepts, providing us with insights that can help improving the resilience of agri-food systems to future unexpected shocks. Both quantitative data, obtained from a farmers survey, and qualitative data, obtained from interviews with other key actors from the agri-food chain, were collected and analysed according to a conceptual framework, adapted from Mathijs and Wauters (2020), that enables a better understanding of how different resources, resilience attributes, and resilience capacities contribute to different resilience actions in response to shock.

Lockdowns and other attempts to control the spread of COVID-19, both Belgium and abroad, affected the Flemish agri-food system in two ways. First, it caused a shift in consumer behaviour, which translated into a large shift at the demand side of the food supply chain. Second, it affected food harvesting, processing, and transport processes around the world, which translated into logistical problems. Our analysis revealed that the experienced impacts resulting from these diverse effect of the COVID-19 crisis varied across different individual actors of the Flemish agri-food system because of specific individual business situations, and across different sectors and food value chains because of overarching characteristics linked to that entity. Similarly, how (well) chain actors were able to deal with the crisis, in other words, whether resilience capacities were present and used, varied across individual business models, sectors, and the position and role of actors in the supply chain. Yet, we could identify some resilience attributes, i.e., system characteristics and dynamics, that helped in having sufficient anticipative, coping and responsive capacity. First, exposure to disturbances, openness and system reserves can, according to our empirical findings, be associated with higher coping and responsive capacity. Further, we found evidence that diversity and flexibility in food production and marketing processes increase coping and responsive capacities. So, although efficiency and economies of scale might be rewarded during non-turbulent times, diversity and risk spreading can increase resilience, especially in a rapid changing world with increasing chances of imposed stresses.

The sanitary measures restricted labour in its operations and border closures resulted in delays in transportations and in migration stops.

These measures resulted in the temporary shortages of some inputs and outputs at some supply chain levels and temporary surpluses of other inputs and outputs at other supply chain levels. These shortages and surpluses then created price increases and decreases respectively, and again at different levels of the supply chain and in different ways for different products. Initially, there was a general fear that these measures and side-effects would impair the agri-food system's basic function, that is, the delivery of food at reasonable prices. We found that - despite there were both barriers and enablers in the Flemish agri-food system which challenged or facilitated the maintenance of this basic function - most farmers and processors were able to continue production in a way that collectively, sufficient levels of food production and food delivery to consumers were sustained. Governmental institutions played an important role in supporting crisis management and mitigating the direct impacts experienced by firms, although they performed less swiftly and agile compared to sector organizations and individual firms.

Labour force and safety equipment are two examples of inputs that have been in temporary shortage at the start of the COVID-19 crisis. This paper illustrated that to cope with such shortages requires either making use of any redundancies built into the system, or finding substitutes for what is short in supply. The available capacities and reserves (in terms of manpower and resources) proved sufficient in the case of the Flemish agri-food system, although in some cases critical levels were reached and therefore intentions to create more variety or back-ups in order to prevent insufficiencies in the future were reported, for example, generating more diversity in supplier network. By way of contrast, products destined for the hospitality industry became in excess supply. We found that surpluses can be stored when inputs or outputs are not perishable in the short run, or, when they cannot be stored, they may be used for alternative purposes. However, the former can only be done if sufficient storage capacity exists and the latter can only be done if the production process is flexible enough to adapt, which may not be the case because of high inelasticity of supply due to high levels of asset specificity, sunk costs and specialization.

Altogether, our impact analysis suggests that the Flemish agri-food system has been reasonably resilient, as its internal functioning and outputs delivered continued to a large extent, despite some disturbances across the supply chain, which occurred because of restrictions in labour, processing, distribution and storage capacity, and a change in demand for food items in stores and supermarkets, as well as a (near) collapse in demand from the hospitality industry. Yet food kept being produced, collected from the farms and transported to the processing plants, and distributed to the selling points, albeit with some temporary delays and glitches. Few empty shelves resulted from the initial acute panic buying of consumers, not because of problems with food production.

The examination of resources used in reaction to the COVID-19 crisis enabled our understanding of whether *resilience capacities* were available and efficiently used, and consequently, whether *resilience actions* took place. However, this approach included an important limitation. Some respondents indicated that impacts were limited. It was not always possible to determine whether their lower experienced impact was because of a higher resilience capacity, or because they were effectively less impacted, e.g., due to less exposure or their exact marketing strategy. In other words, estimating resilience capacities was sometimes difficult because of its correlation with experienced impacts. For example, in the case of the farmers, our data provided some indications that the lower impact that farmers in some subsectors have experienced was more due to coincidence – or even luck – than to their inherent level of resilience, not the least because timing was a crucial determinant for exposure. Similarly, we found that better anticipatory capacity could lead to lower impact, e.g. ensuring that mouth masks were quickly available diminished the chance of problems with safety on the workforce.

Due to our time frame of interest, we have neither been able to investigate if and how farmers' income levels return back to normal, nor

whether and how food processing firms will be able to recover from the losses resulting from the increased costs they had. At the same time, our findings indicate that the resilience of the Flemish agri-food system might be impaired by the COVID-19 crisis in the long term, as, amongst others, many actors from all links in the food supply chain were confronted with increased costs, albeit the reported (financial) impacts varied across companies, sectors, and segments. Indeed, over time, the economic and financial problems observed could result in unemployment and bankruptcies, and this might not only be the case for firms in the agri-food sector. Eventually, the crisis might maybe even reduce consumers' purchasing power, which would imply the crisis induces a wholly different long-term impact on the overall economy compared to the short-term impacts reported in this paper. Therefore, further research is needed to evaluate the long-term impacts of and responses to this crisis. Similarly, we think future research should examine whether the crisis influences (attitudes towards) the logistics and supply/price negotiations in agri-food systems, as many of our respondents suggested that this crisis has further emphasized certain existing issues or notorious developing trends in the food value chain, which mostly relate to how agri-food systems are organized and how prices are negotiated. Because for example retailers managed to find alternative supply

solutions in case shelves threatened to become empty, we presume at least they will probably not be triggered by the crisis to review their bargaining strategies or to diversify their supplier base.

Declaration of Competing Interest

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

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Appendix A. Questionnaire for farmers: variables and measurement

Variable	Measurement	Statement or question in survey
Part 1: General farm(er) characteristics		
Birth year	Numerical entry	
Sex	Multiple choice	Male – Female
Farm type	Multiple choice	Specialized arable – Specialized horticultural – Specialized permanent crops – Specialized grazing livestock (dairy, beef, sheep or goat) – Specialized pens (pig, poultry or rabbit) – Combinations of crops – Combinations of animal husbandry – combinations of crops and livestock – Other
Main production focus	Open question	
Organic farming	Dummy	Indicate what applies to your farm (multiple answers are possible)
Short supply chain sales		
Broadening activities (e.g., farm tourism, care farming, organized company visits)		
On-farm processing (e.g., farm butchery)		
Share of production destined for short supply chain sales	A scale from 1 (10%) to 10 (100%)	
Business cycle phase	Multiple choice	Starting up – Established and growing – Established and stable – Established and shrinking – Preparing take-over – Winding down for retirement
Share of household income from non-agricultural activities	A scale from 1 (0%) to 11 (100%)	
Wholesale (auction, cooperative, contract farming, etc.)	Dummy	What were the main sales channels for your farm before the COVID-19 crisis?
Direct sale on the farm (self-pick, farm shop, subscriptions, etc.)		
Direct sales in the neighbourhood (e.g., farmers markets)		
Local sales through third parties (shops, local cooperatives, etc.)		
Local sales to the hospitality industry		
Sales via web shop		
Expected general impact during the rest of the year	A scale from 1 (very negative) to 5 (very positive)	How do you estimate the impact of the corona crisis on your farm for the rest of the year?
Part 2: Farmers' self-reported impact of COVID-19 crisis		
General impact	A scale from 1 (very negative) to 5 (very positive)	To date, the overall impact of the corona crisis on my business has been
Impact on turnover	A scale from 1 (much lower than usual) to 5 (much higher than usual) and an option "not applicable"	For the following statements, please indicate whether there is an impact for you and your farm from the COVID-19 crisis
General		
Sales		
Prices for output		
Impact on input costs		
Prices paid for labour		
Prices paid for input materials		
Impact on sales according to sales channel	A scale from 1 (much less) to 5 (much more) and an option "I am still not selling through this sales channel"	Indicate if or how your sales changed via the following sales channels due to the corona crisis
Wholesale		
On-farm sale		

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Variable	Measurement	Statement or question in survey
Direct sales in neighbourhood Local sales through third party Local sales to catering sector Online sales Other		
Impact on overall farm management Access to input materials (e.g., feed) Availability of permanent workers Availability of seasonal workers Availability of family labour Repayment capacity	A scale from 1 (much lower than usual) to 5 (much higher than usual) and an option "not applicable"	For the following statements, please indicate whether there is an impact for you and your farm from the COVID-19 crisis
Comply with safety regulations Myself My staff	A scale from 1 (very difficult) to 5 (very easy)	To what extent do you/your workers manage to comply with the general safety regulations (social distancing, hand hygiene, no non-essential movements, avoid contact with other people as much as possible)?
Hindrance from safety regulations	A scale from 1 (very little) to 5 (very much)	To what extent are your activities hindered by the safety measures?
Impact on wellbeing Worries about future of farm Income satisfaction Conflicts within household Physical exhaustion from work Mental exhaustion from work Negative impact (relational/financial) from work on family or relatives Negative impact from work on social life Perceived appreciation by society Worries about health and safety on my farm	A scale from 1 (much less than before corona) to 5 (much more than before corona) and an option "I wish not to answer"	Indicate for the following statements whether they apply to you to a greater or lesser extent since the corona crisis
Fatigue/exhaustion Gloominess Burnout Alcohol addiction Depression Suicidal thoughts Difficult work-life balance Anxiety or panic attacks Irritability or frustration	A scale from 1 (much less a problem) to 5 (much more a problem) and an option "I wish not to answer"	Indicate for the following aspects to what extent they are now, due to the corona crisis, much less or much more of a problem to you
Part 3: Farmers' self-reported coping behaviour in the face of the COVID-19 crisis		
General Need for taking measures Finding solutions Finding help	A scale from 1 (totally disagree) to 5 (totally agree)	I do not need to take additional measures because I am not experiencing any problems due to the corona crisis I find solutions for the problems induced by the corona crisis I know where I can call for help if I encounter problems due to the impact of the corona crisis on my farm
Operational coping Apply for temporary unemployment for my staff Apply for bridging loans at the bank Apply for the one-off corona compensation premium which compensates loss in turnover Apply for the one-off nuisance premium which compensates the (partial) closure of a business Apply for the emergency fund Use the VLIF1 guarantee scheme for bridging loans Request delay of repayment from bank Request delay of payment of invoices Tap into own financial reserves Save costs Search other marketing channels for (part of) my products Adjust my cultivation plan (Temporarily) cease certain activities Temporarily employ those who are in technical unemployment or (bridge) pension Use volunteers to help with the farm work Work harder Change supplier(s) No need to adjust or do anything	Dummy	What strategies do you apply to deal with the impact of the corona crisis on your business operations? You can select multiple options, you can also select nothing if nothing applies
Psychological coping Talking about it with partner, family and/or friends Talking about it with colleagues Seeking help from a general practitioner Seeking help from a psychologist Seeking help from 'Farmers at a cross point' Seeking help from aid organizations	Dummy	Which of the following are you doing to deal with the impact of the corona crisis on your well-being? You can select multiple options, you can also select nothing if nothing applies.

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Variable	Measurement	Statement or question in survey
Seeking help from agricultural organizations I have nowhere to talk I have no need to talk		
Expected long-term coping/responding Postponing planned investments This is a difficult situation for the time being, but I do not expect it to fundamentally change my farm Considering to change my farm (e.g., other products, other division of labour, other sales channels, etc.)	Dummy	Do you think this corona crisis will affect your and your farm's long-term plans? Indicate what applies to you. You can choose several options, you can also choose nothing if nothing applies to you
Considering early termination of business Postponing a planned takeover Considering to speed up a planned takeover Crisis has reinforced my conviction that my plans for the future of my farm are the right ones		
Vision on long-term impact Which of the three statements below corresponds most closely to your views on the consequences of the corona crisis?	Multiple choice	(1) I do not think that the corona crisis will change the agricultural sector; (2) The corona crisis is a temporary obstacle on the road, but in the long term it will not really affect the agricultural sector; (3) I believe that the corona crisis is going to have a lasting impact on the agricultural sector
Do you wish to add something extra about the problems, measures, opportunities and consequences of the corona crisis?	Open question – text entry	

Appendix B. Interview outline

Item	Research questions/aims	Interview guide questions
Impact	Which impacts occurred, which system functions were disrupted? <i>Obtain information on specific business situations and the impact on the entire food chain</i>	<ul style="list-style-type: none"> - What were the consequences of the COVID-19 crisis for the Flemish farmers/ processing industry/supply sector/sale and distribution of products? - Was the crisis a major shock for the sector and its various links? Do you think the sector was resilient to the crisis? - Why was the impact so serious/moderate for your company/sector? - Of which specific problems (in the supply chain, on farms, processing companies, in the logistics between the different links in the chain, etc.) caused by the COVID-19 crisis are you aware? - Are there also positive effects within certain segments of the sector? - Was there a product 'stuck' somewhere throughout the flow, causing the chain to get stuck? Can you explain in detail how this happened exactly? What were the consequences? - Try to distinguish between impacts on food production, food processing, distribution, logistics, labour availability, product flows, prices, and ask when exactly these impacts occurred
Exposure	<i>Find out whether certain agricultural sectors, farms, firms, or supply chain links, were not actually affected by the crisis, and try to unravel due to which characteristics they remained untouched</i>	<ul style="list-style-type: none"> - Do you think this crisis will induce a long-term impact? Why (not)? - What effects did the COVID-19 crisis have on the food supply chain? - Which link(s) in the chain did you think was/were most affected? Why? What were the consequences? Was this impact also felt at or translated to other links in the chain? - Do you know about problems caused by the fact that food could hardly be consumed in the catering industry all of a sudden, but mainly had to be bought in shops for home consumption? If so, which ones, and why? Are there companies in the food chain that were more affected by this than others? If so, why?
Resilience capacity	<i>Distinguish between:</i> <i>(1) Anticipatory capacity</i> Were actors able to anticipate this event? Which precautionary action did they take? Did it help to alleviate the impact? What enabled this anticipatory capacity? <i>(2) Coping capacity</i> Were there firms or chain actors who noticed the consequences of the COVID-19 crisis, but were not immediately put in a precarious situation by them (e.g., because of a buffer)? <i>(3) Responsive capacity</i> Were actors able to make the necessary adjustments in response to the COVID-19 crisis and its consequences/ impacts? What characteristics enabled this adaptability?	<ul style="list-style-type: none"> - In your opinion, where were the bottlenecks in the food chain? - What strategies/measures have been applied to deal with the problems caused by the corona crisis? Why, how quickly and easily were they put in place? Were the effects of the crisis well cushioned by these responses? - Do you think your sector reacted appropriately to the crisis? What could have been better? What should not have happened? - How has the government played a role in dealing with the crisis? - What characteristics of the different links have contributed to the resilience of businesses/the sector to this crisis? What characteristics have contributed to the rapid implementation of effective measures? - Are there types of companies in the food chain that hardly had to make any adjustments? Why was that, what made those companies so robust? - Which characteristics contributed to the capacity of businesses/the sector to deal with this crisis in an appropriate manner (or which characteristics made it extremely difficult to react in appropriately)? - Were the firms/sectors/links in the chain able to adapt well and quickly or not? - If adjustments had to be made, was it easier for some companies than others? Why?

References

- Béné, C., 2020. Resilience of local food systems and links to food security – a review of some important concepts in the context of COVID-19 and other shocks. *Food Secur.* 805–822.
- Berkes, F., 2007. Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Nat. Hazards* 41 (2), 283–295.
- Bhamra, R., Dani, S., Burnard, K., 2011. Resilience: the concept, a literature review and future directions. *Int. J. Prod. Res.* 49 (18), 5375–5393.
- Bullock, J.M., Dhanjal-Adams, K.L., Milne, A., Oliver, T.H., Todman, L.C., Whitmore, A.P., Pywell, R.F., 2017. Resilience and food security: rethinking an ecological concept. *J. Ecol.* 105 (4), 880–884.
- Buzby, J.C., Chandran, R., 2003. The Belgian dioxin crisis and its effects on agricultural production and exports. In: Buzby, J.C. (Ed.), *International Trade and Food Safety: Economic Theory and Case Studies*. United States Department of Agriculture (USDA), pp. 125–139.
- Cabell, J.F., Oelofse, M., 2012. An indicator framework for assessing agroecosystem resilience. *Ecol. Soc.* 17 (1).
- Carpenter, S., Walker, B., Anderies, J.M., Abel, N., 2001. From metaphor to measurement: resilience of what to what? *Ecosystems* 4 (8), 765–781.
- De Roo, M., 2020. Groenten en fruit trotseren coronavirus, 14 April 2020. Available at: <https://www.tijd.be/ondernemen/logistiek/groenten-en-fruit-trotseren-coronavirus/10220647.html> [Accessed February 4, 2021].
- De Samber, J., 2021. In de ban van corona. Resultaten van de bevraging bij LMN-landbouwers in september 2020. Departement Landbouw en Visserij. Brussel. January 2021. Available at: https://lv.vlaanderen.be/sites/default/files/attachment/s/coronaenquete_0.pdf [Accessed February 4, 2021].
- Departement Landbouw en Visserij, 2020a. Corona: maatregelen en veelgestelde vragen voor landbouw, tuinbouw, en zeevisserij, 31 July 2020. Available at: <https://lv.vlaanderen.be/nl/nieuws/corona-maatregelen-en-veelgestelde-vragen-voor-landbouw-tuinbouw-en-zeevisserij> [Accessed November 1, 2020].
- Departement Landbouw en Visserij, 2020b. Landbouwcijfers, 1 May 2020. Available at: <https://lv.vlaanderen.be/nl/voorlichting-info/publicaties-cijfers/landbouwcijfers> [Accessed October 27, 2020].
- EC., 2020. Green lanes - Ensuring the free flow of goods and services. Transportation during the pandemic. [WWW Document], 16 March 2020. URL: <https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fec.europa.eu%2Finfo%2Flive-work-travel-eu%2Fcoronavirus-response%2Ftransportation-during-pandemic-en&data=04%7C01%7CS.Vadivelan%40elsevier.com%7Cb721326954fe4818b6f608d8fda505b%7C9274ee3f94254109a27f9b15c10675d%7C0%7C0%7C637540660537441055%7CUnknown%7CTWFPbGZsb3d8eyJWIjoIMC4wLjAwMDAilCJlQjoiV2luMzIiLCJBTiI6lk1haWwLlCJXVCi6Mn0%3D%7C1000&sdata=VvevGeeri52%2BI9%2Byn1RKJ%2FWXc8YaEn2daJn0%2B1n7Y%3D&reserved=0> (accessed 2.4.21).
- European Commission, 2020. Farm to Fork Strategy – For a Fair, Healthy and Environmentally-Friendly Food System.
- Coronavirus: Half of humanity now on lockdown as 90 countries call for confinement [WWW Document], 2020. <https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.euronews.com%2F2020%2F04%2F02%2Fcoronavirus-in-europe-spain-s-death-toll-hits-10-000-after-record-950-new-deaths-in-24-hou%250D&data=04%7C01%7CS.Vadivelan%40elsevier.com%7Cb721326954fe4818b6f608d8fda505b%7C9274ee3f94254109a27f9b15c10675d%7C0%7C0%7C637540660537441055%7CUnknown%7CTWFPbGZsb3d8eyJWIjoIMC4wLjAwMDAilCJlQjoiV2luMzIiLCJBTiI6lk1haWwLlCJXVCi6Mn0%3D%7C1000&sdata=hmuXD3eD1icyzlbGVuK8KUxubf%2FhNrPBWlqGRoBBzUs%3D&reserved=0> (accessed 10.24.20).
- Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T., Rockström, J., 2010. Resilience thinking: integrating resilience, adaptability and transformability. *Ecol. Soc.* 15 (4), 20.
- Hodgson, J., Eakin, H., 2015. Adapting a social-ecological resilience framework for food systems. *J. Environ. Stud. Sci.* 5 (3), 474–484.
- Kamalahmadi, M., Parast, M.M., 2016. A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research. *Int. J. Prod. Econ.* 171, 116–133. Available at: <https://doi.org/10.1016/j.ijpe.2015.10.023>.
- Karia, R., Gupta, I., Khandait, H., Yadav, Ashima, Yadav, Anmol, 2020. COVID-19 and its modes of transmission. *SN Compr. Clin. Med.* 2, 1798–1801.
- Landbouwleven, 2020a. Bijna alle voedingsbedrijven voelen gevolgen coronavirus, 12 March 2020. Available at: <https://www.landbouwleven.be/art/d-20200311-3YZUKM?referer=%2Farchives%2Fsearch%3Fdatefilter%3Dlastyear%26sort%3Ddate%2520asc%26word%3Dcorona%2520> [Accessed February 11, 2021].
- Landbouwleven, 2020b. Landbouw en corona: welke sectoren voelen de zwaarste klappen?, 11 June 2020. Available at: <https://www.landbouwleven.be/art/d-20200609-GGHJNU> [Accessed February 4, 2021].
- Lievens, E., Bonjean, I., Mathijs, E., 2018. Cooperatives adapting to market conditions: insights from a comparative study of apple and pear farming in Poland, Italy and Belgium. In: *Sustainable Agrifood Systems, Value Chains and Power Structures*. 13th European IFSA Symposium, Chania, Greece: KU Leuven, p. 12.
- Mathijs, E., Wauters, E., 2020. Making Farming Systems Truly Resilient. *EuroChoices* 19 (2), 72–76.
- Meuwisen, M.P.M., Feindt, P.H., Spiegel, A., Termeer, C.J.A.M., Mathijs, E., de Mey, Y., Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vignani, M., Zawalińska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroeghe, W., Ciechomska, A., Accatino, F., Kopainsky, B., Poortvliet, P.M., Candel, J.J.L., Maye, D., Severini, S., Senni, S., Soriano, B., Lagerkvist, C.-J., Peneva, M., Gavrilescu, C., Reidsma, P., 2019. A framework to assess the resilience of farming systems. *Agric. Syst.* 176, 102656.
- Olsson, L., Jerneck, A., Thoren, H., Persson, J., O'Byrne, D., 2015. Why resilience is unappealing to social science: theoretical and empirical investigations of the scientific use of resilience. *Sci. Adv.* 1 (e1400217).
- Ostrom, E., 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325 (July), 419–422.
- Paganini, N., Adinata, K., Buthelezi, N., Harris, D., Lemke, S., Luis, A., Koppelin, J., Karriem, A., Ncube, F., Nervi Aguirre, E., Ramba, T., Raimundo, I., Sulejmanović, N., Swanby, H., Tevera, D., Stöber, S., 2020. Growing and eating food during the COVID-19 pandemic: farmers' perspectives on local food system resilience to shocks in southern Africa and Indonesia. *Sustainability* 12 (20), 8556.
- Platteau, J., Lambrechts, G., Roels, K., Van Bogaert, T., 2018. Uitdagingen voor de Vlaamse land- en tuinbouw. Landbouwrapport 2018. Departement Landbouw en Visserij, Brussel. Available at: www.vlaanderen.be/landbouwrapport.
- Renson, I., 2020. Plots komt de lokale boer weer in beeld (2 May 2020).
- Rothan, H.A., Byrareddy, S.N., 2020. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. *J. Autoimmun.* 109 (February), 102433. Available at: <https://doi.org/10.1016/j.jaut.2020.102433>.
- Statistiek Vlaanderen, 2019. Land-en tuinbouwbedrijven. Available at: https://www.statistiekvlaanderen.be/nl/land-en-tuinbouwbedrijven#vlaanderen_telt_ruim_23.000_land-en_tuinbouwbedrijven [Accessed February 4, 2020].
- Stephens, E.C., Martin, G., van Wijk, M., Timsina, J., Snow, V., 2020. Impacts of COVID-19 on agricultural and food systems worldwide and on progress to the sustainable development goals. *Agric. Syst.* 183, 102873.
- Sukhwani, V., Deshkar, S., Shaw, R., 2020. Covid-19 lockdown, food systems and urban-rural partnership: case of Nagpur, India. *Int. J. Environ. Res. Public Health* 17 (16), 1–23.
- Sun, J., He, W.T., Wang, L., Lai, A., Ji, X., Zhai, X., Li, G., Suchard, M.A., Tian, J., Zhou, J., Veit, M., Su, S., 2020. COVID-19: Epidemiology, Evolution, and Cross-Disciplinary Perspectives. *Trends Mol. Med.* 26, 483–495.
- Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Kruetli, P., Grant, M., Six, J., 2015. Food system resilience: defining the concept. *Glob. Food Secur.* 6, 17–23.
- United Nations, 2020. End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Department of Economic and Social Affairs Sustainable Development. Available at: <https://sdgs.un.org/goals/goal2> [Accessed November 1, 2020].
- Van Fleteren, D., 2020. Overleefde de aardappelsector een nieuwe berg aan overschotten?, 4 September 2020. Available at: <https://www.mo.be/analyse/aardappelteelt-aardappelcontracten-corona-overschot-droogte-milieu> [Accessed February 4, 2021].
- Vander Gracht, K., Bernolet, L., 2020. Coronavirus goed voor korte keten: veel meer bestellingen, 20 March 2020. Available at: <https://www.ringtv.be/nieuws/coronavirus-goed-voor-korte-keten-veel-meer-bestellingen> [Accessed February 13, 2021].
- VILT, 2020a. Korte keten zit in de lift, 19 May 2020. Available at: <https://vilt.be/nl/nieuws/korte-keten-zit-in-de-lift> [Accessed February 4, 2021].
- VILT, 2020b. Prijzen in zowat hele landbouwsector sterk gedaald, 8 April 2020. Available at: <https://vilt.be/nl/nieuws/prijzen-in-zowat-hele-landbouwsector-sterk-gedaald> [Accessed February 4, 2021].
- VILT, 2020c. Sierteelt en varkenssector meest getroffen door corona, 18 June 2020. Available at: <https://vilt.be/nl/nieuws/sierteelt-en-varkenssector-meest-getroffen-door-corona> [Accessed February 4, 2021].
- VLAIO, 2020. Maatregelen land- en tuinbouw door coronacrisis. Vlaams Agentschap Innoveren & Ondernemen, 20 March 2020. Available at: <https://www.vlaio.be/nl/nieuws/maatregelen-land-en-tuinbouw-door-coronacrisis> [Accessed February 4, 2021].
- VLAM, 2020. Impact van coronacrisis op consumptie verse voeding - update en blik op de toekomst. Webinar, 23 June 2020.
- Q&A on coronaviruses (COVID-19) [WWW Document], 2020. <https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.who.int%2Femergencies%2Fdiseases%2Fnovel-coronavirus-2019%2Fquestion-and-answers-hub%2Fq-a-detail%2Fq-a-coronaviruses&data=04%7C01%7CS.Vadivelan%40elsevier.com%7Cb721326954fe4818b6f608d8fda505b%7C9274ee3f94254109a27f9b15c10675d%7C0%7C0%7C637540660537441055%7CUnknown%7CTWFPbGZsb3d8eyJWIjoIMC4wLjAwMDAilCJlQjoiV2luMzIiLCJBTiI6lk1haWwLlCJXVCi6Mn0%3D%7C1000&sdata=U4lykByQ0qrJEvt25ufxcZuUz79L1WrcxNRQX8C%2F6E%3D&reserved=0> (accessed 10.14.20).