



From surplus-to-waste: A study of systemic overproduction, surplus and food waste in horticultural supply chains

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ABSTRACT

Until recently, food waste prevention intervention has largely offered 'end of pipe solutions' that focus on causes of food waste at specific points in supply chains and on dealing with the physical waste material itself. Recent research has taken a different approach by emphasizing the systemic nature of the food waste problem and the need for its in-depth exploration. This paper offers a systems-based understanding of food waste, which allows for an account of the interconnected processes that underpin waste creation along the whole supply chain. Through a qualitative inquiry on practices and processes of surplus and waste creation in the Australian horticulture industry, the research findings precisely delineate 'surplus-to-waste lock-ins'. That is, the institutional, cultural, and material factors that enable the creation of food waste through the related categories of over-production and surplus formation. The article's identification and analysis of surplus-to-waste lock-ins is grounded in a socio-technical transitions perspective and extends transition studies to agrifood systems and horticultural food waste. This research positions systemic food waste theoretically as a symptom of 'system-lock-in', which may thwart efforts to prevent food waste, and thus bridges micro and macro levels of analysis. These findings translate into three key recommendations for industry, policy and research: that approaches addressing systemic processes of waste creation are essential to unlocking food waste prevention, that food waste prevention should target the identified system processes contributing to food chain lock-ins, and that transparent monitoring and disclosure of food surplus is a prerequisite for systemic food waste prevention across the whole supply chain.

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1. Introduction

Global food wastage is a significant challenge for progressively realising sustainable development objectives like world food security. Global food production is resource intensive. It contributes an estimated 19–29% to greenhouse gas (GHG) emissions worldwide (Vermeulen et al., 2012) and accounts for 70% of global fresh water use (Lemaire and Limbourg, 2019). Yet, depending on the measurement protocol deployed, 30–80% of food mass and nutrition value are discarded globally (Alexander et al., 2017; Corrado

et al., 2019; Vulcano and Ciccarese, 2017). Such significant levels of waste are problematic due to the threats posed by resource degradation and climate change and considering the distributional inequities that underlie food insecurity currently (Kummu et al., 2012; Springmann et al., 2018). Accordingly, UN member states have agreed to the target of halving per capita food waste by 2030 as part of the Sustainable Development Goals (FAO, 2019).

As a multi-faceted sustainability challenge, food waste has become the latest food-related issue to undergo a conceptual shift from a problem at discrete points of supply chains to a problem embedded within food system dynamics. Accordingly, research has begun framing food waste as the result of complex, non-linear interactions within food chains shaped by broader food systems rather than as an outcome of individual behavior (Göbel et al., 2015, p.1429; Redlingshöfer et al., 2020, p.8). Consistent with systems thinking, this strand of research within food waste scholarship focuses on the fundamental causes of waste rather than dealing

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with the waste material once it exists.

A growing body of research from natural scientists, who employ varying methods for quantifying food waste, reveal 'food overproduction' and 'food surplus' to be significant factors in food waste generation at a global level and in economically developed countries (Hall et al., 2009; Hic et al., 2016). Hence, scholars developing systemic understandings of food waste have emphasized the importance of further research on the surplus-waste nexus (Chaboud and Daviron, 2017; Messner et al., 2020; Mourad, 2016; Papargyropoulou et al., 2014; Pedersen et al., 2015; Vulcano and Ciccicarese, 2017). Few studies have explored and explained how and why overproduction, surplus and waste exist and interrelate in real-world contexts, and how they are driven by underlying system settings. One exception is a study by Kuokkanen et al. (2017) that explored the relation between agricultural policy and system processes locking food chains into unsustainable production practices.

This research seeks to advance systemic understandings of food waste by providing an in-depth description and explanation of the food chain dynamics that connect and enable over-production, surplus and waste. Specifically, two research questions guide this study: 'What are the causes of overproduction and food waste at the production stage of the Australian horticulture supply chain?' and 'How does overproduction contribute to food waste along the Australian horticulture supply chain?' In pursuit of these answers, data were collected from twenty-nine supply chain actors through a series of face-to-face interviews conducted in the Australian horticulture industry between 2018 and 2019.

In this paper, the food chain dynamics that connect and enable overproduction, surplus and waste are referred to as 'surplus-to-waste lock-ins' to identify and organize the various interactions that connect surplus to waste along the supply chain. An understanding of 'surplus-to-waste lock ins' is developed through the theoretical lens of socio-technical transitions theory, which is used here to advance systemic understandings of food waste. Specifically, socio-technical lock-in - which represents the aspects and interrelationships that reinforce and 'stabilize (unsustainable) systems'- provides an analytical frame that helps render visible 'blockages' in the food system that thwart efforts to prevent food waste (Geels, 2011, p.25). At the same time, the paper contributes to transition studies by exploring the "specific mechanisms through which lock-in becomes manifested" as well as specific aspects of "regime persistence and preconditions for the development of transition pathways" (Klitkou et al., 2015, p.23). As such, this paper conceptualizes food waste as a symptom of lock-in and food system resistance, thereby advancing and strengthening the empirical and conceptual basis of the systemic perspective of food waste.

Having broadly situated the research problem of food waste within a systems context, the following section unpacks and problematizes the three key concepts: overproduction, surplus and waste. The literature on food systems and food waste is then examined, identifying a key gap regarding the complex 'mechanisms' that frustrate efforts to reduce food waste. Next, the concept of 'lock-ins' from socio-technical transition studies is introduced as a theoretical frame through which to apprehend and understand systemic surplus and food waste and its broader significance beyond horticulture and beyond the Australian case study. This is followed by the methodology section, which outlines the qualitative research methodology with its empirical basis of data generated from semi-structured interviews across multiple sectors of Australian horticulture. The findings section brings forth the voices of horticultural actors that experience the day-to-day practices of the sector in context of broader supply chain operations. This section is organized into the four key emergent themes: a) industry characteristics that contribute to food waste; b) industry practices that encourage formation of surplus; c) the failings of surplus

recovery from waste; and d) surplus as an amplifier of waste creation. To finish, the discussion and conclusion sections cement the structural nature of overproduction beyond on-farm decision-makers, which leads to recommendations to navigate these structural constraints via measures addressing the specific lock-in points in research, policy and practice.

2. Literature and background

2.1. Systemic overproduction, surplus and waste

As stated in the Introduction, system approaches to food waste prevention are under-developed in food waste scholarship. Until recently, the literature across the natural sciences had a tendency to focus on 'end of pipe' solutions, including the recovery of value from food surplus and waste, re-distribution, recycling or valorization (Garrone et al., 2016; Kirchherr et al., 2017; Raak et al., 2017; Zaman, 2015). Similarly, the social sciences, with a few exceptions, largely addressed food waste from a 'consumer behavior' standpoint (Aschemann-Witzel et al., 2015; Principato, 2018; Schanes et al., 2018; Stancu et al., 2016). With these bodies of work contributing to understandings of 'what to do' with existing food waste, there are fewer holistic approaches that focus on how to 'prevent waste before it occurs'. Shifting the focus to a 'front of pipe' approach broadens understandings toward a whole of system perspective which examines food waste as embedded in, and as an outcome of, complex, non-linear production and consumption dynamics (Göbel et al., 2015; Mourad, 2015; Redlingshöfer et al., 2020; Thyberg and Tonjes, 2016; Urrutia et al., 2019). Inevitably, this enrolls broader dynamics into the analysis, including the role of policy, politics, economy, markets and institutions, which act as levers in the creation of food waste. As such, a food systems approach is central to unlocking the interrelated dynamics that produce large volumes of horticultural waste across the supply chain.

'Food systems' offers a conceptual framework that provides a non-linear understanding of interactions across food supply chains. It encompasses the outcomes of these interactions, and the ways feedback loops, outcomes and external factors influence how food systems, including food chains, function (Ingram et al., 2013). Accordingly, 'food systems' has become the predominant way to conceptualize food-related issues and interventions to address them (Ericksen, 2008). Food waste, despite gaining increased attention as a major environmental and social challenge, has only been a 'marginal' concern of food system studies and only minimal research on the significance of food waste in food systems is currently available (Hodgins and Parizeau, 2020, p.43). Halloran et al. (2014, p.295), for instance, have called for "systemic evidence" of the detailed linkages between food system design, operation and food waste as an outcome. Bengtsson et al. (2018, p.1542) have encouraged research to elaborate "what factors leave food systems prone to producing large amounts of surplus/discarded food", while Redlingshöfer et al. (2020, p.9) suggested that future research should "focus much more on the drivers and determinants of food waste generation in all food system sectors". Other research has highlighted the need for deeper analysis of systemic food waste (Vulcano and Ciccicarese, 2017, p.46), including its "decision processes and actors" (O'Rourke and Lollo, 2015, p.242) as well as relevant "relationships and automatisms in the food chain" (Göbel et al., 2015, p.1441).

Relative to consumer-focused studies, a small body of recent work within the interdisciplinary field of food waste research positions 'overproduction' as a fundamental characteristic of food systems that, in combination with other factors, leads to food surplus that turns to waste (Chaboud and Daviron, 2017; Mourad,

2016; Pedersen et al., 2015; Vulcano and Ciccarese, 2017). Research from environmental science has shown that overproduction contributes to the gap between production and consumption that gives rise to food surplus throughout a supply chain (Hic et al., 2016, p.4270; Papargyropoulou et al., 2014, p.112). Findings that the food production stage, i.e. farm waste, is disproportionately responsible for food surplus and waste support a focus on production as a key point where the structure of food chains promote food surplus creation (Alexander et al., 2017; Johnson et al., 2018; Porter et al., 2018; Raak et al., 2017; Vulcano and Ciccarese, 2017). As understandings of food waste as a systemic phenomenon have emerged, multiple gaps in knowledge about overproduction, surplus and waste generation in primary production have been revealed. There have been calls for further research on farm waste generation (Beausang et al., 2017; Redlingshöfer et al., 2017), especially studies that cover a range of multiple crops (Hartikainen et al., 2018), and address unrecorded and unclassified waste at the pre-harvest stage (Schneider et al., 2019).

Beyond quantification of overproduction and surplus, social scientific work within food waste scholarship has suggested various food systems characteristics that may contribute to overproduction. These causal factors include: a common lack of demand transparency across a complex food supply chain (Calvo-Porrall et al., 2016; Halloran et al., 2014; Lemaire and Limbourg, 2019), the emphasis on specialization and industrialization of food commodity chains (Canali et al., 2013; Mourad, 2016), regulatory interventions (or the lack thereof) that have the effect of incentivizing overproduction such as production-oriented subsidies (Bengtsson et al., 2018; Pritchard, 2012), routine encouragement of overconsumption (Banwell and Dixon, 2013; Friel et al., 2014) and exercises of supermarket power over suppliers (Devin and Richards, 2018; Feedback, 2018; Ghosh and Eriksson, 2019). Kuokkanen et al. (2017) have applied a socio-technical perspective to identify underlying system processes that have been locking Finnish food systems into unsustainable overproduction. They exposed underlying mechanisms of overproduction that reinforce lock-in through their linkages to agronomic intensification and agricultural policy, without placing a central focus on systemic food waste creation. As such, the exact combination of causal factors of overproduction, the inherent mechanisms by which they are linked to food waste outcomes and the potential interventions to address them, are shaping and being shaped by the context of the supply chain and broader food system and require further in-depth research.

Responding to these knowledge gaps, this paper contributes to systems-based understandings of food waste to uncover and explain how systemic practices and processes in the Australian horticultural supply chain give rise to overproduction, surplus and ultimately food waste. The next section of this paper outlines socio-technical transitions theory as a framework for establishing a broader theoretical understanding of the features of complex food systems that both promote, and rely on, systemic overproduction and the creation of waste.

2.2. Socio-technical transitions theory and the dynamics of overproduction

Preventing food waste in a complex system, such as a horticultural supply chain, requires a transition toward more sustainable, or less environmentally destructive, practices (El Bilali, 2019; Hinrichs, 2014; Meynard et al., 2018). Transition studies, and in particular socio-technical transition theory, has emerged as a significant body of work in addressing complex phenomena at the intersection of society and technical systems, referred to as regimes (Murphy, 2015). A socio-technical regime refers to dominant systems with social and technical configurations, such as water,

energy, agrifood, housing and transport (Geels, 2010). The various components of a regime include, among other things, a network of actors, technologies, infrastructure, norms and rules (Lachman, 2013). Geels (2010, p.502) argues that incumbent regimes are often stabilized via corporate-driven networks with strong links and interdependencies with policy makers. Radical alternatives to current regime practice, termed 'niches', challenge or disrupt the status quo while various factors, termed lock-ins, counter such change by reinforcing the existing regime (Geels, 2014; Köhler et al., 2019). The ensuing interactions and dynamics give rise to a 'multi-level perspective' of system transitions to sustainability. Sociotechnical transitions theory is useful for conceptualizing the structural nature of overproduction in food chains through its emphasis on: (a) how and why a particular socio-technical system emerges; and (b) the ways in which systems dynamics resist change, but nonetheless transform over time.

The concept of a socio-technical 'lock-in' is especially useful for understanding how food systems and the food chains embedded within them reinforce suboptimal outcomes (in this case, high levels of food waste) and why such outcomes are difficult to resolve (Geels, 2011, 2014; Seto et al., 2016; Unruh, 2000). Lock-ins explain the "efficient convergence of established ways of seeing and doing things" (Svingstedt and Corvellec, 2018, p.5). A 'lock-in analysis', therefore, focuses on the overlapping mechanisms through which a system becomes entrenched and reinforced, and how these mechanisms resist transition to a more sustainable sociotechnical system (Meynard et al., 2018, p.53).

Research has differentiated between distinct types of lock-in mechanisms and their interactions within the incumbent socio-technical regime. These mechanisms may be institutional (e.g. existing legislation and policies), technical (e.g. business models and technologies), cultural (e.g. accepted views and paradigms) and material (e.g. existing infrastructures and investments) (Corvellec et al., 2013; Seto et al., 2016). Lock-ins within complex systems, however, defy such distinct groupings and linear relationships. Accordingly, lock-in analysis of complex systems tends to find "nuanced multi-rational understandings" of different aspects to a system that collectively reinforce the system, rather than distinct lock-in mechanisms unrelated to each other (Svingstedt and Corvellec, 2018, p.5). For these reasons, and as shown later in this paper, lock-in analysis of food systems defies neat categorizations, highlighting complexity of present food chain characteristics and the manifold ways they compound to perpetuate the status quo.

An especially powerful type of institutional lock-in occurs in socio-technical regimes whereby private and public institutions and technologies have co-developed and co-benefited from increased revenue and economic returns over time (Unruh, 2000, p.825). Rather than aiming to check and balance each other's political processes, public regulatory interventions and corporate governance share a common interest of reinforcing the incumbent socio-technical regime, frequently and persistently leading to "market and policy failure" (Unruh, 2000, p.817). Critically, socio-technical regime actors are not seen as institutionally locked-in and inert due to systemic constraints, but as actors that intentionally resist change even if resistance is counter to broader social goals such as sustainable development (Geels, 2014, p.35; Seto et al., 2016, p.433). In agrifood systems, this resistance to change (i.e. lock-in) may come in the form of existing infrastructure design, sunk investments and regulatory standards perpetuating and reinforcing 'business as usual', which in turn contours how the problem of food waste is understood and addressed.

Sustainable transitions, including the reduction or prevention of structural food waste as an unsustainable food system outcome, require "escaping the lock-in conditions" (Unruh, 2002, p.317). By locating specific lock-in points and mechanisms within a socio-

technical regime and rendering them visible, stakeholders can identify and engage in consciously dismantling lock-ins to develop tangible pathways toward sustainable change (Geels, 2014; Svingstedt and Corvellec, 2018). Accordingly, transition research has highlighted the need for further research into the “specific mechanisms through which lock-ins become manifested” (Klitkou et al., 2015, p.23) and studies on whole industries, rather than single cases, that produce transitions (El Bilali, 2019, p.361), both of which this paper contributes to.

Unruh (2002, p.320) added a caveat: breaking such deeply entrenched and intransigent institutional lock-in, stabilized by an alliance of business and political elites, is unlikely to be initiated from within the system itself. Rather, change will likely require an exogenous force, such as an ‘external shock’. While lock-in analysis may be able to provide a viable agenda for systems change, such change is ultimately subject to mediation by power and politics. The following section turns to the research methodology to demonstrate how data was gathered to identify lock-ins in horticultural supply chains.

3. Methodology

This study follows the interpretivist epistemological tradition, where the researcher seeks a deep understanding of a phenomenon through the lived experiences of actors closest to the subject matter. In Australia’s horticultural supply chain, these are growers, processors, peak body representatives and technical experts. Potential research respondents were identified through a non-probability, purposeful sampling approach targeting a diverse cross section of the Australian horticulture industry to maximize the range of insights and perspectives (Zikmund, 2003). Based on an industry overview of key market segments (IBIS World, 2019), the research covered six relevant sectors of the Australian horticulture supply chain. The sampling strategy ensured participation by growers and initial processors supplying to Australian supermarkets and wholesalers, which are the predominant mass-market channels for fresh fruit and vegetables (Salardini, 2019). Hence, the sample was representative of the market in regard to capturing a range of relevant perspectives.

The method of data collection was a series of recorded semi-structured interviews with people working across the horticultural sector (for example of this method see Cresswell and Poth, 2018). Interviews took place at participants’ offices and were conducted face-to-face. Personal interviews with key industry actors are more difficult to obtain than phone or video interviews due to constraints of time, travelling and availability. However, the additional efforts to support a strict-face-to-face interview approach were rewarded with increased opportunities for interaction, first-hand observations, and information shared by respondents beyond the interviews themselves. The initial planned sample consisted of 70 respondents with ultimately 29 participating in the research, which represents a response rate of 41%.

As noted above, the research questions guiding this study are: What are the causes of overproduction and food waste at the production stage of the Australian horticultural supply chain? and How does overproduction contribute to food waste along the Australian horticultural supply chain? To address this, an open-ended interview instrument was developed which included general questions and follow-up questions about management practices in regard to food waste, overproduction and surplus within Australian horticulture. Interview questions addressed prevailing practices and priorities in relation to food waste at the production stage. Moreover, questions were aimed at clarifying and identifying practices, constraints and processes relevant to overproduction and the conditions under which surplus produce is discarded on-farm.

The data set consisted of 28 recorded and transcribed interview sessions (see Table 1) comprising almost 20 hours of interviews. Data analysis was informed by “adaptive theory” (Layder, 2006, 2018), a research methodology that explains social phenomena by connecting human activity to social structures (Van Gramberg, 2006). Specifically, adaptive theory draws on the explanatory framework of ‘social domains’, which proposes a multilayered social reality of immediate and personal domains, such as ‘psychobiography’ and ‘situated activity’, as well as remote and structural dimensions, such as ‘social settings’ and ‘contextual resources’ (Carter and Sealey, 2000). This means that data analysis followed a procedure of thematic coding including life world phenomena emerging from the data as well as theoretical codes related to social domains. Emerging themes and concepts are thus constituted by descriptive as well as conceptual elements. This is followed by an interpretation and causal explanation of data based on underlying social domains and their specific capacity to transform social reality (Hewege and Perera, 2013; Layder, 2018). The research findings were thus able to establish and explain system phenomena based on inferences from causal sequences, mechanisms and relationships, an approach called “explanatory causality” (Shadish, 2010, p.9; also see Grin et al., 2010, p.97; Layder, 2018, p.42).

The research findings reported below purposefully focus on the voices of growers in recognition of the value of first-hand experience with food surplus creation that turns to waste.

4. Research findings: food surplus production and food waste

This section reports the key findings from the research interviews in relation to four systems phenomena. The findings are reported in narrative style recounting the underlying layers and networks of empirical data and concept indicators to highlight the specific points where systemic overproduction lock-ins and waste creation occur. This section presents the findings, with the first two themes addressing Research Question One on causes of overproduction and food waste, and the second two themes relating to Research Question Two on the relationships between overproduction, surplus and food waste. The theoretical interpretation of findings will be explored in the discussion section further below.

4.1. Industry characteristics that contribute to food waste

An industry peak body representative from Melbourne proposed the expression of “growers boxed into a corner” to capture the growers’ perceived transition from power as the nation’s ‘backbone’ to a minor actor facing numerous constraints within a complex marketplace. Now, market actors and institutions profoundly shape farm management decisions, in turn constraining the growers’ ability to determine fully how much is grown, what is grown and how it is grown. An important point to understand is that “growing vegetables is a business, farmers do it for money”, as a Queensland vegetable grower explained. A Victorian grower similarly stated that, “Our sole form of income is what we sell. There’s no other magic fountain”. Growing food for a living is thus predominantly determined by the conditions of commercial reality.

The position of growers is epitomized in their repeated description of themselves as ‘price takers’ not ‘price setters’. One South East Queensland vegetable grower explained how the lost connection to consumers relates to lost price power: “We have done one thing very poorly for a very long time, we left it to retailers to tell our story. Now, [the consumers] run away and say: you are on your own!” In the highly concentrated and oversupplied Australian trade environment, the oligopolistic position of supermarkets has been determining the prevailing agri-business model in which growers have to compete. The interviews frequently

Table 1
Overview of research participants.

Ref.	Position	Organisation	Industry	Length (mins.)	Location
01	Technical Manager	Industry Association	FRUIT	39:00	Brisbane
02a	Owner*	Grower	VEG	55:00	South East Queensland
02b	Owner*	Grower	VEG	55:00	South East Queensland
03	Managing Director	Grower/Wholesale/Agent/Distributor	WHS/FRUIT	30:47	Brisbane
04	Managing Director	Wholesale/Agent/Distributor	WHS/FRUIT	49:04	Brisbane
05	Owner/Industry Representative	Grower/Industry Association	FRUIT	47:48	South East Queensland
06	Owner/CEO	Grower/Industry Association	FRUIT	47:47	Brisbane
07	Owner/Executive Officer	Grower/Industry Association	FRUIT	56:48	South East Queensland
08	Business Manager	Grower/Wholesale/Agent/Distributor	VEG	56:13	South East Queensland
09	Owner/Industry Representative	Grower/Peak Industry Body	VEG	55:00	South East Queensland
10	Technical Director	Grower	FRUIT	38:47	South East Queensland
11	Technical Manager	Peak Industry Body	FRUIT/VEG	39:30	Melbourne
12	Director	Wholesale/Agent/Distributor	WHS	40:59	Melbourne
13	Technical Manager	Industry Association	FRUIT	37:49	Melbourne
14	Industry Manager	Peak Industry Body	FRUIT/VEG	39:16	Melbourne
15	Owner	Grower	VEG	38:16	South East Victoria
16	Director	Grower	VEG	46:40	South East Queensland
17	Technical Manager	Peak Industry Body	FRUIT/VEG	40:26	South East Queensland
18	Food Supply Manager	Other Industry Services	OTHER	20:35	Brisbane
19	Owner/Industry Representative	Grower/Peak Industry Body	VEG	41:04	South East Queensland
20	General Manager	Other Industry Services	OTHER	44:31	South East Queensland
21	Production Manager	Grower	VEG	37:31	South East Victoria
22	Owner	Wholesale/Agent/Distributor	WHS	34:32	Melbourne
23	Senior Officer	Peak Industry Body	FRUIT/VEG	39:11	Brisbane
24	Owner/CEO	Grower/Industry Association	FRUIT	38:01	Northern Rivers
25	Director	Wholesale/Agent/Distributor	WHS	42:24	Brisbane
26	Managing Director	Grower	VEG	32:23	South East Queensland
27	Owner/Director	Grower/Wholesale/Agent/Distributor	FRUIT	44:50	South East Queensland
28	Director	Other Industry Services	OTHER	37:31	South East Queensland

* Interview session 2 combined two growers in one session.

describe how supermarkets control market access as almost no viable alternative mass distribution channels exist. Crucially, supermarkets are also the primary interface between producers and the consumer market, which further limits market access for growers and creates information and power asymmetries. This privileged position in the supply chain allows supermarkets to design their business model around exclusively selling what they define as premium grade product purchased at lowest available cost, causing large amounts of produce considered outside of the supermarket definitions to go to waste.

Research participants commonly described the implementation of supermarket specifications and cosmetic standards as an example of their disempowered position. There was wide awareness and belief among research participants of the very substantial scale of on-farm food waste due to supermarket standards, some estimates ranging from 20% to 50% of production. Cosmetic standards are a matter of definitions, which predominantly relate to size, shape and color of produce and not eating qualities such as taste and nutrition. Respondents commonly expressed disbelief that supermarket standards reflect *real* consumer preferences. On the contrary, supermarkets were seen as deploying marketing practices that respondents described as 'conditioning', 'education', 'training' and 'manipulation' to instill and establish expectations of what 'perfect fruit' look like. Moreover, some respondents reported having observed the unfair use of supermarket standards as a negotiation tool to downgrade price or to control market access.

Ensuring the cosmetic appeal of fruit and vegetables has, therefore, become a priority in the Australian horticulture industry. Some participants regret the lack of a 'cohesive industry approach' that 'speaks on behalf of what's best for all farmers and takes a long view' on farm waste rather than fulfilling the demands of supermarkets. Other participants believe it is government leadership that is needed to change the prevailing agri-business model in regard to supermarket standards. "It sits very much on the shoulders

of the government. They are the policy makers, their decisions have a ripple effect, particularly for small growers", as a Melbourne distributor observed. However, government regulation is seen as unlikely since Australia is firmly committed to liberalized agricultural trade. As government and industry advocate self-reliance in an 'open market', respondents were clearly aware that the waste problem is essentially up to the individual grower.

In the absence of citizen/consumer support as well as industry action or government regulation to address waste due to cosmetic supermarket standards, it has become an important 'business skill' of growers to pre-empt how supermarkets will apply their standards. Some vegetable growers reported that they do this by abandoning the imperfect crop in the field rather than paying for the crop to be harvested only to be rejected. In the absence of a physical waste stream to be moved to waste transfer stations, the practice of on-farm waste disposal is widely seen as *natural* and quite a number of growers did not consider grading rejects left in the field as food waste at all. One vegetable grower explained, "We have no problem with waste, it will return to the soil as nutrition". Another grower added, "It is food for the next crop". Not all growers agreed on waste as 'natural' as some respondents recognized the financial, personal and resource-related inputs lost in the process. Moreover, a waste management expert pointed out that on-farm disposal without a true composting process represents at best a 'suboptimal resource use', motivated by disposal rather than an approach to improving soil health.

Despite its very substantial scale, grading waste remains 'intentionally unseen' and 'excused', as a Brisbane distributor remarked. Respondents suggested there is some amount of conditioning inherent in the acceptance of farm waste as natural; "I think it's psychological because the big end of town tells [the growers] that produce has to be perfect, that it is what the people want. And that comes directly from supermarkets". Inherent in these critiques is the assumption that, within the prevailing governance

arrangements of the Australian food supply chain, only supermarkets themselves can reduce the number of unharvested crops that go to waste on-farms.

4.2. Industry practices that encourage surplus formation

The strong majority of informants concurred that overproduction and resulting surplus was a highly prevalent feature in the Australian horticulture industry. One grower and processor stated, “[Surplus] is huge and it’s being wasted”. Others agreed, there is “overproduction in vegetables” and “domestically and even worse in the export market”. One industry sustainability manager summed up the matter most concisely; “They [growers] all grow too much!”. With the existence of overproduction and surplus thus confirmed, the respondents from the horticultural industry offered further deep insights into the dominant processes that generate surplus.

From interviews with actors in the horticultural sector, it is clear that overproducing is considered a standard practice in the industry. A South East Queensland vegetable grower declared that “Everybody does it”. The most common reason for overproducing is to hedge against risks related to weather events, the timing of growing cycles, or changes in domestic or export market conditions. Interviewees also spoke of a tendency inherent in the industry to ‘gamble’ on potential commercial opportunities, which requires being ‘always ready to sell when others cannot’. Moreover, growers are very strongly ‘connected to productivity’ and have a deeply entrenched belief that ‘yields must be maximized as they are the key to profitability’. A number of growers summed up the prevailing sentiment that ‘growing more is always better’.

Food surpluses caused confusion for stakeholders as their existence conflicts with mainstream policy narratives that emphasize projections about how much food production is needed to feed future populations. As one actor put it, “We have got oversupply and then we’ve got to double food production, I don’t know how to mill these two together in Australia”. Similarly, another horticulture industry representative considered surplus as a supply demand conundrum: “Consumption per capita is decreasing but we are generally going up in production”. The output of Australian agriculture in key sectors has been exceeding the demand of domestic markets for many years, and respondents are aware that productivity growth has been outpacing population growth. Still, government and industry organizations strongly emphasize further growth and further productivity increases as a top policy priority across various platforms. A sustainability extension manager explained how growing and governing might be critically at odds: “The government says we need 40 percent more product. Well if [supermarkets] actually reviewed their product specs, the 40 percent is sitting there, on-farm now, you wouldn’t have to grow anymore”. A technical farm manager added, “The 40 percent is probably being produced already, it’s just not being utilized”.

Because of the persistent pressures to increase productivity, growers described being in a debt spiral, that is, ever-increasing levels of debt, due to the convergence of rising input costs, stagnating market prices and the continuous need for investments into more growth and productivity. The resulting financial squeeze of low profit margins and high debt translates into pressures to produce cash flow and to keep growing, with or without profit. One vegetable grower from the Lockyer Valley, Queensland, summarized the commercial reality of the need to continuously grow more: “The industry is set up now so we have to overproduce. There is no margin to grow less”.

Pressure to overproduce also derives from competition in a highly concentrated and oversupplied marketplace, which, as a Queensland technical manager explained, “Has in itself ways to

encourage oversupply”. Australian growers seeking access to mass markets have no option but to invest into securing supply contracts with major supermarkets, which represent by far the most dominant route to market. To safeguard their continued relationships with supermarkets, growers must be ready to fill orders around the year, irrespective of profit or loss. The key objective is never to be short in supply, as that would open a window for a competitor creating a lost opportunity and potentially weaken vital supply relationships. One grower explained, “If I can’t supply, someone else will – cheaper!”, which makes “undersupplying a very bad business”.

To succeed in competition, respondents spoke about specializing in growing a narrow range of crops intensively to exploit economies of scale. This in turn increases the market supply of particular fruit and vegetables while increasing the exposure of crops to external factors like pests and diseases. Growers also work towards narrow windows of profit opportunity within the growing season for the crop they specialized in, and they accept narrow profit margins in order to meet the lowest market price. All these factors combined mean growers gamble to remain competitive. A vegetable distributor explained that winning or losing the gamble of narrow margins, for instance, ends with some growers reaching market with their production output while others get saddled with sizeable surpluses. The risks taken to remain competitive are especially high due to the lack of transparency and information around demand. Aggregated and accessible data on real market demand are presently not available to producers from within the supply chain, which leaves growers no option but to follow the cues of supermarket buyers or try to ‘listen to the market and look over the fence’, at times asking themselves, as one Queensland vegetable grower said, “Are we in a safe place if we don’t overproduce?”

Several growers see surplus mostly related to the business model chosen by producers. Some businesses supplying the mass market have transitioned to an operational model that prioritizes steady and stable supply patterns over betting on large yields of produce. Such growers manage their business based on pre-orders and producing to demand. They generally reported only negligible surplus and waste and stable operating margins. The majority of growers, however, being fully invested in the race of intensive growth and larger yields, have to keep producing more at lower cost to make ends meet, which they do by simply ‘producing the maximum they can’.

4.3. The failings of surplus recovery from waste

Once surplus has formed its physical presence on farms, growers face the immediate pressure of managing an oversupplied perishable crop, within a narrow timeframe and location, and as market prices rapidly decline. The key priority of management is minimizing economic loss either by way of maximizing cost-recovery or cost-effective disposal. Some of the evidence provided by this research indicates the current supply chain infrastructure appears inadequate in its support for either goal.

During times of temporary oversupply such as gluts or peak season, supermarkets and central wholesale markets will work with growers to ‘sell through’ and digest some of the excess produce, mostly via price reductions and push promotions.¹ Those channels represent almost the entire market available to growers. As a Melbourne based distributor explained, “Growers have no alternative mechanisms to sell surplus product in large quantities”. As there is finite demand for surplus produce and natural limits for

¹ Promotions pushing product down the supply chain by inducing shoppers to increase purchase, e.g. price discounts, coupons, or promotion packs.

price reductions, the common result is that large amounts of surplus produce remains unsold on-farm. A number of interviewees described how, almost without exception, food surplus thus created is discarded on the farm itself, as transportation cost, especially in light of narrow profit margins, makes it uneconomical to move it to processors or transfer stations. Growers generally plough food surpluses back into the soil, while waste already harvested is often left in piles, fed to livestock or put out onto the field as 'compost'.

Some growers considered export channels to dispose of surplus, mostly by selling to export agents. Yet, export markets require strategic investment into export readiness, into compliance with import protocols and into demand creation in destination markets. Some representatives of industries with export business explained how it is not simple and straightforward to move rapidly from supplying domestic supermarkets to export. Importers have specific service requirements (e.g. for packaging and certification) and need long-term stable service, which presents its own challenges to producers. As such, some respondents cautioned against considering export markets as 'dumping grounds for surplus'. A vegetable grower also observed that export markets are also commonly subject to oversupply due to similar competition dynamics that lead to oversupply domestically; hence the existence of export markets may, to an extent, even compound the processes that cause surplus and waste.

In recent years, processing and value-adding has increasingly gained popularity as a potential avenue to dispose of surplus without producing less. In principle, growers, or other supply chain actors, can process surplus or even waste into new products, for example, guacamole, banana flour or neutraceuticals. However, the research participants described multiple difficulties with putting the concept into practice on a larger scale. On-farm value-adding requires significant investments into equipment and working capital. As an alternative, some respondents with a processing background explained, surplus can be delivered to third-party processors, which reduces investment and risk. However, they added that produce has to be competitive in meeting the processor's sourcing requirements, such as transportation cost, timeliness for perishable products, product characteristics, product hygiene and traceability, and supply stability, all of which might drive up the cost of diverting surplus to processors and make it more economical for processors to grow their own produce, rather than using surplus from around the country.

Indeed, research participants viewed value-adding as representing an entirely new skillset, even a 'whole new supply chain' with substantial investments required into product development, branding, registration, distribution, and demand creation within the very same market channels that were unable to absorb the surplus in the first place. Accordingly, for growers to transition towards value-adding to surplus food and innovative use of the waste resource, they must be prepared to make significant changes, from infrastructure through to knowledge. Moreover, the value-added products will have to compete in an Australian processing industry that has been forced into steady decline due to high operating cost and international low price competition, making it likely that value-adding itself will create new waste chains. Considering existing pressures, growers are not commonly able to take such risks and make such investments.

Growers also mentioned some other options to redistribute surplus product rather than disposing it on-farm. These include donations to food rescue organizations, sales to local fruit and vegetable markets, on-farm sales and local diversion to stock feed. However, respondents noted that the especially high levels of surplus and the lack of alternate distribution channels beyond mass consumer markets severely limit re-purposing of food surpluses.

The failure to regain value from surplus hastens its transition to food waste, which the next section explores further.

4.4. Surplus as an amplifier of waste creation

The in-depth analysis revealed system mechanisms that showed how surplus engenders and accelerates the creation of waste. Surplus thus emerges not only as a contributing cause of waste, but as an amplifier of existing causes of waste creation. Three mechanisms of waste amplification emerged from the research data:

4.4.1. Surplus increases the rate of waste

Interview data revealed that industry practices, such as cosmetic standards, cause food waste even in the absence of significant overproduction and surplus. As a technical director from Brisbane explained, "Once surplus is removed, the problem of supermarket standards and specifications is still there", which leads to a "certain amount of waste due to a basic grading reject rate of about 20% every day". One vegetable grower pinpointed the impact of surplus on waste generation: "There is always a percentage of base waste, but a lot more with excessive numbers".

Overproduction causes large surplus during gluts and peak season, boosting harvest quantities and corresponding surplus and waste volumes. One technical farm manager explained, "Peak season harvest amounts could reach four times the normal harvest, potentially causing four times the amount of waste". Moreover, growers described how field and shed waste do not only increase *in line* with harvest volume, but potentially at an *increased rate* of rejects and discards due to harvesting processes running closer to the limits of their operational handling capacity and the need to move large influxes of highly perishable produce to market within much shorter time-frames. For example, during peak, surplus grading has to be faster and broader to cope with staggered plantings coming into harvest quickly and simultaneously. A Victorian grower explained how they accelerate grading during peak season: "We generally pick [a patch] two or three times, but if the next patch is ready, we'll leave the old ones and we'll just go and pick the next ones, and then we'll just mulch it into the soil". As such, peak season harvest practices contribute to increased rates of waste creation.

4.4.2. Declining prices increase waste

From a producer's perspective, market prices heavily impact on whether a crop goes to harvest or to surplus and waste. Low prices mean the costs of growing and harvesting surplus may not be recoverable at the given or rapidly declining market price point; conversely, harvesting might result in growers operating at a loss. Because oversupplying is an engrained feature of how growers conduct farming, 'price depletion', as an industry representative called it, has become a corresponding characteristic leading to continuously diminishing profit margins for growers already operating on very narrow margins. Crops under sustained oversupply and depleted margins are more sensitive to downwards market price trends and may fall below thresholds of financial viability faster than more profitable crops. Thus, the overproduction of these crops, which drives, and is also encouraged by, the downward market price trends, contributes disproportionately to waste.

Some respondents described how promotional activities to sell-through surplus are commonly used to mitigate the amount of surplus that goes to waste as market prices decline. However, growers realise that promotions are a limited means of preventing surplus turning to waste. These limitations include the short amount of time to sell due to perishability, the decreasing financial returns as produce ages and the consumers' finite ability to digest

surplus product. Ultimately, surplus meets what a Victorian grower called 'market resistance', when "You can't move product any longer". A fruit industry representative summed it up by saying, "Once the harvest is economically not viable, it is the financially responsible thing to do, not to pick and instead to have food waste".

4.4.3. Changing standards increase waste

An oversupplied market is a buyer's market, which in Australia is primarily two major supermarkets. A number of interviews highlighted how during supply shortages, supermarkets may buy produce that is not fully compliant with their specifications. A Queensland vegetable distributor stated, "[The supermarkets] will give us a degree of flexibility if they are in short supply, to get some product on the shelves". Consequently, waste generation is much reduced or even ceases altogether during supply shortages. During peak supply, however, waste becomes prevalent as the oversupplied market offers abundant choice to supermarkets. This allows supermarkets to strictly apply their specifications and deny any 'standard variations', as some respondents called the flexibility sometimes granted by supermarkets, thereby effectively driving up wastage rates. During this period, for instance, the oversupply of premium produce often leads to produce in lesser grades turning into waste, further contributing to trade-related waste on-farm and in pack-houses. A technical farm manager observed, "There is no outlet for seconds during peak season. Stuff that would normally get packed in 'second class' will just get dumped".

5. Discussion

Research participants revealed a strong connection between overproduction on-farm leading to surplus that turns into waste within Australian horticultural supply chains. In respect of Research Question One, fundamental characteristics of the broader supply chain, such as the relationship between growers and the supermarkets, reveal the structural nature of overproduction and farm waste creation beyond on-farm decision-makers. Meanwhile, responding to Research Question Two, a large amount of surplus actually stays on the farm and turns to waste due to the lack of infrastructure enabling its beneficial use. As such, much of the burden associated with the food waste generated affects growers more than other supply chain actors. To explore these characteristics further, and by drawing on the well-recognized concept of lock-ins from socio-technical transitions theory, this discussion section brings together the literature, theory and data to expose the 'surplus-to-waste lock-in' mechanisms that reinforce systemic overproduction leading to surplus and waste in the Australian food supply chain. This study identifies three key overlapping lock-ins, which were introduced in the section on socio-technical theory (see 2.2) and which are explored below under the following headings: institutional, cultural and technical-material lock-ins.

5.1. Institutional lock-ins

The data provides insights relating to institutional lock-ins in the food system. The interests of supermarkets, industry representatives and government converge to govern food in ways that reinforce retail market concentration and growth and productivity maximization. Specifically, the growers' practices within the food supply chain were profoundly shaped by their relationships with superior and dominant forces in the supply chain, by the lack of regulatory counterbalance and by a systemic disconnectedness from consumers. These findings are consistent with the fact that Australian horticulture is predominantly comprised of intensive, specialized agriculture and highly centralized supermarket distribution infrastructures (Bjørkhaug and Richards, 2008). This

dominant food chain for fruit and vegetables is supported by Australia's low regulatory intervention into agricultural markets (Larder et al., 2017) that strongly favors incumbent industry networks. Meanwhile, overproduction is normalized via the political-economic focus on growth and productivity (Lawrence et al., 2012). For instance, the industry and government vision is to almost double output of an already oversupplied industry (NFF, 2018). Consequently, government and industry bodies prefer to leave the waste problem to individual growers, in a similar way to how food waste responsibility is shifted to individual consumers.

This institutional lock-in mechanism also relates to the powerful regulatory role of supermarkets. The research reveals that growers have been increasingly facing institutional and regulatory pressure from private governance mechanisms, especially supermarket standards, rather than government regulation. As such, regulation of standards devolved from government to supermarkets, reinforcing the status quo that favors prevailing interests (Seto et al., 2016). Findings illustrate that the supermarkets model, which relies on stable and centralized supplies, supports the reported inconsistent implementation of their standards and specifications. By having large supplies to choose from, and strong contractual rights and "institutional power to impose specific standards", supermarkets can exclusively sell fruit and vegetables that look a particular way (Klitkou et al., 2015, p.34). While overproduction to satisfy the interests and standards of supermarkets reinforces itself by depressing the prices for a particular fruit or vegetable, farmers continue to pursue profit by producing more food and so become locked-in to investments into technologies and infrastructure for maximizing production, which debt in turn keeps them trying to produce more food surplus. These dynamics feed the systemic need for overproduction, while the share of the benefits "depends on one's institutional perspective" (Seto et al., 2016, p.437). Because supermarkets are the main buyers, there are not only few alternative channels to distribute product, but also the actual demand from consumers is obscured. In other words, oversupply in a concentrated marketplace obscures and distorts real market demand and leaves growers no direction but always to produce the maximum.

The power of supermarkets in Australia is indicative of deep seated institutional-technical lock-in resulting from a form of governance which presumes industry and markets will self-regulate (Richards et al., 2012, p.252; Unruh, 2000, p.824). Rather, Australia's relatively weak competition laws and comprehensive industry de-regulation have allowed supermarkets to accrue disproportionate power compared to other supply chain actors. The institutional lock-in occurs when Australian governments refrain from regulating supermarket standards, but also from the pivotal role private supermarket governance has assumed in regulating the Australian food industry (Carey et al., 2017). As such, the state reliance on private actors to set and enforce standards serves to further exacerbate institutional lock-in and transition resistance.

5.2. Cultural lock-ins

A second, and closely related, lock-in mechanism in favor of overproduction relates to the cultural understandings of 'what fruit and vegetables should look like' that in turn influences production and consumption decisions. The research reveals a deep cultural lock-in related to the cognitive conditioning in regard to imperfect-looking produce and its associated waste. Research participants firmly believe that consumer perceptions and expectations on perfect produce are socially constructed. Specifically, they believe consumer standards have been created through long-term 'manipulation', and 'conditioning', by dint of commercial marketing practices. Equally, growers have developed a 'business skill' to

proactively discard any produce that will likely be rejected by the trade, as well as an acceptance of 'financial responsibility' to prevent economic waste by discarding produce on-farm as food waste.

Correspondingly, the resulting on-farm waste is often not regarded as waste at all, but rather as nutrients being returned to the soil. This concept of waste as 'natural' and as something that helps soil health reveals a deep cognitive dissonance between growers' acute awareness of waste as a real economic loss and a real loss of resources, and their acquiescence to waste as a natural part of doing business. Existing cultural and cognitive conditioning regarding the perceptions of imperfect produce, combined with the growers' interpretation of food surplus going to waste as 'natural', correspond with the high levels of food waste generated at the production and initial processing stages (Australian Government, 2019), revealing a deep-seated lock-in into waste from production and consumption related cultural dynamics.

5.3. Technical-material lock-ins

A final lock-in mechanism derives from the prevailing agribusiness model and the associated material infrastructure, practices and processes in place. Transition research has shown how "business models can constitute a hindrance to change" (Svingstedt and Corvellec, 2018, p.6). This paper has elaborated two important dynamics of the horticulture food chain model. Firstly, it described the journey of food from the field, via surplus to its final destination as food waste. The research findings have revealed the deep relationships between surplus and waste and the underlying mechanisms that support and enable this connection. Secondly, the research findings also emphasized the systemic nature of this transition. They described the specific industry settings and characteristics that determine what and how much is grown, the processes and dominant practices that necessitate and reinforce overproduction, and the specific material and ideological resources that represent an industry infrastructure supporting surplus production but inadequate for surplus and waste prevention.

Horticulture supply chain processes and their governance encourage structural overproduction and food surplus formation. This means existing supply chains, for instance, due to the deeply engrained systemic focus on yield, are inherently ill-suited to sustainable change, such as reducing food waste (Ferguson, 2016). Rather, the very processes causing surplus to form in the first place also facilitate and expedite its transition to waste. Once surplus has formed, price reductions and promotions erode market prices leading to supermarkets asserting their power by raising standards to reject increasing amounts of produce that will not sell. The research has shown substantial management constraints related to overcoming the 'waste miles' of perishable surplus produce to ensure its meaningful re-use and to prevent its transformation to waste; these are the lack of adequate infrastructure to manage surplus, the ambiguous economic value of 'waste as a resource' and the absence of relevant industry and policy priority. The research findings propose, therefore, that surplus is a closely linked symptomatic indicator of impending waste creation, and, as such, the surplus creating effects, or 'surplus footprint' of system processes play a crucial role in food waste creation. Accordingly, food waste prevention targeted at processes of waste creation requires protocols of measurement and disclosure of surplus along the whole supply chain.

6. Conclusions

The research findings illustrate how key actors, such as powerful supermarkets, prevailing supply chain characteristics such as the dominant concentrated distribution model reliant on surplus, and broader systems dynamics, such as competitive focus on growth

and output volume within industrial farming, drive overproduction. It shows in context how these mechanisms, and related processes, lead to food surplus that transitions to waste on-farm or in post-production stages. The lock-ins identified suggest that any program to reduce overproduction and concomitant food waste due to its governance arrangements will be met with high levels of resistance. The prevailing business model and deep-seated cultural and cognitive perceptions regarding the nature of product quality and waste not only promote overproduction and surplus formation but create a dependency on these features for the supply chain to function. Consequently, Australian horticultural food chains lack the purpose and infrastructure to recover value from food surplus. Moreover, rather than preventing surplus from going to waste, supply chain practices accelerate food waste creation due to their fundamental reliance on overproduction and surplus-creating processes. The research findings indicate that monitoring surplus may be considered a contributing method of food waste prevention. Beyond surplus monitoring, the findings also suggest that, without altering the fundamental characteristics of current supply chains, systemic overproduction will continue, ensuring large volumes of food are wasted.

This paper contributes to the in-depth understanding of systemic processes and mechanisms underlying overproduction, surplus and food waste creation by identifying and explaining relevant system phenomena within the Australian horticulture supply chain. The theoretical perspective of lock-in allows a demonstration of the broader significance of the research findings for sustainable food systems, specifically a theoretical conception of food waste as symptomatic of food system lock-in and resistance, enabling further theorizing of systemic food waste prevention from a socio-technical system perspective. At the same time, the detailed analysis of 'food waste lock-ins' contributes to socio-technical theory by increasing understanding of specific aspects of regime persistence as well as preconditions for transitions.

The identification of specific phenomena of food chain lock-ins also provides tangible direction for gradual interventions by policy makers, industry managers and food waste researchers alike. In this regard, the findings suggest three key recommendations: Firstly, future efforts to combat, measure and conceptualize food waste should address systemic processes of food waste creation along the whole supply chain rather than focusing on single points or individual actors. Secondly, horticulture food chain governance should target interventions combating systemic food waste at the processes contributing to institutional, cultural, and technical-material lock-ins. The lock-in analysis thus presents not only a diagnosis of the present state, but also a prescriptive agenda for future change. Thirdly, further research, and related governance responses, should focus on exploring and monitoring how surplus flows through food chains, i.e. what we term the 'surplus footprint'. A central conclusion of this research is that such governance arrangements should focus on open and transparent monitoring and disclosure of surplus volumes along whole food chains as a prerequisite for systemic food waste prevention.

CRediT authorship contribution statement

Rudolf Messner: Conceptualization, Investigation, Formal analysis, Writing - original draft. **Hope Johnson:** Writing - review & editing. **Carol Richards:** Writing - review & editing.

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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