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Food Security and the 'Total Ecology' of Glasshouse Agrifood Value Chains

The United Kingdom has a food security problem.[1] It is a problem that centres on the ways in which agrifood value chains operate and the material conditions within which workers are employed. In the later months of 2022, in meeting after meeting with growers in the UK's glasshouse industry, a common refrain ran like this: 'Starting from Christmas, you'll … have empty shelves. Not just import substitution, but empty shelves'.[2] Growers and other industry professionals were foreseeing winter food shortages and a food security crisis. Growers were deciding not to plant crops or to delay delivery of propagated plants. They were attempting to mitigate against escalating energy costs resulting from the Russian invasion of Ukraine and enduring labour supply constraints. The result was empty glasshouses or much reduced and later output. The primary reason identified was the low contract prices offered by supermarket retailers that did not recognise growers' increasing costs from a range of inflationary pressures.

Fast forward to the end of February 2023 and UK newspaper headlines were filled with news of 'tomato-gate' – supermarket shelves empty of fresh salad vegetables and retailer rationing of sales to customers. The then Secretary of State for Environment, Food and Rural Affairs, like the supermarket retailers, ascribed the shortages to weather and climate change issues in Morocco and southern Spain impacting on the winter supply of fresh produce. The crisis, though, highlighted the fragility of UK food supply security in the context of the 'perfect storm' (House of Lords 2023: 18) of departure from the

[1] Recognising that the concept of food security is wide ranging, the focus of this book is on food supply security; the ability of the national, regional and global value chains through which food is supplied to ensure effective and sustainable provisioning of food (see Lang 2020, Caraher *et al.* 2023, House of Commons 2023, House of Lords 2023).

[2] Interview with G5 (see footnote 18 for an explanation of the interview reference nomenclature).

European Union (EU), new trade barriers,[3] military conflict in Russia and Ukraine, continuing labour supply problems and climate change, not least because supermarket shelves in the EU were seemingly full. UK glasshouse growers highlighted their decisions in 2022 to plant late or to not plant at all due to high energy costs, the unwillingness of retailers to reflect a raft of increasing cost pressures in the prices paid to growers and a continuing shortage of workers to grow and harvest crops.[4]

'Tomato-gate' was the manifestation of a food security and wider structural crisis faced by glasshouse agrifood producers and the food industry. At the surface, it reflected the UK's increasing reliance on imported fresh food, with the UK share of total tomato supply falling from 37 per cent in 1988 to 16 per cent in 2022.[5] Concomitantly, glasshouse agrifood production fell by 5.7 per cent between 2021 and 2022, 'the seventh consecutive year … since the 2015 peak production' (Bradshaw and Wentworth 2023: 4). The crisis also reflected the precarity of growers and workers in the UK's fresh produce value chain. Attempting to meet value chain pressures of low margins, supermarket lead-firm dominance, labour shortages in a tight labour market, alongside escalating energy prices created a perfect storm for many UK growers. One grower warned that the industry will 'collapse' without migrant workers, although there was no apparent consideration of whether the working conditions resulting from the UK's Seasonal Worker Visa (SWV) programme could be improved.[6] These dynamics, which came to a head in 'tomato-gate', reflected the UK's position as a net importer of fresh food, reliant on a combination of national, pan Europe and global value chains (GVCs) for its food security (Smith, F. 2023).

This is not a new problem. Seventy years earlier, in the aftermath of the Second World War, the UK also faced significant food security issues. Worries over food supply, continued post-War rationing, constrained access to adequate labour and energy supplies and the challenges these presented to domestic food production dominated the agenda. Writing in relation to the Lea Valley, one of the UK's foremost regional centres of glasshouse agrifood production, Wilson Miller (1983: 38) noted that the:

> intensive crop production of food crops … was disrupted in the 1950s by declining labor supplies, rising costs of heating oil, and expansion of alternative landuses.

[3] See Simpson (2024a, b) on non-tariff barriers impacting on the horticulture industry.

[4] Reports of 165 per cent cost increases for energy, fertiliser by 40 per cent and labour by 13 per cent were common. Escalating energy costs were compounded by the Conservative government's decision to remove energy price support to the glasshouse industry from March 2023, creating additional uncertainty among growers (Cheshire 2021a, Evans 2021, Case 2023, Horton and Butler 2023, Leggett and Race 2023, Smith, O. 2023).

[5] Calculated from DEFRA Horticulture Statistics.

[6] 'Grower warns that industry will collapse without migrant workers'. *Hort News*, 7 June 2023. Accessed 8 June 2023.

Family labor was long the mainstay, but … [w]omen were drawn from work in the greenhouses by higher pay in other kinds of employment such as clothing and pharmaceutical manufactures on the west bank of the River Lea. The overall labor problem in the greenhouse activity worsened as the operators became elderly and were not replace by young workers.[7]

Military conscripts had yet to return, national service was further limiting labour supply and glasshouse workers were being lost to expanding industrial activity. In a National Farmers' Union (NFU) report to the Ministry of Agriculture these labour supply constraints were recognised:

In some areas of acute labour scarcity and intense industrial competition it is often extremely difficult to attract British labour. In general these are areas of intensive horticultural production where … widespread mechanisation is impracticable. Resort has therefore had to be made to foreign labour.[8]

Equally, at a meeting between growers and the Ministries of Agriculture and Energy in 1954, the 'increasing cost of fuel' was impacting on grower operations as they were unable to pass on the increases 'in the price of their commodity'.[9] This led Bewley (1956: 522) to conclude that 'the glasshouse industry is probably the only one where costs of production are rising while the value of its products are falling'.

What was different in the immediate post-War period, however, was that the power of the supermarket retailers at the top of the agrifood value chain had yet to be established in a food system that was then reliant largely on wholesale markets and small grocery shops (Webber 1972). What was also different were the sourcing patterns of labour in the industry compared to today when labour supply has 'gone increasingly global'. Understanding the long-running relationships between value chain configuration of corporate and inter-firm power relations, labour supply and employment relations and technology is, I argue, central to explaining the enduring structural crisis of fresh agrifood in the UK.

Food supply security has, then, remained a major issue for over seventy years, during which time the enrolling of sufficient labour at a price deemed

[7] Energy shortages and increasing energy costs were impacting on glasshouse growers in immediate post-War Britain, and the Ministry of Energy and Power was encouraging growers to reduce energy consumption (Horticultural Liaison Group. Minutes of the twentieth meeting, 24 May 1948; Minutes of the twenty-second meeting, 27 October 1948. TNA MAF43/106; Committee on the Efficient Use of Fuel, 'How Glasshouse Growers Can Save Fuel', Fuel Efficiency Bulletin No. 46. TNA MAF105/13; Ministry of Fuel and Power. Minutes of a meeting, 17 April 1954. TNA MAF105/13). As we shall see later, labour shortages were also a recurring issue that led to the development of new programmes for accessing migrant labour.

[8] The National Farmers' Union. Manpower Policy for Agriculture. Report of the Labour Committee. TNA MAF186/100.

[9] Minutes of a meeting held on 14 April with representatives of the NFU, Lea Valley and West Sussex growers, Ministry of Agriculture and Fisheries and Ministry of Fuel and Power. TNA MAF105/13.

acceptable by growers has been impacted by wider value chain relations and the technical capacities of growers to invest in technologies to enable more efficient and less labour-intensive production (see also Mitchell 2023). Today the UK is characterised by significant food supply insecurity with a little over half of all the country's food (by value) currently produced in the UK and domestic production below 25 per cent in some key crops such as fruits and vegetables (Lang 2020, DEFRA 2022a). It is in this context that UK food security and the former Conservative government's rhetorical aim of 're-shoring' of agrifood value chains have been at the heart of recent policy announcements (e.g., DEFRA 2022a), particularly since the UK's departure from the EU and increasing concerns over securing food supplies. The consequence of reliance on food imports, however, is adding to the carbon footprint of food miles and the maintenance of an agrifood system dependent on cheap supermarket food prices. This led the former Director General of MI5 to characterise food security as a national security issue.[10] This book assesses how we reached this place and what can be done about it. It does so by combining an approach that centres the interconnections between value chain dynamics, labour regimes and techno-science[11] in the governance of food supply security. The book sheds light on how grower and lead-firm relations intersect with the labour process and labour supply constraints, as well as with ongoing techno-scientific transformations aimed at enhancing grower and supply chain efficiencies.

A value chain approach casts light on how the UK's fresh agrifood sector is dominated today by powerful supermarket retailers driving low grower margins and is reliant on a seasonally variable combination of imports and domestic food production. There is also a reliance on a labour regime of relatively low-wage, seasonal and migrant workers. It is a system of food provisioning that connects global, regional and domestic value chains in the all-year-round supply of fresh fruits and vegetables to consumers.[12] But it is a system of food provisioning fraught with fragilities and challenges. *Fields of Glass: Labour Regimes, Techno-Science and Biopolitics in Agrifood Value Chains* places this contemporary challenge in a historical perspective to examine how growers and other actors in the agrifood value chain have grappled with the regulation and management of biophysical crop growing processes, precarious labour regimes, and a sector increasingly dominated by the pressures arising from the power of lead-firm retailers. Over the past seventy years, the migrant labour regime, while taking different forms over time, has been central to the

[10] Baroness Manningham-Buller, Henry Plumb Lecture to the NFU, 28 November 2022.

[11] Techno-science is understood, most broadly, as the application of scientific endeavours to technological innovation and development, underpinned by differential forms of state and private capital investment.

[12] See Pasquali *et al.* (2021), Barrientos (2022) and Visser and Alford (2024) for parallel consideration of regional and national value chain combinations beyond the predominant focus on *global* value chains (e.g., Gereffi *et al.* 2005, Ponte *et al.* 2019).

challenge of how the state provides 'sufficient' labour supply to growers without undermining systems of labour control critical to increasingly industrialised glasshouse agrifood production.[13] In other words, the book examines the combined social (provision of sufficient labour at costs deemed suitable to growers facing pressure in the value chain) and ecological (controlling and managing nature to produce crops) indeterminacy of labour regimes (Smith 2006, Baglioni and Campling 2017, Baglioni *et al.* 2022c). This indeterminacy is derived from the situation that 'as with labour, nature can never entirely be dominated by humans' (Baglioni *et al.* 2022c: 325). There is, then, a double indeterminacy to agrifood production and the book understands glasshouse agrifood production in these social and ecological contexts. The focus on glasshouse agrifood production recognises that there are parallels with other fresh produce production systems in, for example, open field contexts (e.g., Rogaly 2008). However, as I discuss in the following section, there are important specificities to the glasshouse production of fresh produce. These specificities revolve around the 'total ecological' system of control that is central to how 'controlled environment agriculture' (CEA) seeks to manage the social and ecological indeterminacy of agrifood production.

THE 'TOTAL ECOLOGY' OF GLASSHOUSE AGRIFOOD VALUE CHAINS

Over time growers, government policymakers and the techno-science base of plant breeding and technological innovation supporting the industry have sought solutions to the knotty double indeterminacy. This has taken the form of various technological and public policy 'fixes' that aim to enhance grower productivity while also attempting to manage programmes to provide flows of relatively precarious migrant labour. For example, one government assessment of the glasshouse sector in the late 1970s found that output had increased by 36 per cent in just over ten years due to the increasing technological intensity of crop production, with associated labour-saving results.[14] Today, glasshouse agrifood production is constructed, at least discursively, in terms of national food security. In part this involves seeing 'protected' glasshouse production as vital to provisioning food and health for the UK population (e.g., DEFRA 2022a). Glasshouse agrifood production is therefore seen as central to enrolling agrarian biopolitical forces in the management, regulation, and calculative capacities of growers and other industry actors (cf. Hetherington 2020). But this biopolitics of agrifood security is also fundamentally about trying to cement capital's control over nature and labour in the production of food commodities as value chain consolidation proceeds. I argue that the technology of

[13] Cf. Mitchell (1996, 2012, 2023) on the USA's Bracero migrant workers programme and its aftermath.

[14] Strategy for Horticulture, Productivity and Total Production. TNA MAF456/17.

the glasshouse is critical to such forms of control. The glasshouse constitutes an attempt to create a 'total ecology' of biopolitical control over labour and nature (see also Harvey *et al.* 2002, Moulton and Popke 2017, Siegmann *et al.* 2024, Smith, A. 2023, 2024).

Indeed, writing in 1898, the Russian anarchist and geographer, Peter Kropotkin, had already highlighted the ways in which techno-scientific developments were enabling an intensification of agrifood production in what he characterised as '[e]ntire fields … covered in glass' in his description of the Lea Valley and the area around Worthing in West Sussex (Kropotkin 1898: 96).[15] It is these two long-standing regional complexes of glasshouse agrifood production in the UK that provide much of the focus for this book. They remain the most important regional production centres in the UK for glasshouse agrifood. Like other such regional complexes of protected agrifood cultivation under glass or plastic in the Netherlands, Spain, Italy and Morocco (Breukers *et al.* 2008, Aznar-Sánchez *et al.* 2011, Corrado *et al.* 2017b, Garrapa 2017, Medland 2019, Salvia 2020, Piro 2021, Prause 2021, Siegmann *et al.* 2024; cf. Howard and Forin (2019) on field tomato regimes in Italy), the West Sussex and Lea Valley regions have variously relied on a combination of domestic and migrant labour and have been centres for the techno-scientific innovations that have structured much of the post-War industry.

What does a focus on the provisioning of fresh vegetables and fruit grown under glass tell us about wider dynamics of food security and global value chains? My argument is that, given the temporalities involved in all fresh crop production, glasshouse agrifood sheds important light on the question of how food security vulnerabilities have been managed over time. It enables an understanding of the ways in which corporate power and control over value chains articulates with the complex dynamics of labour supply and the organisation of the labour process. It also provides insights into how the biophysicality of food production and the role of techno-scientific innovation in the management of 'natural' growing processes intersect. All these dimensions are central to a sector that purports to enhance CEA and grower efficiencies. This focus also sheds light on the vulnerabilities that the model of food provisioning, established by lead-firm retailers and wedded to the supply of all year-round fresh food, creates for food supply security (Freidberg 2009).

A distinction is drawn between field-based agrifood production (e.g., Rogaly 2008) and 'protected' cropping in the 'total ecologies' of glasshouse environments (see Harvey *et al.* 2002, Moulton and Popke 2017). This conception of 'total ecology' emphasises that CEA is an attempt to bound, control and

[15] For Kropotkin, intensified 'hothouse' growing was one of three social formations underpinning more collectivist societal organisation, alongside the decentralisation of industry and small-scale industry and 'petty trades' (Kropotkin 1898: 107, Seligman 1899: 336). Today glasshouse agrifood is far from such a vision as large-scale, capital-intensive and industrialised forms of production have become the norm.

fully enrol the biophysicality of natural plant growth and biological processes into a totalising and intensive system of agrifood crop production. It is an attempt to socio-technically manage 'nature' in the interests of intensifying food production. The 'total ecology' is, in other words, an attempt to surpass the social and ecological indeterminacy of agrifood production. Unlike open field agrifood production and growing berries in plastic tunnels which are open to the environment, the 'total ecology' of the enclosed glasshouse creates an environment of control of both nature and human labour in which, for example, technologies seeking complete control and regulation of the biophysical growing environment (e.g., automated computerised systems of climate control) are extended to the control of human labour productivity (e.g., labour monitoring systems) (see Chapter 9). These integrated systems have become a way to intensify the agrifood production process. The 'total ecology' of glasshouse agrifood, however, is never complete. Biophysical dynamics such as pathogens, plant disease, growing time, seasonality and weather conditions all limit and bound the possibilities of human control over the crop production process (cf. Mann and Dickinson 1978, Guthman 2019). Furthermore, the enrolling of human labour to produce and harvest crops has been a structurally significant limit on creating a fully controlled food production system. The 'total ecology' is, then, a fractured system of protected agrifood production. Fundamentally, these indeterminacies are governed by the power relations of the value chain.

I make this argument concerning the 'total ecology' of the glasshouse because of the specific forms of technological and environmental control, the divergent temporalities and seasonality of cropping, and the distinct labour regimes that comprise CEA. Glasshouse agrifood largely involves the production of tomatoes, cucumbers, peppers, berries and leafy vegetables and is characterised by a labour regime combining reliance on UK nationals and long-term EU migrants with 'settled status' and relatively low-wage, seasonal migrant labour sourced via government programmes. It involves a segmented labour process in which different categories of workers become allocated to different segments (Chapters 5 and 6). This labour regime combines with the ecological and technological specificities of crop management and growing under glass that enables longer seasonal crop production. Today this is being enhanced by recent initiatives to create 'high-tech', digitally automated regional clusters of glasshouse 'AgTech' activity to enhance food supply security in the context of labour shortages and value chain pressures (see UK-RAS 2018, DEFRA 2022b; Chapter 9). There is, in other words, a critical labour–ecology–technology nexus to understanding food security in agrifood value chains. It is this nexus that provides the focus for the book.

Fields of Glass places this nexus in both historical and global contexts. With respect to historical context, the book examines how the current struggles over value chain agrifood security are part of much longer attempts to control the food supply value chain both domestically and internationally since the Second

World War. The book extends research on labour intensification in field crop production to consider the specificity of technologically and labour-intensive growing under glass for how we understand value chain, labour regime and food security dynamics. It does so by examining the technological and employment transformations in the sector over the last seventy years. With respect to global context, the book places the UK's agrifood value chain in its wider international context. The international reach of the sector is structured around the supply chain strategies of the main supermarket lead firms and a variegated geography of growers, in which the UK supply base provides a critical role in combining domestic, pan-regional and global value chain strategies, alongside the international supply of migrant workers to the industry.

CONCEPTUALISING THE 'TOTAL ECOLOGY'

Glasshouse agrifood production can be conceptualised as an attempt by growers, scientists and the state to construct a 'total ecology'; a food growing system characterised by the biopolitical management and regulation of agrarian systems. At the heart of this 'total ecology' is the attempt simultaneously to control the biophysical, natural growing dynamics of plants, and the labour process, and to establish as far as possible a fully optimised system for food production (see Harvey *et al.* 2002, Moulton and Popke 2017). The 'total ecology' is, then, an attempt to manage the social and ecological indeterminacy of agrifood production (Baglioni and Campling 2017). Glasshouse agrifood production 'is best viewed as an apparatus of environmental security that works to mobilize new technologies, materials, and affective relations so as to intensify the management of and control over the agricultural milieu' (Moulton and Popke 2017: 722). It is *the* central mechanism by which near all-year-round production of fresh vegetables in the UK has been enabled, alongside the import of food in pan-regional and global value chains.

Over the post-War period, state policy was oriented, through a network of research institutes, extension organisations and investment frameworks (discussed in Chapter 7), to 'modernise' the agrifood production base and to draw on the 'white heat' of technological advances around plant breeding and cropping technologies. These techno-scientific interventions were, at the same time, an attempt to control as far as possible the biophysicality of crop production and to consolidate the labour process through labour-saving innovations as a way to enhance the turnover time of capital invested in the agrifood production process. Understanding this 'total ecology' as the articulation, or combination, of techno-scientific endeavours with the changing labour regime of glasshouse agrifood is thus central to the arguments pursued here. This articulation has been transformed over time. Most recent attention has been focused on the possibilities for robotic and digital technologies in glasshouse agrifood (e.g., UK-RAS 2018, Smith 2024); a new frontier of techno-science to apply what has become known as 'AgTech' (e.g., Goodman 2023) to

the optimisation of crop production, and the integration of these technologies with robotic platforms to enhance crop husbandry and harvesting. The socio-technical base on which 'AgTech' solutions are produced is a fragmented ecology of tech firms, growers and university collaborations supported in part by an equally fragmented system of competitive state funding allocated via UK public investment in scientific research and development. However, through much of the latter half of the twentieth century, the techno-science base was more closely articulated with a network of government funded research institutes, which worked closely with extension workers and growers in the innovation process (see Chapters 5 and 6). This techno-science system enabled a closer interaction between the innovation system and the needs of growers than today,[16] but was one of the casualties of state austerity programmes starting from the 1970s (see Chapter 5).

The 'total ecology' is also situated within the wider political economy of value chain power relations and a labour regime seeking to 'supply' workers to the industry and to regulate and govern the agrifood labour process. The ability of growers to invest in product, process and technological upgrading to create efficiencies in the crop production process by enacting forms of enhanced control over natural growing processes has been shaped by the material constraints set by lead-firms in agrifood value chains (cf. Humphrey and Schmitz 2002, Dolan and Humphrey 2004, Gereffi *et al.* 2005, Gibbon and Ponte 2005, Barrientos 2019). UK glasshouse agrifood production is a critical element in a wider set of pan-European and global value chain relations of fresh food provisioning, often controlled by some of the largest UK producers (Chapter 4). In other words, any understanding of UK agrifood production and food security has to be set within the context of the wider production networks through which food is sourced and supplied to UK lead-firms and the socio-technical regimes of research and development and of labour control governing glasshouse crop production.

The 'total ecology' can be understood more abstractly as part of the 'metabolic interaction' between the application of 'living labor' to the 'natural processes' of plant growth at the heart of biophysical, nature-centred agrifood regimes (Moulton and Popke 2017: 726). In its most totalising form, CEA represents an attempt to create a fully controlled ecological environment for the entire cropping and husbandry process. Harvey *et al.* (2002: 106) argue that the high 'capital and labour investment of glasshouse production impels a logic of high success rate and high yield per plant'. The industry is therefore characterised by a continual innovation process seeking to intensify production and the labour process (Beynon and Quilley 2005, Smith, A. 2023). This entails attempts to control biophysical growing processes as far as possible

[16] See, for example, comments by Tim Mordan, Deputy Director of Innovation, Productivity and Science, DEFRA at House of Lord's Horticulture Committee enquiry meeting, 7 September 2023. Available at: https://parliamentlive.tv/event/index/44971625-701e-4eb7-aa34-2e8b4685ce49.

through manipulation and regulation of the crop growing environment and the work involved in crop production. The 'total ecology' is, in other words, a critical part of the biopolitical regulation of agrarian life and food supply. It is also a system of ecological control, with implications for increasing capital concentration in the industry. While glasshouse horticulture was established around relatively small-scale household and family production units, ownership has become increasingly concentrated and capital intensity and increasingly large-scale production have developed to create the kinds of economies of scale required to sustain a 'total' environment and the supply requirements of lead-firms. There has been a shift towards larger conglomerates, some with international operations, as firms have sought to functionally upgrade in the agrifood value chain.

Glasshouse agrifood production can be seen, then, as a system which aims at – but rarely achieves – total biopolitical control of both food production and the labour required to grow crops. The 'total ecology' has become the primary way that actors in the industry have sought to deal with the social and ecological indeterminacy of agrifood value chains. Moulton and Popke (2017: 724) sought to understand such a 'total ecology' as 'a complex – one in which practices of human labor associated with farming are mediated in novel ways by the technologies and materials that are incorporated into the greenhouse'. Likewise, Harvey *et al.* (2002: 106) have seen tomato production systems under glass as 'a total ecological system', incorporating seven primary dimensions of growing cultures, atmospheric control, seed technologies, nutrients and irrigation, pollination, pest and disease control, and adoption of computerised climate control. Despite making recourse to Marx's (1976: 637) and Fitzsimmons and Goodman's (1998) arguments over 'the metabolic interaction' between labour, food supply chains, and the biopolitical regulation and control of food production, Moulton and Popke's (2017) analysis of glasshouse and protected agriculture does not examine in detail the labour regimes involved in food production. Nor is this a particular focus for Harvey *et al.* (2002), despite their recognition of the role of lead-firm practices. The role of migrant wage labour in the production of glasshouse agrifood has therefore been a somewhat neglected matter in analyses of the 'total ecology'.[17] While Moulton and Popke (2017: 726) highlight the role that 'the greenhouse provides [as] an example of the ever-increasing tendency of capital to insert itself into the metabolism between human biopolitical labor and the natural processes on which life depends', their focus is on the transformation of grower practice rather than the always fragile enrolling of human labour in the biopolitical process of agrifood production.

Overcoming this relative silence is important because it is the interaction of living labour, biophysical and techno-scientific systems that structures the

[17] Although see Siegmann *et al.* 2024. Beynon and Quilley (2005) do partly take a labour process focus on the impacts of technological change.

indeterminacies at the heart of these 'total' systems of control. My argument is that they are never *total* ecologies, even if that is the aim of growers and other industry actors. Glasshouse food production is always shot through with fragilities and 'obstacles … and surprises' (Boyd *et al.* 2001: 556), contradictions, tensions, and disease problems. The provisioning of sufficient labour at a price deemed suitable by growers in the context of wider commercial pressures is also fraught with long-term challenges (Mitchell 2012, 2023). The 'total ecology' is consequently structured around the limitations resulting from the labour regime established by commercial pressures in the value chain, not least those of labour supply challenges, which underpin the continuing lack of food security in the UK. There is, then, a social indeterminacy to the 'total ecology' (see Smith 2006, Baglioni and Campling 2017, Baglioni *et al.* 2022c). But equally, there is an 'ecological indeterminacy' as growers seek to control nature in the food production process because of the ecological barriers set by nature to ensuring 'smooth' food provisioning (Baglioni and Campling 2017). By centring the labour regime and techno-science in a value chain context, this book explains the calculative capacities of an industry seeking to control these indeterminacies. However, the process of establishing the glasshouse agrifood labour regime establishes fundamental fragilities in the overall process of surveillance and control that characterise the 'total ecology'. CEA is, then, a biopolitical project of the state seeking to ensure the provision of sufficient food to sustain the populace (cf. Foucault 2007, Nally 2011), in the context of challenging value chain power relations and precarious labour regimes that together create a fragility at the heart of the 'total ecology'.

The main argument of *Fields of Glass* is that these are not simply agrifood value chains, but *agrarian biopolitical articulations* which bring together the circuits of value production and circulation between growers and lead-firms, labour regimes, techno-scientific formations and the transformation of nature (Chapter 2). This concept is advanced to understand the application of scientific technologies, state regulation and investment, and grower practices to the arrangement of biophysical processes of crop production, productivity improvements and food supply, *and* the simultaneous calculation, provision, control and management of labour regimes in agrifood production by migration programmes, and labour-saving and productivity-enhancing processes in the face of enduring labour supply constraints. The adoption of techno-scientific approaches over time has meant that biopolitical systems of regulation and governance can be understood in agrarian contexts as the ways in which human subjects (growers and workers, state-funded scientists) and produced biological resources (food) are part of an articulated system of material (labour, land, capital), techno-scientific and ecological forces (cf. Hetherington 2020). Food provisioning and food security are then 'at the very centre of [any] account of biopower' (Foucault 2007, Nally 2011: 38).

Fields of Glass aims to make two main contributions. First, by considering the role that labour regimes play in the calculative capacities of agrifood

value chains seeking to administer 'natural' growing practices (see Baglioni *et al.* 2022a), the book provides an extensive, historical account of 'the metabolic interaction' (Marx 1976: 637; see also FitzSimmons and Goodman 1998, Moulton and Popke 2017) between labour regimes, technologies and the biopolitical regulation, administration, and control of glasshouse food production. It aims to fill a gap in much existing work on agrarian biopolitics and agrifood value chains which eschews a treatment of labour regimes in the construction of these articulated dynamics.

Second, the *agrarian biopolitical articulations* framing discussed in the following chapter examines processes at the heart of glasshouse agrifood production to illuminate the causalities in agrarian value chains. These are shaped by lead-firms, growers, state policy, and techno-scientific practices, seeking to manage and control the biophysical processes of crop production. In other words, the multi-sited, multi-actor framing of value chain analysis enables an elaboration of how agrarian biopolitics is deployed in, and varies across, a whole system perspective to shape upgrading and other accumulation strategies in the chain (cf. Stock and Gardezi 2021). By deploying the concept of *agrarian biopolitical articulations*, the book formulates new perspectives that bridge the hitherto distinct worlds of value chain research, agrarian political economy, labour regime theory, and agrarian techno-science.

FIELDS OF GLASS: METHODS AND STRUCTURE

Fields of Glass is informed by research conducted primarily on the UK's two main regional glasshouse agrifood production clusters; the Lea Valley and West Sussex (see Chapter 3). Together these clusters comprise nearly one-fifth of the UK's glasshouse production area. The research has involved a combination of interviews with several of the most significant UK glasshouse growers (owners and managers of glasshouse agrifood business operations), and with a wide range of key informants in technological innovation firms, labour organisations, and the agrifood industry more broadly, as well as in local and national policy communities.[18] For a hard to access group of key informants, purposive and snowball sampling strategies were adopted. The purposive sampling strategy focused on capturing variation in firm position in the value chain and in terms of company size and operations (Oliver 2011). This was combined with snowball sampling to access key players via the networks of businesses operating in the sector (Parker *et al.* 2019). Sampling ended when a point of saturation was reached, through triangulating responses from interviewees, ensuring that the key conceptual categories framing the research

[18] All material derived from interviews has been anonymised and informants are referred to via a coding system (e.g., G1 … Gn (growers and workers), I1 … In (institutions), and T1 … Tn (technology firms)).

had been explored as fully as possible (Corbin and Strauss 2008). Interviews lasted between forty-five minutes and two and a half hours and were undertaken in respondents' offices, on-site in glasshouses, and online. Wherever possible site visits were made to capture observational data on each operation in terms of scale, degree of modernisation, technological adoption, and the organisation of the labour process. Observations were undertaken of the nature of the tasks performed by workers. Interviews with labour representatives and labour supply organisations were also conducted to contextualise the perspectives of grower capital and technology development companies. Notes from site visits were set alongside detailed interview transcripts, which produced over 200 pages of interview material for analysis. Analysis took the form of iteratively working back and forth between conceptual categories and the interview data.

Research also involved extensive archival work at The National Archives (TNA), West Sussex Records Office (WSRO), Essex Records Office (ERO), Warwick Modern Records Centre (MRC), Camden Local Studies and Archives Centre, Worthing Local Studies Centre and the archives at the Museum of English Rural Life (MERL). The research involved immersion in these rich archival resources to trace through the historical relationships between the 'total ecology', labour regimes, value chains and state policy. It resulted in over 100,000 words of notes which were analysed iteratively alongside the conceptual categories and interview materials. The research was further supplemented throughout by attendance at key industry events and grower conferences, and with analysis of extensive industry 'grey' literatures and reports, and trade and employment data.

The book is organised as follows. The next chapter elaborates the conceptual framing around *agrarian biopolitical articulations* which is used to understand the ways in which value chain relations, labour regimes, and ecological struggles to secure food production come together in the context of the agrarian political economy of glasshouse agrifood production. Chapter 3 sets out the regional and national contexts which provide the focus for the book. Chapter 4 elaborates the value chain relations in the glasshouse agrifood sector and how these have transformed over time as supermarket lead-firms have become dominant players. Chapter 5 examines the labour regime of post-War glasshouse agrifood production and how it became reliant on migrant labour in an uneven manner across the two regions. Chapter 6 provides an analysis of the contemporary seasonal migrant labour regime and its precarity. Chapter 7 then turns to the role that the state has played in seeking to provide the conditions for the upgrading and technological transformation of the labour regime in the glasshouse industry over the post-War period. This is followed in Chapter 8 by an examination of the articulation of grower and state innovation processes in the development of hydroponic technologies, which have become the primary mechanism by which the industry has sought to establish a 'total ecology'. Chapter 9 examines how emergent

forms of digital technological solutions – 'AgTech' – are being developed and deployed in the context of the seasonal migrant worker regime and the limits to a contemporary technological transformation of the labour regime. Chapter 10 concludes the book and looks forward towards an alternative agrifood future in which fairer value chain relations and decent working conditions are more central.