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Increasing Resilience of the UK Fresh Fruit and Vegetable System to Water-Related Risks

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Abstract: The many economic, regulatory and environmental pressures on growing, processing, distributing and retailing UK-produced fresh fruit and vegetables (FF&V) are managed by a complex set of actors before reaching the consumer. Much of this production takes place in the driest parts of the country which are characterised as “water scarce”. While physical risk is a key component of water-related risks to growers, different actors in the system face other types of risk, such as supply chain risks, food safety risks, reputational risks and/or regulatory risks. In this paper we reveal how different types of actors in the UK FF&V system perceive and frame water-related risks, what risk management strategies they employ and how they envision a FF&V system more resilient to water-related risks. Using interviews with actors from across the system, as well as governmental and nongovernmental actors influencing the system, we unpack the complex nature of the FF&V system. This provides insights into the different ways system actors assemble around water-risk and highlights that, if resilience-building activities at the individual actor level are not coordinated, there is a high risk that they are undermining overall system resilience.

Keywords: fresh fruit and vegetable systems; water risk; resilience; food system actors

1. Introduction

Enhancing resilience to water-related risk is already a key issue for the UK’s fresh fruit and vegetable (FF&V) system. This is because most production in the UK takes place in the driest parts of the country, where water resources are most stressed, and imports are from countries which are characterised as “water scarce” [1]. Projected climate change is likely to exacerbate challenges for FF&V supply chains [2], whilst a changing policy-scape, aimed at balancing water distribution with changing demand for urban, industrial and ecosystem services, coupled with changing precipitation patterns, will alter water availability for FF&V production and hence supply. Meanwhile, the demand for FF&V, and the water required to produce it, is likely to rise due to consumers being urged to increase their FF&V intake in general, while also substituting meat and dairy products with plant-based foods, for health and environmental reasons [3,4]. Although changes in supply methods can help ensure a constant supply (e.g., air-freighting fresh fruit from Ghana and green beans from Kenya), there may be obscure aspects of the FF&V system that, left unaddressed, might be particularly vulnerable at a given moment in time and/or more problematic in the future. It is therefore important to consider how to increase the resilience of the FF&V system to stresses and shocks, be they social, economic, political, technical and/or environmental.

1.1. A “Food System” Context for Framing Risk and Resilience

The “food system” is increasingly used as a conceptual and analytical tool to describe the processes and actors in the food sector in a unified way [5–7]. A food system is made up of food system *activities* (growing, harvesting, processing, packaging, transporting, marketing, consuming and disposing of food and food-related items) and food system actors carrying out the activities, all influenced by various “drivers” that influence how these activities are performed. Drivers can include a wide range of economic, social or environmental forces, such as prices, equity considerations, regulatory frameworks or resource constraints, and each actor responds to these drivers in different ways. Taken together, the food system activities result in a number of food system *outcomes*. The primary outcome is food security, i.e., providing consumers “with physical, economic and social access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” [8]. There are, however, numerous other socioeconomic outcomes (e.g., employment and associated livelihoods, equity) and environmental outcomes (e.g., impacts on biodiversity, soils, water and GHG emissions). All outcomes feed back to either amplify or dampen socioeconomic and environmental drivers [5,9].

The UK FF&V system consists of a variety of different actors within and outside the UK, such as growers, input suppliers, processors, purchasing agencies, supermarkets, transport and storage operators, restaurants and caterers and consumers, though the system has so far not been mapped in all its detail. It is shaped by a complex mix of policy-scapes, demographics, demands, market set-up and infrastructure that mediate between them, and the environmental conditions in the growing areas. Currently, per capita FF&V consumption in the UK is among the highest in Europe, with 46% of the population consuming one to four portions per day and a third consuming more than five portions per day [10]. Nevertheless, the system relies on imports especially for out-of-season crops and exotics [1]. Despite the seamless interplay of the various actors and the current set up, the FF&V system has shown bottlenecks and vulnerabilities to different types of shocks and stresses. Especially in light of recommendations to increase the intake of FF&V in western diets to combat both the various negative health outcomes of current diets and their impacts on GHG emissions [3], we need to find new ways to analyse shortcomings and develop measures to increase the resilience of the FF&V system to disruptions.

One of the key risks that the FF&V system in the UK and elsewhere faces is related to water, as large amounts of water are used in production [1] and a significant amount is used in processing [11]. Although most agriculture in the UK is rainfed, domestic production of fruit and vegetables (including potatoes) is concentrated in the driest regions of the country and water is used at the driest times of year when resources are most constrained [12]. Therefore, supplementary irrigation is widely used for outdoor growing and protected horticulture. Water is predominantly withdrawn from surface and groundwater resources [13], and the volume and timing of withdrawals is controlled by the water regulatory body via a system of licensing [14]. A reliable supply of clean water is critical to growers to ensure production and quality, as well as ultimately to consumers and all the actors in between.

1.2. Water-Related Risks in the UK FF&V System

There are different types of water-related risks, and actors along the supply chain are likely to experience them differently. Water-related risk for FF&V manifests itself in five main ways: (i) water scarcity, (ii) water excess, (iii) rainfall variability, (iv) water quality degradation, and (v) water policy and regulation. Water-related risks can therefore be perceived in various ways by the different actors within the FF&V system. In general, two types of risks can be differentiated: short-term shocks (e.g., flood, water-quality related food scare) and long-term stresses (e.g., climate change, change in irrigation regulations). These main types of risks can be primary in nature (e.g., physical changes to water quantity and/or quality) or secondary (e.g., food contamination due to pollutants in the water, or customer behaviour change due to negative press about sourcing from water scarce areas).

Nearly a fifth of all holdings growing potatoes, vegetables and soft fruit in England and Wales are in catchments defined as being “overabstracted” [12] and only 10–15% are located in catchments where additional water abstraction would be available during summer low-flow periods. East England, for example, has a significant agrifood industry that contributes some 3 billion GBP per year to the region’s rural economy [15,16] and is a region of high water demand.

1.3. Framing FF&V System Resilience

Resilience concepts have been developed and used by different disciplines including ecology, engineering and social sciences. Many definitions in the agriculture domain are based on ecological concepts, but some are increasingly being adapted for a more generic approach to understanding social–ecological systems [6]. The “resilience” term is now gaining considerable traction in food security communities, and especially in relation to the COVID-19 crisis [17,18].

In this paper we use the resilience concepts recently developed by the Global Food Security “Resilience of the UK Food System” programme [19]. Food system resilience is here seen as “the system’s capacity to deliver a desired set of outcomes when exposed to stresses and shocks”. It further distinguishes between three different notions of resilience: (1) *Robustness*—the ability of the food system to resist disruptions to desired outcomes, (2) *Recovery*—the ability of the food system to return to desired outcomes following disruption, and (3) *Reorientation*—the ability to accept alternative outcomes preceding or following disruption.

The perceptions of risk to a given disruption (i.e., stresses and/or shocks) for a particular food system activity can be conceptualised as a driver shaping the relevant actor’s behaviour in response to their perceived risk. For example, how a grower understands and perceives the risk of drought on crop yields determines how they aim to increase resilience to that particular risk. This could include investing in irrigation equipment and reservoir building to increase robustness of their production system, or reorientation by swapping to more drought-tolerant crops. A retailer might diversify sourcing from different growers to include various geographical areas. The use of these measures influences in turn the overall output of the individual actor with respect to quantity and quality of his/her activity, and the level of resilience. The different perspectives the range of actors in the system have for risks and stresses, and the array of resilience-enhancing strategies they can employ, means that framing resilience and devising measures to build resilience in a full system context is not straightforward. A starting point is to be clear about each actor’s perception of resilience “of what” (i.e., the subject), “to what” (i.e., the shock or stress) and “for whom” (i.e., which actor) [20]. One can then consider the interactions between the individual actors’ perceptions and actions so as to derive how best to enhance overall system resilience.

1.4. Aim

This paper aims to reveal the different framings that the UK’s FF&V system actors use for water risk and the risk mitigation measures they employ to enhance resilience. We base the analysis on the three questions—resilience (i) of what? (ii) to what? and (iii) for whom?

Resilience of what? Here we want to understand what it is that an actor in the FF&V system wants to make more resilient and how their framing of FF&V relates to it.

Resilience to what? Here we seek to describe the perceptions that different FF&V actors have with respect to water-related risks that might translate into shocks and stresses to their operations.

Resilience for whom? Here we explore who the key actors are in the UK’s FF&V system and how they perceive FF&V.

Answering all three questions clarifies actors’ perceptions and hence the motivation for their interventions to enhance their resilience to their perceived risks. In order to build resilience at the system level, however, we also aimed to explore a further question:

How do resilience-building strategies interact? Here we consider how the strategies of one actor can impact the effectiveness of another actor's resilience-building strategies, which can thereby either amplify or dampen the overall system resilience.

The paper is structured as follows. Section 2 explains the methods used to elicit the framings of various UK FF&V food system actors with respect to water risks and the set of strategies they employ to deal with them. For this, the authors carried out a set of interviews with actors across the UK FF&V system. Section 3 presents the results of the interviews and the analysis of risk framings, resilience-building strategies and how actors perceive and deal with their interconnectedness within the system. Section 4 analyses the results with respect to the interaction of the value-chain position and risks faced by each actor, the way resilience-building measures are impacting each other across actor groups and how risk perceptions shape the choice of resilience measures. Section 5 then discusses the implications of these results and sets out a number of recommendations for enhancing the resilience of the UK FF&V system to water-related risks.

2. Methods

2.1. Data Collection

Understanding the structure of the FF&V system in the UK and how the different FF&V actors in the UK perceive water risks was based on interviewing actors across the FF&V system from producers to retailers. (An analysis of how consumers influence and interact with water-related risk and resilience of the UK's FF&V System was beyond the scope of this study.) Interviews were conducted in two stages: Stage 1 was a scoping exercise to inform the design of the structured interview process in Stage 2.

Stage 1 was characterised by an open, exploratory design. Telephone interviews with 8 representatives of the range of activities in the UK's FF&V System were conducted, recorded and transcribed. Interviews were loosely structured around four topic areas: (1) a description of participants' businesses/organisations, their backgrounds and daily activities; (2) a discussion of system interactions and understanding; (3) an explanation of participants' thoughts and experiences with water-related risk and resilience; and (4) a comment on the most important uncertainties that participants identified as most influential for the future of the UK's FF&V system. The boundaries of the system itself were purposefully left open to allow the participants to define it themselves. Understanding system boundaries and structure was achieved by an extensive use of snowball sampling and inquiring about participants' interactions with actors engaged in other activities (hereafter referred to as "actor groups", Table 1). The insights gained in this scoping exercise informed the system characteristics, most relevant actor groups and topics to be included in the interview process of Stage 2.

Table 1. Numbers of Stage 1 and 2 interviews by actor group.

Actor Group	Stage 1	Stage 2	Total
1. Growers	3	13	16
2. Packers/producer groups	2	4	6
3. Retailers/wholesalers	3	9	12
4. Food processors/manufacturers		6	6
5. Food services		3	3
Total	8	35	43

Stage 2 employed a structured telephone interview questionnaire to gather comparable data from a further 35 participants focused on the most important actor groups identified in Stage 1 (Table 1). The actors were not only a diverse group in terms of their varying food systems activities, but also in relation to how they practise those activities. The grower group, for example, included hydroponic

tomato farms, soft fruit orchards, field-grown vegetables, plant nurseries and large-scale greenhouse operations. Food processors ranged from baby food manufacturers to industrial sandwich packers, washers and packers of leafy greens, to manufacturers of frozen meals. Following Bryman [21], Stage 2 used a stratified sampling technique centred around the goal of an equal participant distribution across the identified actor groups to enhance comparability of results. This goal was not achieved entirely due to large variance in the size of actor groups and their responsiveness. Internet searches and snowball sampling identified participating businesses and organizations. Participants answered 18 questions clustered in six topic areas: (i) their business or organizational context, (ii) the water-related risks they have experienced, (iii) their water management strategies and planning timeframes, (iv) their understanding of resilience, (v) their preferences and constraints concerning water-related risk management and (vi) their perspectives on system-wide resilience-building activities.

2.2. Data Analysis

An analytical coding matrix [22] was used to synthesise the interviews, which tracked participants' perspectives of four main themes: (i) water-related risk and causes thereof, (ii) water-related risk management, (iii) understanding of resilience and (iv) systems thinking. Close reading sessions of the interview transcripts identified the individual experience of each participant for each theme [23]. The individual experiences of each group were then aggregated. Finally, a comparison of the perspectives of each actor group identified similarities and differences within the system. Using a food systems lens, data analysis focused on assessing the variation of practices within and across actor groups. A second strand of inquiry evaluated how the relationships between different actors influence both each other's and overall system resilience to water-related risks.

3. Results

3.1. Resilience for Whom?

Although the order of the three key questions is introduced in Section 1 as “Of what, to what and for whom?” we start with the “for whom” as this defines the actor groups around which interviewees were structured. The interviewees for Stage 1 and Stage 2 were classified according to their role in the UK FF&V system (Table 1).

3.2. Resilience of What?

During the interviews, four different perspectives of FF&V as a material emerged, based on the specific activities carried out by an actor. The actors saw FF&V either as a crop, an ingredient, a commodity or a set of specifications.

Crops: Crops grow in the ground, in soil, on bushes, on trees, in greenhouses, and respond to the environment in which they are situated. Those that cultivate crops wait to have value attributed to them by others.

Ingredients: FF&V are selected and then processed into a food product because they comprise a particular set of values and characteristics that contribute to the value of that food product. Transition from crop to ingredient is mediated by actors with shared values.

Commodities: Commodities are FF&V that are attributed a financial value only. They are reticulated through a supply chain from some point of origin and are rearranged into another product with a greater economic value. Commodities are mediated by markets.

Specifications: Here FF&V is attributed a specific set of qualities, including taste, size, quantity and appearance. FF&V must satisfy criteria for these qualities in order to qualify as FF&V, otherwise it is seen as either unusable or as something else, e.g., waste.

Figure 1 shows the proportion of FF&V system actors that have the different perspectives of FF&V material. All growers perceived FF&V as a designated crop which requires resources (economic, labour, water etc.) to deliver a marketable yield: “*These days, costs dictate that every crop has to do well.*”

There's no averaging, and certainly with us, that pressure is far more, because we only have one crop" (grower). Other actor groups perceived FF&V differently, with only 15% of retailers/wholesalers seeing it as a crop, while 85% perceive it in terms of specification. Understanding the differences in the perspectives of the FF&V system actors is important as their framing of a particular FF&V will determine what an actor perceives as risks to the FF&V they deal with, and which resilience-building measures this actor will employ. This framing of the material nature also translates from an understanding of FF&V as a crop (by the grower) to perceiving it as an input for their activity. This change in perception is important for understanding the risk mitigation strategies discussed in Section 3.4.

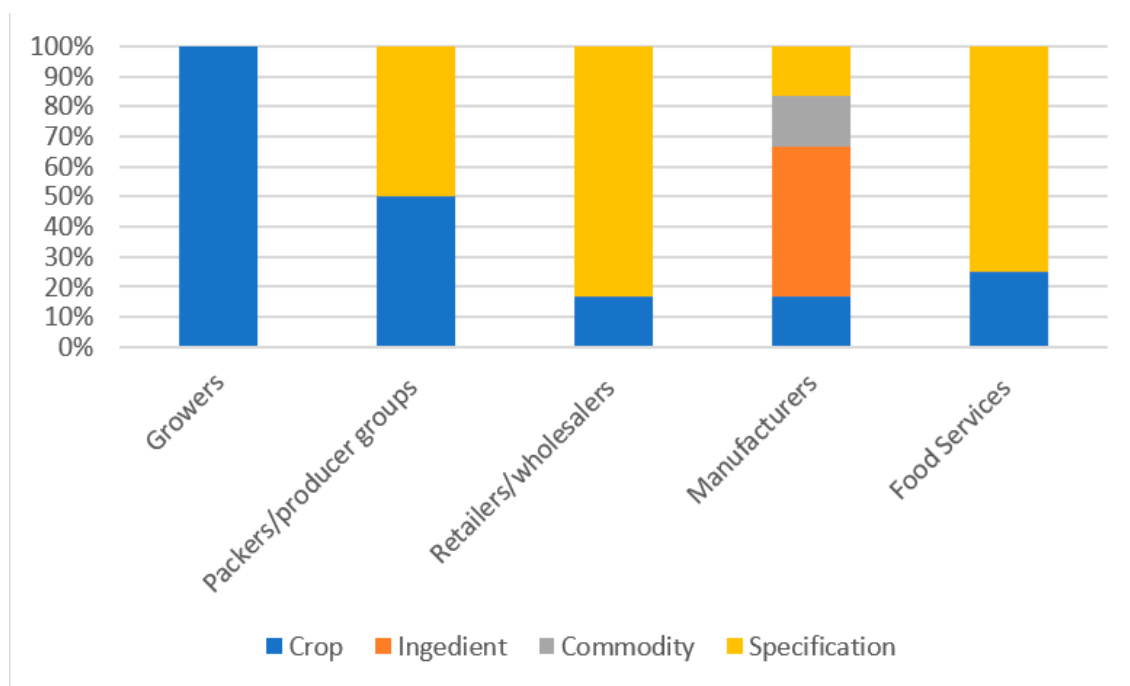


Figure 1. Perspectives of the material nature of FF&V for different FF&V system actors.

3.3. Resilience to What?

Actor groups identified five major water-related risks that affect the UK FF&V system: water scarcity, water excess, rainfall variability, water quality degradation, and water policy and regulation. They also differentiated them as “direct” or “indirect”. For example, for a grower, a drought is a direct risk to production, whereas an indirect risk could be crops failing to meet the requirements of those further down the supply chain; for a manufacturer, a direct risk could be a microbial contamination of produce, whereas an indirect risk could be a change in food safety regulations.

3.3.1. Different Types of Water-Related Risks

The different FF&V actors described water-related risks either as water scarcity, water excess, rainfall variability, water quality degradation or as related to water policy and regulation:

- (1) **Water scarcity.** Low levels of rainfall, limited water storage, limited irrigation infrastructure and/or limited access to water sources (e.g., abstraction from groundwater, rivers and lakes). For growers, water scarcity can impact crop production and without risk mitigation, yield and quality of crops can be reduced: *“This year was a particularly bad year and we’d run out of water close to the end of July. We had to put in a significantly reduced irrigation scheme several weeks before, which meant that lots of crops were suffering because they didn’t get the water they needed . . . ”* (grower).
- (2) **Water excess.** Excess water from heavy rains, hail, floods and snowmelt can also lead to crop failure due to affecting production methods and harvesting. It can also affect physical infrastructure: “

... where we live, it's definitely prone to flooding. It must have been three or four years ago where there was a lot of flooding. In our area, the lake actually rose up by a meter and a half ... so one of the greenhouses got flooded ... it was a very bad flood" (grower).

- (3) Rainfall variability. This can make crop and irrigation programming problematic, and can compromise the chances of successful yields. Further, rainfall variability, particularly when dry periods are followed by particularly wet periods, and when it is uncertain how long dry periods will last, makes investment in drought risk mitigation problematic. Uncertainty in rainfall variability is primarily a direct risk for growers: "We've got our weather data going back to 1948 and there's a clear change in weather patterns. We don't seem to get summer showers anymore ... instead you get a long dry spell followed by torrential rain" (grower). "You get soil erosion, and also if it has been dry for a long time, the water runs straight off and doesn't soak in because of compaction" (grower). It also complicates their decision making and investment in irrigation for risk management: "Imagine if we invest in all this and it is wet for the next 5 years? When you get an un-forecast rain event and you think, could I have waited? ... or, there is 50% chance of 5 or 6 mm and you go (sigh), because you can't catch up ... if you get behind you can't catch up ... I am risking the income of my business ... I can't afford to run a high-risk irrigation system" (grower).
- (4) Growers are worried that they will react unnecessarily, over-react, or not be prepared at all, "unable to catch up" (grower). The result of this uncertainty is that growers can be passive to water risks: "Farmers tend to be reactive as opposed to proactive. I would like to think that we can handle things the best we can, but how far do you go?" (grower).
- (5) Water quality degradation (including microbiological risks). Water can be too saline for optimum crop growth, or can carry microbial or other forms of contamination that present food safety risks. In addition to risks for growers, downstream actors are concerned about water quality. For some hydroponic operations and other specialised growers, agrichemical contamination is also of concern: "If we were collecting, it worries me that with a reservoir, we are in a large farming area and farmers are not that careful when they spray herbicides, if that lands of the roof of the greenhouse and we collect it for a reservoir, if it had a certain amount of herbicide in it, it would really mess me up" (grower). Microbial contamination directly affects packers (of salads, in particular), food services and food manufacturers where products are intended to be eaten raw.
- (6) *Water policy and regulation.* Water availability for irrigation can vary as policy and/or regulation dictate the redistribution of water for other uses, e.g., environmental or domestic needs. Water policy and regulation pose other risks. While some actors must adhere to water policy off-farm (e.g., processors having to limit quality of water discharge), policy regarding abstraction and irrigation licences plays a more significant role in shaping risk amongst growers: "Abstraction licences are always under review. The headroom has been removed for most farmers. For small farmers, their water allocation is limited to 100% of their use at the year 2000. For large farms, abstraction has been limited to 75% of the 2000 level. Since the year 2000, the years have been relatively wet for the region but only when compared to the 70s. If the weather starts to dry up then we need to have some headroom for irrigation, or a reservoir, but where is the water going to come from?" (grower). Here the concern amongst growers is how changes in abstraction and irrigation licences work to lower the overall volume of water available to them, which has the effect of lowering the spare volume that would be used to supplement low rainfall, denoted as "headroom". Reduced headroom makes farmers more vulnerable to water scarcity and rainfall uncertainty, and also makes them feel less confident to make investments if they are uncertain of what water will be available to them: "If I've got 30 years I've got some confidence that I've got that water for thirty years, and therefore I can make an investment in the business. If I need a new potato store I can think about building a new potato store. If I need to invest in some machinery, or some pipe to go down underground or whatever it might be, some extension to the underground main... whatever it might be I can think about investing it because I've got the security of knowing that water is there" (grower).

3.3.2. How Perception of Risk Differs among Actor Groups

While all the FF&V actors are connected within the FF&V system, and indeed many interact with each other, they do not necessarily perceive themselves as part of a system—most are closely focused on their part of it. It is therefore important to understand their specific perceptions of FF&V and of water-related risk. To understand how different actors build resilience to water-related risk in the system, there is a need to know which risks they perceive as direct and indirect, and of these, which ones actors think are most potentially impactful. In addition, it is important to understand if and how the risk perceptions of actors within the FF&V system are interacting with each other, in that the same type of water-related risk could be direct for one actor and then “translate” into an indirect risk for another actor. Table 2 indicates this type of “risk translation”—water scarcity and water excess are direct risks to growers, seeing FF&V as a crop, and result directly into a reduction of their production. This reduction in production then constitutes an interruption in supply to packers, retailers/wholesalers, manufacturer and food services; thus water scarcity for one actor translates into a supply risk for another one. Water excess is also seen as a direct threat by packers, retailers/wholesalers, manufacturer and food services if the infrastructure they rely on is damaged, for example, due to flooding. But none of the actors saw it as an indirect risk. Rainfall variability is seen as a direct risk to production by growers while it is not mentioned by the other food system actors either as a direct or indirect risk. Water quality degradation is seen as an important direct risk influencing FF&V quality by all actors except the retailers. This could be related to the fact that FF&V is seen by the retailers mainly as a set of specifications. Again though, none of the actors saw this type of risk translating into an indirect risk to their operations. Policy and regulations are perceived by the growers mainly as a direct risk to their crop if it restricts their access to water resources in time of scarcity, and is thus seen as similar to the water scarcity category. For the four other actor categories, policy and regulation is seen as an indirect risk, affecting the quality of FF&V products and their supply.

Table 2. Exposure of FF&V actors to different water-related risks. Numbers in brackets indicate the number of interviewees who noted a given risk *.

Risk (To What?)	Direct Risk		Indirect Risk	
	For Whom?	Of What?	For Whom	Of What?
Water Scarcity:	Growers (6)	Reduced production	Packers (4), Retailers/Wholesalers (12), Manufacturers (6), Food Services (3)	Interrupted supply
Water Excess:	Growers (2)	Reduced production	Packers (2), Retailers/Wholesalers (2), Manufacturers (2), Food Services (2)	Interrupted supply
	Packers (1), Retailers/Wholesalers (2), Manufacturers (2) and Food Services (1)	Infrastructure		
Rainfall Variability:	Growers (4)	Reduced or excess production		

Table 2. Cont.

Risk (To What?)	Direct Risk		Indirect Risk	
	For Whom?	Of What?	For Whom	Of What?
Water Quality and Pollution:	Growers (2), Manufactures (2), Packers (3) and Food Services (2)	Quality		
Policy and Regulation:	Growers (2)	Water access in drought	Packers (4), Retailers/Wholesalers (12), Manufacturers (6), Food Services (3)	Quality standards

* As some interviewees noted several risks, and some only one risk, the summation for a given actor group across all risks is not necessarily the same as the number in that actor group as given in Table 1.

The “translation of risk” from one set of actors to another shows that it is important to analyse risk perceptions of the different FF&V actors not just from the point of view of a single actor alone as this might only reveal half the story of how risk “moves through the system”. Understanding what each actor perceives as a threat to their operation is of course needed to understand what measures they pursue to build their resilience. However, the full picture of impacts can be only seen by analysing how the same type of water-related risk can constitute both a direct and indirect risk to different actors, and can transform from a direct risk to one actor into an indirect risk for another. This full picture is then also important for analysing if and how resilience-building measures of different actors are interacting with each other.

3.4. Resilience-Building Strategies

The various FF&V system actors use a wide range of resilience-building strategies to mitigate the perceived water-related risks (Table 3). The individual interventions will depend on the actor’s operations, their perception of FF&V and what the risk relates to, and if these risks are direct or indirect. Another important aspect of resilience building is what type of resilience building an actor pursues: does he/she want to build a robust (where a shock or stress cannot enter) or a recoverable system/activity or is there a need for reorientation? (See Section 1.3).

For growers, enhancing resilience to water scarcity is generally associated with building robustness by investing in irrigation equipment, reservoirs and providing headroom (where abstraction licences permit this). This is to ensure sufficient water for all the crops. Where water is limited, higher-valued crops are given priority over lesser-valued crops, and are allocated the majority of whatever water is available. This maintains some income for the grower, but also exposes them to their market closing as the customers for their main crops move to other suppliers. For growers, effectively managing water-risk determines their degree “of doing well”, i.e., recouping the investment that has been made growing the crop, to provide an income for the grower and to facilitate growing more crops. This success also depends on the extent to which a crop can satisfy the demands of downstream actors.

Food manufacturers mainly consider FF&V as an ingredient while some also appreciate it for its specific specifications (taste, size, quantity, appearance and price). However, they are also interested in the ethics and sustainability of growing methods —“we want to ensure that our ingredients are ethically and sustainably sourced” (manufacturer). Where FF&V is assigned a particular set of values, as in an ingredient, a different relation between grower and manufacturer is produced, and a different approach to managing water-related risk is needed “... we work closely with our grower to highlight improvements across statutory (organic) and agronomic levels” (manufacturer). In this arrangement, the successful transition of crop to ingredient is a shared endeavour; that is, the risks and resilience strategies are shared.

For retailers and other downstream FF&V system actors, resilience of supply is enhanced by either being flexible about specifications or by finding alternative suppliers. Diversity of suppliers is a primary strategy of actors who deal with commodities: *“short term contracts mean that you can change suppliers as quickly as you like”* (wholesaler). Enhancing resilience to water-related risks becomes a matter of how effectively an alternative supply can be found: *“We had a challenging summer . . . we had to procure from outside of the UK We had to fly in iceberg lettuces from America”* (packer). Price also matters—for large wholesalers FF&V is a designated commodity, which may only be concerned with price, *“ . . . people mainly buy commodities based on price”* (wholesaler). This alternative sourcing strategy, although increasing the resilience of supply for downstream actors, can also work to undermine the resilience at the grower level as the new supply infrastructure, once established, means their market may not return after their production returns to normal.

As the intervention of one actor will influence the risks to others, it is also important to understand how risk moves through the system. For many downstream enterprises, a mutually dependent relationship is described: *“we can’t do anything if we don’t have a crop”* (manufacturer). The crop must satisfy the particular attributes of downstream actors in order to generate an income, *“to do well”* for all actors along the supply chain; water-related risks do not only affect crops, but also specifications. If a crop cannot satisfy these criteria, it does not successfully translate into an income and in turn does not contribute to the supply of FF&V for the retailer.

Table 3. Resilience-building strategies articulated by actor groups and what it is they intend to make more resilient. Numbers in brackets indicate the number of interviewees who noted a given risk *.

Resilience Strategy	Actor Group who Noted Value of the Given Strategy	Example Purpose	Aimed at Increasing Resilience of What
Infrastructure (reservoirs and irrigation)	Growers (10) Packers (3) Manufacturers (2)	Reservoirs and irrigation systems provide Growers with the ability to supplement low rainfall, thereby working to mitigate drought-related and water-related risk	Production
Abstraction Licences and Headroom	Growers (2)	Abstraction licences give Growers permission to draw water from ground and surface water sources to be used for irrigation to supplement low rainfall. Headroom is the amount of water available to Growers above their normal irrigation needs and acts as a buffer.	Production
Crop Prioritisation and Sacrifice	Growers (3)	Where low rainfall exceeds reserve water capacity (i.e., from reservoirs or abstraction headroom), Growers will prioritise certain crops to ensure these receive their full water needs at the cost of other crops.	Production

Table 3. Cont.

Resilience Strategy	Actor Group who Noted Value of the Given Strategy	Example Purpose	Aimed at Increasing Resilience of What
Speculative Growing	Growers (1)	Growers may plant more than is required in an attempt to offset partial crop failure due to seasonal variability.	Production
Alternative Supply Base	Manufacturers (3), Retailers/Wholesalers (7), Food Service (2), Packers (1)	Here actors who have the capacity to switch rapidly between suppliers of FF&V can do so in order to mitigate any water risk to supply. This can include shipping/flying in FF&V from overseas.	Supply
Precision Water Technology	Growers (2), Packers (2)	Investment in precision irrigation, hydroponics and water recycling/treatment is practised among some specialised Growers (e.g., tomatoes, nurseries) in an effort to lower water dependency.	Production
Strategy Development and Planning with Grower base	Manufacturers (1), Retailers/Wholesalers (3)	Here the resilience strategy is to work on an ongoing basis with grower base to ensure best practice options for water management and risk management are maintained.	Production–Supply
Flexible Specifications	Manufacturers (1), Retailers/Wholesalers (3), Food Service (2)	Here actors can rearrange expectations of what constitutes FF&V for them in order to allow different versions of FF&V to proceed through the supply system, e.g., accepting small fruit or stained onions.	Production–Supply
Catchment Level Strategy Planning	Growers (2), Manufacturers (1), Retailers/Wholesalers (2)	Here different actors convene in an attempt to garner a broad understanding of risk, sustainability and resilience of the water catchments they utilise and have an impact on.	Production–Supply

* As some interviewees noted the value of several resilience strategies, and some only one, the summation for a given actor group across all strategies is not necessarily the same as the number in that actor group as given in Table 1.

Enhancing resilience at the *system* level can be more likely if there is an open and honest relationship across the whole supply chain. This is the case in, for instance, *values-led* food manufacture, which empowers all actors along the supply chain [24]. All actors are made more resilient by shared risk management planning and open communication: *“We are a values-led company, and one of our values is to be open and honest, which I guess paved the way for being open and honest in terms of communication with our suppliers. I suppose they also see us as a positive brand in the UK, so I guess it is in their interest too, to be open and honest about their growing conditions, which could impact our product, that is probably one of the main reasons that we have such a good relationship”* (manufacturer). Put another way, both grower and manufacturer are made resilient through sharing mutual risks and mutual outcomes. *“In terms of the growers we have in place, we are well aware of their sustainability strategy and their plans for creating a buffer. So it isn’t something that we considered a risk and we are always reassured that this was in place”* (manufacturer).

Table 3 summarises the range of resilience-building strategies articulated by actor groups. For some actors, the examples mean individual investment or actions (e.g., growers having to invest in a reservoir). Other actors may see the benefit to themselves of another actor’s actions (e.g., a packer seeing the value in a grower investing in a reservoir but not having to do it themselves).

4. Discussion

4.1. Position in the Value Chain Determines Risk Perception

A reduction in growers’ production produces a particularly vulnerable arrangement for them that can be compounded by their relationship with the rest of the system: *“... So you face the risk, if you are the one who’s shrinking, the customer (retailer) is saying to you, ‘well look I’m sorry but there’s not much point in dealing with you, you are getting smaller, not bigger, I’m going to deal with these other people who are still willing to grow as much or even expand’”*. It also suggests that most activities should be aimed at the farm level [25], because it is where most vulnerability is thought to currently lie.

For other actors in the FF&V system, rainfall uncertainty can be experienced as a matter of timing and issues with shifting seasonal supplies. For instance, a provider of food services commented: *“... we have noticed over the past years how this has changed—we could say that for the next four months the product will be in season, but this has changed with weather conditions. We can’t rely on certain pricing ... so we are trying different suppliers, what we can’t find here, we will find somewhere else.”* Here it is also clear how such a risk management approach also works to compound the concerns expressed in the previous example.

For food manufacturers who deal with FF&V as commodities, the impact of water-related risk is indirect, on price volatility—*“the impact of water stress issues on commodities is price ... volatility in price can be a real problem for business ... I don’t really see water stress in the UK.”*

There is also a risk of flooding for logistics and infrastructure in general, although these are not highlighted as specific or significant risks to the supply of FF&V per se.

The different perspectives that the actors in the system have on FF&V (i.e., crops, ingredients, commodities or specifications) are fundamental to their perceptions of water-related risk and hence how they approach enhancing their resilience. While all risks can affect all actors, most of the direct risks are carried by growers. The likelihood of others facing risks is lower (e.g., flooding of supermarket warehouses) or better controlled (e.g., microbiological contamination in food processing). Nonetheless, downstream actors ultimately depend on supply from growers, and hence face supply-chain risks.

The different framings of the FF&V system actors are of course connected to each other, though the actors themselves might not be aware that their framing of FF&V differs from that of another actor. Thus, an apple produced on a farm where the farmer sees it as a crop and manages it accordingly “changes its meaning” and becomes an ingredient or a commodity for a manufacturer, and a set of specifications for a retailer. This change in framings along the FF&V system is important to note as it conditions how a particular FF&V material is managed along the system. This raises a number of

questions: Do the differences in FF&V framings and subsequent use of resilience-building measures matter for building an overall resilient system? Is a system only resilient if all its actors and their activities are resilient in their own right? Can a resilient system be built if actors frame the answers to the resilience questions differently?

4.2. Risk Perception Determines Resilience-Building Activities

The degree to which given actors are resilient can be conceptualised as their ability to deal with the perceived risks, but goals for resilience building will differ among different types of actors, which in turn leads to using different resilience-building interventions.

Further, the aims of resilience building for an individual actor will also likely differ to the aim of resilience building for the UK's FF&V system as a whole, i.e., maintaining a steady supply of a range of affordable produce for the consumer. Whichever the aim, resilience building could be to make given activities and/or desired outcomes more *robust* in the face of shocks and stresses (i.e., maintain the status quo). Alternatively, it could be to enhance the ability to *recover* (i.e., return to the status quo). However, a third framing for resilience building can be to accept different outcomes from an actor's activities or the system as a whole and thus *reorient* (i.e., not aiming to maintain or return to the status quo). All three approaches to resilience building require reorganisation of activities.

The specific drivers and perceptions of each subgroup determine how they perceive risk, what type of resilience they are striving for and therefore how they interact with other actors. It is not possible to understand the FF&V system as a whole without taking this close look at the individual dynamics that it entails—some actions reinforcing, and some undermining, others' strategies.

The types of risk that different actors perceive determine which resilience-building activities are important for them. It also suggests that most activities should be aimed at the farm level, because it is where most vulnerability is thought to currently lie. This is not the case, however, as overall resilience of the system is not optimised.

4.3. Relationship between Individual Actors' Resilience and System Resilience

To ensure a positive long-term future of the FF&V system itself (for the sake of creating livelihoods) as well as its intent (nourishing people), actors need to be resilient to water-related risks and develop respective practices to manage different water-related risks. Every actor group has its own set of resilience-building strategies. Sometimes those strategies overlap and reinforce each other, but many times they are not coordinated. This creates an especially difficult situation for (small-scale) growers who bear most of the risk, but often lack resources or information to invest in more resilient practices.

5. Conclusions

The lack of integrated resilience practices across actor groups may not necessarily be a problem if the desired outcome is merely food security. But resilience at an individual actor level, or individual outcome level, does not imply system resilience. If we also care about supporting rural livelihoods and the survival of small-scale farmers in the UK and elsewhere, it is important to streamline support from downstream supply chain actors for the farm level.

Policy makers need to take the heterogeneity of actors and their differing framings of risk and resilience-building mechanisms into account when targeting policy measures. As the strategy of one actor might increase the vulnerability of other actors within the system, water policy formulation needs to embrace the implications of risk management strategies of individual actors. It also needs to take account of overall FF&V system resilience in order to safeguard against different strategies undermining each other.

Platforms are needed through which strategy development, capacity development and capital investment (reservoirs, irrigation infrastructure, cold storage etc.) interventions can be devised for the system's most vulnerable actors. Such platforms need to be developed in a precompetitive space so that all actors can convene, discuss and understand the risks at different levels of the system and

develop resilience-building strategies that do not inadvertently compromise the resilience of overall supply or that of any individual actor.

It is clear that resilience-building activities can (a) have a positive impact on the resilience of others, i.e., better water practices on farms can have a positive impact on downstream actors (and on the environment); or (b) compound the risks for others, i.e., abandoning one supply base for another increases the resilience of supply but compounds the risks for the abandoned supply base.

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