TOMORROW'S HARVEST:

EXPLORING ENGLISH AGRICULTURE'S VEGETAL FUTURES

by

ROB BOOTH

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School of Geography, Earth, and Environmental Sciences

College of Life and Environmental Sciences

University of Birmingham

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ABSTRACT

This thesis explores how agriculture in England is affected by the future in the present. It analyses imaginaries and discourses about the future of farming, as well as the ways in which the materialities of agriculture, particularly its ecologies and technologies, shape future possibilities. This interest in materialities leads to an interrogation of how expectations and trajectories of agricultural change shape and are shaped by people's relationships with plants in agricultural systems.

Accordingly, this thesis draws on a range of disciplinary traditions and theoretical approaches. Although rooted in human geography it also borrows from political economy, Science and Technology Studies, environmental sociology, philosophy, and history. In bringing together these disciplinary traditions it builds bridges between old and new materialisms by engaging with post-structuralist thought and more-than-human geographies from a Marxian perspective. This combination of disciplinary and theoretical aspects leads to what I call a 'political ecological approach to the future'. Via this paradigm I offer a novel intervention into contemporary debates regarding both how to understand the future in the present and the relations between humans and 'nature'.

Further originality is offered by the way this approach informed the semi-structured interviews, participant observation and critical discourse analysis which form this research's methodology. These methods facilitated the collection of a wide range of empirical data over the course of 2022. This data shapes the three interrelated empirical

chapters at the the heart of this thesis. The first concerns regulation and practices associated with novel forms of plant breeding, particularly gene editing. The second examines the emergent field of vertical farming. The third explores the contemporary politics of agricultural scale and how such politics affect and are affected by historically-shaped relationships with different agricultural plants and technologies.

Together, these empirical chapters and the preceding theoretical framework make several key arguments. Centrally, this thesis shows how the future is produced in the present via not just ideas and talk, but also by material practices within agricultural systems. In considering these practices the influence of plants is also explored. I argue that the materialities and capacities of plants shape even the most advanced and intensified forms of contemporary farming in a way that should not be overlooked. Nevertheless, I argue that this does not mean that undue agency should be attributed to plants' capacity to dictate English farming futures. Rather I look to historicise current relations with plants and how these relations are expressed through novel technologies and discourses which are already influencing the future of English farming. These technologies and their related discourses continue to intensify and stretch an instrumental, alienated, and accelerated way of relating with plants in capitalist agricultural systems. Importantly, I argue that these are realities with deep historical roots, which serve as a reminder of the extent to which the future is shaped and constrained by diverse forms of power in the present, over both people and plants.

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LIST OF ABBREVIATIONS

ACRE = Advisory Committee on Releases into the Environment

CAP = Common Agricultural Policy

CEA = Controlled-Environment Agriculture

Defra = Department for Environment, Food and Rural Affairs

ELMS = Environmental Land Management Scheme

EU = European Union

GMO = Genetically Modified Organism

NFU = National Farmers' Union (of England and Wales)

NPBT = Novel Plant Breeding Technique

SME = Small to Medium Sized Enterprise

STS = Science and Technology Studies

UK = United Kingdom

1. INTRODUCTION: ESTABLISHING HORIZONS

1.1 Shifting Futures

This thesis examines people's relationships with the future of English agriculture. In doing so it links the implicit and explicit relationships that individuals involved with food production have with the future to the broader political and ecological futurities of contemporary agricultural processes. In order to explore this, I draw on ethnographic research conducted with farmers, agricultural workers, campaigners, and scientists in 2022. Via this empirical engagement, I connect discourses, histories, and imaginaries of farming futures to the everyday practices and experiences of people involved in English agriculture and associated forms of technological development. I also connect these themes with a particular attention to how people involved with agricultural systems see and enact the future through and with the forms of plant life upon which all agriculture relies. In doing so I also look to make connections between old and new materialisms. In this regard I believe I offer a novel and timely contribution to both social scientific approaches to the future and relationships within and between 'society' and 'the environment'. Given the exigencies of the current historical moment, working through such questions in the foundational sector of agriculture is vital.

Between this project's initial formulation and the production of this thesis the futures of English agriculture have been warped and stretched. I had initially foreseen focusing on the United Kingdom's (UK) ongoing departure from the European Union (EU) which continues to create anxiety along the agricultural supply chain. As a result of Brexit, the significant area-based subsidy payments upon which many English farmers had long depended are still being phased out and future trading relationships are in flux. The supply of agricultural labour from Europe also became uncertain in an unprecedented way. Meanwhile, the growing impacts of the climate and nature crises associated with the 'Capitalocene' (Moore, 2017; 2018) have become increasingly clear for English farms. 2018 saw a significant heatwave-induced drought and by the end of June of that year soil moisture conditions were, at that time, the driest on record (AHDB, 2018). According to the Department for Environment, Food and Rural Affairs (Defra), in 2018 'extreme weather conditions led to poor yields and pushed up the price of key inputs' (Defra, 2020a: 38). This was followed by a 2019 during which excessive rainfall in parts of the country brought the year's wheat harvest to a 'shuddering halt' (PA Media, 2019). Yet, these realities did not seemingly translate into what could be considered a form of crisis futurity in the agri-food sector. National legislation was created, however, in 2019 which necessitated the British economy reach net-zero emissions by 2050.

Despite enthusiastic proposals at the time from the National Farmers' Union (NFU) (2020) about reaching net zero, the years in which I have been conducting this doctoral research have seen little shift in the policy responses to these stark realities of an agricultural future defined by heightened environmental uncertainty. Despite the government claiming to see agriculture and land use as integral to their net zero strategy,

the Environmental Land Management Scheme (ELMS) designed to replace the EU's Common Agricultural Policy (CAP) in England has emerged slowly and lacked ambition in a way that has frustrated farmers and campaigners alike (Evans, 2022; Speed, 2023). This came after much initial hope and promise. Despite this, ELMS is still considered to be the vector via which agricultural production in England will deliver environmental goals (Defra, 2019). The future ramifications of this faith look uncertain at best.

These political ecological realities shaped the foundation of my initial research agenda. However, during the period my PhD took place these trajectories became entangled with unforeseen events. Firstly, in 2020 the COVID-19 pandemic further made visible the contingency of our food supply chains. Then Russia's invasion of Ukraine in 2022 combined with the 'bullwhip' effects (Scarpin et al., 2022) on the supply chain of the post-pandemic conjuncture and corporate opportunism (Clapp and Howard, 2022) to drive up the cost of both producing and consuming food.

By the middle of 2022 fertilizer costs had skyrocketed. In February 2023 empty supermarket shelves previously replete with different varieties of imported tomatoes were being reported (Ungoed-Thomas and Bryant, 2023). By March 2023 the inflation of food costs across Britain was sitting at 15% (Romei, 2023). All the while, the climate crisis intensified. During 2022, when I was conducting my fieldwork, the record for the hottest temperature ever in the United Kingdom, a reading of 38.7 degrees Celsius in Cambridge, was shattered by 1.6 degrees (Met Office, 2023). Across the globe extreme heat and drought has put pressure on production of everything from Indian rice (Rehbar, 2022) to Argentine soybeans (Sigal and Raszewski, 2023).

These ongoing events shaped my own relationship with what the future of English agriculture could or should be like. I came to see how the future is always already about land, soil and the political ecological histories which have produced the current social-ecological configuration we understand as 'English agriculture' or the 'food system'. In this research, I start with an unambiguously critical approach towards contemporary agricultural forms that recognises the ecological damage that industrialised farming has wrought across the world. I link this acknowledgement with a belief in a need for a transition towards agroecology (Altieri, 2018) and food sovereignty (Tilzey, 2017) and the irreconcilability of contemporary social forms with a liveable and equitable ecological future.

Recognition of this fact is at the heart of this project, and this also shapes my interest in the 'more-than-human'[1] lifeforms and biophysical processes implicated in all agricultural systems. Different visions and discourses articulate with different understandings of the nature and capacities of these lifeforms, processes and, in the case of agricultural technology, materialities. How these assemblages come to define the future and be defined by social-ecological processes as historical forces is the central pillar of this thesis. In order to make this foundational question more approachable, however, I came to focus during the process of my research on one particular modality of agricultural life in particular: that which social scientists and philosophers consider 'vegetal'. Or, to put it more plainly, the relations between humans and plants in agriculture and associated knowledge practices.

[1] A phrase I adopt throughout given both its positive framing and its popularity in human geography, compared to 'non-human' or 'extra-human'.

1.2 Planting Ideas

Plants are integral to farming. Our relations with crops underpin contemporary human lifeways. The philosopher Timothy Morton (2017), for example, describes what he considers the enduring impact of Mesopotamian 'agricultural logistics' and 'agricultural religion' in forming humankind's current social-ecological formation. James Scott (2017), on the other hand, homes in on the materiality of grains in the development of early states and their amenability to taxation and the possibility of domination over those who grow them. What is of interest to me, however, are the historical-material circumstances which give rise to different social-ecological formations within which the relationships between plants and humans change. This reality is acknowledged in recent work which describes the current epoch as the 'Plantationocene' (Barua, 2023; Haraway, 2015; Wolford, 2021). As Wolford (2021: 1623) describes it, this is a periodization which highlights 'the long-distance simplification of landscapes; alienation of land and labor; and transportation of genomes, plants, animals, and people'.

These historical tenets are vital to understanding the relations between people and plants cultivated everyday in English agricultural systems, as well as the futures they portend. As such, I connect an interest in 'vegetal political ecology' (Argüelles and March, 2021; Fleming, 2017) with how the future of climatic and ecological uncertainty bears down on the present. In confronting the 'catastrophism' (Heron, 2023) of the current moment, our relations with plants in agricultural systems are already taking on new forms. As a result of the arboreal capacity for carbon sequestration, afforestation is

seen as a necessary emissions mediation strategy. As a result of its rapid growth, miscanthus grass is touted as a future biofuel capable of facilitating carbon capture and storage. In agricultural systems, new crop varieties are envisioned which are capable of increasing yields despite the rising frequency of drought. Finally, those who advocate for a 'perennial vision' of a future agriculture strike at the very heart of the Mesopotamian agrilogistics Morton laments, highlighting the capacity of innovative plant breeding techniques to create novel cereal crops capable of producing energy rich seeds without the deleterious consequences of annual tillage.

So anticipated futures are changing our relationships with plants, agricultural production and the institutions which shape and mediate how plants are cultivated for agricultural purposes. Exploring these dynamics empirically, as I do below, leads to consideration of concepts like care, control, and conviviality via a material engagement with farming in practice. Yet exploration of these practices on the ground also necessitates connection with the overarching discourses and logics which shape understandings of agricultural futures. It is via this interplay between the material and the semiotic that agricultural futures are produced, and possible future plant-human relationships form as aspects of different 'socio-technical imaginaries' (Jasanoff and Kim, 2015). For example, discourses associated with, on the one hand, 'eco-modernist' or 'green capitalist' agriculture and, on the other hand, 'degrowth' or 'agroecology' prefigure very different relationships, temporalities, practices, and institutions between humans and between plants and humans. These are conceptual poles which will be interrogated in greater depth throughout this work. What is often at stake, however, is the way in which humans, and therefore agricultural landscapes and technologies, are understood or enacted to

be a part of nature or a separate external force. This also speaks to understandings of capacity and the potentiality of humans to manipulate non-human life, with understandable consequences for how multi-species relations in agriculture are understood and re-imagined.

These considerations often manifest themselves in the analysis below via discussions of the materialities and agencies of plant life and the multi-species temporalities agriculture creates. 'Agency' here means the ways in which and the extent to which plant life in agricultural systems is able to exert power over the formation of future agricultural forms via their inherent (yet historically-mediated) biophysical characteristics and lifeways. This leads to weighing up assertions about whether social-ecological processes like agriculture are best understood as multi-species endeavours of collaboration or evidence of the ongoing anthropocentric domination of humans over other forms of life. Within this work I navigate between the two poles in a way that looks to historicise the relationships between humans and plants in agricultural systems, suggesting that the move towards domination is an ongoing and intensifying, but always incomplete, process. One register through which these tensions emerge is a focus on the contested political ecological temporalities of agricultural systems within which the lived rhythms and teleologies of plant life are attempted to be subsumed to the rhythms of capitalist clock-time. This temporal aspect is, I argue, deeply implicated with a concern with futurity, an idea I unpack in detail in the next chapter.

Finally, returning to the idea of the 'Plantationocene', however, this work does not take this moment of crisis futurity and the agricultural imaginaries it animates as a moment

of unlimited possibility. As I researched and wrote this thesis the importance of recognising the social-ecological dynamics structuring the possibilities of agricultural futures crystallized in my work. In this regard, the significance of the historical development and dynamics of capitalism, and its material ramifications and drivers, has increasingly suffused this thesis. These dynamics are returned to throughout via both theorisation and empirical observation. This perspective, however, does not necessitate a certain approach towards the political ecological tensions regarding humans' capacities and responsibilities in the current epoch. In this sense, this thesis weighs into ongoing disagreements between theorists like Jason W. Moore (2015a) and Kohei Saito (2023). Nor, it is necessary to add, does a specific vision of an alternative agriculture emerge from this standpoint and disciplinary position alone.

An approach that foregrounds historicity and materialism articulates with existing work on food regime theory (McMichael, 2009; Tilzey, 2017). Food regime analysis looks to bring 'a structured perspective to the understanding of agriculture and food's role in capital accumulation across time and space' (McMichael, 2009: 14). Prause, Hackfort and Lindgren (2021) argue that the third food regime, previously described by Friedmann as the corporate-environmental food regime, is undergoing processes of digitalisation along food chains globally. This has led to diverse speculation about the future of food production given various technological advances associated with artificial intelligence and other technical developments. Technological advances in food production have long been associated with utopian visions of the future (Belasco, 2006). This thesis explores these visions but also seeks to situate their development and unpack their logic. In looking to achieve these aims I engage with the future in a way inspired by existing

scholarship in political ecology. In order to further develop this introductory chapter, I now set out the tenets of such an approach in more detail.

1.3 What Future?

Conceptions of the future saturate the social sciences. Sometimes these conceptions are as implicit as a belief in the utility of extrapolating from past trends. Sometimes, however, these conceptions form explicit objects of inquiry. Reinhart Koselleck (2004), for example, analysed the historical development of political prognosis as a distinctly modernist epistemological practice. It is this tendency which shapes an inherent futurist dimension within much social scientific research. The anticipatory tendencies of this form of prognosis can, in turn, be linked to today's interest in the potential for the social sciences to offer 'foresight' and to facilitate the 'pre-emption' of potential social ills (cf. Massumi, 2007; Anderson, 2010). In fact, any social scientific work that proposes reform, mitigation or adaptation by policy, practice or ideational change has a future-orientation that attributes a degree of plasticity and mutability to that which is yet to come. That includes this work. This also speaks to the inherent futurity of any conception of 'agency' or 'power' as the capacity to impact the time that follows the present (cf. Bastian, 2009).

However, the future is not just something imagined that can be tweaked or manipulated. Consideration of the future, as part of the temporal nature of reality, presupposes an ontological interest that goes beyond the articulation and circulation of different imagined futures. As the work of Elizabeth Grosz (2005) asserts: to think about the future

is to think about ontology, difference, and 'nature'. Further, these two dimensions together remind us that the future is something that is ultimately *lived* (Adam and Groves, 2007), and not exclusively by humans. In total, this can be seen to have contributed to a shift towards a more materialist analysis of the future in social theory (Tutton, 2017). These more materialist approaches articulate with a recognition that the future of human society in the 21st century is one of latent, emergent, and extant environmental and ecological threats which require radical remedial action. In this thesis, these questions are linked to ontological questions of what the future is and how different temporalities and rhythms manifest themselves in the multi-species worlds of agriculture. However, as I have begun to emphasise above, I ensure this speculative or ontological moment is always undergirded by a *historical* aspect which takes seriously the way in which structures and dynamics of capitalist social life mediate and shape – and are mediated and shaped by – conceptions of a desirable, liveable, or inevitable future. As my research progressed, I moved closer and closer to an approach that sees historicism and materialism as essential to understanding the future.

Along these lines, theorists across the social sciences and humanities have long made diverse efforts to analyse the generation, structuration, representation and experience of spatio-temporality and the future. Accordingly, I draw on work from human geography, anthropology, sociology, philosophy, environmental humanities, Science and Technology Studies (STS) and political economy. I draw these traditions together under the banner of political ecology, taking as my starting point the idea that 'the human transformation of natural ecosystems cannot be understood without consideration of the political and economic structures and institutions within which the transformations

are embedded' (Neumann, 2005: 9). It is because of its interdisciplinary connections, its interest in moving beyond anthropocentric social science and its inherently critical dimensions that I have chosen to write this thesis from a political ecological perspective. Further, as Moragues-Faus and Marsden (2017) suggest, the socio-material processes and relations involved with the production and consumption of food offer an ideal lens for political ecological analysis and also provide continuity with a rich vein of work traceable to the origins of political ecology. Founding works in political ecology addressing agriculture by the likes of Piers Blaikie (1985) and Michael Watts (1983) underline this synergy.

More recently, however, Ryan Galt (2013) has highlighted the need for an increased political ecological scrutiny of 'first-world' agriculture. This is an analytical sphere within which agrarian political economy has historically dominated via approaches like the abovementioned food regime theory. In focusing on the production of food in the United Kingdom, this thesis follows Galt's lead. Further, Galt (2013) outlines three aspects of a first-world political ecology of agriculture which strongly influence this thesis and move the discipline beyond Neumann's foundational principal quote above:

1. An openness to poststructuralist theory
2. A concern with ontology
3. An attendant recognition of the agency of more-than-human 'nature' in the social-ecological processes of agriculture

As such this work is an attempt to critically build on the existing literature within the political ecology of agriculture framed by Galt and exemplified by, for example, Tilzey (2017). However, this thesis offers novelty in that it combines such existing approaches with an interest in the political ecological dimensions of materiality, temporality and futurity within food systems and associated innovation. This is predicated upon a recognition that futurity – as a register of spatio-temporality and as an ontological facet of ongoing social processes – is a contested dimension of human social formations which has an impact on, and is impacted by, social-ecological processes such as farming. The influence of critical human geographers' writings on the relationships between space, time and society is important here, particularly the work of David Harvey (1996; 2000).

This combined interest in the future and the vegetal distinguishes this thesis from existing research in this field. Further, it enriches existing scholarship regarding futurity through an engagement across scales and register of the future through empirical fieldwork. A political ecological approach can, when applied towards temporalities and the future, provide a novel direction from which to explore the tensions and contestations between social constructions and representations of temporality and futurity whilst also attending to the tensions between the human and the extra-human temporal and biophysical processes within which these social phenomena are enmeshed. Political ecology is, however, already a broad church and establishing a distinct future-oriented niche within the field requires some groundwork around how to approach a concept as slippery as the future.

1.4 Research Questions

Rather than trying to offer a parsimonious definition of what 'the future' 'is', I instead start by establishing what I take to be three relevant, interlinked dimensions of futurity. Each provokes a foundational question which shapes this thesis. Firstly, it is necessary to attend to the human, socio-political and experiential dimensions of futurity as practiced, experienced, represented, contested, and *produced* by individuals and institutions. In this case, this concerns individuals and institutions involved in the social processes of food production, its transformation, and its regulation. As such, I explore the social construction and contestation of space-times and futurities across the agricultural sector, from farms to laboratories to parliament. This first dimension of the focus of this research concerns the relationship between temporality and the future *in the present*. This dimension is similar to what Barbara Adam and Chris Groves (2007: 176) describe as 'present futures', a term which 'refers to the standpoint of the present … it encapsulates both the factual approaches of science and economics and process-based perspectives on futurity and the lived future'. Process and practice-based approaches to understanding the ways the future saturates and shapes the present are elaborated upon below in this chapter's second section. This focus leads to the first central question which informs this project:

> Q1. How are peoples' relationships with the future formed in the present and how does this affect agriculture and agricultural change?

This question emerges below regarding contesting political discourses of appropriate pathways towards agricultural change, how environmental discourses legitimate the promotion of novel or emergent agricultural forms in the present or how uncertainty about the future creates agricultural policy and practice.

Secondly, this thesis acknowledges the imbrication of these lived human social futurities with the materiality, agency, and temporalities of the 'more-than-human' and biophysical world. Whereas the first question addresses socially mediated and produced experiences of social temporality and futurity, this second dimension looks to integrate this analysis with work addressing what can be described as 'objective' or 'real' ontological unfolding or emergence. This is similar to Adam and Groves' (2007: 176) view of the 'future present' which 'encompasses the future as both an effecting process and/or as living'. This interest attends to the ontological aspect of Galt's (2013) call for for future political ecological research on agriculture. Against constructivist approaches, it recognises the future as something real, beyond human experience, which is entangled with the expression and emergence of both more-than-human life and the abiotic material processes of geology or climate change. This interest facilitates dialogue with the more-than-human and new materialist approaches which have become increasingly influential in human geography. Yet it also articulates with a historical-materialist approach that sees the materiality of human social-ecological life as foundational and rejects approaches that are satisfied with analysis only at the level of the ideological or discursive. It is that historical-materialist approach which has come to define how I answer this second question:

Q2. To what extent do plants, and humans' relations with plants, shape how the future is envisioned, practiced, and manifested within agriculture?

Finally, I seek to address how different possible and more desirable futures are being constrained or catalysed by extant political ecological processes and the contestations and tensions between existing temporalities and futurities. This approach looks for possibilities for positively transforming the future and critiques existing trajectories of future agricultures in the present. This future-oriented approach is novel in that it looks to leverage an attention to the futurity of social processes to inform transformative change in the face of environmental and ecological crises. However, these intentions provide their own complexities about how to approach emancipatory or utopian futures which articulate with interwoven questions around futurity, the more-than-human world, and the historical power dynamics. This final dimension of the political ecological theory of futurity feeds back into how the above questions must be answered, asking:

Q3. How do different ways of conceptualising and materialising the future enable or constrain agricultural transformation in the present?

This final question subtends the discussion to follow in ways that, unfortunately, recognise the constraints, path-dependencies, and power dynamics of the existing food system, rather than in ways that celebrate possibility and the openness of the future. In making these points it addresses both modes of relating to the future in practice which I encountered in my research, and theoretical approaches to the future via which to interpret such encounters. Cross-pollination between these research questions

generates insight and opens space for critique. For example, they come together in instances where the capacity of plants is forecasted into the future in a way which opens up or delimits horizons of agricultural change. This is shown acutely in discussions about how, for example, emergent ways of imagining what plants can do and what can be done to plants creates the possibility of transformative landscape change or when the capacity to control plants via novel agricultural systems that harness vegetal vitality are mediated by anticipations of economic viability. In looking to answer these questions my research took unexpected turns, resulting in the structure which I now set out below.

1.5 Structural Overview

The next chapter, '**Literature Review: Towards a Political Ecology of the Future**', builds on this introduction by establishing the theoretical and conceptual resources mobilised in this thesis. It does this by critically reviewing relevant social scientific literature addressing the future in and of itself, the future of agriculture and approaches to social-ecological and technological change. In doing so, it interrogates questions about scale, vegetal political ecology and historicity which permeate this thesis. As a result, it establishes key foundations of the chapters which follow. Firstly, it sets out how the future shapes the present not only via discourses and imaginaries but also through materialities, histories, institutions, and agricultural practices in the present. This contributes to a rejection of the idea that the future is radically open and ultimately helps build an approach to the relationships between humans and more-than-human life in agricultural systems that rejects both a flat ontology and a strategic acceptance of total human separateness from and domination over the more-than-human world.

Chapter Three, '**Methodology: Between Theory and Practice'**, demonstrates how I looked to operationalise these ideas through my research and how the research process in turn shaped my theoretical approach. In doing so it foregrounds the relationship between theory and method and sets out how I conducted my qualitative empirical field research and why I adopted the approach that I did. In doing so it makes a case for ethnographic research approach being the most appropriate way to both make connections across scales of futurity and interrogate the materiality and historicity of the future in a way that connects discourses and imaginaries with the practical and the embodied.

Chapter Four, '**Phenotypic Intent**', begins to apply these methodological orientations in the context of my empirical research exploring the ongoing deregulation of the release of gene-edited plants in England. It connects an interest with discourses and imaginaries about the future prospect of gene-edited crops for food production with a concern for the history and practices associated with contemporary plant breeding in England. It carries forward the theoretical tenets of this thesis in its exploration of the epistemological questions which resonate from a consideration of the genetic as a site of contested knowledge practices and ontological potentiality. In doing so it also allows for the mobilisation of concepts unpacked in Chapter Two such as intensification, alienation, and anticipation, whilst simultaneously connecting these ideas with the current power balance and institutional landscape of English agricultural production.

Chapter Five, '**A Spectrum of Control'**, presents further empirical data from my research, this time regarding the future of the nascent vertical farming sector in England.

It explores these futures in practice, in terms of the relations with plants and futures these Controlled Environment Agriculture (CEA) facilities create in situ, as well as articulating these horticultural practices with the dynamics of the food system which have incentivised their possibility. In this regard, it looks to historicise vertical farming as an intensification of agricultural control within industrialised capitalist food systems. This is not, however, exclusively an argument against control *per se*, rather I take the extreme example of vertical farming as a limit case for unpacking the dynamics of control and, significantly, care in agricultural systems now and in the future.

Chapter Six, entitled '**Growing Viability'**, explores how the future is understood in discourses and practices of agriculture and horticulture in England. It does so through a critical exploration of the contemporary politics and production of agricultural scale in England. In doing so, it looks to nuance the way scale is mobilised in regard to agricultural futures, rejecting the fetishization of scale as something that can be achieved in a fashion divorced from the political ecological realities of agriculture in practice. To do this I draw on semi-structured interviews with farmers, site visits to farms, participant observation at farming events and my own time working on a commercial horticulture operation in the East of England.

Finally, the final chapter, '**Conclusions: From Alienation to Recalibration?**', reasserts the content of the previous chapters and sets out the consistent arguments and themes which run through them. It then explicitly returns to the research questions established above, answering them each in turn in relation to the empirical materials and theoretical framework set out in the chapters to follow. In doing so it summarises what this thesis

offers to the literature in terms of its empirical grounding and its ambitious theoretical framework. It is to that theoretical framework which I now turn.

2. LITERATURE REVIEW: TOWARDS A POLITICAL ECOLOGY OF THE FUTURE

'A bee puts to shame many an architect in the construction of her cells. But what distinguishes the worst architect from the best of bees is this, that the architect raises his structure in imagination before he erects it in reality.'

(Marx, 1990: 117)

2.1 Introduction: Architects and Bees

The quote above typifies how Karl Marx understood human labour as defined by imagined futures in the present. For Marx, human activity relies on practical futurities in a fashion integral to humanity's 'species-being'. This comparison between human and bee also leads to consideration of our own social-ecological relationships with 'more-than-human' life. Further, Marx's writing was always suffused with a transformative energy and his transhistorical and anthropological theorising was no exception, oriented as it often was with developing a 'scientific' understanding of how societies change through time and how such processes could be understood and steered without recourse to speculation or wishful thinking. A reflexive and conscious architectural futurity was part of that transformative vision. These interwoven reflections on Marx map directly on to the research questions established in this thesis's introduction and will be taken up in turn by this chapter's three sections.

The first section focuses on how different relations with the future are produced through agricultural practices and processes. Here the work of David Harvey and Theodore Schatzki offers an entry point for considering social scientific approaches to futurity and the way technologies co-produce futurities and futures. Examples from agriculture are mobilised throughout. The second section build on this discussion by exploring how 'more-than-human' life influences and is influenced by agricultural processes, temporalities, and futurities. This thesis's specific concern with plants in agriculture is expanded upon and contextualised here, connecting this work with ongoing debates in contemporary political ecological thought about how we should understand the relations of or between humans and/in nature. To do this I introduce work by Jason W. Moore, Andreas Malm, Bram Büscher, Mark Tilzey, and others. This segues into an exploration of relevant social scientific literature concerning human-plant relationships in agricultural processes. The third section addresses this thesis's third research question by asking how differing relations with the future enable or constrain socio-ecological transformation and, by extension, agricultural change. To do this, I assert the importance of adopting a theoretical approach towards the future that takes historicity seriously and resists the urge to invoke an open future or a flat ontology.

This chapter provides the conceptual resources which support the empirical core of this thesis and the arguments generated therein. As the first chapter established, the political ecological approach to 'first-world' agriculture encouraged by Galt (2013) serves as a starting point. Resultantly, this chapter builds on Galt's encouragement to combine new materialist or post-structuralist thought with more historical-materialist approaches. In doing so it integrates work from the environmental humanities, human geography,

sociology, STS, and anthropology. Ultimately, the approach set out below represents a crystallisation of my efforts to think generatively and politically ecologically with and about the future.

In this chapter I argue that shared and individual forms of futurity are co-produced as part of the spatio-temporal fabric of social life, which shapes and is shaped by social-ecological processes such as agriculture. I also stress how relations with the future are not simply imagined trajectories of change but are also embodied, affective and material. These engagements with the future are also co-produced or constrained, to an extent, by relations between humans, the socio-technical configurations these relationships between humans shape, and the more-than-human (in this case vegetal) forms of life which contribute to the historical natures they produce. Accordingly, this results in an understanding of power and futurity which is not reducible to an aggregate of individual agentic motivations or a flat ontology that sees all actors as equally influential agents. Rather, I engage with the future in a way sensitive to the historical structures and immanent forms of power and spatio-temporality which work towards reproducing the present in the future, but never succeed in doing so totally or seamlessly.

To flesh these ideas out further, my work draws on the ideas of Jason W. Moore (2015a) and asserts the inseparability of the social and the ecological within the 'web of life' as manifest in contemporary English agriculture. This leads to an approach that sees agency and spatio-temporality as relationally constituted across diverse lifeforms whilst, significantly, retaining the dialectical acuity to try and distinguish causation (as a

driver of futurity) within the emergent *historical natures* of agricultural landscapes. The work of Mark Tilzey (2017) on the political ecology of agriculture and Bram Büscher (2021; 2022) on alienation and intensification is looked to in order to build a bridge between this historical approach and my empirical work in the historical and geographical circumstances of English agriculture in 2022. It is, however, with the work of David Harvey that these considerations begin.

2.2 Futures in Process and Practice

2.2.1 Moments and Space-Times

The future is social. But if we are to understand the imagination and enactment of the future of agriculture as something produced socially then we must start by asking how, and via what processes, futures are formed. David Harvey's work in *Justice, Nature, and the Geography of Difference* (1996) and *Spaces of Hope* (2000) allows the experience of futurity to be situated within broader processes that unevenly generate and construct spatio-temporalities across society. *Justice, Nature, and the Geography of Difference*, in particular, offers an approach that helps disassemble and re-entangle the mutually political and ecological nature of futurity. In this text, Harvey (1996: 49) sets out a dialectical understanding of social-ecological life which 'emphasizes the understanding of processes, flows, fluxes, and relations over the analysis of elements, things, structures, and organized systems'. Harvey postulates that every social process is characterised by the internal relations between concurrent and irreducible 'moments': discourse/language, beliefs/values/desires, institutions/rituals, material practices,

social relations, and power (Harvey, 1996: 77-95). Translation and relations between these overlapping moments shape social processes and, in turn, 'reifications of free-flowing processes are always occurring to create actual 'permanences' in the social and material world' (Harvey, 1996: 81).

In the context of agriculture, we can understand a singular farm, for example, as one such *relative permanence*[2] within which an amalgamation of political ecological processes operates across and between each of the six moments of social reality. Discourses around good agricultural practice, for example, will always be related to the materialities which they regard, the imaginaries of future superior farming management systems they presuppose, the institutions which mediate their possibility (such as banks), the social relations which determine the private ownership of agricultural landholdings and the various forms of power which flow through each moment and make change towards a discursively valorised mode of growing possible (or not).

Power is, within this scheme, best understood as the meta-moment which signifies capacity to influence the determination of differential outcomes. It is a concept that will be returned to repeatedly in this chapter and thesis. To have power is to shape the future, in a historical sense, in the way interests and logics crystallize as relative permanences. This power does not necessarily have to be vested in a person or even a plant, but can also be immanent to a system, for example, the capitalist mode of production (Mau, 2023). Relatedly, any power over the future is also power to determine how the future can

[2] Please note I prefer the term 'relative permanences' to just 'permanences' given how I feel this better reflects the reality of partial and ongoing social change.

be imagined or discussed, how material configurations permit or foreclose different futures, via, for example, agricultural technology or climate change, and how these processes congeal materially in landscapes or are reproduced by institutions. These foundational considerations of power's ontology have, of course, been long a site of interest for social scientific scholars (Lukes, 2005). Recent work by Soren Mau (2023) offers an overview of approaches to power within and outside of Marxian thought, including the relationship between domination as power, ideology, and consent and, centrally, impersonal forms of power that manifest through social relations as 'mute compulsion'. This last mode, in particular, I have found to be particularly relevant for the empirical chapters to follow.

Power is also vital to considering how 'processes do not operate *in* but *actively construct* space and time' (Harvey, 1996: 53). Harvey asserts the spatio-temporalities of human experience are emergent from both material processes like agriculture and the 'cultural, metaphorical, and intellectual skills' of humans (Harvey, 1996: 210-211). Further, process-derived representations of space and time structure society, for example calendars and clocks which, in turn, regulate and are regulated by biophysical processes of socio-ecological reproduction (Harvey, 1996: 212). The ramifications for the political-ecological temporalities of agriculture are clear here, from just-in-time supply chains to the seasonality of fruit production. Processes are political ecological, processes shape space-times and space-times shape processes.

But this is not a seamless dialectic of the imposition and reproduction of structuring spatio-temporalities. Processes and their reproduction are always subject to

contestation and modulation by people. For example, Harvey observes an 'environmentalist' appreciation of spatio-temporality critical of 'market temporalities' (1996: 229-231) which resonates explicitly, for example, with discourses and movements such as 'Slow Food' (Hendrikx and Lagendijk, 2022). This is an approach Harvey takes further in his consideration of the way an appreciation of spatio-temporality can facilitate a better understanding of the globally distributed material processes that contribute to the ongoing relative permanences within contemporary social formations in the form of, for example, the agri-food chain. As he asserts: 'we need to know how space and time get defined by the quite different material processes which give us our daily sustenance' (Harvey, 1996: 233). We also need to know how those material processes are in turn shaped by socially dynamic relationships with 'the future'.

2.2.2 Towards a Political Ecological Theory of Futurity

Within the array of theoretical approaches mobilised here, the legacy of foundational empirical approaches to political ecology by the likes of Blaikie (1985; Blaikie et al., 1986), Watts (1983) and others (Peet et al., 2011) is particularly important. From this lineage interest in the material consequences of power dynamics, the effects and ideological drivers of environmental knowledge practices and an attention to the role of states and markets is ever present throughout this thesis. These longstanding political ecological foci are also supplemented by an attention to more recent theoretical debates pursuant to the work of John Bellamy Foster (1999) and Paul Burkett (1999) on the ecology of capitalism and capitalism's ecologies (Saito, 2023). Finally, I also include critical geographic work by David Harvey within this rubric, as I am establishing.

As a result of these influences, I understand futurity – lived relations with futures such as differential forms of foreboding or prediction - as a spatio-temporal phenomenon emergent from socio-ecological life. As Harvey (2000: 230) puts it:

> 'Values and goals (what we might call the 'teleological' as the well as the 'utopian' moment of reflexive thought) are not imposed as universal abstractions from outside but arrived at through a living process…'

So, relations with the future are bound up in how we understand, represent, and practically reproduce spatio-temporalities via social reproduction and labour. The way such temporalities or future-orientations circulate are, furthermore, always subject to contestation and reproduction.

This is not to say, however, that human experience and representation is the only source of spatio-temporality and futurity. Subjective experience of time is always infused with the reality of objective time as ontological unfolding in two senses. Firstly, in an ecological sense, in that we share the biosphere with myriad other life forms upon whom we depend on and, as agriculture shows, with whose rhythms and emergence we must contend to reproduce our shared existence. Secondly, in the sense of spatio-temporal unfolding or process in an ontological sense; what Elizabeth Grosz (2005) might understand as '*time as life'* or what Adam and Groves (2007: 96) call the '*future present*' which 'encompasses the future as both an effecting process and/or as living'. This thesis rejects any constructivism which sees the future as only a figment of human imagination and looks to analyse how human experience of this future is mediated across the

moments of social process outlined by Harvey, with institutions and power relations, for example, facilitating the reproduction of certain social phenomena and not others and shaping what we understand to be possible or desirable multi-species futures.

In this regard, as well as being a lived dimension of everyday practice, futures are forecasted and invoked via diverse practices, discourses, imaginaries, and institutions – which represent future-oriented aspects of what Jason W. Moore (2015a: 57) calls 'measures of reality'. For example, Reinhart Koselleck (2004) describes how early modern European conceptions of both 'history' and 'the future' were redefined when dominant epistemologies of religious futures were subsumed by a conception of history as a force driving society into a contingent and novel future. This change had revolutionary socio-political material ramifications. But these are not just *a priori* ideational shifts with material results. Social process is saturated by the internal relations between discursive, institutional, material, social relational and value-oriented fragments.

Further, social relationships with, and understandings of, the future are always themselves relational, simultaneously co-producing experiences of space and time. Futurities manifest as 'present futures' (Adam and Groves, 2007) are, at least then, in part, a question of the spatio-temporality of a given social formation. This notably illustrates itself, for example, in the currently widespread conception of temporality as a linear process in which the future is an empty vessel to be determined in the present, an idea rooted in the materialities and knowledge practices of post-Enlightenment law, science and economics (Adam and Groves, 2007). These are significant knowledge

practices which emerge, as vectors for ‘measures of reality’, in varying configurations throughout this work. Agricultural processes provide us with many examples of such configurations, ranging from long-term climate models to consumer-oriented behavioural economics. That said, this is not a work concerned explicitly with the anticipatory logics which have come to interest geographers and environmental sociologists following the influential work of Ben Anderson (2010).

Harvey’s work helps to think through the question posed in the first chapter regarding the social generation of futurity within agriculture. It fosters recognition of the contested constitution and generation of spatio-temporal future orientations via social processes, practices, and their internally related moments. By way of an example, the vision an arable farmer may have for the future of their farm may well be in tension with the future imaginaries of policymakers, retailers, housebuilders, or futures traders. Each projection also results from the spatio-temporalities generated and juggled by actors within different fields, each of which circulate with contrasting levels of legitimacy and authority, each with their own permutation of how the future should be understood, who shapes it, what is desirable and the capacity they carry for bending the future to their will. These agricultural futurities are also irrevocably intertwined with other horizons of expectation by which the affective life of the farmer is already overdetermined, be that personal health, familial discord, or religious conviction.

Further, these realities are political in their contingency. Farmers will attempt to enact the future they are striving towards through their agricultural practices, be that a future of intensification, agri-environmental stewardship, or abandonment. Agricultural

practices will, in turn, produce their own sense of what the future holds as a result of the relations they create between, for example, soil health, climate change, personal on-farm circumstances, and global commodity markets. Equally, it is important to remember that any such projects envisioned by the farmers or plant breeders will also almost certainly be in tension with the vitality of, for example, the blackgrass emerging across patches of their holding or the accumulation of prions developing in their ruminants.

How plants, people, and their institutions co-produce, reproduce and transform contemporary agricultural landscapes is fundamental to this work. 'Analysis,' for Harvey (1996: 82), 'should confront how such permanences can occur, how fluid internal relations can be converted into social causation'. As such, this approach encourages reflection on what it is that makes the future the same or different and what it is that facilitates continuity or catalyses change. In a slightly different framing, but making a similar point, Moore (2015a: 36) refers to agency 'as the capacity to induce historical change (to produce ruptures), or to reproduce extant historical arrangements (to reproduce equilibrium).' These are massive concepts which, given the methodological basis of this project in empirical field research, require thinking through in terms of how they affect the practices which I conducted, watched people conducting and discussed during my research.

2.2.3 Experiential Futurities in Practice

If social processes, such as agriculture, coproduce space-times and, hence, futurities then the *practices* of which these processes are composed are vital to understanding

how futures and futurities are generated and experienced. Furthermore, tangential to Galt's (2013) criticism set out above, much extant social scientific work concerning the way farmers and food producers currently understand and enact the future is rooted in a humanistic and rationalistic paradigm of agency which neither interrogates explicitly the role of futurity and the inherently 'futural' (Bryant and Knight, 2019) nature of quotidian social life, nor looks to integrate understandings of agency and analysis with theory more attentive to the affective and more-than-human dimension of social life (Darnhofer, 2020). Anthropologists have begun to attend to these futural dimensions in other realms through ethnographic research (Ringel, 2014; Nielsen, 2014; Salazar et al., 2017) as too have practice theory-oriented sociologists (Welch et al., 2020). From a more agriculturally-oriented perspective, rural sociologist Michael Carolan (2020; 2016; 2022) has also attended to these questions in recent research, particularly regarding emergent forms of agricultural technology. However, it is to approaches to practice theory typified by the work of sociologist Theodore Schatzki (2006; 2009; 2010a; 2010b; 2011; 2019) which I turn to to help develop this approach further.

I turn to Schatzki as he explicitly asserts that Harvey underplays and ignores the 'experiential' moments of which broader processual spatio-temporalities are formed (2010b: 82). Schatzki's approach addresses this via two fundamental principles: firstly, that 'the past and future of human time do not come before or after its present; they are, instead, simultaneous with it' (Schatzki, 2010b: 65) and, secondly, that 'the timespace of human activity consists in acting toward ends departing from what motivates at arrays of places and paths anchored at entities' (Schatzki, 2010b: 62). Vital within this is Schatzki's understanding of futurity and teleology as fundamental to all human action.

The social organization of practices generates the teleologies – 'the end-project-action orderings' or 'teleoaffective structures' (Schatzki, 2009: 39) – which in turn co-produce the timespaces of people's lives. For Schatzki, futurity saturates all action and everything that is encompassed within practical activity is 'social' – regardless of humanity or sentience (Schatzki, 2010a).

Schatzki's thinking encourages attention to the embodied, affective individual practices of everyday life on, say, a farm. This disposition is elaborated upon thematically in work by anthropologists Bryant & Knight (2019) who demonstrate the gains that can be sought from ethnographically seeking and unpacking the various interacting 'teleoaffective structures' that permeate everyday life in any context. Bryant and Knight's interest in future-oriented affect and atmospheres, such as hope and expectation, links this work to the affective and non-representational turn in human geography, such as Anderson (2006; 2007; 2016). People are oriented towards the future in ways that are not reducible to discourses and imaginaries, and these embodied, atmospheric, and emotional questions are of interest to this work.

Connected to this recognition, however, are significant questions of methodological scale. Fundamentally, this is not a piece of work rooted solely in analysing micro-level on-farm practice in the spirit of Schatzki's analysis. Although rooted in the timespaces of agricultural production in England, political ecological analysis requires articulation of human-environment practices with contested futurities and the power relations which co-determine them. It is necessary then, before proceeding, to scratch further at the issue of scale. In this vein, Schatzki explicitly criticises Harvey's work in *Justice, Nature*

and the Geography of Difference as constructing a stratified ontology of spatio-temporality in which an objective 'economic space-time' floats above, qualitatively different to, the experiential spacetimes of humans within society (Schatzki, 2010b: 79-87). For Schatzki, there is nothing more to the space-times and timespaces of capitalist social reality than the sum-total network of what is experienced by humans within the total global mesh of practice-material arrangement nexuses. There is no emergent future or teleology beyond the social futures and teleologies of individuals engaged and active within activity timespaces – activity timespace is the unity of objective and subjective spacetime.

Ultimately, Schatzki offers a 'flat ontology' (Schatzki, 2010b: 83). Such a phrase alludes to Schatzki's affinity, although not alignment with, Actor Network Theory, and his pragmatic and open-ended invitation to what is or isn't social and the role of the more-than-human and materiality within social life (Schatzki, 2010a). This is taken up in detail below. As for the criticism of Harvey, this work accepts Schatzki's greater attentiveness to affect, experiential temporalities, and lived practice, endeavouring to treat it as additive to the approach set out above from a methodological perspective. In *Spaces of Hope* (2000) Harvey *does* attempt to attend to the question of the embodied individual, both as a site of accumulation for capital (possibly lending credence to Schatzki's criticism), but also as an integral component to the envisioning and manifestation of alternative futures. I assert that it is possible to accept the teleoaffectivity of social life and practices whilst articulating this interest with a broader critical analysis at different scales beyond that of practice that remains consistent with the work of Harvey and Jason W. Moore (2015a: 41) who, although using similar terminology as Schatzki regarding

‘bundles’ asserts the importance of historicity and causation, yet argues that ‘concrete historical wholes—such as capitalism—cannot be constructed by ‘adding up’ the Social and Environmental parts’.

As such, although this is not a thesis oriented exclusively towards the daily decision-making structures of farmers and the on-farm teleoaffective structures which shape specific situational futurities, it still takes an interest in diverse *presents* via empirical research. Yet whereas Schatzki squares the circle of objective time by both flattening and humanising the present as accessible only via social practice, this work recognizes the present (and future) of agriculture – the distributed event of ongoing crop growth for example – as at once social and historical, whilst simultaneously being a present which exceeds the socio-historical in its multi-species vitality. In this regard the influence of both historical materialism and Critical Realism (Cox, 2013) is apparent here, as exemplified in consideration of these questions in agriculture by Tilzey (2017).

The political ecological approach of this project, then, looks to articulate these facets with the power-structures, social relations, materialities, institutions and discourses which shape them. Although, for Schatzki, these are all encompassed through a practice-oriented analytic, I again see recourse to this approach to the moments of social process derived from Harvey as a useful analytical tool which helps articulate practices with critique and efforts to envision and enact alternative agricultural futures. Following Jessop, Brenner, and Jones (2008) I adopt, in the first instance, a more ‘polymorphic’ approach that recognises the mutually constitutive nature of scales and eschews, at this juncture, a subscription to a flat ontology that prioritises networks of

practices at the expense of all. This choice is also based upon a belief that it is central for these purposes to recognise that some practices warp the spacetimes of others to a greater extent and inflict certain temporalities, spatialities and futurities from without. As a critical political ecological project this analysis is rooted in an interest in the socio-ecological outcomes of these relations. As such, the political economic regulation of agriculture is of notable interest to this project, as too are both particular place-based futurities across my field-sites and more diffuse networks associated with agricultural innovation. Scale is recognised as something that is produced politically ecologically, as well as referring to consideration of extent and methodological focus (Neumann, 2009). These ideas are taken up in further detail in Chapter Six.

In essence, I reject Schatzki's assertion that futures can be understood as equivalent to sum of their aggregate social actors' practices and intentions. This resonates with a Marxian approach (although not certain forms of Analytical Marxism such as that of G.A. Cohen, see Callinicos, 2006). For example, it is encapsulated via Büscher's recent assertion that, although not *real*, the contemporary experience of capitalism's biopolitical intensification is experienced as 'more-than-life' and as an as a 'coercive external force' (Marx, 1976: 381 cited in Büscher, 2021). It is also fundamental to Soren Mau's (2023) recent work on economic power, in which he asserts that there is a logic of mute compulsion immanent to the historical logic of capitalism, exploring the ways in which power is exerted over the future in impersonal ways that are not irreducible to the acts of individuals but emerge from the totality of capitalist social relations.

2.2.4 Teleo-affective Formations, Sociotechnical Imaginaries and Technology

In looking to reconcile tensions between lived futures in practice and social change, Daniel Welch's (2017) concept of 'teleoaffective formations' is useful. This concept refers to 'a configuration across multiple practices, conditioned by a relational nexus of general understandings, that enjoins those practices to common ends' (Welch, 2017: 67). Such an approach is reminiscent of work oriented towards assemblage thinking (Anderson et al., 2012). Indeed, Welch frames such formations as 'practice-discourse assemblages' and Foucauldian *dispositifs* which are variegated across those who reproduce them through practice via a 'nexus of general understandings' (Welch, 2017: 66).

Fundamentally, these formations are understood to undergird teleoaffective structures and 'instantiate an axiology or cosmology which subtends practices' (Welch, 2017: 67). The concept of teleoaffective formations can help unpick how shared understandings about the future of food production come to influence agricultural practices and vice versa. It also allows for a demonstration of the centrality of materiality in not just emergent ontological futures, but also process of making 'present futures' visible, legitimate, and efficacious. Exemplary teleoaffective formations which can currently be pointed to as 'subtending' the agricultural practice of those involved with food production in England range from net-zero targets, to changing horizons of subsidy provision to anticipations of increasing fertilizer costs or worsening water stresses in certain parts of the country.

When discussing existing concepts which represent teleoaffective formations, Welch (2017: 66) references 'sociotechnical imaginaries' as set out by Jasanoff and Kim as 'collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects' (2009: 120; 2015). In embedding future-oriented imaginaries within broader processes of governance, technological development, institutions, and discourses, Jasanoff and Kim develop a frame through which to consider the futurities generated and generative of agricultural practices and their regulation. They recognise, for example, the always multiple and contested nature of future imaginaries and the power dynamics inherent to contestations between the enactment of different envisioned futures (Jasanoff and Kim, 2009: 123). Further, Jasanoff (2015: 31-32) acknowledges how sociotechnical imaginaries articulate with conceptualisations of space, time, continuity, and societal materiality like existing infrastructures.

Although Jasanoff (2015: 22-23) praises the insights of Actor Network Theory as encouraging dissolution of certain ideational boundaries solidified by power relations (such as 'nature-culture'), she also stresses the need for approaches inspired by Actor Network Theory to integrate critical political theory and avoid being 'too promiscuous in attributing cause and agency' (Jasanoff, 2015: 24). In the context of UK agriculture, various sociotechnical imaginaries circulate and achieve varying degrees of materialisation, ranging from 'sustainable intensification' (Committee on Climate Change, 2020) to a 'small farm future' (Smaje, 2020). Agriculture is a perfect site to examine such tensions, particularly given the 'future essentialism' (Schiølin, 2020) of much contemporary discourse around, for example, robotics and automation as part of

the ‘fourth agricultural revolution’, including within academia (Barrett and Rose, 2020). Consideration of these trajectories forms much of the empirical work to follow.

Importantly, discussion of ‘sociotechnical imaginaries’ foregrounds the important role that technologies play in contemporary farming practices and envisioned agricultural trajectories. This also serves as a reminder of the extent to which agricultural technologies shape agricultural practices (and vice versa) and how we should consider the role these technologies play in shaping agricultural futures. STS scholars have long taken interest in the production, circulation and dissolution of hype, anticipation, and expectation regarding envisioned technological futures, whilst simultaneously attending to the materiality of future in the present. Such work is typified by the likes of Borup et al. (2006), and predominantly takes an interest in describing the sociological circulation and contestation of scientific expectations amongst both scientists and the public. Throughout such work, the performativity, recursivity and efficacy of future expectations in ontologically shaping futures is highlighted (cf. Oomen et al., 2021; De Coss-Corzo, 2022), the temporalities of technological innovation and development are scrutinised and, further, the ontological resonance of ‘technology’ as a fundamentally material social process is attended to.

2.2.5 Materiality, Meaning and Counterfoil Research

Richard Tutton (2017) takes this trajectory of STS scholarship even closer to the aims of this project, charting an increasing interest in the materiality of futures, highlighting how there has seen a shift from ‘representational accounts’ of the future, towards more materialist understandings of the future as set out by Adam and Groves (2007). Thought

oriented towards the performativity of representations of the future – in other words a recognition that visions of futures make futures and vice versa – also encompasses theorising around the material 'lock-ins' and path dependencies that technological development can create (Tutton, 2017: 483). The ramifications for this idea for contemporary agriculture in England are diverse. Within agricultural practices we must begin asking not just what technological futures are envisioned for agriculture, but what the qualities and capacities of the technologies themselves (in their nascent or emergent forms) suggest for the future of agriculture as a broader social process. This pertinence is demonstrated by Michael Carolan's (2020) work exploring 'automated agri-food futures' in an American context. Carolan explores the processes 'that make certain (futured) socio-technical dispositifs more real than others' as digital platforms anticipate worlds and 'help make them real' (2020: 200-201). Equally, Sarah Hackfort (2023) explores how digital agricultural practices are institutionalised through corporate lock-ins which foreclose alternative futures.

Significantly, Tutton (2017) asserts that the future must be understood as an 'entanglement of matter and meaning'. This resonates with the recognition that the future, as a form of spatio-temporality, is implicated with the internally related moments of social practice that are not reducible to ideas or imaginaries alone. Yet Tutton's article focuses more on the imaginaries discussed above than the concrete interplay of materiality and discourses and representations in a field such as agriculture. There is work, however, oriented towards agriculture, that has begun to correct this, with a particular eye on visions of technological development (e.g. Jönsson, 2016; 2020; Nimmo, 2021).

As Harvey (2003) reminds us, technology as a facet of material production is only ever co-productive of futures and relative permanences within broader social foundations. Food production in the United Kingdom is saturated by the teleoaffectivity and impacts of technological development, as well as the associated structures or formations which shape and steer this development. Such assertions are integral to the critical approaches to STS that emerge as a vital disciplinary strand of this research's conceptual apparatus. These STS-inspired approaches often are imbued with a futurity and future-orientation too, within which technology is a product of social relations but is also capable of materialising certain aspects of social formations and carrying them into the future. As Moore (2023) puts it 'there is no such thing as a technological accident'. This tenet of this work is also articulated clearly, for example, in Langdon Winner's foundational article *Do Artifacts Have Politics?* (1980). Winner uses the example of tomato harvesting machinery in California as indicative of the kind of social relational and spatio-temporal effects that agricultural technologies can have in directions which are shaped by the power interests which shaped their conditions of possibility.

That socially determined technological change in turn impacts the emergence of social futures is touched upon in Martin Arboleda's recent work advocating for a revitalized Marxian STS. Arboleda argues convincingly for a critical STS that adopts a relational consideration of agency which includes, to an extent, the agency of technological forms, stating that:

> ‘human agency is not to be understood as a bounded and distinct realm of existence, but rather as interwoven with the rest of nature (including nature in industrial-technological form.’ (Arboleda, 2017: 11)

This thesis follows Arboleda in asking questions about the future of agricultural practices and the way emergent technologies will shape food production in the coming years. As Winner (1980, p. 128) asserts, to adopt and develop specific technologies is to ‘choose a particular form of political life’. Similarly, work by and inspired by thinkers like Ivan Illich (2001) regarding the technological appropriateness of specific tools for creating desired futures is also relevant (e.g. Kerschner et al., 2018). A comprehensive critical engagement with the work of Illich is beyond the scope of this chapter, and although this is not a project entirely in the spirit of his ideas, the prompt he offers to undertake ‘counterfoil’ research in *Tools for Conviviality* (2009) is pertinent. Counterfoil research constitutes inquiry which goes against the grain to critically deconstruct predominant trajectories of technological development. This is an increasingly common focus in contemporary research exploring agricultural change in Britain. Recent work by Maye and Ingram (2023), for example, highlights the growing influence of research which explores the emergence of directionality and path-dependencies emergent from digital agriculture’s unfolding futures and growing ubiquity.

Maye and Ingram’s work, however, fails to historicise or contextualise these questions in socio-ecological relations, proliferating only questions rather than generating critical insight. Power relations and their capacity to delineate or destroy relative permanences as part of contemporary capitalist agriculture must be considered. As the quote from

Arboleda above indicates, questions of agency and technology within this rubric is crucial. In considering the production of technological agency as part of the interwoven tapestry of socio-ecological life within contemporary capitalism, Arboleda helps build a bridge to this thesis's next section which looks to complicate these discussions further by considering the role of vegetal life in contemporary agriculture.

2.3 Futures in the Web of Life

2.3.1 Vegetal Political Ecologies

If technological artifacts are implicated with co-producing the future of agriculture in England, then so too are plants. In this vein, this thesis takes an explicit interest in *plantiness* (Head and Atchison, 2016) and the growing scholarly interest in 'vegetal geographies' (Barua, 2023; Lawrence, 2021) and 'vegetal political ecologies' (Argüelles and March, 2021; Fleming, 2017). These approaches, in turn, form part of the 'more-than-human' or 'multi-species' turn in theory-building and empirical research across social sciences in recent decades (e.g. Galvin, 2018; Haraway, 2008; 2016; Lorimer, 2015; Tsing, 2017; Whatmore, 2002).

Theoretical attention to plant life in particular has taken various shapes, as outlined by Lawrence (2021). This includes contributions ranging from the philosophical (Marder, 2013) and psychological (McMullen, 2022) explorations of 'agency', to historical explorations of botanical understandings of plant sexuality (Sandford, 2022), efforts to

revisit Deleuze and Foucault through consideration of plants (Nealon, 2015) and plant-oriented ethnographic explorations of agricultural frontiers (Lapegna, 2016). Social scientists are increasingly thinking plants as distinctively agentic with ramifications for broader understandings of human social forms to the extent that the term 'Plantationocene' (Barua, 2023) has been added to the already significant roster of epochal monikers in circulation (Lorimer, 2017). A desire to approach agency more openly and to, if not politicise ontology (Joronen and Häkli, 2017), then to think ontology politically inflects much of this work, including, to a degree, this thesis.

What I look to do along these lines is examine how vegetal (and related) lifeforms affect the future *and* futurity of agriculture. The questions, then, we must ask are: how can we understand the agency and/or future-orientation of the 'more-than-human' world in the context of English agriculture? What impacts does this have on the futurities of human participants in agriculture? Is the future of contemporary agriculture structured by the human 'domination' of plants? And what different ways of practicing agriculture do these ways of thinking allow us to conceive? First, to begin answering these questions, we can return to Schatzki, whose work introduces a problematic important to this task: should we understand diverse agencies, temporalities, and futurities as a unified totality or as a suite of ongoing entanglements, dialectics, and interactions?

2.3.2 Interactionism and Mediated Action

Schatzki asserts that any material, sentient or otherwise, becomes 'social' once part of any human practical activity (2010a: 133). He juxtaposes this social ontology to two other approaches: firstly, 'interactionism' – which 'treats society (history, human practice) and

materiality (nature, environment) as separate realms, between which interactions and relations exist' (2010a: 133) and, secondly, 'mediated action', which Schatzki equates with Actor Network Theory (2010a: 134; see also Murdoch, 1998). Schatzki suggest that Actor Network Theory's idea that social reality is formed of networks of human and non-human actors affirms his understanding of material involvement in practice-arrangement nexuses. Yet he states that his approach pushes beyond Actor Network Theory by focussing on how practical activity co-constitutes social reality alongside material arrangements (2010a: 135). Such efforts are inspired by an abovementioned flat ontology and similar moves towards a broad concept of 'the social' in agriculture have produced significant and notable interventions from Whatmore (2002) and FitzSimmons and Goodman (1998). Critiques of such approaches, of which I am supportive, have already been noted in this chapter via the work of Jasanoff (2015) and Arboleda (2017).

Schatzki's assessment of 'interactionism' is less favourable, and he consciously resists any terminology pertaining to 'dialectics', 'exchange' or 'interaction' between nature and society for risk of reproducing dualisms and betraying his flat ontology (2010a: 133). By this logic, the implication of social time for the acceleration of crop physiological development is not the domination of human temporalities over more-than-human life but the construction of a novel social timespace in which the practice of plant breeding creates new temporalities within which both humans and plants are a part. Notable past approaches towards human and non-human temporal entanglements, like Barbara Adam's 'timescapes' (1998), would fall, at first glance, into the category of interactionism. As too would much Marxian-inspired more-than-human geography or political ecology which speaks the language of the 'metabolic rift' (Foster, 1999; Saito,

2023), as would the more dialectical approached offered by Harvey (1996) and Moore (2015a).

This is significant given the influence of the work of Harvey and Moore on this thesis. At first glance, there are similarities between the approach taken by Schatzki and Moore. Like Schatzki, Jason W. Moore is insistent on the necessity to avoid slipping into dualisms, which he argues serve only to reproduce the Cartesian separationism inherent to the worldview of the capitalist 'project'. And further, like Schatzki, Moore sees capitalist *process* (as opposed to the capitalist *project*) as defined by 'bundles' (2015a: 7) of humans and other forms of life in diverse ecological permutations flowing through and around each other over time. Society, for Moore, is always already permeated by the 'double internality' of humans in the web-of-life or *oikeios*, which is 'a way of naming the creative, historical, and dialectical relation between, and also always within, human and extra-human natures' (2015a: 35). For Moore, adopting this position allows us to see that 'nature's status undergoes a radical shift: a transition from nature as resource to nature as matrix' (2015a: 88). Like Schatzki, Moore opposes his approach to the interactionism he sees emergent in the work of metabolic rift theorists like John Bellamy Foster (1999) and Paul Burkett (1999), as well as across the broader social and natural sciences that reproduce the 'green arithmetic' that the world can be understood as various combinations of Nature *and* Society.

Yet Moore's approach differs from Schatzki's. Moore explicitly rejects invocations of a *flat* ontology in which the future is mutually made in an aggregated sense, suggesting such an approach is sought in order 'evade the thorny issue of historical facts altogether'

(2015a: 75). Moore is, at root, a historian and, as such, attributions of causality are fundamental aspects of his work. Within this, the historical transformations associated with the rise of the capitalist mode of production and the impact it has had on ecologies worldwide over the last six centuries are central objects of critical analysis. Although Moore recognises the 'species-specificity of humans' he asserts that human social life 'is co-produced within the web of life because everything that humans do is a flow of flows, in which the rest of nature is always moving through us' (2015a: 7). Accordingly, he remains attentive to the agency of diverse forms of life as co-producing 'historical natures' as part of capitalist ecologies. He does not, however, use this as a veil for a flat ontology, pointing out the extent to which historical changes associated with the capitalist mode of production have resulted in violent and oppressive historical transformations within nature.

To reconcile historical causality and diverse conceptions of agency in a way that allows us to think about futures and futurities of capitalist agriculture, Moore advocates a dialectical approach. For example, in consideration of the historical role of the capitalist value form, Moore encourages that it be understood as a 'gravitational field' across history, co-producing socio-ecological outcomes via 'a dialectic of exploitation and appropriation that illuminates capitalism's peculiar relation with, and within, nature' (2015a: 16). For Moore, contra Schatzki's dismissal, 'dialectics is about more than interaction' (2015a: 47), it is about the tensions within and the emergence and transformation of totalities, including the *oikeios*. This interest in historicity and the confidence to point to human social forms as historically co-productive of ecological outcomes is apparent in Moore's extensive work on agricultural history (2010a; 2010b;

2015b). Moore (2015a) argues that current agricultural processes are representative of the drive of capitalist modernity to replace use-value with exchange value, a process which has become reliant on producing 'cheap nature' and the need to produce 'cheap food' to suppress wages and facilitate the extraction of surplus value from labour. Resultant from this historical trajectory's reliance is a moment at which the 'end of the road' (2010b) of capitalist agriculture is in sight. Such anticipations recall James O'Connor's (1991) conceptualisation of the 'second contradiction' of capitalism regarding the capitalist mode of production's degradation of its own ecological sources of profitability.

Moore's approach offers the beginnings of a bridge between nature-society dualisms and ahistorical flat ontologies capable of critical insight. As such his work reoccurs throughout this thesis. However, alone it is not sufficient. Firstly, it requires consideration alongside the abovementioned theoretical contributions of Harvey. Secondly, it involves introducing and juxtaposing the work of Tilzey (2017) and Büscher (2021; 2022). This first issue is taken up immediately, whereas the latter is returned to below.

Firstly, then, can this approach be taken forward in a way that is consistent with the ideas already derived from Harvey's work? I argue this is possible. In *Spaces of Hope* (2000), Harvey also mobilises the metaphor of the 'web of life' later utilised by Moore, writing also of the need for dialectical methods in order to 'understand the multiple intersecting material processes that so tightly imprison us in the fine-spun web of contemporary socio-ecological life' (2000: 199). Further, Harvey (1996: 194) shares Moore's critique

(2015a: 5) of approaches which highlight the centrality of the metabolic rift inherent to capitalist socio-ecology, arguing such perspectives tends towards fatalism and catastrophism. Harvey, unsurprisingly, also looks to Marx to root these arguments, stating: 'there is, as Marx insisted, nothing 'unnatural' about the historical geography of human development' (2000: 230). Harvey (1996) also asserts the inseparability of the materiality of the biophysical world from space-time and its experience by people. Moore (2015a) also engages with territory familiar to Harvey's work and engaged with above, asserting, for example, the importance and internal relationality of ideas, discourses, and knowledge practices within historical natures' development under capitalism, including the way in which these processes create space-times integral to capitalism within specific social processes of, for example, knowledge production or institutional regulation. I argue that such knowledge practices produce space-times imbued with diverse futurities as part of these processes.

So, where then does this leave the efforts to develop a political ecological approach to futurity in the context of UK agriculture? In recognising some utility in Schatzki's work but moving towards the approach endorsed by Moore we arrive at a perspective that asserts that to separate nature and society is not a tenable ontological position for political ecological analysis in the 21st century. Instead, via Moore's work, I argue that the emergence of futures and the generation of futurity is always already formed of both human and other elements of the web-of-life.

However, I also recognise the necessity of a critical, dialectical, and historical approach that rejects the vicissitudes of a flat ontology and does not shy away from efforts at

situated historical distinction, differentiation, and the attribution of causality. Futures in contemporary agriculture are made by both people, plants and the abiotic materials which come together in the various fossil-fuel animated configurations we understand as 'technology' and '(industrial) farming'. This helps us begin to unravel the idea of future-making as a multi-species process which also results in the *historical* formation of relative permanences. But, as in the first section, we encounter the question of scale. Moore is operating at a world-historical scale, whereas I attempt to make connections across contemporaneous processes whilst still looking for historicity and forms of structured contingency in the longue durée. Therefore, further consideration is required to gel Moore's work with the specific angle upon which this research focuses and the agricultural practices that includes. This need is enhanced by the reality that critics like Tilzey (2017) suggest Moore, in fact, reproduces a flat ontology within his work via collapsing the social aspect of the ecological into the ongoing dynamics of the web-of-life. How, then, should we theoretically approach the idea of plant and human futurity co-producing agriculture in situ in England in the 21st century? To answer this question, we must turn more specifically to the question of plants, agriculture, agency and further explore a selection of relevant work from adjacent disciplines.

2.3.3 Planting Power

The concepts of agency and power, vital to recent considerations within the vegetal turn and more-than-human geographies more broadly, allow us to link history, futurity, and practice in this work. Thinking with agency allows for consideration of more-than-human futurity as intentionality or teleo-affective action *in situ* given how agriculture produces diverse socio-ecological futures within which various forms of life are either implicated

and activated or suppressed and eliminated. Power relations between people and between species affect these dynamics. I am, however, not capable of offering any novel insight into plant agency as understood as plant psychology or the nature of plant intentionality. Instead, I am keen to ask how we should understand different plants' roles in shaping present and future agricultural practices from a political ecological perspective.

Central to this task is a relational approach to agency, as Moore (2015a: 36) advocates, agency:

> 'is not a property of Nature and (or) Society — not even of humanity's spectacular forms of sociality. Agency is, rather, an emergent property of definite configurations of human activity with the rest of life. And vice versa.'

Moore's temporal horizon is oriented towards the longue durée. How to think this idea in practical quotidian agricultural activity and its futural resonances requires further scrutiny. Post-structuralist and/or more-than-human scholars have already advocated approaches to agency which are relational yet offer different perspectives of what that means. Consider, for example, Barbara Adam and Chris Groves's book *Future Matters: Action, Knowledge, Ethics* (2007), in which they draw extensively on the work of Hans Jonas and Deleuze and Guattari. Adam and Groves explore *lived futures* across species. Lived futures are defined by the attribution of salience and associated forms of intentionality in which:

> ‘the future of an organism, from its own ‘point of view’, is therefore neither an empty future nor the abstract future of natural science … It is an implicit structure which ‘pulls’ the organism towards it, shaping its actions and progressively unfurling its potential along the way as it strives to realise itself.’ (Adam and Groves, 2007: 130).

This is a supposition extended to all organic sentient life: embodied existence in the present cannot be separated from its imbrication with latent and potential futures. The resonance of such approaches with emergent ideas from neuroscience concerning ‘the free energy principle’ are notable (Calvo and Friston, 2017), as too are connections with Schatzkian thought.

Adam and Groves take this more atomistic conception of competitive agency (cf. Brice, 2014) further towards relationality by introducing work by Deleuze to develop the idea of systemically entangled *living futures*. Futures, we are reminded, should not be considered as post-hoc evidence of diverse sites of rational intentionality. Instead, we must acknowledge the *living future* as a relational phenomenon which is always more than the sum of its parts. Organisms extend themselves into the future to ‘govern’ their actualised forms and, in doing so, become embroiled in a web of potential futures in tension with the capacities of the organism and the systemic relations, networks and assemblages within which anything invariably exists. Radically diverse futurities permeate the ontological status of all organisms and ‘this virtual aspect of things, both tamed and untamed, is no less real than their actual structure: it surrounds them like a halo’ (Adam and Groves, 2007: 135).

Elizabeth Grosz (2005; 2011) works in a similar vein, also drawing extensively on Deleuze and Guattari, as well as Darwin. Her work also stresses the way that such ontologies foster alter-temporalities ripe with potential for the catalysing alternative social forms. This takes us, also, away from Schatzki's pragmatic assertions around causality and prefiguration to an understanding of the agency and the future shaped by the fizzing potential of latent virtuality. 'The future,' reads Grosz (2005: 110), 'is not contained in (and thus pre-empted by) the present but erupts unexpectedly away from it'. Building on this idea, Loewen Walker (2014) takes the Deleuzian conception of the 'living present' as allowing for a feminist, new materialist reconception of relational spatio-temporality reframed in terms of radical potential and possibility (cf. Gray, 2022).

These are provocative ontological considerations. Within these perspectives relational agency is understood broadly as unfolding, unpredictable ontological immanence saturated by potential and the capacity for the generation of difference within an ontological totality. Engagement with these directions speaks to Galt's (2013) call to work with rather than against post-structuralist thought. Further, these ideas are affectively appealing at a time when it so easy to see only further harm in the future of socio-ecological relations within capitalism's ecology. Yet to what extent are these ontologies manifest in observed social-ecological life in English agriculture? Or are they simply transhistorical or ahistorical examples of idealism? If so, to what extent are they compatible with an approach that draws extensively on a more Marxian political ecological base? I would argue that although thought provoking, they are are not sufficient for my task of devising a political ecological approach to futurity. To make this case, it is necessary to further examine plant and agriculture-oriented empirical

literature working with these concepts. In order to do this, I consider three interwoven conceptual double-helixes: labour and value, time and futurity, and care and control.

2.3.4 Labour, Value, and Time

Labour offers a starting point for critical consideration of relational agency in agricultural vegetal geographies. Much work has been done in this sphere regarding the labour of animals (Barua, 2016; Beldo, 2017). Increasingly such approaches are being applied to considerations of the relationships between humans and plants (Ernwein et al., 2021). For Barua (2016), the lens of more-than-human labour – and the reconceptualization of agricultural processes and agency it requires – offers an approach that bridges the gap between more-than-human geographies and political ecologies.

This move, however, requires several conceptual clarifications to underline that it does not involve simply equating human and non-human labour. Intrinsic to this is a deconstruction of production (including agriculture) as a foreseen, rationalistic, and humanist endeavour. Drawing on the work of Hallam and Ingold (2014), Barua engages directly with the quote from Marx at the very beginning of this chapter, stating: 'intentionality and functionality are immanent in the labour process as opposed to an imposition of prior design upon an external nature' and, subsequently, 'production is akin to a process of growth' (2019: 653). Elsewhere, Barua borrows Ingold's (2000) conception of tasks and taskscapes to rethink production such as agriculture as rhythmic and processual, within which 'both [humans and more-than-human life] submit to a productive dynamic immanent to the world' (Barua, 2016: 729). This rhythmicity is, for Barua, a result of more-than-human participation in labour, the

biophysical temporalities of which ensure that empty, capitalist *Time* is never truly totally hegemonic (cf. discussion below regarding Kolinjivadi et al., 2020).

Bram Büscher (2021), however, argues that Barua's perspective is indicative of a flight into ahistorical immanence. This is significant given my desire to delineate historical logics and differential forms of agency across time and how they shape agricultural futures. Yet, I would argue that Barua succeeds in departing from this weakness in his more recent work on the vegetal and the Plantationocene (2023). Through considerations of various political ecological trajectories in Northern India, he offers an example of how to attend to complex, relational agencies through research which attends to and valorises plant-life without falling back into an ahistoricism, contrary to Büscher's criticism of his work. In this regard Barua explicitly references the influence of Jason W. Moore. Of particular interest is Barua's discussions of vegetal economies in the Plantationocene as tending towards intensified simplification. These concepts re-emerge throughout this thesis and are echoed below regarding the discussion of care and control. Vegetal temporalities are also significant for Barua, who connects the temporalities of tea growth with the politics of land in which colonial legacies remain significant.

Jeremy Brice's writings (2014; 2021) draw similarly on the concepts of time, agency, labour, and value in ethnographic work informed by a different vegetal empirical context: Australian viticulture. Brice (2014) maps out his understanding of relational vegetal agency in an agricultural context. He rejects the idea that plant agency can be considered exclusively in terms of agentic capacities towards achieving delineated objectives,

dismissing such perspectives as anthropocentric. Rather, plant agency must be considered as heteronomous and relational given how plants are 'inextricably 'rooted' in, and engaged in constant material interchange with, the soil and atmosphere from which they grow' (2014: 945) (cf. Hustak and Myers, 2012). This echoes earlier consideration of Adam and Groves' (2007) move from *lived* to *lively* futures. Brice looks to situate these ontological claims within analysis of human-plant relationships as manifest in viticultural practice and the resonant and interpenetrating capacities for affect generated therein, giving particular attention to embodied knowledge and time reckoning within these processes. In this regard, Brice takes a lead from 'relational materialist' approaches, as described by Anderson and Harrison (2010), as well as looking again to Ingold's work (2000).

In later work, however, Brice turns to more historical-materialist conceptual resources to consider value (2021), offering a reading of Marxist value theory which can include vegetal life as co-productive of the temporal reckonings and rhythms via which capitalist value is measured. Brice's move towards Marxian concepts of value and time as socio-historically specific modalities of human-plant relationships in Australian viticulture offers the critical historicity this project seeks.

Kolinjivadi et al. (2020) offer further connections between relational agency and time and temporality from a political ecological perspective. Significantly, they contrast the linear 'capital T' *Time* of capital accumulation with 'lower-case t' *time*, characterised by biophysical rhythms of emergence and becoming. In analysing the 'alter-temporalities' of the production of landrace *tinawon* rice by Ifugao people in the Philippines the authors

demonstrate how, through efforts to desynchronize agriculture from *Time* and move towards an open-ended *time*, it becomes possible to 'delink the capital-centric logic of *Time* from possibilities and potentialities of the future' (Kolinjivadi et al., 2020: 16). Through the collaborative, multi-species process of *tinawon* cultivation the alienating temporality of *Time* and its empty future is desynchronised, creating a counter-hegemonic timescape through interwoven agencies and affordances.

Agriculture and plantiness help co-create new temporalities, and by extension new futurities and futures. As they point out, however, novel, emergent temporalities and socionatures are routinely mediated, commodified, and resynchronised with processes unfolding in *Time*. This is underwritten by the manner in which capitalist hegemonic common-sense constructs and legitimises *Time* as *time* itself (Kolinjivadi et al., 2020: 8). An important touchstone here is James Scott's influential considerations of different plants' physical qualities as affording different types of agriculture (Scott, 2017) – cereal grains being exemplary of the capacity for state domination as of their phenotypical properties facilitating storage and tubers affording 'escape' agriculture given their resilience and subterranean development (Nally and Kearns, 2020). In this direction, Fleming (2017) and Matthan (2022) reference Scott's work too, concerning walnut trees in Kyrgyzstan and onions in India respectively. What these examples show is how taking plantiness and vegetal materialities seriously is possible without recourse to a flat ontology. Rather, these scholars retain an attention to extractive and/or colonial capitalist human social forms, resistance to such forms *and* the historical role of plants within these dynamics.

Leila Rezvani (2021) also attends to questions of temporality, with a more explicit focus on futurity. Following fieldwork with Breton horticulturalists, she compares the relationships of attention, care and 'response-ability' (Haraway, 2008) of farmers involved with the sharing and development of heritage seeds with those who use industrial seed hybrids incapable of reproducing. Invoking the work of Grosz (2011), Rezvani casts the processes of working with hybrid F1 seeds as exemplifying a form of 'robotic' futurity, in comparison to the convivial, communicative emergence inherent to working with peasant seeds. This is a conviviality which encompasses both plants' developmental relationships with humans, but also between emergent plant life and the ecologies in which they are situated, a relationship which is itself inherent to future seeds produced by such plants. This creates a different agroecological timescape, productive of a different relationship with the future, characterised by a greater openness to change, but also predicated on greater uncertainty and risk mediated by the skills of the cultivators able to read and react to the seed's development into a future plant.

For Rezvani, this construction of alter-temporalities is an act of 'interspecies resistance', within which plants are crucial actors who emerge and become into an ecological future that is preserved in the form of a past-future within the germ of seeds. And, although Rezvani draws on Grosz's ideas of immanence and temporality, she is careful to situate them in a specific and shifting historico-geographical context and attend to the subjectivities and lifeways of Breton growers. Rezvani's idea of robotic futurity echoes a long philosophical lineage of thinking plants as machines unpacked by Gerber and Hiernaux (2022). The practical ramifications of this ontological understanding emerge in each empirical chapter.

2.3.5 Care and Control

Further, the juxtaposition of 'counter-hegemonic' or 'alternative' ways of producing food with industrial agriculture offered by Rezvani links to the increasingly commonplace focus on types of *care* in agriculture, as well as its corollary *control*. Much work in this regard concerning vegetal political ecology has tended to focus on forms of domestic gardening (Ginn, 2014) or urban food production (Elton, 2021), although Cusworth (2023) has made some tentative steps here in connecting such considerations with more productivist forms of agriculture in the Global North.

The work of Puig de la Bellacasa is particularly influential here, whose approach in an article (2015) and subsequent monograph (2017), sets out how 'focusing on experiences of soil care as an involvement with the temporal rhythms of more than human worlds troubles the anthropocentric traction of predominant timescales' (2015: 695). Parallel to Kolinjivadi et al.'s work, Puig de la Bellacasa asserts how attentiveness to the polyphonic temporalities of living soil, as affectively manifested by certain farmers and through certain agricultural practices, can facilitate an alternative to the 'technoscientific futurity' which she sees as underlying the exhaustion and erosion of global soils. This alternative is 'care time' – in which the future is recast as a multi-species fora of reciprocal care relationships (Puig de la Bellacasa, 2015).

Care is important throughout this thesis, given the attention it has received in recent scholarship and the resonances it created with my empirical materials. To care for something is to be imbued with an affective and embodied relationship with a shared future. From a 'futural' perspective, an ethic of care I read as inculcating a desire to

create an accommodating a future as possible for its object. Complexity arises, of course, from what is considered 'accommodating'. Care is a practice-oriented, dynamic, and relational analytic, and it appears throughout this work in various forms, including critical attention that highlights the danger of its deployment as an ahistorical normatively beneficent affective currency (Johns-Putra, 2013). Such thinking valorises care beyond the circumstances that allow for its modulation and generation. Care is engaged with in empirical work that explores the ambiguous nature of care in plant-based agriculture by Jamie Wang (2021) in the context of Singaporean urban agriculture and by Sophie Chao (2018), who considers palm oil plantations in Malaysia as unlikely sites of intense care ethics for vegetal life.

Such recognition of the ambiguity of care connects in this thesis with a a parallel interest in *control* over both human and more-than-human lives in agricultural systems. Such control is linked significantly to the simplification of agricultural ecologies inherent to the Plantationocene, as highlighted by Barua (2023). To simplify as a means of control is to mediate risk and tame the future, given the proclivities and uncertainties of ecological lives and intentions in agricultural systems which exceed human control. Julie Guthman's (2019) recent monograph on strawberry production in California captures this tension. Guthman, who adopts a method of assemblage thinking but it is relatively conservative in attributing vegetal agency, offers a blueprint for historically sensitive political ecological work on vegetal capitalist economies, despite not going as far as Moore in asserting non-human vitality.

Consideration of control over other species in agriculture necessitates explicit critical theoretical consideration of power and domination within these systems. In *Mute Compulsion*, Soren Mau (2023) considers the ways in which capitalist agricultural change in the 20th century represents the real subsumption of nature, insofar as nature, or vegetal agricultural life to be more specific, comes to be produced in a way that is shaped by the logic of capital via, for example, agricultural biotechnology (see Chapter Four) or changing labour relations. This came despite the previous difficulties to move from the formal subsumption of agriculture, wherein agricultural produce was incorporated into capitalist value chains, but farming changed little, to the real subsumption of agricultural processes themselves. Mau asserts this was as a result of the recaltricant nature of agriculture's ecological basis in vegetal ecologies. This dynamic of real subsumption has significant ramifications for the future of agriculture, given how the very fabric of food production has come to be imbricated and shaped by capitalist dynamics and the impersonal and immanent power of capitalist development. Mau draws on the ontologically-oriented work of Andreas Malm in *The Progress of this Storm* (2018) to support his argument. Malm understands certain humans within capitalist life as having come to dominate non-human life in qualitatively different ways than ever before as a result of the historical logic of the value form.

Connections can be made here to relevant work which applies thought derived from the work of the Frankfurt School to human-environment relations in the social sciences. This is typified most concisely by Gunderson (2015; 2016). From this perspective, human domination over nature, for example via agriculture, has shifted qualitatively in the modern era in terms of its intensity and rationale. This ratcheting up of control over

nature is also intrinsically linked to the ways within which humans seek to control each other via the social relations associated with capitalist modernity. Both are shaped by a logic of instrumentalisation, commodification and disenchantment. Changing agricultural practices can be understood to be 'guided by instrumental rationality: meeting an arbitrary goal (usually profit-maximization) through the most suitable (efficient) means available' (Gunderson, 2015: 228). Importantly, however, this thought does not drift exclusively into idealism, and, as I argue as regards forms of temporality and futurity, the 'Frankfurt School claimed understandings of nature are derived from praxis' (Gunderson, 2015: 226).

Nevertheless, this thesis looks to complicate such perspectives. Firstly, following Gunderson by acknowledging the ways in which this approach simplifies and possibly romanticizes pre-capitalist social-ecological relations. As Duncan (1996) shows in the case of imperial Rome and agricultural degradation across the Mediterranean basin, controlling and extractive agricultural forms long predate the emergence of capitalism. Secondly, throughout this thesis I draw into a question the ways in which a future-oriented logic of instrumentalisation and profit maximisation can be read as the *exclusive* driver of the outlooks and intentions of the people with whom I conducted research. This is a necessary consideration at a time when, discourses, if not necessarily sensibilities, oriented towards sustainability permeate society to an unprecedented degree, driving green capitalist (e.g. Friedmann, 2005) and eco-modernist imaginaries (Symons, 2018).

Furthermore, Gunderson (2016) also acknowledges the extent to which the ecological sciences had minimal impact on how the Frankfurt School theorised social-ecological relationships. Given my desire to adopt a political ecological I look to remedy this. The work of Richard Levins and Richard Lewontin in *The Dialectical Biologist* (1985) allows for this in a fashion consistent with my approach. For Levins and Lewontin all organisms must be understood as both subject and object in their environment – both attempting to control and inevitably being controlled by their ecologies, resulting in ecological contestation and flux and natural history. Following Harvey (1996), this dialectical approach creates possibilities for the study not just of ecological, but also of social-ecological life. In acknowledging this reality, I try to attend to how plants also exercise environment-making influence over agricultural systems. Yet, as I set out below, I try to do so in a way that retains attentive to historical specificity and the capacities and logics generated by capitalist modernity's influence over agriculture.

The above examples demonstrate how attention to labour, value, time, care, and control help to unpick and unpack relational multi-species agencies in agricultural settings whilst retaining critical attention to historical specificities and the role of institutional and/or practical social forms within socio-ecological configurations such as agriculture. Fundamentally, what I am trying to show is that plants and humans shape agricultural ecologies together, alongside myriad other species. Plants are put to work in agricultural systems in ways that shape but are also shaped by those systems. They are also bred and engineered prior to entering those systems in ways which shape their futures. These relations between plants and humans, however, take on historically specific forms and are not best understood through lens of immanence and becoming. For example,

contemporary agriculture in England is shaped by centuries of efforts towards the real subsumption of agriculture into the rhythms of capitalist accumulation. Yet this, I argue, will never reduce plants and their impact on the future to the status of objects. And this reality will manifest itself in multi-species agricultural temporalities and the practices of care and control oriented towards steering them towards human objectives. I attempt to demonstrate these dynamics in diverse empirical circumstances in the chapters to follow.

To conclude this chapter, however, it is necessary to mobilise the theoretical development up to this point towards how to best think the future within normative critical social science research, the focus of the third research question established in this thesis's introduction. In doing so, the perspective derived from Moore's work above is revisited and finessed.

2.4 Political Possibility and Historical Contingency

2.4.1 From Immanence to Alienation

The previous section highlighted ways vegetal life co-produces agricultural futures, whilst recognising how differentiation, distinction, historicization, and critical evaluation are necessary to this work. This final section carries these ideas forward in order to consider how best to critically understand, analyse, and reproduce futurities which best act as both a theoretical lens for understanding social life and a catalyst for different

agricultural practice and a transformed social-ecological politics. It foreshadows ways of understanding the future encountered in my empirical material, but mostly focuses on the theoretical and scholarly approaches to the future via which I interrogate that data. I start by returning to the work of Bram Büscher discussed above.

In Büscher's (2021; 2022) articles on what he calls the non-human turn he does not dismiss non-human agency out of hand, rather he warns against the tendency to reduce more-than-human theory to the naming of transhistorical relational and/or ontological immanence and agency. This move, it is demonstrated, risks a descent into an ahistoricism which overstates the contingency of social-ecological manifestations of something like agricultural. Doing so risks idealistic analysis of contemporary political ecological problems which make normative arguments and critique difficult. Büscher suggests such analyses are ahistorical in that they veer towards a 'selectivity' which abrogates work from unpicking the historical, social determinants which created such conditions for different multi-species relations in the first place, focusing rather on the shared biological lens of mutually constituted productive immanence. For Büscher this is linked to a tendency, very relevant to the subject of this chapter, to convey extant socio-ecological relations as fundamentally contingent. Finally, the recourse to ontology can lead to an idealist dead end in which striving to decentre the human 'should accompany, not displace or downplay, the distinctly human burden to bear the cumulative historical weight of the violence and pressures of capitalist entanglements and to self-consciously organise to challenge and unmake these' (Büscher, 2021: 13).

But what does this mean for efforts to develop a fruitful political ecological understanding of the future? Fundamentally, it offers a way of thinking about the past, present and future that can lead to practical assertions about how things are now and how they should rather be in the future. An emphasis on historicity enforces the need to analyse and assess how different social processes and teleoaffective formations reproduce, reinforce, and modulate different spatio-temporalities within socio-ecological relations, as well as their results. As Büscher reminds us, a focus on ontological immanence does not disappear the extant effects of dualist thinking within, for example, agriculture. Recall Rezvani's (2021) analysis of 'robotic futurity'. Discounting this outlook as deviant to a *true* ontology of shared productive immanence and considering that the end of the matter is insufficient. Equally, approaches valorising care without sufficient consideration of the circumstances that facilitate or modulate what care is and how care-full environments can be created risks lacking material salience, as suggested by Johns-Putra (2013). It does not allow for the deconstruction of the social processes which form temporalities and futurities which modulate socio-ecological relations – for better or worse.

For Büscher (2021; 2022), this ahistoricism can be offset by a dialectical attention to both the 'basic' and 'surplus' alienation of humans from nature via social productive forms. These are concepts borrowed from Biro (2005), who defines 'basic' alienation as the initial biophysical permutations which saw humans develop distinct forms of political economy and sociality and 'surplus' alienation as the historical reproduction and variegation of human-environment relations as modulating the extent to which such forms are predicated upon 'domination' of the non-human world (Büscher, 2021: 8). This

is a fundamental acknowledgement that within the entanglements of socio-ecological relations, such as in agriculture, we must recognise the distinct facets which give human social formations observable and irrefutable biopolitical control over the more-than-human world (with significant ecological consequences). Büscher does not himself define alienation concisely, allowing the term some give. I, too, will not define it here rigidly, but let it emerge in ways that are not always straightforward during my empirical chapters.

Büscher draws on work by Malm (2019) and Soper (1995) to underline his position that without a recognition of basic alienation it becomes difficult to analyse the processes of *intensification* produced and aggravated by recent centuries of capitalist development. Büscher's influences, however, are at odds with the world-ecological approach encouraged by Moore, as evidenced by Malm's embrace of 'analytical dualism' and explicit criticism of Moore (2019). Büscher's work brackets consideration of Moore (2021: 71), but others, notably Tilzey (2017) and Saito (2023), have argued that Moore's own approach is representative of such ahistorical or idealist work. I would argue, however, that Moore, alongside David Harvey, offers the foundational structure upon which this thesis is based. Nevertheless, Moore's approach requires the addition of Büscher's perspective and the attention to alienation that follows in order to help analyse the contemporary moment of English agriculture as I encountered it during my empirical research. Arguably, naming the historical logic of alienation, both basic and surplus, brings this works position closer to critics of Moore, such as the stratified social ontology which underpins Tilzey's (2017) analysis of the political ecology of the contemporary food system.

Tilzey's approach, which has roots in Critical Realism (Bhaskar, 1989; 1993) and the political ecological work of Bellamy Foster (1999) and Burkett (1999), rejects Moore's work as overlooking the significance of what he calls the 'authoritative' domain of 'non-hybrid … structural causality' (2017: 28). This differs from and exceeds the transhistorical use value of, say, food or water and the 'allocative' political ecological dynamics of securing and distributing sufficient food and water in various, historico-geographically contingent ways that facilitate social reproduction.

For Tilzey, the authoritative realm is saturated with cultural or semiotic logics which feed back into the allocative realm but are not reducible to it. The capitalist drive for exponential growth in the generation of surplus value can be understood as part of this 'level'. Arguably, this resonates with the idea of 'surplus alienation', discussed above. However, the moment of stratification and the assertion of non-hybridity is, for me, a scission at odds with the work of Harvey in *Justice, Nature, and the Geography of Difference* (1996) discussed at the beginning of this chapter wherein social reality is best understood dialectically as overdetermined by simultaneous moments in such a way that the semiotic or discursive moment can never be divorced from the material. This, as set out above, serves to buttress the way Moore's double-internality and the always already entangled nature of the human and the ecological in agricultural systems re-emerges throughout this piece of research.

Nevertheless, I agree with Tilzey that an attention to the historical specificity of capitalist social relations is necessary. The addition of Büscher's perspectives facilitates this and, while it moves the approach adopted away from a straightforward re-assertion of

Moore's world-ecological thought, it does not move it towards a strict stratified delineation of any 'non-hybrid' social ontological level either, as found in Tilzey's work. I believe my approach allows for consideration of changing historical relationships between humans and plants which recognises the intensification of such dynamics as facilitated by capitalist agriculture, yet still recognises the role of the vegetal (and other more-than-human dynamics) within that determination.

Fundamentally, Büscher offers a counterpoint to the contingency of new materialism and the necessity of such outcomes in historical materialism: 'histories of the probable' (2021: 10). This idea, that the 'deep historical weight' (Büscher, 2021: 10) of institutions, discourses, and structures, does not render the future either determined or entirely open, but, instead, somewhere between harks back to the idea of the entrenched but contested relative permanences postulated by Harvey (1996). Its utility in considering the future can be demonstrated in an agricultural milieu by juxtaposition with the work of Michael Carolan (2016, 2022), whose examination of hydroponic agriculture in Colorado and vertical farming investment during and after the COVID-19 pandemic are useful foils for discussion regularly returned to during this thesis.

2.4.2 Opening and Structuring the Future

Carolan (2016), like Adam and Groves (2007), draws on Deleuzian ideas of the 'virtual' and 'actual' to assert that the present is rich with possibility and potentiality. In doing so, he argues that any approach towards the future must acknowledge the capacity for change in the present catalysed by heightened attention to the more-than-representational experiences of affect, emotion and embodied social practice. As

Carolan (2016: 146) puts it: 'we cannot expect much novelty to be generated from talk'. Engaging with the emotional, affective, and practiced present can illuminate the 'margin for maneuverability' (Massumi cited in Carolan, 2016) within the 'thick present' in ways discourse alone cannot. This is valid and in keeping with an interest in the teleoaffectivity of practices and processes. As a modality of futurity, this serves as both a theoretical vantage point and as a principle applicable to everyday practice. For Carolan, this recognition also necessitates a refutation of the linear futurity of modernist planning, which sees policymaking as a series of levers to create different futures, and the teleological conceptions of rational agency that characterises much social science. Instead, we must use this reimagination of the future to work to create situations in the present which foster creativity, novelty, and the possibility of 'making difference stick' (Carolan, 2016: 146).

Carolan also shows that looking at agriculture can prove fruitful for this endeavour. These ideas are built upon at a parallel angle in a later article, wherein Carolan (2022) advocates a theory of change grounded in a belief in the capacity for 'everyday resistance' and 'bottom-up capitalism' to counter homogenous capital 't' *Time* in agriculture and beyond. Carolan's approach is a complementary additive in some respects, insofar as it resonates with the need to connect Harvey's framework more attentive to the more-than-representational. It also broadly aligns with the intent of this project to destabilise conceptions of spatio-temporality and futurity towards critical ends. Such an approach also arguably complements ideas from Moore about ecological immanence, who, for example, argues for 'an open conception of life-making, one that views the boundaries of the organic as ever-shifting' (2015a: 7).

One can also note similar approaches in other work asserting a radical openness to the future, often via recourse to Deleuze and Guattari or Isabelle Stengers (Bell, 2017). Such tendencies take on more methodologically explicit qualities in recent publications around 'speculative research' (Wilkie et al., 2017). Within this paradigm the stated purpose in conducting research is to 'cultivate a sense of the possible that concerns, but does not owe its existence to, the ways in which the actual determines the distribution of what is probably, either statistically or algorithmically' (Savransky et al., 2017: 7). Simply taking the 'future' as an object of social scientific inquiry akin to other structures or concepts is not considered sufficient and a more experimental approach informs their efforts towards a speculative yet 'deep empiricism' (Savransky et al., 2017: 10). The approach taken so far should make clear this approach does not underpin the methodology of this work.

This is because, fundamentally, I believe bringing an interest in structure and permanence back into the equation is necessary. This helps create theorising on the radical potentiality of the thick present that also has resonances for how we understand and critically engage with agricultural practices and social life in general. As Harvey (1996) discusses, social processes can become entrenched forming relative permanences over time through the ubiquity and hegemony of ideas and discourses, the mechanisms and practices of institutions and the material realities of monetary distribution, infrastructure or, in the last instance, biophysical possibility. Although Carolan may point to the plasticity of discourses and the mutability of agricultural practices, his example of a small-scale hydroponic agricultural future in Colorado is conditioned *a priori* by federal and state legislation, institutions, the capacity to invest in

hydroponic equipment and the generation and distribution of sufficient electricity for basement horticulture. You cannot set up a small hydroponic farm in your basement if you cannot afford electricity or live off-grid.

My approach has parallels with David Harvey's critique of the open future he sees invoked in the work of Henri Lefebvre. Harvey asserts that '[Lefebvre] refuses to confront the underlying problem: that to materialize a space is to engage with closure (however temporary) which is an authoritarian act' (2000: 183). We can read space here in a broader sense, at least encompassing temporality and, to go as far as Moore, as inseparable from 'nature' writ large. Harvey continues to argue that 'the fixity of structures tends to increase with time making the conditions of change more rather than less sclerotic' (Harvey, 2000: 183).

The text from which these quotes come, *Spaces of Hope* (2000), proved particularly useful throughout my research. Harvey's work encourages a future-oriented position which, like the prefigurative sensibilities of Olin Wright (2010), Gibson-Graham (2006), or Levitas (2013), generates research that looks to the present and the past to mobilise transformative social change, as opposed to 'confecting' alternative futures, and working backwards from there, in line with Marx's oft-cited dictum rejecting 'recipes for the cook-shops of the future' (1990: 47). As the previous chapter should have established, where Harvey differs from thinkers like Gibson-Graham is in his embedding of these principles within a dialectical materialism that attends to the spatio-temporality of social processes. As Harvey (2000: 182) puts it: 'if space and time are viewed as social

constructs … then the production of space and time must be incorporated into utopian thought.'

On an individual level, too, we must not discount the determining and conditioning effects of power and subjectivation and its impact on future orientation in practice, nor should we, from a critical ecological position, overlook the significance of the subject and political subjectivity in these seemingly abstract debates (Heron, 2021). But beyond the individual, we must recognise that within the idea of the 'lively future' and its ramifications for a 'thick' present, that the dynamic concatenations of the 'actual' and 'virtual' within the socio-material processes of agricultural production are constrained by very 'real' material, institutional, social relational and power dynamics within which many humans are looking to bolster their species-specific privileges. These are vestiges of the past contracted into the present as relative permanences that cannot be discounted, as well as qualities of the lived present that preclude and foreclose different potentialities and create instead 'histories of the probable' (Büscher, 2021). Although it may be expedient to consider the future as radically open, I maintain it is naïve to discount the realities of socio-ecological structuration.

These reflections have informed, then, consideration of the third dynamic of a political ecological futurity, in their attempts to formulate an understanding of the plasticity of the future. Recourse to an approach interested only in highlighting more-than-human flourishing or ontological immanence, or that falls back on an idealist call for decentring the human and promoting an ethic of care to the future, does not offer sufficient analytical tools to unpick the socio-material processes of agriculture, the spatio-

temporalities they generate, their attendant futurities and the extent to which this facilitates, mediates, or reproduces ecological harm. The political ecological tradition within which it builds helps make this possible.

2.4.3 Summarising the Framework

This chapter has looked to develop a theoretical framework which begins to answer the research questions in the introductory chapter. In doing so I have also offered a review of the relevant diverse literatures with which I engage in this thesis. I have demonstrated the space I occupy within the field, which I deign to consider a *political ecological approach to futurity*. This framework engages with new materialisms and more-than-human geographies, integrating some aspects of such ways of thought into a Marxian approach that, however, rejects any ideas of a network-centric world defined by a flat ontology. This has ramifications for a future-oriented approach in that I look to historicise the current situations manifesting in English agriculture to read how they create specific relations between humans, plants, and the future. As such, this framework permeates the empirical material to follow in a way which is characterised by the following interwoven arguments:

1. Relationships with the future shape and are shaped via the lived processes of agriculture. These relationships with the future are spatio-temporal, historically specific and exceed talk and the imagination in how they are shaped by extant materialities, technologies and infrastructures. Further, power dynamics as manifest in society shape efforts to reproduce certain futures as relative permanences. I explore these facets in both lived reality and via attempts to

historicise and theorise how these are shaped by social structures and the logic of capitalism in the context of agriculture. Thinking with teleoaffective formations (Welch, 2017) and socio-technical imaginaries (Jasanoff and Kim, 2015) helps enable this in practice.

2. Different relationships with the future which emerge from practices and logics within and outside of agriculture create different relationships with plants, producing different forms of plant life, agricultural technologies, and ecologies. Yet these are always partly shaped by the plants themselves, despite the best efforts at their subsumption by the logic of capitalist agricultural development. Further, these relations are better understood and critiqued via an approach that recognises their historically specific configurations – their *historical natures* – rather than from a perspective that focuses on distributing agency as broadly as possible or foregrounding a transhistorical ontological interest in immanence.

3. Finally, this thesis addresses both attitudes to the future reproduced by research participants and other scholars. In doing so it argues for the need to take historicity, structure, and extant power dynamics seriously. It is via such an approach that tendencies and trajectories of potential agricultural futures can be named and critiqued.

These statements each resonate with the methodological approach I used to undertake my research in different ways. It is the formulation and execution of that methodology to which I now turn.

3. METHODOLOGY: BETWEEN THEORY AND PRACTICE

3.1 Practical and Theoretical Questions

I proposed this research project in early 2019. Since then, widely held predictions about horticultural labour shortages, ever-increasing temperatures and extreme weather have been vindicated. However, what was then the future has also manifested unexpected shocks like the COVID-19 pandemic, escalating conflict, supply chain disruption and drastic inflation across the agri-food chain. These shifting realities, in turn, shaped and impacted how my methodology emerged. In reality, my research evolved as a product of this period of uncertainty and the uncanny temporalities of pandemic and 'post'-pandemic life. The early 2020s proved a generative yet unsettling moment to be looking towards the future of food production.

There was a lot going on. When I started collecting data in early 2022, indoor face-to-face interactions remained a source of anxiety for many. Russia's invasion of Ukraine became a frequent source of conversation and speculation, ranging from optimism about price increases for wheat to predictions that this might be the beginning of the end for our globalised food system. Over the arid summer months, the fields, and farms I visited in south eastern England looked parched for want of rain. I walked long distances in rural

areas in the record-breaking heat of July 2022. It felt, at the time, that my research was happening in a shifting political ecological atmosphere in which 'unprecedented' events and uncertainty were becoming 'the new normal'. This affective reality had an impact on my own research practice and embodied experience as a researcher. I frequently found the quotidian anxieties of conducting social research mingling with broader personal doubts regarding the future of agriculture in England. I felt inspired and energised by some research encounters and drained and pessimistic as a result of others. This anxiety only hardened my resolve to carry out my research and achieve my aim of developing my personal understanding of what the (generally speaking) future *is*, how people relate to it and how, within the world of agriculture, the future is shaped by relations between people, plants, things, and the past.

As forwarded in the preceding chapter I do not believe the future is completely unknowable. As a result of the research which created this thesis, I know more about how different groups of people are approaching the future of agriculture discursively and in practice. I also know more about the technologies, innovations, institutions, and diverse beings which will co-produce this future to varying degrees across varying timescales. It was not, of course, a straightforward process. At times my research felt *messy* (Law, 2004) and the nature of the project and my interests shifted during the process, theoretically and practically. It also felt, on occasion, that the more I learned the less I knew and the more my own personal convictions were disrupted. Further, the theoretical and empirical aspects of this work were always intertwined. As Andrew Sayer (1992: 2) puts it 'there is method not only in empirical research but in theorizing'. The

entanglements between epistemology and methodology ever-present in social research become even more acute when dealing with a slippery concept like ‘the future’.

These tensions shape this chapter. They set the parameters for the discussion in the second section in which I ask and answer the foundational questions pertaining to my methodology in practice, evaluating what I did, why I did it, how it felt, where I believe I fell short in my ambitions and why and how this work emerged as it did via analysis and the writing process. The processual nature of social research as lived experience becomes apparent. Fundamentally, my methodological approach involved three core qualitative research methods: semi-structured interviews, participant observation and critical discourse analysis (Chouliaraki and Fairclough, 1999) of a variety of texts which together represent a multi-sited ethnography in a more geographical than anthropological sense (Hitchings and Latham, 2020b). The reality, in practice, was of course more complicated than these labels afford. The third and final section then reflects on the representational and ethical questions resultant from my methodological choices.

3.2 Methods in Practice

3.2.1 Considering the Field

Throughout the 12 months I spent gathering data across the south and east of England my research manifested itself in multiple ways, some expected and some surprising. I

spent autumnal weeks working long hours in polytunnels and fields, getting up early to harvest leeks in the mist, box up fennel in the sun, wash cabbage in the rain and tear down tomato plants until my clothes and arms were stained green. I also spent spring days servicing indoor growing rooms harvesting and packing microgreens. I was out on the first day of a very early wheat harvest riding along in a tractor with a young farmer in his early 20s. I also sat with older producers who reflected on the changing environmental and economic conditions they had worked with in the preceding decades in contrast to a future characterised by deep uncertainty and potential suffering.

On more than one occasion conversations expanded into considerations of planetary futures and the extent to which the lives of future generations would look markedly different to the present. Some participants were optimistic and jovial. Others were more taciturn. Some were deeply pessimistic. This included one encounter I had with an individual at an industry event on agricultural technology who told me, with little prompting, his predictions of post-oil civilizational collapse in the coming years. This was a one off during my time at similar events and trade shows. Normally, my presence being met the rest of the time with an equal mix of polite engagement and relative disinterestedness, possibly due to my lack of intention to purchase or invest anything. I often felt like an outsider in these agricultural spaces, a naïve city-dweller just passing through whose legitimacy was often under scrutiny, although I had least had the advantage of being a middle-class white man in spaces dominated by such people (cf. Chiswell and Wheeler, 2016).

As with many researchers operating in the early 2020s a significant proportion of my research also took place online via Zoom interviews, discourse analysis and digital participant observation. A combination of the Omicron coronavirus wave in late 2021, limited funding and my reliance on public transport for research mobility meant I undertook dozens of online interviews with farmers, campaigners, entrepreneurs, engineers, and plant scientists throughout 2022. I benefitted from the increased prevalence and usage of video calls during the pandemic, helping my remote conversations to flow more organically. Similarly, the COVID-19 pandemic ushered in an as yet ongoing boost to the popularity of online conferences and webinars where people from across the country (or world) could come together to discuss the latest developments in agricultural innovation and technology, a format that seems particularly popular amongst those involved with CEA and vertical farming.

On top of this data collection at home, I also engaged with a range of documents and discourses, from parliamentary transcripts and legislation to YouTube tours of vertical farms and diverse sources of farming news to gauge and palpitate the atmospheric futurities permeated out through various media streams and variously received beyond every horizon. To enter the field, I did not necessarily have to leave my house. This encouraged supportive consideration of emerging critiques of traditional understandings of fieldwork. Guasco (2022), for example, reflects on an 'ethic of not going there' in regard to her own experiences of doctoral fieldwork. A particular challenge for me, in this direction, was rural mobility in terms of my ability to visit farms without the ability to drive. My solution to this was integrating walking ethnographically into my research (Ingold, 2010), yet this is surely not possible for everyone from an accessibility

perspective. Equally, from an accessibility perspective, both the potential of exposure to COVID-19 and the need to be sensitive to differential sums of research funding within the academy I also argue require critical consideration of what constitutes the field, and this ethos permeated my research strategy to an extent.

Further, given the nature of my empirical foci, my underlying and profound intellectual interest and personal investment in the topic, as well as the escalation of uncertainty and intensity throughout which my research was conducted, I experienced my research in diverse embodied, affective, and emotional registers. At times the combination of worsening meteorological realities, grim news stories, supply chain uncertainty and inability to attract research participants or solicit invitations for site visits or interviews left me feeling deeply powerless in the face of a system so complex, interlinked and historically sedimented that transformational change felt difficult to even comprehend. Julian Brigstocke (2016) writes of 'exhausted futures' and destroyed futurities via his own creative visual methodologies and, at times, this was certainly an affective resonance palpable within my own research. At other times, particularly when out walking in the hills, valleys and plains of south-eastern England or working with farmers or growers, I felt infused with potential and hope that my research would yield personally enriching ideas, concepts and ways of thinking and doing in the world.

The process of research is itself, when considered reflexively, about the generation of futures. So, through the practice of social research I myself generated futurities and affects of both openness and structuration. These facets were amplified by the pivot towards vegetal geographies I cultivated which is discussed further below. In my

encounters with plants themselves and with the relationships between other humans and plants (ranging from the horticultural to the experimental) I learned new ways of practicing being-with plants and thinking ontologically which I believe will form part of my lifeways for as long as I am able to remain in reasonable cognitive health. In this regard, as I imagine is the case for most research, just as my data collection strategy changed throughout the process, so too did I. For the purposes of this chapter, though, it is necessary to consider the most significant change which evolved over the course of my doctoral research: my shifting and narrowing conceptual focus and the methodological ramifications of this emergence.

3.2.2 Strategy & Flux

Between the conception of my project and the conclusion of my data collection my research design, strategy and conceptual focus changed significantly. My initial intent had been to conduct a more singularly place-based ethnographic study of a particular locale and the futurities, anticipatory logics, and imaginaries of agricultural producers in that area, whilst simultaneously conducting participant observation through farm work where possible over a single period of time. The impact of Brexit, in particular, was originally supposed to prove a focus. For both practical methodological reasons and theoretical reasons, however, the focus of my research changed. Firstly, during the process of conducting my literature review and developing my conceptual ideas my engagement with theoretical work led me towards an approach that operated across multiple scales and sites, looking for connectedness and the entanglements between, for example, socio-technical imaginaries, agricultural practices, inter-species relationships and on-farm affective atmospheres, including in more historical and

institutional ways. I felt that my theoretical ambition and emerging interests, at this stage in my research career at least, would lend themselves well to a broader scope.

My engagement with future-oriented STS during the process of the literature review also turned my head towards greater consideration of the role of institutions, innovation and technological change in the discourses and manifestations of futures in English agriculture. I was particularly drawn to what I considered to be a significant gap in the social scientific literature at the time regarding the growing investment oriented towards CEA and vertical farming. This interest was exacerbated and oriented by attendant popular discourses around horticultural labour, automation, and the pandemic, as well as general hype about vertical farming itself (see Chapter Five). In addition to this, the necessity to engage with the more-than-human literature around agricultural futurity discussed in the previous chapter also pointed me towards vegetal geographies and theoretical approaches to plantiness. In this regard, my concern with the conceptual breadth of my project and my engagement with these emergent theoretical approaches led me towards a focus exclusively on the mobilisation, deployment, and imbrication of plant life within industrial agricultural systems, an empirical consideration I also found to be overlooked in the extant literature.

Although many of these ideas had been formed by the time that I had completed my initial literature review prior to commencing fieldwork, the difficulties I had in successfully recruiting conventional farmers to participate in my research discussed in detail below exacerbated and intensified the turn towards a multi-sited 'mid-range' approach (Hine, 2007) that also considered innovators, scientists, campaigners, and other stakeholders

as potential interlocutors for the purpose of my research. Inspired by these developments, my research plan evolved gradually towards a more spatio-temporally diffuse approach that, in reality, then coagulated into three distinct yet significantly interlinked case studies which each represent an empirical chapter in this thesis. This move was supported by a number of scholars whose work is engaged with below. Particularly significant in the choice to move towards a more 'multi-sited ethnography' was the summary of such methodologies by George Marcus (1995), who highlights their capacity for engaging with systems, political economies, and histories. Further consideration is given below of this choice of method, in terms in particular of its participant observation aspects and scale.

What are these 'case studies' then and how did they emerge? The first empirical chapter explores the ongoing legislation around and development of gene-edited crops in England. The second explores vertical farming and CEA. The third empirical chapter explores ways and means of discussing and mobilising agricultural scale differently in order to induce transformation in the future. In terms of rationale for the choice of these topics each represent a field wherein plant life is mobilised in diverse, contradictory, or complementary fashions in order to foresee and fashion agricultural futures differently. Each are also 'matters of concern' (Latour, 2004) insofar as they both permeate or inform agriculture as processes but also exist in broader discourse as sites of contention, resistance, or mobilisation. To borrow from the methodological literature, these areas were selected as 'instrumental' case studies (Stake, 1995: 3) which were used to open up consideration of the broader questions highlighted in the preceding chapters in ways that are most thought-provoking and timely, if not necessarily typical (Stake, 1995: 4).

The gene editing question which comes under scrutiny was an ongoing legislative process throughout the time I was collecting data and attracted significant support and opposition from across the world of food, farming, and land management. In engaging with the legislation directly I realised that the understandings of plant life it mobilised, its inherent futurity and impact and its imbrication with historical political economic realities made it an ideal subject for attention and articulation with questions around law as a future-oriented knowledge practice (Adam and Groves, 2007) and a geographical concept with vegetal ramifications.

In terms of vertical farming, as discussed above I had identified it as both an emerging trend in terms of investment and a significant gap in the literature. On top of this it is touted widely in media and governmental discourses as 'the future' whilst simultaneously offering a distinctive and provocative spatio-temporal reformulation of human-plant relationships. Finally, as regards the chapter considering more conventional forms of farming and efforts to change or transform them via the discursive politics of agricultural scale, this represents more consistency with my initial research interests. It also provided an opportunity to critique widely reproduced discourses of agricultural scale whilst integrating a vegetal political ecology perspective.

Fundamentally, this conceptual focus was shaped by the nature of those farms and farmers who gave me access to their land and ideas, either in interview form or via participant observation. As Hammersley and Atkinson (2007: 32) remind us, the choice of 'case' is often mediated by access. Whereas the first chapter draws on interviews and, to a great extent, discursive and theoretical materials, the latter chapters are the

products of more explicitly ethnographic work which combine participant observation resultant from 5 weeks of working on two farm sites, interviews conducted online and in person and, in addition, participant observation of diverse meetings, webinars and events, as well as engagement with diverse discursive materials. It is to the practicalities of these aspects of the research which I now turn.

3.2.3 Ethnography and Participant Observation

In defining my data collection as an ethnographic endeavour, it is first necessary to justify and unpack why and how my research is best understood in this way and, within that, what role participant observation played and why. Hitchings and Latham (2020b) illuminate recent debates over what constitutes ethnography in human geography, highlighting the tensions between anthropological conceptions of ethnography and more recent adoptions of ethnography by geographers. The length of time immersed in research sites is one measure used to justify ethnographic authority. In total I spent around 200 hours conducting participant observation working on farms during my research. In addition, I spent many more hours around the farm in the mornings and evenings. This time is split between two weeks working full time with Grant at New House Farm in spring, mostly in his indoor growing rooms, and three weeks working full time at Nettle Bank Farm in the autumn[3]. The farms were highlighted and approached using publicly available contact information found online. New House Farm was chosen due to its regenerative focus combined with its integrated CEA set up. Nettle Bank was

[3] All names of people and places are pseudonymised in order to protect their anonymity.

chosen as representative of a larger commercial scale farm working with self-proclaimed alternative methods.

This participant observation is supplemented by an additional 50 hours attending in-person events, exhibitions and online conferences and webinars throughout the year. This approach can be characterised as 'event ethnography' (Koch, 2023). This involves participant observation undertaken at public-facing events which allow observation of the imaginaries, power dynamics and social relations within a specific sector or community of practice. The event ethnography I undertook included agricultural trade shows and exhibitions, symposiums on agricultural innovation at a well-established agricultural research institute, engagement with two networks designed to promote agricultural innovation and attendance at an online conference on CEA. Participation at these events involved listening to experts giving talks and observing demonstrations of new technologies. There were also discussions in the margins with other attendees which helped shaped my thinking and created avenues for future discussions. These events and opportunities were found using social media and signing up to the e-mail newsletters of relevant organisations. At smaller events like symposiums, I informed organisers in advance that I would be attending for research purposes but at public facing, larger events like agricultural exhibitions I attended as a member of the public. One particular advantage of these events was encountering novel or emergent approaches to agricultural technology in material form and talking to the people who developed them about what future they foresaw for their innovation and why they were necessary.

Given the total time I spent undertaking participant observation exceeds the times listed by Hitchings and Latham (2020b: 974) for the approach characterised by more concentrated ethnographic research in one's own country this seemingly qualifies my work according to this metric as, if not an anthropological ethnography, then at least as a geographical one. In addition, as Hitchings and Latham highlight, my participant observation was complemented by dozens of informal discussions, 43 semi-structured interviews and extensive Critical Discourse Analysis (discussed below). In this sense my ethnography was multi-modal but also a lived research period over a protracted period of time. Along these lines I prefer to follow Watson and Till's (2009: 121) consideration of what constitutes ethnography as:

> 'an intersubjective form of qualitative research through which relationships of researcher and researched, insider and outsider, self and other, body and environment, and field and home are negotiated.'

In order to preserve this process for future analysis I maintained daily field notes throughout the year, even when not technically out 'in the field'. An example of exert of these notes can be found at Appendix A. This dovetailed with my ongoing Critical Discourse Analysis set out below. The purpose of this was to remain rooted in the present and the rhythms of mainstream agricultural policy discourse, the changing seasons and weather and my own emotional futural resonances whilst remaining focused on the futures under scrutiny. I returned to these field diaries as sources of data and conceptual re-engagement throughout the process of writing up, particularly those during my period of working on farms. I coded them in an iterative way for key themes such as control,

care, and multi-species engagement but they served as a theoretical and empirical catalyst for much of Chapter Six.

This more processual understanding of ethnography also elides with Herbert's (2000) arguments in favour of ethnography as an appropriate methodological approach for human geographical research, which influenced my research design and conceptualisation. Fundamentally, for Herbert, ethnography is well suited to qualitative research which takes a serious interest in systems, relationalities, flows and processes. This allows for an open-ended approach to research which looks to explore a conjuncture, its practices in situ, and its affective atmospheres. This is a philosophy with which my research is imbued, although, as my research questions and theoretical framework have established, I clearly brought a priori conceptual apparatuses from without to my empirical undertakings, including, notably, a concern with ontological questions and the generation of spatio-temporalities. Further, Herbert highlights two further dimensions of ethnographic research of significance to my project's ethos which shaped its methodological underpinning: the significance of participant observation as a way to engage with practical activity and lived experience in motion and the emotional and sensorial valences of this way of doing research. These are of particular significance for my research given my interest in futures and futurities and more-than-human life for reasons to which I will now turn.

In recent times anthropologists have looked to demonstrate the efficacy and potential of ethnographic methods for engaging with the futuristic, the future and the futural. Bryant and Knight (2019: 16), for example, offer rich ethnographic encounters with various

dimensions of the future and posit a way of understanding ethnography – which could easily be understood as a 'presentist' method as possible given its situatedness in unfurling social process – as always imbued with the teleoaffective resonances of the future. This is an ethos which I carried with me in diverse ways during my participant observation, manifesting variously as discussions about the future of the earth's climate in a geological sense, engagement with the life cycles and finitude of plants or the rhythms of logistically producing food for future sale on commercial markets. Bryant and Knight draw on the work of Schatzki to undergird this interest in the futural and participant observation and my active labouring on farms served to embed myself within the temporalities and rhythms which generate the future, not just via imaginaries and discourse, but in practice: meeting deadlines for deliveries, getting up before the sun and, significantly, taking and creating (vegetal) life alongside seasonal flows. These realities affected my experience of different agricultural timescapes, landscapes and taskscapes and the creation of futures therein.

However, after a while habit and familiarity set in and I became less attuned to present-futures and more in step with future-presents (Adam and Groves, 2007). At a parallel angle, Salazar et al. (2017) also tout the salience of ethnographic methods for an 'anthropology of the future'. Whereas the tendencies towards design-based or similar forms of speculative ethnography invoked by Salazar et al. do not necessarily resonate with this project they do name two facets of a future-oriented ethnographic project that certainly do. Firstly, via their recognition of the political capacity of what they call 'anticipatory ethnographies' to produce future-oriented knowledges derived from participant observation and discussion that looks to influence the political discourse

and normative trajectories of a field of social life (in this case agriculture and agricultural and innovation). This I have aspired towards given my engagement at both the farm-level and the legislative level. Secondly, as regards their recognition of the relevance of what they call the 'ontological turn' in anthropological theory to future-oriented ethnography, given the connections possible to make here with my interest in alternative futures, contingency and the more-than-human world.

In this regard, my interest in the role of the vegetal as a cogredient of both my research process and agricultural lifeways is significant. Geographers have dealt with methodological questions in recent years regarding how best to marry emergent theoretical developments with methodological practice (Dowling et al., 2017). In this regard, I have not proved particularly ambitious. I found my existing ethnographic approach sufficient in at least beginning to explore these questions, although I had some frustrations and highlight some shortcomings below. In future work I may look to employ more participatory or creative methods. Nevertheless, ethnography and participant observation, as embodied and practical forms of research which, in my case, involved active agricultural labour, did offer a suitable methodological advantage in terms of engaging with the more-than-human world via its metabolism through labour. As a political ecological method, such an approach has long proved popular, including, more recently, for researchers exploring human-plant relationships (e.g. Fleming, 2017). The capacities for working ethnographically in ways that challenge methodological anthropocentrism have been remarked upon by advocates of multi-species ethnography who reflect on anthropological interpellations of both animals and plants (Kirksey and Helmreich, 2010). In the more explicitly geographical sphere Hannah Pitt (2015) and

Sarah Elton (2021) offer important resources which I drew upon in conducting my research, emphasizing the capacity of working with plants ethnographically to draw on different kinds of embodied practices and conceptual foci. Pitt, for example, highlights the significance of both engaging with plants directly and soliciting the knowledges or engagements of others. As Pitt discusses I too was a 'novice' (Ingold, 2000) in the agricultural work that I began to undertake but, through repeated practice, understood the materialities of fennel, the proclivities of peas and the recaltricance of tomatoes better through repeated work and discussion. Participant observation proved a key method for me in enriching my research in this way.

Yet in addition to Pitt's pedagogical conceit, I introduced more auto-didactic elements into my ethnographic practice through botanical readings and horticultural practices in my own life, although these more auto-ethnographic elements of my research do not feature but, in the long run, have already proved enriching. Elton (2021) also asserts the significance of work and participation in activities involving cultivation, but also stresses two further dimensions of ethnographic work with plants which shaped my own research practice. Firstly, the need to attend to the time and temporalities of plants, which I strived to do given my theoretical interest in the dialectical relationship between 'time' and 'Time' (Kolinjivadi et al., 2020). This however proved difficult in terms of situated engagement over prolonged time and was necessarily more patchwork given my multi-sited project. Further, Elton emphasis the importance of scaling out to connect the intimate vegetal with the broader political ecological context, a facet of my research which leads to both the questions of scalar interconnection in the preceding chapter and the disciplinary influence of STS on my work.

These aspects surrounding direct practical engagement with the futural and the vegetal are, of course, vital ingredients of my research design but, as the above work in this and the theory-oriented chapters asserted, this is a research project which moved away from a solely embedded or taskscape-bound approach towards efforts at more multi-scalar, historical and conjunctural analysis in an effort to combine theoretical ambition and methodological modesty. This is still, however, compatible with the ethnographic approach I discuss above, given the extent to which the participant observation elements were but one aspect of my empirical data collection. In this regard, the influence of STS returns to the frame in order to articulate these diverse interests. In this regard, Christine Hine's (2007) writing on a methodological embrace of ethnographic research in pursuit of 'middle range methodology' in STS is significant. Hine asserts how a 'multi-sited imaginary' can allow pursuit of institutional dynamics, complexity, and other aspects relevant to science studies and this research. In this regard, my ethnographic engagements with conferences and events at which various forms of agricultural scientific expertise beyond the practical horticultural skillset of my participant observation on farms was mobilised are significant. These encounters enabled for the abstraction of my experience working on farms and interviewing people and articulation into broader discourses and socio-technical imaginaries of agricultural futures, innovations and what 'progress' may or may not look like.

Yet these engagements were not purely discursive, involving often as they did incipient technological forms on display, demonstrations and, on one occasion, cultivar trials – re-emphasising again the materiality of the future (Tutton, 2017; Esguerra, 2019). In this respect I found Maria Kaika's (2018) incitement that research in the present conjuncture

should aspire to move between the ‘frog and the eagle’ as part of a ‘scholarship of presence’ that constantly looks to make connections between the practical-observed and abstract-theoretical highly compelling. In making this connection towards ‘middle range’ methodology, however, it was vital that my participant observational research was complemented by both semi-structured interviews and critical discourse analysis, both of which I now consider in further detail.

3.2.4 Semi-structured Interviews

Semi-structured interviews have long been an established method for collecting data within human geography (Dowling et al., 2016; Hitchings and Latham, 2020a) and conducting ‘formal’ recorded interviews had always been an intention of mine. My initial plan had been to interview as many farmers as possible across the county of Kent in South Eastern England throughout the course of the year and conduct additional interviews with people involved with technology, innovation, plant breeding and campaigning where possible. To start with, I mapped and databased the publicly available contact details of 100 potential horticultural or arable farms as an initial sample, as well as 20 vertical farming operations. In this regard, my initial strategy was recruitment through ‘convenience sampling’ via publicly available contact information and then subsequently by ‘snowballing’ from existing participants (Lune and Berg, 2017: 38-39). I also mapped national level stakeholders involved with, for example, notable agricultural technological developments and campaigning on food and farming issues. My initial target for interviews were vertical farms and national level stakeholders as in early 2022 there was still some uncertainty following the recent Omicron coronavirus wave and I considered these participants to be more amenable to online interviewing.

This proved correct and recruitment and data collection started strongly prior to my first period of participant observation working as a grower in early March.

Following this period, I focussed on recruiting farmers, requesting on-farm interviews but also offering the potential for remote interviews if desirable. Recruitment, however, proved difficult. As other researchers have shown (Kuehne, 2016; Thomas et al., 2019), social research with farmers poses distinct challenges in terms of access, rapport, and knowledge differentials. In my experience farmers deserve a reputation as a 'hard to reach group' for interviews. This was, I believe, exacerbated by the recent pandemic (particularly given the high average age of many farmers), the extreme uncertainty surrounding farming futures at the time, as well as my lack of an initial starting point within a given farming community from which to snowball. I also encountered the fact that farmers seem to also be, considering their relatively small percentage of the population, a sought-after group and multiple participants reported they had been approached for or participated in other research projects.

As I continually failed to recruit significant numbers of farmers to participate in my research, my broader case study approach emerged as a research strategy oriented towards offsetting these issues. This also prompted reflection on the realities of what constitutes 'failure' in geographic research and, as Harrowell et al. (2018) suggest is necessary I am happy to share my experiences of failure and how I sought to overcome these setbacks. In combination with the refined focus on vegetal geographies, and my growing influence from STS-oriented scholarship, I feel I developed a suitable alternative pathway towards achieving greater data collection via interviews over the course of the

year. In total over the course of the year I conducted 43 formal interviews lasting between 30 minutes and around 2 hours. Of these, nine were conducted in person and 34 conducted via Zoom. Those interviews conducted in person were with people involved with growing crops either commercially or for research purposes and each involved a farm walk or short tour of the premises which accompanied a semi-structured interview. This was particularly beneficial for attending to ideas around engaging with agricultural and horticultural materialities *in situ*. This was a focus which I definitely lost out in given the number of remote interviews I ended up carrying out, but which was hopefully offset by my participant observation work on farms and other ethnographic observations and engagement. It is hard to get a sense of the social-ecological realities of horticultural life through the discursive moment alone. In person interviews were recorded using a Dictaphone and transcribed into word processing software after the research encounter. Field notes were also written up regarding the ethnographic experience of each farm visit and my travel to, from and around the farm sites. A table summarising my interview participants and their anonymised information can be found at Appendix B. Examples of interview schedules used can be found at Appendix C.

The coronavirus pandemic unsurprisingly created a heightened interest in the advantages and shortcomings of using online tools to conduct qualitative social research remotely (Nind et al., 2021). Many advantages have been cited for these methods for the purposes of future research including easier and cheaper access for participants and researchers alike, as well as greater temporal flexibility (Archibald et al., 2019). Keen et al. (2022) assert that data garnered through remote digital interviewing can be of just as much richness as that accrued through traditional methods. In my

experience this was the case and I experienced few of the issues named by Archibald et al. (2019) around connectivity issues or call quality issues. It is likely, however, that my participants skewed towards those with greater digital literacy, however this was also an outcome of my strategic pivot towards the three case studies I pursued more explicitly. Online interviews were conducted via Zoom. They were recorded and transcribed automatically for future analysis purposes, with transcripts revisited whilst listening to recording to ensure accuracy and coherence before further analysis. The transcripts were often incorrect or unreliable but mostly comprehensible and easily amendable.

I was keen to let the interviews flow relatively organically. My interview schedule included a few subjects with all my participants, including their experiences and histories of working in their fields and, notably, their future visions for English agriculture, horticulture, and associated technology in the decades to come. In retrospect I think this worked well with my personal 'style' of interviewing (Hitchings and Latham, 2020b: 7-8). Across the interviews, I borrowed a scenario-oriented approach from futures studies methods (Krawczyk and Slaughter, 2010), within which I encouraged and probed participants to imagine the future of English agriculture in 10- and 50-years time. I also prompted all participants with the same line of questioning regarding their emotional resonances with the future, regarding their optimism or pessimism about their envisioned trajectories of change or stasis. In this direction, my line of questioning was at times met with limited responses as a result of its relatively abstract or thought-provoking nature and in future I would be more inclined to prompt potential participants with questions like this in advance of their discussions. Despite my own stated normative positioning as a critical researcher, I did not seek to make my own positionality known

during the interviews, however, did prompt or offer counterarguments in a passive sense when participants were offering views which clearly resonated with certain political ecological visions of the future. In total, the interviews proved to be a deeply enriching experience, during which I encountered and learned from a diverse range of individuals working in their own ways to realise a future they wish to see in the world. Nevertheless, the issues around farmer recruitment were a significant frustration and certainly served as a teaching moment for any future research I will look to conduct in this direction.

In order to analyse my interview data, I initially uploaded the transcripts to NVivo and undertook a thematic analysis (Braun and Clarke, 2006), creating codes and themes prior to reviewing the data in line with my own theoretical interests. I created cross-thesis codes and themes for work across all the chapters, as well as more specific ones for thematically discrete areas of concern across each empirical chapter. However, as discussed above, I found that my existing analytical approach relating to my ethnographic field notes and my more iterative and ad hoc analysis across my time collecting data felt more engaging and compelling than trying to fit everything into codes. I found that, in trying to undertake a 'scholarship of presence' (Kaika, 2018), moving between the practical frog's earthly view and the conjunctural eagle's perspective, my existing theoretical knowledge and grounding were always already in play. The big theoretical themes and questions discussed in Chapter Two had already penetrated the very process of data collection itself so the idea of letting the data speak exclusively for itself felt awkward. In this regard I found justification and inspiration from the work of Jackson and Mazzei (2013) regarding 'plugging in' theory and data and vice versa. Jackson and Mazzei argue for an approach that recognises the processual nature of social reality,

of which qualitative research is of course a part. Citing Grosz (2008) they call for analysis of interview data 'as a production of knowledge that might emerge as a creation out of chaos' (Jackson and Mazzei, 2013: 263). The work of Jackson and Mazzei is deeply influenced by Deleuze and Guattari, from whom the phrase 'plugging in' is derived.

Therefore, this engagement is another instance of this work's variable engagement with post-structuralist theorising, as forwarded in Galt's (2013) recurrent sketch of a first-world political ecology. Furthermore, the openness and immanence of a Deleuzian ontology underpins Jackson and Mazzei's approach, whilst also, of course, influencing an approach to futurity in theory and practice about which I am sceptical. How, then, can such ideas be reconciled with my work? In response to this I would argue that the abstract nature of much of the theory I look to mobilise, in conjunction with the object of my research – futures and futurity – and my ambition to work across scales (frog/eagle) in an explicitly critical fashion creates a position where my own presence in the analytical process cannot be ignored. However, at the same time, as I have made clear, I do not seek to utilise this recognition as a means to totally disavow my own capacity to make assertions about historicity, causality and futurity that would belie my critical intentions and Marxian interests.

3.2.5 Critical Discourse Analysis

The final aspect of my data collection which requires examination regards the diverse range of texts with which I engaged during and after my year of fieldwork. As a whole, this aspect of my research strategy aligns with the principles of Critical Discourse Analysis (CDA) as established by Chouliaraki and Fairclough (1999). Before addressing the

practicalities of my own approach, it is necessary to first address why I adopted this particular approach towards textual analysis and how it articulates with the rest of my research. Fundamentally, CDA recognises discourses, and the texts via which they are conveyed, as one relational moment of social reality. In this direction Chouliaraki and Fairclough (1999: 28-29) draw directly on the work of Harvey to make this point. For the purpose of my research, which as the preceding chapter establishes, is intent on exploring futures and futurities as generated by and within processes and practices, rather than exclusively as imagined facets of the present, this recognition is important. Attention to discourses that is sensitive to this articulation can help bridge scalar gaps and research practices whilst retaining an interest in the institutional resonances of teleoaffective regimes (Welch, 2017) and spatio-temporal imaginaries. As Chouliaraki and Fairclough (1999: 38) put it: 'analysis of 'conjunctures' – cross-institutional assemblies of practices around specific projects – might be a productive way of of operationalising [discourse analysis]'.

As a result of this effort towards relationality and a rejection of discourse and imagination as the integral medium of social reality, CDA works well when forming part of a broader portfolio of research methods, 'particularly ethnography' as Chouliaraki and Fairclough (1999: 61) point out. Further, in line with my own objectives and as the name clearly suggests, CDA is a fundamentally critical method that looks to explore discourses in a way which unveils their ideological underpinnings and opens spaces for alternative discourses that can help co-develop (but never alone forge) alternative futures. Finally, the framework of CDA established by Chouliaraki and Fairclough is rooted in a dialectically inclined recognition of the spatio-temporal and historical facets of

discourses as emergent through social reality over time, in turn seeing discursive production as a practice which contributes to the generation of spatio-temporalities and futurities.

How, then, did these principles affect how I sought after and engaged with diverse texts throughout my research? The texts with which I worked emerged in two distinct stages during both of which strategy analysis was informed by the framework for stages of CDA (Chouliaraki and Fairclough, 1999). The first stream of engagement represents a more diachronic, iterative, and ethnographic approach to discourse analysis wherein throughout my doctoral research I amassed, tracked, and analysed texts in the public sphere pertaining to agriculture in England via mainstream news media, farming news publications, radio broadcasts and podcasts, social media, policy developments, legislations and reports produced by business organisation, non-governmental organisations, and charities. Analysis of these materials contributed to my ethnographic field notes throughout 2022. Whilst engaging with these materials was at times ad hoc and contributed more to the atmospheric sense of my own research and futurity, I was also keen to integrate vital steps of CDA such as conjunctural and historical contextualisation, connection between discursive forms and other social moments, and attention to the temporalities invoked, conjured, or marginalised within discourses.

These principles were more rigidly applied, however, in the more targeted and systematic CDA I undertook to inform and develop my empirical chapters' specific foci. In this regard I gathered extensive textual materials pertaining to the development of gene editing (and its controversial predecessor GMO), vertical farming/CEA and current efforts to

transform or transition English agriculture and horticulture more generally. These resources, which represent a mixture of academic and non-academic materials, were amassed using keyword searches via Google, Google Scholar, podcast providers, YouTube, and Twitter. Materials used are referenced accordingly in each chapter. In interrogating a diverse range of documents, I drew upon different modes of engagement with different disciplinary traditions. For example, Chapter Four includes a greater exploration of legal texts which draws on scholarship to interrogate legislation as a future-making knowledge practice (Adam and Groves, 2007), whereas Chapter Five engages with audio-visual material.

In each document I read and annotated and analysed materials according to CDA's principles (Chouliaraki and Fairclough, 1999: 61). The first stage, recognition of a problem, in each instance was a desire to interrogate the future claims made in each text. Within this the next practical aspect of CDA, conjunctural analysis, is of course significant. Therefore, posing the question: what does the way this text represents the future tell us about the present? Included in this is also, of course, the nature of futurity in the present. These critical and temporal facets were broadly shared across analysis of texts pertaining to different interests within each chapter. The next stage, connection to practices, was of course articulated differently across each chapter which pertains to diverging practices. Each has similar logics, however, and practical and material relations with and invocations of plant life were of course of central importance to the rubric via which I worked to explore the texts in question. The next stage, analysis of the discourse itself, was also relatively consistent across the chapters, oriented, as I was, towards overarching themes of futurity, possibility, plant-human relations, and the

political ecological and normative ramifications of both my own vision of the future of agriculture and those presented with varying degrees of subtlety across texts. In this regard the final stages set out by Chouliaraki and Fairclough regarding highlighting the historical roots and ideological functions of discourse were vital to my analysis as is hopefully apparent from the work to follow. CDA, thus, formed an integral aspect of my research and, although it is limited in its capacity to engage with materials in situ, it allows for the kind of mid-range, future oriented work that I set out to aspire to in the preceding theoretical chapter.

3.3 Representation, Reflections and Ethics

3.3.1 Writing Up, Representation and Exclusion

Writing as a form of communication crystallises diverse present states into a static form which flattens time, space and social process whilst also serving to invoke temporalities, affects and, hopefully in this case, the envisioning and manifestation of alternative futures. On the one hand, distilling three years of reading and researching in writing creates a document that defies linear temporalities. That the stitches and shards of any written piece are invisible to the reader in the last instance is a gift to the author. This, of course, also allows for the occlusion of all the choices and exclusions of the writing process. Mirroring Harvey's critique of Lefebvre invoked in the previous chapter, to write is to foreclose. Within this document then I have made myriad foreclosures in how I have elected to present my findings. In keeping with my own ongoing theoretical formation some of the tensions between the post-structuralist tendencies with which I engage and

the critical geographical or political ecological tradition within which I work emerged during the writing process. It was necessary to consider the extent to which I was to look to play with form and content in a way that looks to modulate the reader's expectations about the future to come. I also needed to ask myself, harking back to this chapter's introduction, to what extent did I wish to offer speculation or foresee the impending arrival of different futures, for better or worse in my written outputs.

As regards the first question, in terms of style, this thesis is presented in a relatively conservative fashion. I have sought to prioritise the need to communicate a broad, interwoven tapestry of theoretical ideas, historicization and empirical data in as clear a way as possible in the tradition of the political ecological work of critical geographers, as opposed to the anthropological writing of those pursuant to the post-structuralist turn in ethnography to which this thesis does in fact turn to for inspiration methodologically at times. This is not to say I do not look to enrich each chapter that follows with ethnographic material and personal reflection wherever possible (and it is possible in the case of some chapters more than others). But, beyond this, the writing of this thesis follows orthodox conceptions of what a social scientific doctoral thesis might look like. Whether this is a shortcoming is unknowable given the now final suppression of any such alternative text which focused more, for example, on my time spent ethnographically walking for research purposes or on my personal efforts at engaging with different vegetal geographies for my own horticultural ends. As regards the second question regarding speculation and my desire to inject my views as to what the future might be like into this project? On this front I have proceeded in such a foresight-oriented direction at times. This follows from my above assertions regarding understanding of social futures as not

entirely ruptural, novel or unknowable and the need for critical research to be interventionist and positional, rather than relativist or retreating into an embrace of ambiguity and complexity. Yet, as I look to assert, these are my personal understandings and extrapolations of extant tendencies as opposed to predictions in the sense of any aspiration towards positivistic credentials. In fact, Robert Stake's (1995: 99) portrait of any case study researcher as an interpreter or artist resonate here: 'the researcher helps the elegant intricacy of understanding, but meticulous readers find the infinite void still lying just beyond'.

The question of suppression and exclusion also emerges in areas where this research does not focus but which are heavily implicated in the below discussion. When you embrace relationality as a facet of social reality and try to work across scales as both frog and eagle the question of exclusion becomes inevitable from a representational perspective (cf. Giraud, 2019). In this regard, certain aspects that I believe are inseparable from the development of radical scholarly praxis regarding food and agriculture (and social life writ large) do not emerge in as much detail as I would like were I to have more money and more time at my disposal. My attention here refers to questions, histories and futures of gender, race, and imperial extraction (Hammelman et al., 2020). The majority of my research participants were male. They were also entirely white with only one exception. This of course speaks to entrenched histories of exclusion in the natural sciences, agriculture and, clearly, emergent technological sectors. This is acknowledged at times throughout the following chapters; however, it does not emerge as a substantive focus until the conclusion, within which I perhaps look to offset this lacuna in envisioning alternative agricultural futures that are more equitable for all and

address histories of patriarchal control, the racialisation and manipulation of bodies from diversely peripheralized locales and histories of imperialist extraction and unequal ecological exchange (Hickel et al., 2022). On this last question, when attempting to abstract to the conjunctural level I do attempt to make the necessary and unavoidable connections where possible between English agriculture and global imperialism in the past, present and future. Again, however, were I to have the opportunity to do this research again perhaps I would have tried to bake this into the rubric of my research at an earlier stage in such a way as to make the writing to follow address such questions more substantively. I hope this necessary articulation can be made in any future opportunities I receive to work on these questions empirically and theoretically.

3.3.2 Ethics

To finish I move from questions of justice, broadly conceived, to questions of research ethics. Given the nature of my participants and subject matter this was not a hugely ethically challenging piece of research, although as with any research project involving humans some issues arose. Confidentiality and anonymity, for example, were of course a concern. All names of locations and individuals within this thesis are anonymised via either omission or the use of pseudonyms. This was particularly necessary when working on and discussing a relatively nascent sector like vertical farming within which there are few players and those operating within it, whether commercial or otherwise, seem to know each and other and, in some cases, have strong opinions on others. Equally, in many instances there are issues of commercial secrecy regarding innovation and associated investment relevant across the work. In order to be sure when discussing

such questions of technological development or agro-ecological practice alike I err on the side of caution and use only publicly available information.

Ethical issues also emerged as a result of the interpersonal nature of social research. This was particularly the case when negotiating the slightly complex reality of working for the people you are also studying, as was the case with my research on farms where I trod a fine line between willing worker and researcher in action. In this case my experience across the two locales was different. When working at New House Farm I found in Grant a willing interlocutor who took great interest in my research and was willing to give his own time and effort to discuss such questions and introduce me to others with similar interests. At Nettle Bank, however, I was always busier, had committed to working longer hours and was surrounded at all times by other workers and was at a distance from those in charge of the farm to a great extent. In this format I was happy to learn from the work and tried to take my chances where possible to ask different questions to different kinds of people. I was always up front about my intentions, but also found that after a single week people seemed to forget that was why I was there which was an advantage in terms of data collection but of course posed some issues in terms of what is acceptable to reproduce when told to you by someone relatively at ease with someone who was, by this point, a familiar face.

The relationships I also developed with people I communicated with on multiple occasions, such as Spencer (Chapter Six) also created issues. Were people willing to talk to me because they wanted to help my research or because they were generous people or because they liked me? There was an instrumentalism to these relationships which at

time felt odd for me. However, given the amount of people who ignored or rejected my invitation I did not think too critically about those who did in fact want to participate. In any case, most relationships have now fizzled out relatively organically by the point that this thesis is approaching completion. In this regard, the temporality of research is again invoked. As the future of agriculture manifests unstoppably in countlessly abundant institutional, vegetal, or affective formations, those who were reflecting on the future with me fade into my past, and vice versa.

4. PHENOTYPIC INTENT

4.1 Introduction

This thesis's empirical core begins with this chapter on biotechnology. It focuses on forms of agricultural biotechnology such as genetic modification and gene editing aimed at breeding agricultural plants. I chose to begin with this topic because it allows a gradient to run through this thesis which begins with the genomic and ends with a thousand-hectare arable farm in Chapter Six. Fundamentally, to genetically engineer a plant in practice is to mobilise anticipatory knowledges about what the plant might become and how it might behave as a result of scientific intervention. Within this process the actual ontological self-expression of plants through time is a central mediating factor. Agricultural results are never guaranteed. Furthermore, such practical realities are inseparable from the ongoing contestation about what the future governance of such technologies should be and to what extent they should be considered *natural*.

This contestation has taken on a specific historical form in England in recent years as an informal coalition of scientists, policymakers and agri-business interests have advocated for an agricultural future within which gene-edited crops play a central role. In doing so they have mobilised contradictory understandings about plant genetics to legitimate and regulate these novel techniques. Within this they mobilise ontological

positions about the fabric of life itself and vegetal being. For some, the future of a prospective agricultural crop is reducible to their spatialised genetic fabric, for others plant genetics only partially explain phenotypical development. Yet both discourses exist on either side of debates surrounding the deregulation of such technologies. This chapter sets out to show why that is the case and to contextualise these views within the current agricultural conjuncture.

The historical contestation over the development and release of genetically modified organisms (GMOs) looms large throughout this chapter. European Union Directive 2001/18 EC defined a GMO as 'an organism … in which the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination'. In agriculture this has usually involved the introduction of exogenous DNA into plants in order to engineer certain prospective desired characteristics. Notably, in the last 20 years further scientific techniques able to engineer crop development have emerged that move beyond the transgenic approach typical of the production of GMOs wherein exogenous DNA from one species is inserted into another. And, although public interest has never reached the same intensity it did during debates about GMOs, Novel Plant Breeding Techniques (NPBTs) have also provoked criticism for the future agricultural systems they herald. NPBTs gained popularity as an umbrella term amongst scientific, regulatory and industry professionals in the 2010s to describe a range of emergent plant breeding methods. These NPBTs deploy techniques which complicate existing ways of regulating GMOs and articulate with changing developments in genomic understanding. The most widely discussed of such techniques is 'gene editing' and, in particular, those using the CRISPR-Cas9 method. As such these NPBTs have provided lawmakers across

Europe with a series of regulatory headaches about how to define them in relation to past technologies. As of early 2024, in the EU, Wales, and Scotland, this has been in order to forbid their introduction. However, in England this has been a question of justifying changing rules, resulting in legislation published in 2023 facilitating the deliberate release of plants produced by NPBTs into agricultural environments.

Discussion of the development and contestation of NPBTs shapes this chapter. As, too, do discussions of the NPBTs in question, and the questions their development has catalysed about how plant life should be understood and worked with. Within these discussions how we understand the inherent 'natural' capacities of plants has political ramifications that manifest themselves through discourses and the future-making knowledge practices (Adam and Groves, 2007) with which they articulate. As such, the discussion interconnects with the future-oriented analyses of this thesis, from everyday anticipatory practices of plant-breeding to the historical establishment of a cross-sectoral coalition that supports and legitimates a gene-edited agricultural future. In doing so, I build upon existing social scientific literature concerning gene editing by the likes of Borg and Policante (2022), Bain, Lindberg and Selfa, Macnaghten and collaborators (Macnaghten and Habets, 2020; Shah et al., 2021) and Maywa Montenegro de Wit (2019; 2022).

As a result of these interests, two fundamental and interlinked questions shape this chapter: firstly, to what extent do NPBTs, particularly gene editing, invoke a qualitatively transformed agricultural future, rather than an intensification of existing trajectories? And, secondly, how should we understand discourses of naturality, 'lively futures' (Adam

and Groves, 2007) and the ontological expression of genes into the future within these political economic questions? These questions, and the answers I offer, are pursuant to the objectives established already within Chapter One of this thesis. As regard the first question, I assert that the development of and expectations around NPBTs are best understood not as a transformative technological leap or harbinger of significant change, but an intensification of existing dynamics within the agri-food system that will shape and be shaped by extant discourses, institutions, materialities and power relations. In terms of the second question, I show how the shifting barriers between the 'natural' and the 'unnatural' are dialectically shaped by epistemological tensions in a sector driven by a quest for control over plant life as a vector for profitability. In doing so I demonstrate how such approaches, including those from a critical perspective, can be rejected in a way that maintains a historical and critical sensibility.

This chapter develops in three subsequent sections. The next section unpacks the history, logics, and practicalities of NPBTs, including much discussed gene editing techniques reliant on CRISPR-Cas technology. This history develops alongside efforts to theorise and historicise the emergence of NPBTs from a political ecological perspective. Within this history, the GMO debates of the 1990s and early 2000s are a recurring reference point, as too are the events following the United Kingdom's departure from the EU that have led to gene editing being deregulated in England. The third section uses empirical material I gathered to first embed historically gene edited futures in existing plant breeding practices and then to explore how they have been legitimated and legislated for in England.

This research included semi-structured interviews with scientists, campaigners, lobbyists, and farmers, as well as site visits to farms, trade shows and agricultural research facilities at a time when the regulatory approach to be taken towards these questions in England was yet to be finalised. Data is also derived from discursive sources as a result of the recent parliamentary processes of legislation and consultation that produced the Genetic Technology (Precision Breeding) Act 2023. These preceding sections allow the fourth section of this chapter to offer a conclusion that reasserts the arguments outlined above.

4.2 From Modification to Editing

4.2.1 Transgenic Histories

To understand the future of genetically edited crops in England it is necessary to understand the history of GMOs and the emergence of NPBTs. Existing research in this space can be augmented by human geographical and political ecological thinking. For example, work by Bain, Lindberg and Selfa (2020) and Shah, Ludwig and Macnaghten (2021) on discourses and imaginaries about the future of gene editing are too disassociated from the historicity, materiality, and spatio-temporal logics of these technologies. This section of this chapter builds on this work in a critical geographical fashion. I choose to start with the first genetically modified transgenic plant available to consumers: the 'Flavr Savr' tomato. The 'Flavr Savr' was manufactured by a company called Calgene and became available to shoppers in the USA from 1994 (Kloppenburg,

2004: 296). By 1996 genetically modified[4] tomato paste was available on the shelves of supermarkets across England and efforts by organisations like Greenpeace and Friends of the Earth to lobby against the deliberate release of transgenic plants as a result of their ecological uncertainties were attracting public attention (House of Commons Science and Technology Committee, 1999). Transgenic produce came to be known in the British press as 'Frankenfoods' (Miller, 1999). As Warren Belasco (2006: xiii) points out, the debates which emerged throughout the 1990s and into the early 2000s carried forward previous tensions and positions regarding the 'future of food' dating back to the 19th century. Central to these debates were questions regarding the cornucopian potential of modern interventions into the fabric of vegetal life. Important too in these discussions, as Belasco (2006) insinuates, were the tensions between those who labelled such novel technologies ruptural and unnatural and those who saw the continuity between these technologies and human seed selection in, say, early agrarian societies in the Fertile Crescent (cf. Kloppenburg, 2004). The legal ramifications of these tensions played out in court cases and governance throughout the latter half of the twentieth century (Stasi, 2023).

Around the turn of the century Barbara Adam (2005) made contemporaneous links between such technical developments and the regulatory futurities involved. Notably, Adam highlighted the ontological ramifications for the future created by these genetic interventions, stressing the capacity for these approaches to 'extend industrial societies' uncontrolled reach into the very, very long-term future' (2005: 213). For Adam, these

[4] See page 119 for a table explaining these terms in relation to each other.

developments represent a qualitative temporal shift from precedents in plant breeding. The processes involved were no longer tied to observations from the '*Merkwelt*' of observable empirical and phenomenal change, but rather interventions into the '*Wirkwelt* of nature's immanent processes – the realm of *natura naturans*' (Adam, 2005: 215). Foreseeing a future within which genetically engineered agricultural lifeforms became commonplace Adam (2005: 216) also accuses scientists of all possessing a desire to 'control' and 'master … the creation of nature to human design'. She argues this results in them overlooking emergent, more relational approaches to understanding ecology, genetics and, significantly, epigenetics (Adam, 2005: 219-220; cf. Meloni and Testa, 2014).

The transgenic agricultural futures which did materialise in vegetal forms were fundamentally shaped by the dynamics of the corporate food regime (Friedmann, 2005; Tilzey, 2017). By 1997, Calgene, the producers of the 'Flavr Savr', had been acquired by Monsanto (Thayer, 1997). Meanwhile, two plants perfectly designed for profitable industrial agricultural monocultures were produced: 'RoundUp Ready' maize and soy and Bt-resistant cotton. Kloppenburg (2004: 296) observes how the area cultivated with these GMO crops proliferated from 2 million acres to 167 million acres between 1996 and 2003.

Yet despite efforts in England at engineering engagement with the process and regulation of biotechnological innovation (Attar and Genus, 2014), public scepticism remained high and the deliberate release of GMO crops for agricultural purposes remained illegal. Public, civil society and media scepticism across Europe contributed to the ongoing

maintenance of a cautious approach. This included forms of direct action like the sabotage of crop trials (e.g. Van Dyck et al., 2022). By 2015, the only GMO-crop licensed across the EU was a Bt-resistant maize grown predominantly in Spain permissible under Regulation 1829/2003 (European Commission, 2015). No GMO crops were being grown in the United Kingdom at that time (Royal Society, 2016). Yet, 2015 was also the year in which the EU issued Directive 2015/452, giving member states greater autonomy of their own licensing for the deliberate release of GMOs. Notably, biotechnological approaches to crop development had been emerging for years prior to this slight relaxation that challenged and continue to challenge this governance regime.

4.2.2 'Novel Plant Breeding Techniques'

Emmanuelle Charpentier and Jennifer Doudna shared the Nobel prize for chemistry for their development of CRISPR-Cas9 gene editing processes in 2020. Press coverage at the time described the technology as 'genetic scissors' capable of improving agriculture via precise improvements to the genetic make-up of crops (Rincon, 2020). CRISPR-Cas9 is one variant of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) technology which facilitates targeted alterations of genes (mutagenesis). Its potential agricultural uses are not limited to crop development, the focus of this chapter, but also extend to genetic-editing livestock, useful microbes (Borg & Policante, 2022) and potentially even plant pests (Legros et al., 2021). This is because its origins lie in the discovery of tendencies within genomic responses found across a wide variety of species originally oriented towards the protection of bacterial life from viruses (Chen et al., 2019). In other words, the technique harnesses existing capacities of many lifeforms to respond

to threats via a shared defensive molecular response. As the Broad Institute (n.d.) explains, the process is as follows:

> 'CRISPR 'spacer' sequences are transcribed into short RNA sequences ('CRISPR RNAs' or 'crRNAs') capable of guiding the system to matching sequences of DNA. When the target DNA is found, Cas9 – one of the enzymes produced by the CRISPR system – binds to the DNA and cuts it, shutting the targeted gene off. Using modified versions of Cas9, researchers can activate gene expression instead of cutting the DNA. These techniques allow researchers to study the gene's function.'

RNA sequences are not the only vehicle for CRISPR delivery, and past techniques have relied on the usage of exogenous agrobacterium as a vector for DNA to be inserted into plants. However, advances in the technique make RNA-delivery via particle bombardment more accurate whilst also removing the need to breed out transgenic material (Chen et al., 2019) associated with agrobacterium.

Advocates of gene editing within the scientific establishment argue that it creates a pathway to a future agriculture in which plants are bred accurately at accelerated speeds with reduced costs. Precision begets control. This creates the possibility of engineering desired traits ranging from disease resistance to herbicide tolerance and improved quality (Kumar et al., 2021). These assertions of 'techno-scientific promise' (Joly, 2010) are boosted in the media landscape by declarations about both the technology's potential for the genomic editing of humans (Cyranoski, 2019) and its compatibility with

emergent modes of plant breeding which employ zeitgeist-appropriate 'big data' approaches like artificial intelligence (Schauenberg, 2023). What has really excited champions of the technology in the agricultural sphere, however, has also proved an ongoing headache to regulators: the capacity for the targeted and fundamental alteration of plant DNA without the (lasting, at least, in some cases) introduction of transgenic DNA. This distinction is, after all, in Europe at least, the basis for the rules around the deliberate release of GMOs in Member States, as will be discussed further below.

CRISPR-Cas9 emerged as one of the more promising elements of a range of NPBTs in the early years of the 21st century. The development of these techniques, I argue, has been shaped by contesting forms of political ecological futurity. Resultantly, various discourses regarding genetics and ontology have arisen from the publicization, discussion and regulation of these emergent techniques. Further, in the European context, their development has been intertwined with commercially driven responses to regulatory structures limiting the release of GMOs in European agricultural setting, including in England.

4.2.3 Genetic Techniques, Genetic Understandings

In 2013, the Advisory Committee for Releases into the Environment (ACRE) produced a report entitled '*ACRE advice: New techniques used in plant breeding*'. The document listed a range of approaches to producing 'novel' forms of plant varieties through breeding techniques which did not fit neatly into contemporary regulatory understandings of transgenic genetic modification. The ACRE document was not simply intended as a catalogue of emergent techniques. It was produced by senior academics

in the world of crop science as part of the ongoing destabilisation of the regulatory regime around GMOs in the EU resulting from the changing knowledge practices being performed with plants in laboratories. Those with influence over and interest in the report would have been working across diverse but articulated teleo-affective formations (Welch et al., 2020) of innovation and enterprise as they looked to create profitable, resilient, high-yielding crop varietals for diverse future agricultures. Institutions like ACRE serve, in theory, to mediate agricultural futures via 'expert' interventions that are at least partly oriented towards mitigating risks arising from capitalist innovation. On the other hand, however, the interested of their members are also mediated by the very real ongoing penetration of corporate interests into agricultural research, as highlighted by Levidow and Tait (1993) three decades ago in the case of ACRE (see also Levins and Lewontin, 1985: 209-225).

Despite these influences, I argue that Barbara Adam's (2005: 219-220) abovementioned assertion scientists are Prometheans simply look to control life requires nuancing. Maywa Montenegro de Wit's (2022) assessment of the more diverse and conflicting rationalities of scientists working with genetic editing techniques is more useful in that highlights the contested or contradictory aspirations of scientific innovation. This presence of ambiguities and tensions within the future imaginaries of agriculture re-emerges throughout this thesis. Within this chapter it serves as a reminder of the way in which technologies are produced by conflicting discourses and broader social relations, rather than scientists possessing the tools and capacities to exercise an unfettered scientific rationality of control over a perfectible future.

Table 1: Plant Breeding Techniques Glossary

Key Term	Meaning
Genetic Modification	Plant breeding involving the introduction of exogenous DNA material into a plant in order produce a transgenic organism.
Gene Editing	Plant breeding techniques including CRISPR-Cas9 that attempt to create changes within the internal logic of a genome of an organism via targeted intervention.
Novel Plant Breeding Techniques (NPBTs)	An umbrella term adopted prior to the dominance of CRISPR-based technologies which include gene editing as well other post or semi-transgenic plant breeding techniques
Precision Bred Organism	A term enshrined in legislation in England by the Genetic Technology (Precision Breeding) Act 2023 meaning an organism of which: *(a)any feature of its genome results from the application of modern biotechnology,* *(b)every feature of its genome that results from the application of modern biotechnology is stable,* *(c)every feature of its genome that results from the application of modern biotechnology could have resulted from traditional processes, whether or not in conjunction with selection techniques, alone, and* *(d)its genome does not contain any feature that results from the application of any artificial modification technique other than modern biotechnology.*

Further, the work of ACRE would have been shaped in England by the contemporaneous European rules regarding the release of plants for agricultural purposes. The crux of the legislation at the time was an attempt to dictate what should and should not be considered a GMO. Section (2) of Article 2 of Directive 2001/18 EC, mentioned above, defines a GMO as an organism that could not be produced through 'natural recombination'. This definition mobilised a popular and longstanding genomic imaginary with both socio-technical and spatial resonances that is central to understanding the future of NPBTs in England at a practical and a societal level. Within this understanding, as typified in Directive 2001/18 EC, the genetic code of an organism is understood as something cartographic and binary that can be altered in one moment, fundamentally changing the nature of the organism that will emerge phenotypically in the future and rendering the resultant organism 'unnatural'.

There is a connection to be made here between this epistemology and pursuant strategies of regulation and what Dominic Berry (2014) calls the 'dehistoricized gene'. For Berry (2014: 28), the dehistoricized gene represents the emergence of a post-Mendelian genetic epistemology which understands genes as 'hard, discrete, interchangeable, and combinable units' which pass from generation to generation with little modulation. This genomic and regulatory epistemology, then, lacks a consideration of the temporality and futurity inherent to the release and cultivation of plant life in agricultural processes. This is at odds with political ecological and human geographical common sense regarding life as process, change and, depending on your stripes, something best understood temporally (Brice, 2014), dialectically (Levins and Lewontin,

1985) or resulting from productive immanence (Grosz, 2005) as manifested through multi-species assemblages.

As Brice (2014: 945) asserts, such conceptions of genetic vegetal agency reproduce an anthropocentric linear time. This clearly resonates with the critique of mechanistic, scientistic futurity forwarded by Adam and Groves (2007) wherein modernist knowledge practices look to both make and flatten 'lively futures' into something comprehensible in the present. However, such a mechanistic conception has been subject to established critique. This comes not from human geographers, but from the scientists at ACRE who highlighted that many of the novel breeding processes listed above challenged the atemporal nature of Directive 2001/18 EC regarding what constitutes a GMO given plants could become, in theory, less transgenic over time after an initial intervention. These ideas of temporality, natural purity and natural recombination have shaped the foundations for recent efforts to legislate for the future in this space. Connections already appear here between regulatory approaches to biotechnology, futurity, the conflicting political ecological temporalities of agriculture and the tensions that come with drawing hard lines between the social and the natural as different understandings of how the future of vegetal life emerges at the genetic level are affecting how the future of agriculture landscapes is being contested in society and what is 'natural' becomes the subject of discursive consultation.

For the members of the ACRE committee in 2013, then, what was worthy of assertion was that this definition, and the techniques listed in the Annexes of Directive 2001/18/EC, had fallen behind the development of plant breeding practices which were

at times transgenic and *at times* not. Some of these techniques, particularly the emergent modes of directed mutagenesis foreshadowing CRISPR-Cas9, produced 'natural' combinations in a sense of the concept that leaned heavily on embracing the vital potentialities of genomic possibility and the capacities of plants to manifest themselves in ways conducive to enhanced agricultural production. In order to explain the scientific reasoning behind these appeals for a different regulatory approach, ACRE produced a complementary report (2013) asserting the epistemological bases for these techniques entitled '*Why a modern understanding of genomes demonstrates the need for a new regulatory system for GMOs'*. Central to this was an argument recognising the:

> '*high degree of natural plasticity and variability between genomes and epigenomes of individuals of the same species as well as within any single individual … it is clear that the introduction of one or a few genes into an existing variety of plant represents a very small alteration in comparison to that which exists across the natural spectrum.'* (ACRE, 2013b: 5).

The potentialities of genetic emergence as unveiled by developments in the life sciences are invoked here to justify regulatory evolution. Concurrently, over the years the barriers to agricultural releases of GMOs in Europe created an economic incentive to connect this departure from a more simplistic genetic understanding to this more open and immanent understanding of genetic futurity. There is a dialectical movement here, on the one hand in terms of the development of genomic understanding and, on the other, in terms of a future-oriented response by plant breeders keen to subvert regulation impeding capital accumulation. As one interviewee, Jane, a senior figure in the world of

plant breeding in the UK, put it, plants bred using the more modern versions of these techniques like CRISPR are:

> *"completely transgene free in the whole, the whole entire process, and the reason for that is because of uncertainty around regulation."* (JM Interview, 24.10.2022)

This shifting approach towards conceptualising genetics moves away from the logic of the 'dehistoricized gene', according to which the cartography of the genotype directly produces a plant according to the futural logic of linear time and causality. In other words, where phenotypical outputs are directly traceable to previous inputs in the form of human interventions. In moving away from this approach, ACRE critiqued a mode of regulation wherein a certain genetic configuration produces an (un)natural result due to the technique in question being considered to produce transgenic crops. Here we can see the tensions between different timescapes of regulation, plant breeding and agricultural ecologies emerging in a novel and complex way. The interrelations between genetic epistemologies, commercial imperatives and regulatory structures are also manifest. In the English context these developments have not developed as foreseen however, and, despite the changing understanding of genetics, the legislative approach adopted towards NPBTs has mobilised similar strategies for this kind of ontological delineation to those adopted by the European Commission at the turn of the millennium.

Further, these changing genomic understandings and their corresponding putative regulatory connotations have not been devoid of criticism. Shah, Ludwig and

Macnaghten (2021) highlight how advocates of CRISPR-Cas9 gene editing have, in fact, underplayed developments in how we understand genomic complexity and, subsequently, argue that we should actually regulate biotechnology in a more precautionary fashion as a result of this complexity, rather than permit new techniques such as directed mutagenesis as regulatory bodies such as ACRE were suggesting at the time. If we are to understand these processes further it must be acknowledged that these changes are socially shaped, contested and, to a degree, plastic dependent on the influence of other teleoaffective formations (Welch, 2017). In the context of my own research, this reality was deeply shaped by the vote in 2016 that triggered the United Kingdom's departure from the EU.

4.2.4 The Future Political Ecology of Brexit

The possibilities and results of Brexit have spawned diverse futural horizons, from the uncertain to the hopeful (Anderson et al., 2019; Anderson and Wilson, 2018). I believe the political ecological dimensions of these realities remain underexplored and attempt to begin to remedy that here. This sub-section sets out why and how advocates of deregulating NPBTs built on the above discourses to argue for their liberalisation. In doing so, it demonstrates how different understandings of the future rooted in the present were mobilised to justify a gene-edited agricultural future by different groups.

Firstly, for many farmers and landowners, potential access to NPBTs was one of the positive aspects offered by leaving the EU. For years, factors like the increasingly limited range of agro-chemicals available to farmers (Hopkinson, 2016) had drawn ire from the farming lobby, with neonicotinoids being the most high-profile example (Case, 2020).

Leaving the EU meant forging a new path with the possibility of more 'risk-based' agri-environmental regulation. This included allowing the NPBTs that the European Commission had classified as GMOs in 2018 (Purnhagen and Wesseler, 2021). In a speech to farmers at the Oxford Farming Conference, then Secretary of State for food, farming, and rural affairs Michael Gove (2018) presented access to gene editing technologies as a post-Brexit 'dividend' for farmers. Although by no means representative of the entire farming population across England, two major industry associations with significant interests in the rural economy supported the deregulation of plant life produced via NPBTs: the NFU, representing farmers, and the CLA, representing businesses and landowners. This was demonstrated by public-facing statements and consultation responses and was bolstered by supportive articles in the farming press via outlets like Farmers Weekly (Tasker, 2020) and the Farmers' Guardian (Kay, 2021). The reasons for this coalescing support in, if not the farming community, then their representative bodies can be attributed to a number of factors.

Significantly, Kyle, an interviewee I spoke with affiliated with a large industry group, highlighted how the current policy environment was feeding such appetite for promises about future increases in agricultural efficiency (KA Interview, 25.8.2022). Departure from the EU meant uncertainty and the removal of the CAP subsidy scheme upon which many farmers rely for profitability (Defra, 2018). As such they were required to think about new ways to maximise their viability. The prospect of gene-edited plants touted to require fewer input costs and produce greater yields arrived at an opportune moment (Defra, 2020b).

This reality is not just defined by expectations about the future, but by very material and contemporary political ecological problems farmers face in the present. For example, the destruction of crops by species considered pests is not an abstraction or a hypothetical situation but a lived and practical concern for plant-based food producers across England. Despite a relatively strong harvest during my fieldwork year, oilseed rape production, for example, has been blighted by cabbage stem flea beetle since the withdrawal of neonicotinoid-based products in 2013. This was mentioned by one farmer I interviewed, Spencer, in the context of necessitating future plant breeding solutions (SS Interview, 11.7.2022). As too were the difficulties faced by English producers of sugar beet by another interviewee who worked for a trade association associated with crop protection products (NS Interview, 10.5.2022). Unsurprisingly, given his position he suggested that regulatory overreach regarding plant protection products was a significant inhibitor of farming productivity. Gene editing represents a coherent fix in terms of the internal logic of industrialised farming. The social-ecological logic of gene editing and the dehistoricized gene is coherent with the vegetal epistemology already mobilised by many farmers involved in agricultural production in England along the lines of the 'robotic futurity' (Rezvani, 2021) discussed in Chapter Two.

Many of these imagined trajectories and motivations are shared with agri-businesses across the supply chain, who anticipate future profits from gene editing's speed and novel horizon of vegetal possibility. During my interviews I spoke with representatives of industry bodies for plant breeders, plant protection product manufacturers and bioindustry more broadly. Each positively reasserted the discourses which have come to differentiate NPBTs from GMOs in terms of risk reduction and their future benefits.

Arguments regarding international competitiveness and attracting capital investment to the English biotechnology sector were also mobilised. As the consultation response from the Bioindustry Association (2021) put it:

> 'by diverging from the CJEU's unscientific ruling, the UK would send a positive international message that the UK wants to have a science-based regulatory system, which in turn would enable more start-ups to be created from our excellent science base, attract global investment, and help deliver on the Government's levelling up agenda.'

This proposition suggests that NPBTs will, in some way, actually serve to break down the corporate control enjoyed over plant varietal breeding by big firms. The corporate domination of seed breeding is well recognised in the academic and grey literature (e.g. Ajates, 2020; IPES-Food, 2017). Advocates of NPBTs like CRISPR-Cas9, however, argue that these big firms benefit from complex and onerous regulatory regimes which make trialling and licensing new plants overly burdensome for smaller and medium-sized enterprises (SMEs) in the sector. The relative cheapness and speed of gene editing, for example, creates the possibility for smaller firms to enter and 'disrupt' the sector. As one interviewee told me:

> *"At the moment, while it's so heavily legislated and so expensive. You know, [gene editing] remains a technology that the only the big boys can afford to use. [The legislation] does give … more potential for the SMEs of our membership."*
> (HR interview, 24.10.2022)

This sentiment is possibly true. However, I believe it will create a similar dynamic to that which exists in the agri-tech food space where smaller start-ups and their intellectual property are hoovered up or agglomerated by larger players (Montenegro de Wit, 2022; Fairbairn and Reisman, 2024).

All told, the liberalisation of the rules in England regarding the deliberate release into the (agricultural) environment of organisms produced via NPBTs has proceeded relatively quickly and, seemingly, without effective resistance. In January 2021, a large public consultation had opened regarding the future approach to be taken towards the technology (Defra, 2021a). Whereas a majority of businesses (64%) and individuals (88%) responded that NPBTs should continue to be regulated as GMOs, a majority of public sector bodies (55%) and academic institutions (58%) supported change. This perhaps complicates the hypotheses that the smooth passage of this reform resulted from a combination of public support and/or exclusively private interests. As regards the question of risk, the view that NPBTs were *less* risky than GMOs was, in fact, a minority position across NGOs, academic institutions, public sector bodies, private firms, and individual citizens (Defra, 2021b). Despite this mixed response from stakeholders, the government's proposals swiftly became a draft bill which then passed into law without significant changes.

By January 2022 the rules for conducting research with gene editing technologies had been relaxed (Defra, 2022a). And, ultimately, following some public contestation and a little parliamentary back and forth, the Genetic Technology (Precision Breeding) Act 2023 received Royal Assent and became law in March 2023. The legislation will be explored in

depth below. In a nutshell, it signifies a departure from the approach for governing the release of plants (and animals) produced by biotechnological methods like CRISPR-Cas9 as currently taken in the EU. It achieved this via the invention of a new socio-legal category for plant life: the 'precision-bred organism'.

The move to liberalise these rules did not unfold totally without resistance. Although the public opposition and press interest achieved by campaigns against GMOs was never reached, a few organisations contested the legislation along lines of ecological uncertainty and food systems justice. Objections were also made regarding the prospects legislating in such a manner would have in terms of both the international and intranational movement of agricultural goods. I would argue that the reasons for this failure compared to historical resistance to GMOs include, but are not limited to, a lack of interest in the risks from the mainstream print media, a government set on quick Brexit dividends, the existing progress of English research institutions in developing these technologies and the success of relevant corporate players in rendering the discourse both simple in terms of a focus on precision and complex in terms of the relevant practicalities of gene editing in practice. Despite these shortcomings, public support has proved mixed, however, as shown by research commissioned by the Food Standards Agency demonstrating perceptions towards genome edited food (Ipsos MORI, 2021) and the consultation discussed above. Enthusiasm, however, has proved higher for consuming gene editing plants rather than animals, which are also included in the scope of the legislation (Ipsos MORI, 2021).

So far, this section has looked to provide historical context to questions about the future of gene editing in England. Firstly, by explaining, exploring, and comparing GMO production and NPBTs, the techniques they require, how they are regulated and the understandings of genetics which underpin them. I then connected these considerations with Brexit, the conjunctural event which facilitated the deregulation of NPBTs and the future-oriented discourses, interests and imaginaries which underpinned such deregulation. Within this moment, the future deliberate release of crops produced by NPBTs has felt often like a *fait accompli* given the weight and foresight of the coalition supporting the changes. This represents the way exiting the EU catalysed grand futuristic imaginaries of societal and agricultural change. But, in this instance, those imaginaries were subtended by ongoing technical disputes which will be explored below. In the conclusion to this section, I look to draw these questions together with explicit reference to some of the theoretical approaches in Chapter Two.

4.2.5 Reflections

The discussion so far demonstrates the entanglements and relationalities between the horizons of the future-making practices of science, law and economics highlighted by Adam and Groves (2007). This is shown in the abovementioned tension between discourses which, on the one hand, stress the complexity and variability of life's emergence as more-than-genetic and, on the other, a well-established epistemology of the genetic 'blueprint' or the 'dehistoricized gene' (Berry, 2014). As I suggest above, this tension must be historicized and understood as an ideological question. It has been influenced in part by the past regulatory approaches towards GMOs in the EU. As the future-oriented knowledge practices of the life sciences became entangled with legal

futures, approaches to genetic engineering emerged that short-circuited the discursive delineation of what constituted a 'safe' or 'natural' future in the form of NPBTs. Yet this was not just related discourses folding over and into each other. Within this interplay between knowledge practices were the teleo-affective realities of scientists looking to secure future funding through embodied scientific techniques, farmers looking to remain viable within a limited horizon of agronomic possibility and bureaucrats attempting to translate the balance of forces between institutions and interest groups into appropriate regulation.

On a parallel tangent that reinvigorates the discussions regarding approaches to more-than-human agency and historicism in Chapter Two, Büscher's (2021; 2022) assertion that the non-human turn amongst social scientific scholars is motivated by conjunctural dynamics of increasing alienation under late capitalism is an interesting foil for exploring changing ontological understandings mobilised by scientists working in this space. Along these lines, Adam (2005: 215) makes the distinction between traditional plant breeding and genetic engineering moving from a future-oriented intervention from the observable *Merkwelt* to the immanent and ontological *Wirkwelt*. These ideas are drawn out in greater detail in Adam's later work with Groves in which they make more explicitly ontological arguments about the world's unfolding towards a 'lively future' should be understood (explored in greater detail in Chapter Two). Since their time of writing, the discourses of genomic science and complexity discussed above can be argued to resonate more with their writing on *natura naturans*, immanence and lively futures.

In other words, the ACRE paper on genomics above, emergent thinking on epigenetics (Meloni and Testa, 2014) and relationalities within the genome (Shah et al., 2021) all represent an approach to genetics that is less 'dehistoricized' and more attuned to the immanence and possibility of life. Borg & Policante's (2022: 135) suggestion that practitioners of technoscience are finally beginning to recognise the limits of their control over nature resonates here. What is significant, however, for the discussion below is how related and contradictory genetic understandings have simultaneously been mobilised in ways that legitimate a future within which gene-edited crops shape English agricultural landscapes, with profitable ramifications for plant breeders and agri-business.

Finally, Jason W. Moore's arguments about the 'end of the road' (2010) for neoliberal agriculture and the quest for various socio-technical and social-ecological fixes for contemporary food production in the face of the 'second contradiction' (O'Connor, 1991) of capitalism are also worth of note. Future gene-edited crops will be produced to offset agronomic and climate crises co-produced by their own designers and realisers. In straightforward terms, genetic editing can be seen to have emerged within the relations between the regulation of GMOs in the EU, the future prospects of an industrial agricultural system facing unprecedented environmental uncertainty and the permeation of digital technologies and computing into the rubric of agri-food capital (Prause et al., 2021).

As a result, I argue genetic editing is better understood as an *intensification* (Büscher, 2021; 2022) within capitalist social-ecological formations rather than something

qualitatively different, despite the quickened and extended social-ecological temporalities it will facilitate as highlighted in Adam's (2005) earlier analysis of GMOs. Borg and Policante's (2022) argument that CRISPR-Cas9 will facilitate a step-change in biotechnology from the lab to the factory is thought-provoking in how it shows the capacity of these emergent technologies to further subsume vital 'lively' processes within circuits of capital. But that kind of subsumption does not represent a step change, I argue it is merely taking on new legal, spatial, and practical forms.

The questions of genetic expression and the socio-natural that emerge from the above discussion also necessitate a return to the aspects of Chapter Two that looks to name and historicise the imbalanced yet dialectical relations between human and plants in agricultural systems. The work of Brice (2014) is again important for asserting a need to understand agency in assemblages like agriculture (or in his case viticulture) as relational. This recognition requires consideration of temporalities and *temporalization* in social-ecological life, rather than the mechanistic futurity of the 'genetic blueprint' (or 'dehistoricized gene') which he criticises for reproducing a rationalist, humanistic understanding of vegetal agency. This is complicated and tested, to an extent, by the case study in question here, given the extent to which 'precision breeding' techniques claim to, in fact, materialise such a dehistoricized understanding of genes and the capacity to engineer their futures through spatially conceived genomic interventions. This tension leads to two important questions: firstly, what is it within vegetal life that makes the ways of manipulating or steering their phenotypical expression possible? And, secondly, what can discussions about deregulation in England tell us about how plants are understood by scientists and lawmakers?

As regards the first question, I offer an initial reflection here that requires further scholarly attention. In the first instance, it is interesting to note the differential capacities interventions concerned are forecasted to have across taxonomic kingdoms. CRISPR-Cas9 relies on the fundamental grammar of living materials at a level that is so historically and evolutionarily engrained in the emergence and transformation of life that the same technique can be used effectively not just plants, but also bacteria and with humans (which are of course allegedly specifically complex). At the other end of the spectrum, many plant breeding techniques mobilise capacities very particular to vegetal life. One specific example cited in the ACRE paper, grafting non-GMO scions to GMO rootstock, harnesses the unique capacities of plants to be hybridised by grafting (cf. Fleming, 2017). Along these lines, in order to better understand the role of materially working with plants within these processes, I turn to the material practices of plant breeding which underpin the above discussions of genetic epistemologies and regulation. This also connects with further empirical engagement with the second question above.

4.3 From Lab to Legislation

4.3.1 Plants Under Scrutiny

It is May 2022. It is unseasonably hot and there are many more hot days to come. I am being shown around one of England's pre-eminent agricultural research facilities by Jenny, a senior technician involved in the daily maintenance and evaluation of diverse

forms of experimental plant life. Whilst we walk and examine our surroundings, we talk about working with plants, CEA, genetic technology, and the future of agriculture in general. Plants are different to animals, Jenny informs me, in ways that mean that gene editing plants should be allowed and encouraged. This is because plants are less like humans than animals and therefore the risks presented of any kind of crossover impacts on human health were notably lower. Jenny did not have a doctorate, she informed me, but did have decades of technical expertise in caring for the plants she was made responsible for by others working in the nearby laboratories. Although she recognised the diverse and astounding capacities inherent to plants, this lack of anticipated similarity with humans in terms of what plants *might* become was sufficient to dismiss risks associated with their genetic alteration.

The built environment of the plant-rearing facilities within which she operated had a distinct spatio-temporal logic. The future of agriculture was being trialled here in small clusters of plants. Jenny told me their methods had improved to such an extent they now only needed to grow a few dozen plants for a successful trial. We visited growing rooms that resembled small bank vaults. They seemed inefficiently used spaces given how few cultivars of wheat were growing inside. We proceeded to large greenhouses with more leafy and diverse vegetal residents, all seemingly growing under the auspices of one harried-looking technician. There is both an intertwined scientific and economistic biopolitics in play here. Different potential cultivars are assessed for their future viability as participants in the industrial food system. Their vigour, speed and fortitude are considered under controlled circumstances intended to give a clear idea of what these plants might be like in the future, initially in field trials, then, ultimately, in competition

with other forms of vegetal life on the open market and the managed field. Gene editing will, in theory, streamline these processes even further.

Each plant does what it can to live as well as possible in the circumstances provided. In the fields surrounding these indoor research facilities, trials of GMO crops have taken place for decades according to strict rules regarding the size, location, and duration of such undertakings. One interviewee I spoke with was Clive, a relatively prominent academic with decades of experience in crop development. He recounted stories about how such trials had become sites of heightened contestation in the 1990s and 2000s. Vandalism and protests necessitated heightened security designed not to keep experimental forms of vegetal life in, but to keep human life out (CB Interview, 28.11.2022). Gene editing trials currently underway had started a few years previously and had not attracted anything like such hostility. They had not roused sufficient future-oriented affective atmospheres to instigate direct action.

My reflections on this visit are important for fleshing out two directions which other scholars have not explored via empirical research. Firstly, considering plant breeding as an embodied and teleo-affective series of different knowledge practices helps reconcile and interweave the political ecological temporalities and futurities of the industrialised contemporary food system and the people working within it. It also brings into focus the diverse forms of vegetal life striving towards their own futures within these systems. Secondly, I connect this interest in the practices and regulations of plant-breeding with future-oriented discourses concerning the release of genetically edited crops in England in the years to come and the above consideration of the discourses and events which

made this possible. These connections lead to a number of observations and assertions. Firstly, as set out above, plant-breeding is a process which operates across interlocking scales of futurities and expectations. These teleo-affective formations (Welch et al., 2020), in turn, shape the material-semiotic assemblages which facilitate their unfolding in research stations' controlled-environment spaces, in field trials and on farms across England. The work of plant breeders and technicians is saturated by affective atmospheres of hope and uncertainty (Bryant and Knight, 2019) that permeate the experience of watching, maintaining, and anticipating the development and health of emergent prospective cultivars.

As Jenny claimed to me during our time exploring her institution's growing spaces, her decades of experience meant that she could tell in advance of her scientific colleagues when plant varieties were not materialising the phenotypic characteristics they had been intended to manifest. This was not couched in any discourses of inter-species understanding or non-representational sensibility of becoming together with plants. Jenny's positivist inclinations gave me the impression she understood this capacity as rooted in the transferal of past visual and tacit experience on to an anticipated future. This was for her about practical expertise, assessment, judgment, and unmet expectations. Within these spaces plants failing to meet their genetic potential were destroyed. However, when others impressed technicians and scientists with their performance and vitality, they were given the chance to live and procreate, subject to further assessment in the future. This spatial form sutures the temporalities of plants' own development with the competitive temporality of foreseen profitability and agricultural vigour. And, further, the spatial forms created look to balance serving the

needs of both plants and technicians. They are optimised for plant wellbeing, controllable variables, and containment for the prevention of cross-contamination. In this sense, both of whom are subject and object (Levins and Lewontin, 1985) of the making of these techno-scientific ecologies.

Yet plant-breeding technicians are but one node in the processes which take agricultural plant varieties from laboratory to market to field to stomach. In addition, a diverse array of scientists, research managers and others within universities and private companies operationalise a variety of plant-breeding methods which the new English legislation defines (in contrast to NPBTs) as 'traditional' plant-breeding techniques. Within this assemblage, diverse materialities and more-than-human contributors of course act, although, to paraphrase Marx, not under circumstance of their own choosing. These 'traditional processes' range from long-established techniques such as sexual fertilisation and grafting to relatively novel techniques which emerged in the 20th century such as induced mutagenesis (via, for example, irradiation) or polyploidy induction (via the introduction of chemicals). The way in which these techniques are positioned in relation to NPBTs is discussed further below. But what is significant for this discussion is how the temporalities and futurities of these processes as experienced by people and plants within the development will co-determine the future introduction of gene-edited crops into English agricultural landscapes.

Much current plant-breeding via these traditional methods involves interventions in plants via an assortment of mechanisms intended to induce desirable genetic changes in plants. The most popular techniques like crossbreeding and induced random

mutagenesis require screening over time across generations and backcrossing in order to breed out introduced elements and ensure stability. These stages can prove time-consuming and can cause crop development to last for years and, correspondingly, become increasingly expensive (Gao, 2021). The temporal cycles of reproduction and gene expression here mesh with the imperatives to bring potentially profitable cultivars to market as soon as possible. The spatio-temporalities of containment and competition in places like Jenny's need to be further finessed. To return to the distinction established by Kolinjivadi et al. (2020), *time* and *Time* again come into conflict.

Brice's (2014; 2021) assertions around the relations between vegetal labour and temporality are also manifest in a controlled microcosm here, given his discussion on how more-than-human times play a role in mediating and delineating value in viticulture. As discussed below, genome editing will putatively serve to accelerate these processes and reduce costs whilst increasing 'precision' compared to existing plant breeding techniques. Plants' own movement towards the future as a mode of living permeates the spatio-temporalities, discourses, and infrastructures via which these processes take place. At the Institute they have mediated this reality to the greatest extent possible via controlled growing spaces (see Chapter Five). But altering, breeding, and assessing plants creates pockets of time where the manifestation of plants' genetic expression is the vital factor during which plants must be waited on and observed. Accelerating and finessing this process grinds down the probabilities of failure and economic losses, but the foundational reliance on vegetal self-expression remains the same. Gene editing looks to further mediate the significance and uncertainty of these temporalities of phenotypical expression via improved a priori technical interventions into plants.

In this regard, my interviews with crop scientists also led to generative discussions about the role of chance and luck within these practices. Perceptions and experiences of chance, luck and probability are futural experiences, the geographies of which are underexplored. These concepts become even more interesting when interwoven within the historical natures created by plant breeding. Existing geographical efforts at considering chance have concerned 'luck' in relation to variegated spatial impacts on human life expectancy (Kearns and Reid-Henry, 2009) and, perhaps most notably, probability in the realm of anticipatory governance and securitisation (Amoore, 2013; Anderson, 2010). However, in interviews I conducted with plant scientists, one working in the academy, the other for a start-up employing gene editing with machine learning, the role of luck and chance emerged as a theme which resonated with the questions at the heart of this thesis concerning the openness of the future and the political ecology of possibility. As Dylan, the scientist involved in the start-up using machine learning, put it:

> *"Conventional breeding is chance, right? You're relying on biological chance, so, the mixing of genetic material during sexual reproduction… but also external chance … background radiation… issues with plastics, chemicals, there are so many things that can cause genetic changes and it's all based on random chance. Whereas what we do [gene editing] is planned, accurate, specific, and checked after the fact…"* (DP Interview, 6.9.2022)

There is much of interest to a political ecological approach to futurity within this, and the theme of control (or a lack thereof) re-emerges as central to understanding the logic of these future-making knowledge practices. As does the complex question of epigenetic

influences on phenotypical development Dylan hints at in his comments regarding ‘external chance’. What is of primary interest here, however, is the way in which these comments speak to the temporal and future-oriented dimensions of conventional plant breeding as a social process that relies on an uncertain and anticipated genetic futures as manifest across types and generations of plants measured against their genetic potential. Genetic potential is forecasted and hoped for by crop scientists involved with initial interventions, assessed by plant technicians in controlled growing and, if successful, meets its ultimate arbiter in the marketplace. These questions of chance and the practicality involved in all life sciences research (and agricultural production) are an initial effort at provoking political ecological consideration of people’s everyday interactions with luck and probability within those sectors and their historical unfolding and social-ecological flux and permanence.

But in terms of how political ecological flux is managed and governed the concept of human *control* and the mediation of chance is integral to agricultural systems. This links back to the consideration of control in Chapter Two, where control is framed as the subsumption of nature by capital (Mau, 2023), including the ecological simplification inherent (Barua, 2023) to agriculture and intensified in the Plantationocene. But control is also, of course, the capacity of plants as ecology-making beings (Levins and Lewontin, 1985). The intensification of control over plants via gene editing represents an attempt to bolster future profitability of vital capital and the ‘mutant ecologies’ (Borg and Policante, 2022) established within contemporary industrial food production. As recognition of genetic indeterminacy develops, so too must the apparatus of control over such uncertainty in the way vegetal life emerges and behaves in agricultural systems.

In fact, the heighted concentration of control over crop varieties has contributed, according to some scientists, to the need for gene-edited crops to diversify agricultural biodiversity. This will also render, in theory, foster greater resilience via increased ecological variety when faced with, for example, plant pests. In particular, as Gao (2021) highlights 'elite' germplasm lines are limited in their future potential given their tightly bred capacities. Dylan discussed this reality too in our discussion, pointing to the need to 'buffer' the food system by using gene editing to speed up the process of breeding in traits from the wild cousins of existing agricultural species in the future (cf. Graddy-Lovelace, 2020). In these scenarios excessive control over crop varietal selection and breeding has resulted in simplification that has created a need, in the eyes of some, to re-introduce complexity and specificity to the plants being bred via gene editing. Comparisons here with the tenets of the agro-ecological vision concerning agro-biodiversity and local specificity cannot go unnoticed (cf. Montenegro De Wit, 2022)

The conception, breeding, development and roll out of new crop varieties is not, however, something that can remain forever in the laboratory, or the sort of controlled environments found at the Institute where Jenny worked. At some point broader field trials are required, and so too are farmers willing to try to introduce new cultivars or growing strategies on farms. Regulators and industry bodies also bring different temporal horizons, expectations, hopes and anxieties into the teleo-affective formation associated with the development of a singular cultivar. Via these processes the futures of agricultural landscapes are determined at desks, in ministerial offices and in boardrooms far from any plant specimens or laboratories. This spatial disaggregation stretches where the future is decided, but not uniformly, concentrating capacities in

different nodes with different forms of expertise lent different weight in balancing future options. These tensions and contestations are distilled in the Genetic Technology (Precision Breeding) Act 2023 in a way that represents their (temporary) overcoming from an English legislative perspective. As such, they are worth exploring in detail as they also facilitate a return to the tension between understandings of life as determinable and as open.

4.3.2 Legislating Genetic Complexity

As discussed above certain members of the scientific community have argued that the existing legislation regarding plant breeding techniques is overly proscriptive given the advances set out, for example, in the ACRE paper on NPBTs. The new approach developed by the Westminster government, however, has been complimented by stakeholders for its breadth, scope, and perceived flexibility for incorporating current techniques. As Clive told me:

> "*But just about everything you can do [with] gene editing at the moment would be allowed under that bill… Defra are doing a great job.*" (CB Interview, 28.11.2022).

This sub-section focuses on the legal geographies (Delaney, 2015; 2016; 2017) mobilised by the legislation, with a particular emphasis on the relation between the legislation, the future and the understood capacities of vegetal life and genetics writ large.

The first section of the Genetic Technology (Precision Breeding) Act 2023 alone raises enormous theoretical questions. It has proved the focus of much discursive contestation

amongst stakeholders. Much of this arises from the establishment therein of what constitutes a 'precision bred organism'. 'Precision bred organisms' are a new legal category of lifeform which, according to the legislation, are created using 'modern biotechnology'. The definition of 'modern biotechnology', derived from the Genetically Modified Organisms (Deliberate Release) Regulations 2002, is capacious, encompassing techniques involving 'the insertion of nucleic acid molecules', such as CRISPR-Cas9, and the 'direct introduction into an organism of heritable material prepared outside the organism including micro-injection, macro-injection and micro-encapsulation'.

However, lifeforms created using these techniques are subject to further requirements in order for organisms to qualify as 'precision bred'. For this to be the case, the following criteria must be met, each of which will be subsequently considered in turn:

> '(b) every feature of its genome that results from the application of modern biotechnology is stable,
> (c) every feature of its genome that results from the application of modern biotechnology could have resulted from traditional processes, whether or not in conjunction with selection techniques, alone, and
> (d) its genome does not contain any feature that results from the application of any artificial modification technique other than modern biotechnology.' (Genetic Technology (Precision Breeding) Act 2023)

Firstly, stability, as a concept, raises questions around futurity, immanence and change within social-ecological configurations including agricultural plants. It also brings these questions into dialogue with the institutions which shape the forms of plant life that permissible within English agricultural systems. The legislation defines stability as the capacity of traits to be 'propagated whenever the organism is reproduced, whether by sexual or asexual reproduction' (Genetic Technology (Precision Breeding) Act 2023). This is a simplification of the definition established in the Plant Varieties Act 1997. The relative stability and demarcation of the phenotypical expression of plants is a vital factor for their licensing and the presence of this idea within the legislation articulates with the above discussion around how contemporary plant breeding will shape the deployment of gene-edited crops in the agricultural landscape. The question of stability has diverse resonances in the world of plant-breeding and agriculture, as complicated by the presence, for example, of F1 hybrid crops (Curry, 2023) in agricultural systems, which are designed to create *instability* insofar as they do not breed true. Within the F1 hybrid plant agricultural genetic control and 'robotic futurity' (Rezvani, 2021) flashes brightly but burns out quickly. In this regard, the argument made by one interviewee I spoke with questioning the validity of stability as a concept altogether is significant. Deborah, a prominent anti-GMO campaigner told me:

> *"that concept of stability is nonsense … if they're sexually active, then all changes can become unstable again. Genetics is fundamentally unstable… that's why we have such an extraordinary and beautiful variety of life on earth."*
>
> (DY Interview, 27.6.2022)

Here we see the invocation of discourses acknowledging the unpredictability of life and its openness, discourses also used to promote the epistemological developments associated with forms of new genomic thinking actually used to *criticise* the legislation. This is similar to the assertions of Shah, Ludwig and Macnaghten (2021) regarding the legitimisation of gene editing technologies. However, the legislation itself mobilises the same static genetic epistemology that has informed past European regulation as discussed above.

Here we can begin to develop a critique of the way in which the legislation translates the socio-technical imaginary associated with genomic editing of crops into material regulation of the future via the knowledge practice of law (Adam and Groves, 2007). This is true of both this idea of stability as well as the previous clause, which delineates what constitutes a precision-bred organism according only to the techniques mobilised in the present rather than their future outcomes as plants. This idea of 'process' rather than 'product' based regulation has been criticised by scientific bodies like The Royal Society (2021) and the Royal Society of Biology (2021). This conception of plant life as being reducible to the mechanism via which it is produced is a result of the need for the law to flatten the future into something bureaucratically comprehensible. This is the futurity of law, defined by a mechanistic conception of life, criticised by Adam and Groves (2007). Yet it is an approach to the future rejected by natural scientists at ACRE.

Yet despite the rejection of process-based understandings of biotechnology, the robotic or machinic futurity of plants continues to echo in inputs from the scientific community on the question of stability. This is associated with an ideological need to downplay the

risks involved with introduced genetically edited plants into agricultural landscapes. It takes shape through reference to the certainties afforded by the 'precision' of NPBTs and an attendant suppression of any consideration of the actual 'living futures' of agricultural socio-ecologies. Contrary to this, Deborah asserted a position more attuned to relational understandings of vegetal political ecologies, foregrounding plants' 'fundamental' role in ecosystems:

> *"With plants [the risk is] massive … because they they spread their pollen everywhere … plants are the fundamental life form in terms of the future … between plants and animals, plants are much more fundamental."* (DY Interview, 27.6.2022)

The invocation of the future here involves an anticipatory dimension that affords substantial influence on to plants in changing agricultural landscapes thanks to the spatio-temporality of how they reproduce and their place in trophic cascades. This view leans into the growing emphasis of vegetal capacities emergent in plant-oriented philosophy (Marder, 2013) or more-than-human geography (Barua, 2023). Again, we see, in ways that are not always straightforward, connections between academic perspectives and the discourses of stakeholders in this sphere.

After stability, the next aspect of the legislation to be considered is the idea that 'precision bred organisms' must represent vegetal lifeforms that, in theory, could have been bred via traditional methods. Whereas an emphasis on stability downplays the capacity for change and unpredictability in plants, arguments mobilised in favour of

deregulating gene editing reliant on equating the outcomes of NPBTs with traditional breeding methods does the opposite. This understanding has formed a central crux of efforts to demarcate 'precision-bred' organisms from their genetically modified predecessors. For example, changes produced using CRISPR-Cas9 are portrayed as being internal or immanent to the *a priori* genetic capacities of agricultural plants, as opposed to changes via transgenic alteration using exogenous DNA. As the NFU (2023) put it:

> 'Gene editing is a group of technologies that make changes within the organism's own DNA by moving, adding, or deleting precise pieces of genetic material. Such changes also happen through conventional breeding techniques or in nature.'

This approach, however, has attracted criticism from both opponents and supporters of the deregulatory process. This is because it implicates a profoundly speculative logic of genetic potentiality into a broadly drafted piece of legislation that, by definition, necessitates enforcement in the future. When asked about the future ramifications of enacting this idea in a parliamentary evidence session, Michael Edenborough, a barrister specialising in intellectual property replied:

> 'could have resulted from' is staggeringly imprecise. Is that 'likely'? Is that 'very possible'? What level of probability is it? … because of the breadth of the way in which things have been defined … you have uncertainty built on uncertainty…'' (Wildlife and Countryside Link, 2022)

Yet, such considerations do not dig into the connotations of using genetic potentiality as a reference point for regulatory legitimacy. Here two discourses are mobilised by the scientific community which test the logic of this assertion in different ways. The first, as vocalised in the consultation response from the Royal Society of Biology (2021) emphasises a more open ontological horizon of genetic change possible via 'traditional' breeding or 'natural selection', including between species via horizontal gene transfer and epigenetic influences. The example of initially exogenous DNA recurrent in the genome of all sweet potatoes is used (Royal Society of Biology, 2021). Within the logic of the legislation, however, such unanticipated changes involving epigenetic factors are not considered part of the rubric of traditional breeding transposed on to 'precision breeding'.

In a different direction, Robin Lovell Badge, of the Royal Society gave evidence in a parliamentary session which asserted the following:

> 'If you have two genes right next to each other in the genome and they both need to be altered … you can do that with genome editing, because you can target both genes at the same time, but to do it by conventional traditional breeding methods may be impossible … it would certainly take an awful long time to ever get both changes together in the genome, because when two genes are next to each other it's very hard to separate them in normal breeding processes.'
> (House of Commons, 2022)

The invocation of time here is important given, as expressed in the law, with sufficient time and genetic flux in the future, such changes could be possible via, for example, crossbreeding and thus are more natural, supporting the adopted regulatory approach despite assertions from the scientific community they would be incredibly unlikely. Also of note is the return of invocations of chance and probability as future-oriented political ecological motifs and the cartographic understanding of the genome referenced earlier in the chapter.

Three considerations *not* to be taken account of when determining whether something could have been produced by traditional breeding are asserted in regulation (5) of the act: '(a) the copy number of the feature, (b) its epigenetic status, or (c) its location in the genome'. Point (a) refers to the number of times that a feature edited in repeats in the genome. Points (b) and (c), however, can be seen as responses to the considerations above, first regarding the epigenetic potentialities of 'traditional breeding' (and, to an extent, NPBTs) and, secondly, squaring the circle highlighted by Dr. Lovell Badge in his parliamentary evidence by simply saying what he asserted should not be considered relevant.

Ultimately, what is demonstrated here are tensions regarding the instrumentalization of diverse genetic discourses and conceptualisations of life towards legislative, political economic ends. To return, again, to Adam and Groves' (2007) conception of law as a future-making process, this instance seems a particularly goal-oriented teleological compromise. Historically valorised discourses of tradition and naturalness are manifested in a very particular way to assert the desirability and safety of these new

techniques. This is in view, perhaps, of the scepticism often manifested by the public towards those seen to be tinkering with the fabric of life itself, as discussed by Shah, Ludwig and Macnaghten (2021).

The final clause of section 1 of the legislation to address builds further on the preceding tensions and argument, as well as clearly linking gene editing's future to the history of GMOs. Here, the idea of exogenous material is invoked, highlighting the ongoing need to distance these techniques from their transgenic forebearers. Yet, the role of exogenous DNA within contemporary applications of CRISPR-Cas9 to agricultural plants was a source of uncertainty amongst participants during my research. Deborah, the campaigner mentioned above discussed how *"the bill defines that no no foreign DNA can be left so they have kind of acknowledged that it goes in"* (DY Interview, 27.6.2022)

Yet the question then becomes similar to the tensions in the ACRE paper discussed above. As, Clive, the crop scientist, told me, many of the plants in development now often start with transgenic material within them which can be subsequently bred out, as he told me some had been done via field trials now running for several years. This results from the common usage of agrobacteria as vectors for the CRISPR-Cas9 process. Yet, more recent developments in gene editing technology no longer necessitate exogenous DNA being introduced, relying instead on RNA (Gao, 2021). This reality serves as a reminder of the way in which legislation must not only deal with the futurity and transformation of plants, but also has to at least attempt to account for the dynamic changes in capitalist industrial agricultural science that characterise regulation in this space and have contributed to the establishment of these questions of 'outdated'

legislation as a matter of concern amongst the coalition that supported changing the regulations in England. In my interviews and in the parliamentary proceedings, ensuring that the regulation was "future-proofed" to further developments was repeatedly mentioned. As one interviewee told me: "*I'm not convinced legislation ever really follows the science, but [this legislation] is good enough to enable the science*" (HR Interview, 24.10.22). The relative breadth and openness of the future possibilities enabled by the legislation was warmly received by supportive stakeholders. These considerations about the future development of the technology and how that is accounted for in the present via regulation serve as a bridge to the next sub-section which explores shared expectations about the future of such technologies in relation to the discussion so far.

4.3.3 Regulating Dynamic Futures

The recursivity and influence of future-oriented discourses within contemporary practices of innovation are well documented (Oomen et al., 2021). This is also linked intrinsically to the materialities of agricultural assemblages in the present (Legun & Burch, 2021). As such this sub-section concludes this section by exploring some of the expectations and anticipatory logics surrounding the development of NPBTs and gene editing techniques in particular that emerge from my empirical research.

Firstly, given the relatively early stage of gene-edited crop development in England, it is necessary to explore the kind of crops and agricultural products that gene editing is forecasted to make possible. In this regard it makes sense first to start with the gene-edited vegetal lifeforms already being produced and consumed elsewhere within the global food system. To do this we can look to the USA, where gene-edited crops are

subject to regulation as conventional agricultural lifeforms. According to the Genetic Literacy Project (2023) three genetically edited products have been commercialized so far as of Autumn 2023: a soybean with reduced saturated fat content, mustard greens with reduced bitterness and tomatoes with higher anti-oxidant content. Many of those under development are also being equipped with traits oriented towards improved commercial appeal via improved taste, purported health benefits and prolonged freshness, such as 'non-browning' mushrooms and apples. The most advanced ongoing research into genetically edited crops in England involves the development of wheat which produces lower levels of the carcinogenic compound asparagine when cooked (Rothamsted Research, 2021).

What is of interest here is the markable influence of commercial imperatives on crop development via NPBTs at this early stage of their global commercialisation. Commercial prospects of producing fruits and vegetables which have a comparative advantage on the supermarket shelves seems to be driving the logic of innovation to this point. So far, the only crop approved by the USDA produced using gene editing that reflects the ambitions of NPBT advocates to offset the impacts of climate change via 'precision breeding' is a 'drought-and-salt tolerant soybean' engineered by the University of Minnesota in 2017. The fact that this was produced by a university is relevant here, given the diverse institutions implicated in plant-breeding and their competing teleo-affective formations regarding agricultural innovation that *do* in the early stages consider use value as well as exchange value. Yet, importantly, it is a soybean. To return to a key, if seemingly crude, point from David Harvey's work: the 'acid test' (2000: 204) of the manifestation of such novel futures in agricultural systems remains profitability, soy

being a particularly lucrative option within contemporary monoculture-oriented agribusiness.

This reality, demonstrated in the above catalogue of commercialised and approved goods, was further highlighted in my discussions with Dylan, who told me:

> *"We would never take a punt [on a new variety] … We always base the work we do on quite deep market research… We also work with partners. It's increasingly what we prefer. If we can deliver traits into partner's genetics. They have very good genetics anyway and they can deliver them faster as well."*
> (DP Interview, 6.9.2022)

Dylan works for a small, AI-driven start-up "leveraging genetic potential" in "market viable ways". When asserting the need to follow the lead of larger agri-businesses, he linked this decision with a previously voiced need to see rapid changes to crop genetics in order to mitigate the impact of climate change in the future. It is easy to see, however, how these logics of integration into existing trajectories and systems will serve to reproduce existing dynamics of the food system given the ways in which commercial viability and the logic of the market will shape the novel forms of plant life which emerge from these new technologies. These may be 'experimental food futures in a sense' (Carolan, 2016), but they are certainly not operating on an open and unpredictable horizon of agronomic possibility at this point in time.

The question of how NPBTs will change farming practices in the future produces similar tensions. Will technologies like gene editing bring about a more ecologically sound agriculture, or serve to reproduce extant industrial agricultural systems and buffer them against environmental uncertainty, extreme weather, and other ramifications of the Capitalocene? Dylan also told me that he foresaw genetic-editing technology creating future agricultural landscapes characterised by much greater genetic diversity given how CRISPR-Cas9 and similar technologies offer the capacity to render novel plants and landraces commercially viable within present agricultural food systems, thus increasing supply chain resilience and agro-biodiversity. This question of agro-biodiversity is echoed in the work of Gao (2021) who both highlights the lack of genetic diversity in current elite lines and the capacity of gene editing to facilitate the 'de novo domestication' of wild relatives of staple crops like quinoa, rice and sorghum which are otherwise difficult to introduce traits from landraces in to.

Here we see the potential widening of the world's agricultural crop base and the embrace of plant's genetic diversity and global lineages as advocated for by campaigners for agroecology. On the other hand, however, we can perhaps label this envisioned future as one within which gene editing facilitates the transgression of and extraction from a new 'genetic frontier' or 'genetic fix' within vegetal agriculture. The resonances with the work of Jason W. Moore (2015a) are clear here, regarding frontier logic, and the search within industrial agriculture for social-ecological fixes to problems internal to its own logic. In other words, the unpredictability and vitality of plant life could be harnessed towards the continued reproduction of our current damaging social-ecological formation within the web of life (Moore, 2015a), rather than as part of a new spatial, geographic frontier. In this

direction, Dylan also told me about how gene editing may be able to render the intensification of the emergent agricultural spatio-temporalities associated with vertical farming viable, citing how tomatoes phenotypical morphological development could be altered to align with such developing spatial designs, prefiguring the idea of genetics as a vector of agro-environmental control over the future discussed further in the next chapter.

This is not to say that the integration of gene editing into agricultural systems and the new genetic frontiers of that reality will allow for the seamless reproduction of industrial agriculture. Montenegro de Wit (2022), for example, sees gene editing as not totally antithetical to an agroecological future, provided there is some transformation towards vastly different political economic circumstances and a break with capitalist agricultural trajectories. These circumstances do not seem imminent in the English context. The articulations, for example, between gene editing and the emergent paradigm of sustainable intensification unpacked by Montenegro de Wit are particularly relevant in England given the increasingly hegemonic status of a socio-technical imaginary of land sparing and increased productivity with less resources. Bain, Lindberg, Selfa (2021) draw comparisons with the idea that these technologies are imagined as comparable to a future 'new Green Revolution'. It is perhaps not a coincidence, after all, that 'precision breeding' shares a descriptor with precision agriculture.

However, this is not to say that the future will look exactly like the present. Particularly given the prospect of techniques like CRISPR-Cas9 continuing to improve rapidly in the coming years, given the alleged efficacy of the technique in question and the possible

genetic horizons made possible by experimentation informed by gene editing's positivist philosophical underpinnings (Montenegro de Wit, 2022). This is something Montenegro de Wit critiques, but as Adam and Groves (2007) show, forms of mechanistic futurity within scientific knowledge practices may be misguided but are, in practice, capable of unleashing powerful innovation. This is a fact Marx and Engels themselves acknowledged many years ago.

Caixia Gao (2021) highlights several other realities which may emerge from future innovation, including quicker trait development and screening ('directed evolution'), plant microbiome engineering and the artificial induction of asexual reproductive capacities (apomixis). The extent to which these capacities will be legitimate under the Genetic Technology (Precision Breeding) Act 2023 remains to be seen. What is likely, however, is that the social-ecological temporalities and landscapes of agricultural systems in England will be altered by the introduction of gene-edited crops beyond simply the presence of plants produced by NPBTs. Further, this transformation will be demonstrably shaped by the imaginaries, institutions, spatial forms, and discourses of the present, as I have demonstrated throughout this chapter. But within these existing formations there are of course contradictions which create the potential for slippages and uncertainties in our agricultural future, for better or worse.

4.4. Conclusions

In this chapter I have furthered my efforts at taking a political ecological approach to the future of agriculture in England via exploration of the history, past and present of

biotechnological crop development. This started with an exploration of how past efforts to regulate GMOs have impacted the recent liberalisation of rules concerning NPBTs. These trajectories were then further contextualised via the UK's departure from the EU. Within this section, different ways of understanding, relating, and controlling plant life emerged. I then demonstrated how these currents relating to future gene editing were imbricated in existing practices and institutions within the plant breeding sector. This led to an analysis of how the new English legislation permitting the release of 'precision-bred' organisms called upon contested ideas regarding how plants manifest futures developed in the previous sectors. The final sub-section of this chapter examined the future development of NPBTs given how, so far, they have clearly been deployed in ways that look to enhance profitability and market competitivity rather than address pressing ecological concerns facing future agricultural systems.

Throughout this discussion I have shown how extant historical realities of the capitalist food system and its systemic 'more-than-life' (Büscher, 2021) imperatives shape the development of such agricultural technologies and the futures they prefigure. This builds on the argument established in Chapter Two rejecting the idea that the future of agriculture is a site of radical possibility, highlighting how new technologies touted as ruptural or capable of being used agro-ecologically (Montenegro de Wit, 2022) serve to reproduce the past in the present and the future. However, beyond this central plank of this thesis's argumentation, other registers of political ecological futurity emerged.

In particular, two related tensions resonate throughout. Firstly, I discussed two competing yet not irreconcilable sensibilities: firstly, that vegetal life is both determinable, predictable, and governable via the future-oriented knowledge practices of science and law. This is represented in conceptions of 'stable' crop development and the 'robotic futurity' (Rezvani, 2021) of the 'dehistoricized gene' (Berry, 2014). Secondly, I highlighted discourses that have emerged which stress the positive indeterminacy and vital potentiality of vegetal life. In one direction, these discourses suffuse the legitimation of liberalised rules around NPBTs, given how advocates argue that we should be able to harness and benefit from the array of possibilities offered by a vital and dynamic vegetal world. Yet, similar discourses have long been mobilised by opponents of GMOs and, latterly, NPBTs given how such vital indeterminacy creates regulatory uncertainties and political ecological temporalities beyond the purview and comprehension of regulation and legislation. I also linked the emergence of this discourse to Büscher's (2021) assertion of the need to look for ideological, conjunctural and practice-based explanations for emergent relational and more-than-human ontologies.

This links to a second tension, which is implicated with the first like a double helix. On the one hand, we encounter the idea that vegetal life in agricultural systems, given its determinacy, can indeed be sufficiently and effectively controlled through both biotechnological intervention and subsequent, legislation, regulation, spatial containment, and enforcement. However, the counterpoint to the alternative discourse of vital vegetal indeterminacy is not the antithetical idea that life cannot, and therefore should not, be controlled. Rather, for both advocates and opponents of such technologies, a doubling down on techniques and practices of control and regulation is

required. I argue that the Genetic Technologies (Precision Breeding) Act 2023 represents an uneasy and unsuccessful compromise between these positions.

It also represents the necessity of distilling a relative permanence from this contested epistemological landscape in the interest of the legal functionality of creating certainty and a degree of equality for those seeking to further accumulate capital, in this instance via mutant ecologies (Borg and Policante, 2022). Here, the political and historical nature of these social-ecological trajectories is demonstrated. As too, as acknowledged above, are broader connections between these tensions and broader ideological movements in society to understand the 'more-than-human'. As Büscher (2021) asserts, just as the scientific discourses emerging above should be read as ideological ramifications and shapers of the conjuncture (perhaps here best labelled 'the Anthropocene'), so too should, I argue, these academic approaches.

I also argue that this reality also demonstrates the limits of an analytical dualism (Malm, 2019), given how it shows how the diverse actors deploy their own forms of analytical dualism in looking to tactically shift the boundaries of the social and the natural in the interest of generating appropriate (de)regulatory outcomes for NPBTs. Instead, I argue these discursive tensions and the changing relationships with plants they create and destabilise are best understood as historical processes of the intensification and modulation of surplus alienation (Büscher, 2021) within agri-food systems. Further, central to this chapter and thesis, is the assertion that these political and historical trajectories are never purely discursive and ideational, but are always ecological, with ramifications for both the present and future of agricultural forms. The processes of plant

breeding in practice which underlie these regulatory and genetic discourses demonstrate that these issues are never closed and control over plants is only ever compromised. As Levins and Lewontin (1985) highlight, within evolutionary dynamics species are always subjects and objects of ecology formation. This is true in the world of plant breeding, which creates, as I argue above, historically specific capitalist ecologies of intervention, tests, and trials which manifest in spatio-temporalities (and futurities) that are never dictated solely by human temporalities and capacities (despite the best efforts of many over thousands of years).

This recognition leads to final consideration of the question in this chapter's introduction about how the 'natural' should be handled within this sphere. Moore's work (2015a) is again important in order to interrogate the *ontological* questions in play here, given how the discussion has mobilised much *epistemological* material in the form of the genetic discourses their impact on the legislative process and its outcomes. Here, the distinction made by Moore (2015a) regarding the differences between the capitalist *project* and the capitalist historical *process* proves generative. In this regard, the project is reliant upon the philosophical nature-culture dualism reproduced by proponents of the historical development of capitalism and integral to its social-ecological logic. As Moore (2015a: 29) puts it:

> *'*Capitalism's governing conceit is that it may do with Nature as it pleases, that Nature is external and may be coded, quantified, and rationalized to serve economic growth, social development, or some other higher good.*'*

This conceit is clearly on display within this question of NPBTs and biotechnology more broadly. So too is the contingency inherent to the shifting ideological considerations of nature generated within the knowledge practices of capitalism's historical development in the sphere of agriculture, as the recent boundary jump of what can be considered natural in the English legislative context demonstrates. That these discourses are fundamentally about reproducing power in the food system is foundational here. Shifting the boundaries between the social and the natural has long been a function of the capitalist *project* and to attempt to control this terrain which has been so central to, for example, the development of the productive forces in agriculture is to operate according to a logic that I would argue it is better to refute.

In this direction, the partial and insufficient nature of the legislative compromise in England is notable. This is because, as Moore stresses, the *historical process* of capitalism is not reducible to the capitalist project and its conceit. The historical process of capitalism, as asserted in Chapter Two, is internal to ecology and (lower case 'n') nature and (lower case 't') time (Kolinjivadi et. al, 2019). Within this process Moore (2015a: 20) reasserts the vital dialectical principle 'humans make environments and environments make humans'. Understanding the development of NPBTs in this way is necessary and illuminating. Once we begin to understand the laboratory as an ecology within which scientist and plant interact as wasp and orchid (Hustak and Myers, 2012; Deleuze and Guattari, 1988) do elsewhere, we can push through some of the tensions discussed in the preceding content of this chapter. Obviously, naturality ceases to be a viable criterion for asserting the legitimacy or viability of any kind of agricultural technology.

But the question of gene editing, for example, is useful for refuting the accusation that this mode of thought instantaneously leads to a flat ontology devoid of consideration of power relations on the one hand, nor an eco-modernist embrace of any and all techno-fixes on the other (extending way beyond CRISPR-Cas9 to solar geoengineering and beyond). Understanding plant breeding as an ecological process not just in permaculture inspired gardens or indigenous agricultural forms but in plant breeding research facilities, greenhouses and laboratories clearly demonstrates the dialectical relationship between human and plant within nature in its contemporary agro-industrial form. This historically determined power relationship wherein both humans and plants are both subject and object (Levins and Lewontin, 1985) is particularly stark when the intervention in the outcome of the plant comes *prior to* its phenotypical and morphological manifestation as a recognisable form of agricultural plant. Historicization need not take place not just at the level of longue durée, but also within practical activities to better develop our understanding of social-ecological relationalities.

Before concluding, the question of the efficacy of modern plant breeding is worthy of reconsideration and reiterates the themes above. Within the denuded ecology of the laboratory or glasshouse as agricultural site of emergence these results do seem to be shaping a future as a result of the fact that the power exerted by people over plant life often proves efficacious in creating a desired result. Objectives are reportedly being achieved, as plants are proving increasingly malleable to new techniques. However, as the above chapter has repeatedly stressed, things become more uncertain and variegated in more complex agricultural social-ecologies within which these nascent

crop varieties will eventually be introduced. In the first instance, however, the practices involved are sufficiently controlled to feed the epistemological validity of the capitalist project and its hubristic and mechanistic futurity, which translates into law. This recognition, of human capacity to engineer laboratory ecologies within nature, can encourage a sceptical approach to NPBTs future potential in current historical circumstances without recourse to attributions of naturality or qualitative rupture. How it articulates with alternative approaches to regulation, the state and technological governance remains to be developed. That is a project that necessitates much further reflection and consideration of its uncertainties are continued in the next chapter in a different, yet already acknowledged context: the vertical farm.

5. A SPECTRUM OF CONTROL

5.1 Introduction

Of the novel ways of producing food touted as 'the future' of agriculture, vertical farming has attracted its share of media attention. The BBC's website alone has recently asked why farming is moving indoors (Hutton, 2019), how vertical farming reinvents agriculture (Baranuik, 2017) whilst reducing imports (BBC News, 2022) and, more recently, what the limits of such an approach are at a time of rising energy prices (Park, 2023). Vertical farming's appeal to journalists is obvious. It is also easy to contrast vertical farming with representations of so-called 'terrestrial' agriculture. Where once there were tractors and muck there will now be gloved technicians and wipe-clean surfaces. Sprawling agricultural vistas will be replaced with confined spaces. The dirty secret that cities still rely on distant soils for their sustenance will finally be transcended. Yet such dichotomies require greater scrutiny than they have received. Breaking down such binaries encourages consideration of how to critically conceptualise and analyse 'vertical farming', which is in itself an 'umbrella term' (Rip and Voß, 2013) representing diverse approaches to growing plants in environmentally-controlled, artificially lit spaces. Central to the arguments to follow is an assertion that vertical farming is, in fact, just one aspect of the broader sector of 'controlled environment agriculture' (CEA), which is itself one aspect of a wider spectrum of agricultural systems within which a logic

of control is inescapable. The intensification of that logic in English agriculture is deeply significant for the future of food production in general.

The uptake of the term CEA in the second-half of the 20th century initially referred to various means of improving existing greenhouse-based horticultural production through environmental interventions concerning, for example, light levels (Mitchell, 2022: 247). Vertical farming as we know it today has emerged as a technical possibility as a result of developments in CEA technology such as hydroponics since the 1970s (cf. Dalrymple, 1973). How, then, should we understand the difference between vertical farming and CEA? Van Delden et. al (2021) delineate vertical farms as 'multi-layer indoor crop production systems without solar light, in which growth conditions are precisely controlled'. Yet, beside vertically stacked shelving units such a definition is complicated by the well-established use of supplementary artificial lighting in greenhouses, notably in the Netherlands (Heuvelink, 2006) or the farm run by 'Shockingly Fresh' in England which stacks plants but still relies on direct sunlight for photosynthesis (Shockingly Fresh, 2023). And, in terms of vertical farming's urbanist associations, one need only look at recent announcements that two of England's largest vertical farm developments will be built in peri-urban parts of small towns in relatively rural areas in Gloucestershire (Jones Food Company, 2021b) and Kent (Duncan, 2022) to further complicate these visions. Despite this ambiguity, I will loosely follow the delineation about the usage of artificial lighting for the purposes of this chapter.

These typological and spatial questions demonstrate the fact that the sector has attracted extensive research and investment but relatively little social scientific inquiry.

Two notable exceptions to this are the work of Jamie Wang (2021) in Singapore and Michael Carolan in the United States (2016; 2022), both addressed below. Bomford (2023) also offers a critical history of the sector in the USA, but this chapter offers novelty in its political ecological roots, empirical material and focus on futurity. In order to move into this gap this chapter uses qualitative research and critical theoretical exploration to approach future visions of vertical farming and associated forms of CEA in England. It builds on ideas from Chapters Two and Four around technological change, expectation, and the relationship between approaches to the future, power, and the dynamics of capitalist agriculture. This allows for a critical assessment of the trajectories and prospects which contribute to vertical farming's ambiguous 'economics of techno-scientific promise' (Joly, 2010). I say ambiguous as since conducting this research, that economics has come under heightened scrutiny as a result of the issues faced by notable vertical farms, such as the bankruptcy and refinancing of AeroFarms, a sectoral leader in the USA (AeroFarms, 2023).

However, this is not solely an investigation into the waning hype (Brown, 2003) associated with vertical farming. Nor is it only an attempt to explain the fluctuating investment climate regarding these novel ways of producing food and the experiences of growers and operators looking to make real their vision of this sector's future. Although these questions are addressed, what I often found most absorbing and theoretically provocative during my research was the way in which vertical farming typifies and distils the spatialities and temporalities of control central to human-environment relations agriculture. As Wang (2021) demonstrates so clearly, indoor growing provokes diverse questions about the nature of inter-species care in food production that offers

productive tensions with adjacent literatures regarding permaculture (Puig de la Bellacasa, 2017) or gardening (for example Ginn, 2014). I build on these discussions and take vertical farming as a limit case for exploring the real subsumption of plant life in agriculture and how multi-species agricultural futures unfold in sites of such putative human control (cf. Mau, 2023).

This chapter plays out along these lines in four further sections. The next section sheds further light on the historical and current state of vertical farming and CEA in England and the possible futures its practitioners and champions and sceptics invoke, challenge, or ignore. It draws on ethnographic accounts from my own time working and visiting sites in the sector and ends by asking what it is that has made vertical farming an appealing investment prospect for the future of agriculture. The third section looks to answer this question, drawing extensively on interviews with stakeholders in the sector, participant observation and relevant texts. The fourth section articulates these perspectives with theoretical debates raised in Chapter Two about human-plant relationships, care, and control. It argues that whilst vertical farming typifies the intensification of agricultural control and attempts to subsume plant life to the instrumental logic of capitalist agriculture, it also offers insights that nuance existing social scientific approaches to agricultural care. I then tie my arguments about the appeal of vertical farming to wider histories and futures of agricultural development and food regime theory (Friedmann, 2005; McMichael, 2009), highlighting the appeal of vertical farms in the context of the emerging digital food regime. I finish by clearly asserting the argument that even if we understand vertical farms as a social-ecological configuration shaped by plants and humans, their appeal to investors and their vision of the future represents the intensifying

logic of food system oriented towards profit, not people, rather than a ruptural move towards a post-agricultural future.

5.2 Getting to the Roots of Vertical Farming

5.2.1 Growing in Rooms

We are inside an artificially lit growing room in a converted farm building. The work goes quickly. I am already slowing down the process. My job is assembling boxes as Stuart, my temporary colleague, fills them with freshly cut herbs and greens. The walls are lined with metal shelf stacks packed with plastic trays. In the trays grow a variety of shoots of various sizes, hefts, and colours. Sunflower and pea shoots look robust and verdant compared to spindly amaranth and bright purple radish. Stuart pulls out trays from the shelves, assesses their health instantaneously, trims off what he needs and places it into biodegradable boxes. This growing operation is a part of a small farming business that prides itself on championing 'progressive' farming methods. Grant, the only full-time member of staff, grows salads, tomatoes, some field vegetables, and heritage wheat on a small but productive plot within spitting distance of the Downs. The small vertical farming operation started recently. The rhythms of production and the whims and proclivities of the different plants are still a source of uncertainty. Peas need soaking before going in the trays. Maize shoots favour darkness and remain covered. Amaranth shoots are fickle but considered valuable enough to justify ongoing efforts to better understand their preferences.

I worked in the growing rooms for two weeks. They had proven more labour-intensive than initially foreseen by Grant. Temperature regulation and pest control remain an issue. The rooms abound with fly paper which fills up quickly. There are rats in the vicinity and the rooms' defences require vigilant observation for signs of potential compromise by any rodents. Matching supply and demand have also proved complicated. Short, repetitive growing cycles and weekly horticultural scheduling create plenty of opportunities for ecological and economic mismatches that see the effective realisation of the moment of production for profit go unrealised. Despite these issues, expansion and growth are seen as inevitable at some point and Grant sees mushrooms as the next step in his explorations in controlled environment agriculture and indoor growing.

Mushroom production was an envisioned trajectory shared by another vertical farming operation I visited during my research. This London-based facility's greater capitalisation, technical knowledge and infrastructural capacities were made clear in how they approached such a new avenue. I was informed that they were currently trialling a few types of mushrooms and tinkering with associated variables to forecast the viability of the work. This was, however, all I was told of their endeavours during my visit and follow-up interview with two of the growers, Lucian, and Oscar. Their growing site resembled the prospective materialisation of vertical farming's mainstream socio-technical imaginary as expressed in the media much more closely than Grant's ad-hoc growing rooms (Jasanoff and Kim, 2015): urban, clean, technical, and 'scientific'.

The scale at Lucian and Oscar's workplace was substantially larger, with rows of solid metal shelving units about 2 metres tall lining growing rooms at least 20 metres long. This

scale and the resultant supply allow for articulation with routes to a more consumers via deals with well-known retailers and supermarkets. With this scale comes seemingly greater precision, scientific rigour, and time-discipline of labour. Quantification and monitoring are central. For example, heat levels varied across the site plan and plants are offered the opportunity to grow at the temperature they have been observed to prefer. Germination rates of their specifically imported seeds, Lucian tells me, come close to 100%. Upon entering I must don clean boots, an overcoat and hairnet. Lucian and Oscar (perhaps knowingly) might meet public expectations about 21st century vertical farmers. They are prepared, in talking through the operation, to make the connections between what they are doing and the food security challenges of an uncertain global future too. The micro-nutrient contents of their produce were particularly vaunted as of significance in a warming world with a growing population. Yet the nature and appearance of the micronutrient rich crops was broadly similar to what Grant grows: namely, microgreens and herbs. Short growth cycles create more frequent opportunities for the realisation of profit.

These examples illuminate some context of two different types of vertical farms I engaged with in my research: smaller DIY operations and more established commercial ventures. Despite their differences they highlight how vertical farms are creating new spatial forms and temporal rhythms oriented towards controlling environments to meet the needs of plants. Accompanying these farms are new embodied practices of plant care, cultivation, harvesting and distribution. They both also demonstrate how vertical farms are intrinsically limited in the type of crops they can grow from a profitability perspective, given the energy intensity of the operations in question. These dynamics and

drawbacks are also true of emergent vertical farming operations on a much larger scale which have succeeded in attracting large amounts of capital investment. It is to such farms I now turn.

5.2.2 Growing in Value

In a promotional video produced by Jones Food Company in early 2022 we see vertical farming taking place at its greatest spatial extent in England (Jones Food Company, 2022a). Some of the aesthetics of the video are familiar from my own site visits. But the JFC1 site in Scunthorpe in North Lincolnshire where the video is shot is significantly larger than Oscar and Lucian's workplace. From the outside the facility resembles a large metal distribution centre. Written text in the video proclaims that over 5,000m^2 of growing space the company is supplying 2,000 UK supermarkets with fresh produce. The environmental credentials associated with vertical farming are stated, with water usage alleged to be more efficient, pesticide usage at zero and yields 100 times greater than other growing systems. This last claim is made without any substantiation. At the time of recording 15% of the facility's energy was coming from its own in-built solar panels. The video claims that this will eventually reach 100% as a result of an agreement with a new energy provider. The video portrays a growing space with relatively few people interacting with the produce. This is due to the increasingly automated nature of JFC1's operations. Given the height of the stacked growing shelves this seems like a spatial necessity.

It is these robotic systems, produced with partners including grocery platform Ocado (Ocado Group, 2019), and the range of crops which Jones Food Company claim to be able to grow that secure their spot amongst the vanguard of vertical growers. Whereas

the smaller operations I visited were only in a position to produce small leafy greens, Jones Food Company's website lists peppers, tomatoes and soft fruit like strawberries and raspberries as possible, but not yet available, options of their growing configurations (Jones Food Company, 2022b). Although these may be possible, this does not mean, however, they are economically viable. For Jones Food Company, however, progress so far is perceived as indicative of a bright future in which 'set-up costs will reduce, energy will be from sustainable sources and the sector will take advantage of the removal of lots of costs from the production of fresh food' (Jones Food Company, 2022c). Jones Food Company's next site, JFC2, was alleged to be the world's largest vertical farm upon opening. Much like JFC1 it will look, from the outside, like a distribution centre in a peri-urban part of a town, this time in Gloucestershire in the west of England. As of February 2024, there has been no announcement that the site is up and running.

The reality of an English firm opening a facility they claim to be the largest in the world belies the relatively recent proliferation of these growing methods in England compared with other parts of the world (van Delden et al., 2021). In Europe, the Netherlands has an advanced and well-capitalised sector (Butturini and Marcelis, 2020: 84-85) which is unsurprising given the success of Dutch controlled-environment horticulture in greenhouses. There is also a longer history of these approaches in Japan and East Asia than in Europe, where are referred to as 'Plant Factories with Artificial Lighting' (Kozai and Niu, 2020). The North American sector is increasingly crowded with more established companies like AeroFarms now competing with a wide range of start ups for investment (Chaffin, 2022). Despite recent concerns around profitability, vertical farming has proved an expanding sector in recent years across the world. And, as I show in England at least,

there is some diversity across the sector in terms of spatialities, principles and supply chains.

But it is necessary to ask how faith in the future possibilities of vertical farming means that a site in England could have become the world's largest vertical farm? Who is financing these investments and why are they attractive sites for capital? In recent years, Jones Food Company has received significant investment from Ocado (Jones Food Company, 2021a), an online retailer which licenses its robotic grocery processing technology across the world. Fischer Farms, a rival, have been backed with significant investment by the asset management firm Gresham House (Worrachate, 2022). Similarly, GrowUp, who are developing a similar site in Kent, have received £100 million from Generate Capital (Duncan, 2022). Other companies have attracted significant public funding, for example, Bristol-based LettUs Grow has benefited from more than £1 million of funding via United Kingdom Research and Innovation (UKRI, 2023). Such UK public investment is dwarfed by the amount that established corporate agri-food giants have discussed bringing to the sector via tailor-made investment vehicles such as Bayer joint-venture with Singaporean state-owned fund Temasek (Bayer, 2020). This is a surely a sign that finance capital and global agri-business, up to 2023 at least, like what they see. The reality of growing investment in vertical farming by both finance and agri-food capital is made more complex and thought provoking given the observations of Cedric Durand (2023) regarding the extent to which current supply chain issues and counter-inflationary monetary approaches are relatively weakening of finance-oriented capital in comparison to so-called 'productive' capital, including agri-food corporations.

In this section I have offered an overview of the English vertical farming sectors, highlighting different spatial forms and what they are capable of growing, in theory and in practice. I have also shown that investment and support come from a variety of sources. But what is it about the future of vertical farming that, for a time at least, seemed so appealing? In this chapter's next section, I will explore this question using material gathered from semi-structured interviews with stakeholders and practitioners within the sector.

5.3 The Techno-Scientific Promise of Vertical Farming

5.3.1 Questioning Vertical Futures

Through semi-structured interviews and site visits I asked three significant and novel questions of stakeholders in the English vertical farming sector:

1. How do circulating socio-technical imaginaries invoke future states of vertical farming in the present?
2. What impact do these expectations have?
3. And how does this relate to what it *already* is – discursively and practically?

To begin answering these questions I first offer the shared central understandings of vertical farming's future as presented by interviewees. I will then nuance these assertions, foregrounding the importance of doubt and uncertainty within how stakeholders understand the future, before segueing into a consideration of how these

outlooks merge with practical activity and more-than-human futures *in situ* within vertical farming facilities in the following section.

Central to the visions of multiple stakeholders with whom I spoke were discourses of 'food security' as a legitimation for investment in and expansion of vertical farming systems. Within the vertical farming sector, such arguments have even become a bit of a cliché, as one interviewee involved in promoting the remarked:

> *"It is probably the most overused figure in our industry... "80% of people are going to live in cities by 20-something" and some variation of the "population is going to go up to 9.5 or 10 billion... you would have read this 100 times already."* (JG Interview, 26.1.2022)

This deliberate alignment with existing productivist, techno-optimistic and neoliberal discourses in the sector is the first reason I forward for the legitimacy and investment associated with vertical farming's future.

As set out by Jarosz (2014: 169), mainstream food security discourses are 'embedded in dominant technocratic, neoliberal development discourses emphasizing increases in production and measurable supply and demand'. Vertical farming advocates draw on these discourses in ways which reveal the sector's affinity with a productivist approach towards the future of agriculture. This is a paradigm that argues for the development of novel ways of producing more food in order to tackle perceived injustices or shortcomings to the existing system. Like other emerging forms of 'precision agriculture',

vertical farming relies on energy-intensification, automation, and distinct forms of environmental control to improve productivity. These sorts of discourses are often attached to promissory narratives of inevitable and linear technological improvements across society, as well as to projections of future population statistics. Assertions about future population growth bearing down on the present has obvious Malthusian histories and connotations. In the world of vertical farming, such predictions often centre on the idea that future hungry people, usually presumed to be city-dwellers, will require feeding via novel techniques of food production. Such claims are widespread in broader discussions of agri-food futures and not without contestation (Latham, 2021). Yet this discourse, so commonly produced it seems to have become somewhat of a shibboleth, only scratches the surface of what other materials presented within the data. Key to understanding the future of vertical farming, it seems from my discussions with participants, are its spatio-temporal connotations.

5.3.2 Prospective Spatialities

Vertical farming has urbanist roots (Despommier, 2010) and urbanisation is taken as a given in many global future food security scenarios (FAO et al., 2023). This has been used as another means by which to legitimate investment in vertical farming. In England, where the population has long been majority urban, advocates of vertical farming see it as an avenue to address the ruptures between the country and the city associated with the classic agrarian question of how agricultural hinterlands can and should best feed proletarianized urban centres (as typified in Kautsky, 1983).

Yet, in my interviews vertical farming was not conceptualised exclusively a means of reducing ecological harms associated with agriculture's metabolic rifts (Bellamy Foster, 1999). More often it is portrayed as contributing to a simplistic need to reduce transport-related emissions or 'food miles'. As one interviewee put it:

> *"You can have [vertical farms] in urban areas … because you can have them anywhere, you can minimize this whole like export/imports [and] minimize these greenhouse gases and all of that."* (AF Interview, 24.1.2022)

Here, the interviewee hints at what he sees as the potential to overcome both the spatial irrationality of the urban/rural divide and the need to import produce from one environment to another. This recognition of the current role of imports of horticultural produce to England (and the Global North) well illustrates the spatial dimensions of the socio-technical imaginaries associated with vertical farming. It is also embedded in a recognition of the global nature of the food system. Carolan (2022) reproduces this discourse of locality in his treatment of the sector in California, calling on the work of Hugh Campbell (2009) to connect these developments with a 'food from somewhere' regime. For Carolan, this capacity to generate hitherto impossible local food chains is central to the lure of vertical farming for customers, growers, and investors. I agree that this is partially the case but believe Carolan overstates the importance of this aspect for reasons I make explicit later on.

I also argue another spatially uneven dynamic is in play here. This is because I see promissory narratives about vertical farming also serving to reproduce existing power

dynamics related to the production and intellectual property enclosure of agricultural hardware and software like seeds or plant-protection products by firms in the Global North. In this regard, it is no coincidence that, as one interviewee pointed out to me, many of the firms operating in England in recent years in this space are agri-tech firms rather than growers (OO Interview, 25.3.2022). This tendency amongst vertical farming companies is displayed in efforts to provide intellectual property and technical expertise to countries in the Middle East by England-based firms like Vertical Future (Peel, 2021) or European or North American competitors (Ali, 2021).

Yet, perhaps the most recurrent spatial facet of the orthodox socio-technical imaginary associated with vertical farming is its compatibility with ideas of 'sustainable intensification' and 'land sparing' (as typified by Lamb et al., 2016). One interviewee, for example, highlighted the capacity of vertical farming to:

> "*take the pressure off growing outdoors in traditional agriculture [and] allow land be managed in the most sensible way… in more responsible, generally less intensive ways.*" (WR Interview, 23.2.2022)

The potential for agricultural concentration facilitated by a future in which vertical farms produce crops in small parcels of urban or peri-urban land is, unsurprisingly, a foundational aspect of this mode of growing's prospective ecological credentials. Insofar as vertical farming is fundamentally about growing more on less land, it can be read as an ideal type of the sort of 'sustainable intensification' that is touted as

necessary in future English agricultural systems within policy documents produced by the likes of Defra (2022b) and the Climate Change Committee (2020).

In academic circles, vertical farming's capacity to facilitate land sparing has already been hypothesized as something that could contribute to the freeing up of agricultural land for bioenergy with carbon capture and storage (Harris and Kountouris, 2020), like vertical farming another unproven technology attracting interest for its affinities with eco-modernist ideology. Arguments about the facilitation of land sparing allowed by vertical farming have reached public-facing narratives too. For example, the co-founder of a Bristol-based vertical farming technology company told *The Guardian* newspaper that increasing the size of the vertical farming sector would mean 'we can focus more of our land on things like tree planting. So, from a biodiversity standpoint, there are massive benefits' (Geddes, 2022). Vertical farms take the concept of land sparing to its logical extreme given how they are oriented towards the total exclusion on external flora and fauna.

It is important, however, to acknowledge that this foreseen capacity to enable such configurations of land-sparing is one part of a constellation of diverse spatial imaginaries of the agri-food chain I encountered during my research. For example, Will, a technician for a vertical farming technology company with a background in soil science, represented a more nuanced approach, telling me how he believed the approaches they are developing are:

> *"... particularly good for the propagation of crops ... so [we're] doing quite a lot of work with soft fruit and then also with trees and trees whips to be able to generate and develop good rootstock for planting out in a glass house or planting straight out."* (WR Interview, 23.2.2022)

In this instance, Will anticipates vertical farming-style facilities replacing or augmenting horticultural nurseries. Thus, they would be filling or diversifying a singular niche within the current spatial manifestations of agri-food supply chains as a result of their heightened capacity for control over spaces of vegetal growth well-oriented to the delicate early stages of plant development.

5.3.3 Anticipated Temporalities

This foreseen role in crop development speaks to how people I spoke to anticipate certain temporalities made possible by vertical farms. The first significant touchstone here is increased growing speeds. This was touched upon above but is worth returning to in more detail. When visiting and working on sites producing microgreens, I was told and saw that the time between germination and harvest was a matter of days. Microgreens are of course a relatively niche product and represent an extreme end of the spectrum in terms of turnover time within such facilities. Basil, a more widely sought after crop, can reach maturation for harvest in a vertical farming set up in around a month according to LED producer Osram (2018) and as reproduced in peer-reviewed experiments oriented towards speeding this process up even further (Larsen et al., 2020). In this sense the temporal logic of vertical farming neatly encapsulates David Harvey's (1989) observations on the post-Fordist tendency to increase turn over time to overcome crises

of profitability. This is, of course, an issue which will be familiar to conventional farmers the world over. But this sought after temporal acceleration of vegetal life's maturation reflects the realities of the relationship within vertical farms between energy dynamics and financial turnover, discussed in greater detail below. Even the most capitalised, advanced vertical farms in the sector still produce relatively calorie-light crops.

Accelerating plant development times leads to consideration of another temporal advantage of these systems from the prospective of entrepreneurs and investors: quicker turnover time for plants not only temporally intensifies value creation, but it also accelerates the production and optimisation of data. Hugh, a data scientist working for a firm producing technology to augment vertical farming systems lamented that plants frustrated him given their biological development slowed down the processes of accruing data that could optimise futures processes (HG Interview, 21.7.2022). These increases in the speed of the rhythms of plant development and harvesting have obvious advantages in terms of future profitability in terms of both the production of food and valuable growing data. Here we begin to see initial convergences between vertical farming technology and the digitalization of the emergent food regime (Prause, Hackfort and Lindgren, 2021) and the valorisation of data in and of itself under platform capitalism (Srnicek, 2017).

The spatialities and temporalities describe above come together in predictions about how vertical farming can offset the need for imports of counter-seasonal horticultural produce in the future. The theoretical aseasonality of vertical farming allows for plant growth all year round. This was foregrounded as a reason to invest in and develop vertical

farming systems when I visited the experimental controlled-environment growing facilities at the NIAB East Malling Research in Kent where the development of vertically farmed strawberries was of particular interest to stakeholders (NIAB, 2022). The anticipation of an extended growing season is appealing to horticultural businesses in somewhere as northernly as England for obvious reasons. As such, Jones Food Company are also collaborating with established horticultural supplier Berry Gardens (and subsidiary of American giant Driscoll's, cf. Guthman, 2021) in this direction (Fresh Produce Journal, 2022).

This, of course, offers future economic advantages to English producers for import substitution, given the reliance on imports from Mediterranean countries like Spain and Morocco during the off-season of a fruit already replete with bountiful historical associations of English summertime. Connections here with Britishness, Brexit, and 'food security' owing to a reduced reliance on imports from the continent arrive easily here. These temporal trajectories are also buttressed by the above narratives about reducing food miles. Less considered are questions of how these urban or peri-urban farms' viability will compete with existing transport logistics and regimes of exploiting migrant labour associated with industrial horticulture.

Equally, it is notable that dietary change towards more seasonally aligned diets is not considered a viable pathway to a more ecologically resilient or socially just food system. Instead, a technical fix is sought. As one slightly more sceptical interviewee put it: "*...in a way, a lot can be solved just by doing what your grandparents would say and eat what is in season in your country*" (GM Interview, 18.2.2022). Such approaches, of course, do

not proffer the same opportunities for profitability as vertical farming does for producers and supermarkets alike, serving as another catalyst for investment.

5.3.4 Extrapolating the Present

As work by the likes of Tutton (2017) or Esguerra (2019) remind us, future visions and discourses are always rooted in present materialities, social relations, practices, and knowledges. But to what extent are stakeholders involved with vertical farming also doing this? In this sub-section, I connect interview and CDA data about vertical farming futures with appeals to its credibility as manifest in existing systems. What emerges consistently are statements about the already existing capacities of present vertical farming systems to reduce agriculture's ecological harms and to allow for greater productivity and lower labour costs via automation.

As regards the first point, the reduced quantities of water required by vertical farms compared to other forms of growing are amongst the most widely cited advantage of vertical farming. Oscar and Lucien explained to me on my during my visit to their farm that their farm used 90% less water than other forms of growing, with water being recycled more effectively too. Van Delden et. al (2021) cite research by Graamans et al. (2018) that suggests the potential of vertical farms to use 99% less water than equivalent open-field systems. The reduced need for pesticides and herbicides given the capacity for environmental control within these systems is also commonly cited and both aspects were acknowledged in my interviews and participant observation. They are also touchstones in the academic scientific literature discussing the sector and its future (Benke and Tomkins, 2017; van Delden et al., 2021). Such efforts to reduce inputs using

technology can be broadly understood as a corollary of the paradigmatic logic of ‘precision agriculture’ or ‘agriculture 4.0’ (Klerkx and Rose, 2020) in which technological developments and datafication allow for reduced usage of harmful agricultural inputs (Bronson, 2022). This allows, in theory, greater sustainability without transforming the social relations or power dynamics of the food system. These capacities for reduced water and pesticide usage in vertical farming is difficult to refute given how existing systems demonstrate this potential in the present. What is also interesting to note, however, is the proliferation of other inputs to vitalise the ecosystem within which plants are growing in vertical farms, such as additional microbiota (Chiaranunt and White, 2023). This is a reality discussed further below.

Assertions about the present deployment of automation, on the other hand, create more speculative assumptions about the future. Automated systems are already a reality in growing facilities in England and across the world. The Jones Food Company facility currently operational in Lincolnshire, JFC1, is partly automated and other large farms under construction across England discussed above will all involve automation. But what automation means in practice is, of course, diverse, ranging from automated irrigation or feeding systems connected to sensory arrays and imaging systems capable of anticipating and assessing plant health concerns without human involvement. The uniform and controllable spatial forms of vertical farming infrastructure make future improvements seem inevitable to some and are a central facet of the logic of these growing systems and the commercial networks and investment interests with which they have successfully connected. Hugh, the data scientist I interviewed, foresaw an

increasingly automated future for vertical farming and lamented the ongoing presence and participation of humans in vertical farming systems as an inconvenience:

> *"You can't have plant scientists looking at your trays… by taking physical observations you destroy the goal of vertical farming which is perfectly controlled environments. Moving the plants, observing them… changing that changes that micro-environment."* (HG Interview, 21.7.2022)

Here we see the teleo-affective horizons associated with the practicalities of changing data science practices encounter the much longer historical development of cycles of agricultural improvement. We also see a sensibility oriented towards micro-environmental control at a very granular level. And we see human capacities for understanding and relating to plants denigrated.

This was, however, not a vision without contestation, particularly regarding current levels of technological sophistication in this regard. Patrick, another vertical grower operating a smaller facility specialising in direct-sales and with a background in industrial chemistry, invoked the uncertainties created by plants as life forms, telling me that:

> "*plants are wonderfully complex, and you know things go wrong … it will be dangerous, I think, at the moment to have a sole automated system without any checks*." (PA Interview, 17.6.2022).

This was, however, before he advocated for eventual automation to reduce the need for the drudgery which he associated with some of the manual tasks associated with growing, in his example, lettuces. The labour-saving potential of these systems is, of course, a significant forecasted economic benefit. Suppressing labour costs has long been a site of contestation for agricultural capitalists in our cheap food regime (Moore, 2015b). That said forecasts of an automated future must be tempered by acknowledgement of the complex economic configurations which render the proliferation of automated systems viable and require embedding in a more profound analysis of the futures of horticultural labour. As Aaron Benanav (2020) shows in his treatment of automation boosterism, the viability and spread of automation is not just a question of technical capacity, but of broader political economic dynamics. That AeroFarms, a global leader in vertical farming, so recently went bankrupt attests to this.

I argue that despite the presence of automation in vertical farms, such discourses also connect vertical farming with more speculative and techno-optimistic forms of futurity. This comes despite the emphasis on realism and existing farms foregrounded by some of my interlocutors. These are by no means novel imaginaries in the agricultural world, as Warren Belasco's (2006) on historical work on cornucopian food futures shows. The utopian dimensions of Dickson Despommier's (2010) original designs for skyscraper farms still permeates this space for many. There is a sectoral melioristic presumption amongst some that cheaper materials and production will be an inevitable product of investment and research, as was vocalised in several of my interviews. This is also, seemingly, a necessity for future expansion and profitability and highlights that the sector relies on a techno-optimistic gamble, as recent financial issues due to energy

costs have shown since my research concluded. Notably, during my discussions cheap renewable energy availability was a specific area where a sense of inevitable improvement emerged. For example, as regards energy, Oscar told me how his:

> *"…boss always talks about that in five years' time batteries are basically going to you know, change the world. And that's going to seriously help vertical farming. Energy prices are going to plummet and then all of sudden vertical farms are running off of, you know, quite cheap energy."* (OO interview, 25.3.2022)

Conversely, the prospect of hydrogen as a source of fuel for transport was highlighted in discussion with a senior figure involved in the allocation of agricultural research funds in England. He informed me that he foresaw that hydrogen-fuelled trucks would be able to transport horticultural produce from the south of Spain to England with negligible environmental impacts or economic costs within the coming years, making him uncertain about English vertical farming's prospects (LN interview, 10.5.2022). This was indicative of a broad spectrum of scepticism about vertical farming's future which was voiced even by those I interviewed with a financial and personal interest in the development of the sector.

5.3.5 Present and Future Obstacles

On multiple occasions, the stakeholders I interviewed recognised the possible and existing pitfalls of vertical farming. This was notable given my research took place at a time of rising energy prices. During my efforts to visit and speak with practitioners of vertical farming I came across multiple firms that had ceased operating or trading in

recent years. In London in recent years, the first commercial scale operation of Grow Up farms, Unit 84, closed in 2017, with their website citing the need for a larger, more energy-efficient site (GrowUp Farms, 2023). Late in 2022 it emerged that Infarm, who recently built a 3000m^2 growing facility near Bedford in the South of England, were to reduce the size of their operations substantially, with a publicly available internal e-mail citing the need for the company to expediate its 'drive towards profitability' (Infarm, 2022). These realities, exacerbated by spiralling energy prices throughout 2022, have seeped into sceptical press coverage of the sectors' development.

Scepticism regarding vertical farming's potential has been voiced and extrapolated by a diverse array of voices outside of the sector from academics (Blom et al., 2022) to journalists (Monbiot, 2022). My research, however, allowed access to the uncertainty within. Most doubts were rooted in the current state of the relatively nascent vertical farming sector in England, the energy system and resulting economic viability of vertical farming in the future. Three notable themes weighing on the imagined future emerged here: past failures, energy prices and infrastructural or start-up costs. Each indicates the capacity for expectations around the future of emergent socio-technical formations to modulate over time and for promises and their credibility to become objects of scrutiny and processes of legitimation by practitioners, investors, and policymakers.

The relationship of necessity between profitability, viability and futurity was clear to all stakeholders with whom I spoke, even those who were explicit in their opposition to the existing agri-food system, such as Patrick. In my interview with Oscar, he informed me that he had heard stories of multiple controlled-environment production sites in the

Netherlands shutting down due to their lack of economic viability and also highlighted that companies focussed on the production of vertical farming systems faced a challenge in finding sufficient demand for their developments from growers (OO Interview, 25.3.2022). The future economic viability of vertical farming growing systems is by no means assured, despite significant capital investment, media interest and technological development. This also seems to contradict my assertions about the opportunities for profitability vertical farms create through intensification and datafication mentioned above and expanded below. Importantly, vertical farming, and controlled-environment agriculture more broadly, rely on an array of purchased external inputs. This includes, but is not limited to, the need to acquire seeds, growing media, feed, pest management products, material infrastructures like shelves, computing capacity, and associated software, creating high overhead costs as well as opportunities for profit if the formula can be perfected.

The formula, however, continues to resist perfection most clearly in the realm of energy supply and demand. Kevin, an engineer who has been involved with designing a host of major controlled-environment projects across England in recent years, told me a story about a set-up in which the operator had elected to compromise on lighting in order to save money. This individual soon realised that his monthly energy bill was running into the thousands and that any slight profit margin he had envisioned for his leafy greens and lettuces was inherently unrealisable (KT Interview, 26.6.2022). This reality came before the significant increases in energy prices which began to become particularly acute in 2022 when most of my interviews took place. Multiple interviewees sounded worried

when reflecting on the impact this would have on vertical farm's business models, with energy representing their most significant cost.

Often this led to comparisons between vertical farming and terrestrial, solar-based CEA systems. Oscar commented that farmers who had access to "free energy from the sun" were at a notable comparative advantage at this moment in time (OO Interview, 25.3.2022). Gabriel, who has a scientific background in crop physiology and now works in the agri-tech sector, vocalised these energetic concerns most clearly:

> *"Energy is a bigger problem … you see companies … they say, "controlled environment [agriculture] will never compete with in season production of the same crop". So… strawberries in the summer in this country will not compete… the field will be more competitive."* (GM interview, 18.2.2022)

For Gabriel, the logic of competition is already thinning out the sector in the present and will build or dissolve the future of vertical farming, an idea developed in further detail throughout this thesis. Alongside these sceptical comparisons with other forms of agriculture often came doubts about the potential of growing a broader variety of crops in vertical farming than currently mobilised, which is again a question linked to the financial relationship between production, time, and the cost of energy. The technical capacities to grow soft fruits boasted by, for example, Jones Food Company are fettered by the demands of a market system that needs food to be cheap, regardless of the reliability of the supply and the shininess of the machinery. On the necessity of growing

leafy greens and similar products that require less time and energy and are therefore cheaper to produce, Jerome commented that:

> "*They don't require a lot of energy… compared to like a potato, for example. [That's] a magnitude bigger energy use … there does come a point ultimately where … you're not going to do certain crops, because the energy involved in doing them is just stupid."* (JG Interview, 26.1.2022)

Interestingly, this realism about future unit-based economics came from someone who also predicted a future in which market logic would inevitably drive down the cost of energy supplies. Although the Jones Food Company website, however, may make claims about the broad range of crops they are able to grow there is a difference between growing experimentally and growing commercially at scale recognised by many (see Chapter Six for further discussion on 'scale'). Growing for the market is a question of unit-based economics rather than technical, phytological care and environmental control. Emergent academic efforts to model the energy use and carbon intensity of vertically-farmed produce indicate the significance of this problem and its mediation of the sector's ecological credentials: across two scenarios produce from vertical farms emitted between 2.3 and 16.7 times as much carbon dioxide as conventional agriculture, with electricity usage accounting for around 75% of this reality (Blom et al., 2022).

Vertical farms are expensive pieces of agricultural infrastructure currently only capable of economically growing calorifically negligible foods. Accordingly, farms face high start up costs and infrastructural overheads. This was also considered a significant

impediment to, and determinant of, the future development of the vertical farming sector. Kevin, the electronic engineer with a long history of design and construction in the sector summarised the issue thus:

> *"If you've got at least a thousand quid per square metre of your farm to pay back to investors and things like that … I find it really hard to understand how people are even making any money out of it… and this is coming from someone who has built these."* (KT Interview, 28.6.2022)

These debt-leveraged temporalities of investment and subsequent productivism are, of course, a trait of diverse forms of industrialised agriculture within which the extension of credit for investment in hardware forecloses futures which do not prioritise productivism. This productivity treadmill will, of course, be familiar to farmers from all walks of life (Levins and Cochrane, 1996). But the fixed costs of establishment, coupled with the speed of advance in certain technological developments like lighting, brings heightened risk of quickly being rendered behind the times. This was remarked upon by multiple participants, who questioned the logic of spending millions of pounds of venture capital funding on a growing operation that could feasibly be behind the curve in terms of, say, lighting efficiency or compatibility with automating hardware by the time it is actually built and operational. Such speculation and prospective shortfalls will undoubtedly play a part in this sector's future. My own scepticism about these ways of growing should also be apparent by now. There was, however, one CEA site I visited which, for me, represented an adventurous food future (Carolan, 2016), which I will consider in more detail shortly.

5.3.6 Downplaying Felt Possibilities

It was considered foreseeable by multiple interviewees that a two-tiered vertical farming sector would emerge consisting of smaller, localist urban growing facilities alongside the sort of gigantic warehouses increasingly integrated to English supermarket supply chains. This echoes the ethnographic examples I offer above and most of those I spoke with and all the sites I visited during my research operated at the more localist and DIY side of this spectrum. Jerome, involved with cross-sectoral collaboration in the sector, highlighted the distinction between:

> *"hyper-urban, hyper-local at quite small scale [vertical farms that] serve the local community… [and] the peri-urban, semi-rural really, quite big and, you know, large scale automation, probably feeding directly into retail."* (JG Interview, 26.1.2022)

Another interviewee, Patrick, highlighted what he saw as the obvious links between infrastructural costs and concentration on a spatial and economic level. He forecasted that it was *inevitable* that large farms at distributive nodes across the country would come to dominate the sector, despite the small DIY-nature of his own farm which he had built with a friend using, to a great extent, their own money as capital. The market, apparently, does not make mistakes in the futures it creates. In considering this more DIY trajectory, however, the arguments put forward by Carolan (2016) on the experimental futurity of hydroponics discussed in Chapter Two are directly relevant. For Carolan, experiments with hydroponic growing by individuals represent a form of adventurous, embodied futurity in practice which could open up affectively resonant

prefigurative trajectories towards substantive social change. Discussions of such a form of futurity-in-practice resonate here, not least given the overlap in subject matter.

One controlled (although not vertical) hydroponic growing space which I visited did indeed *feel* like a prospective way to produce spatially concentrated yields of horticultural produce in urban environments at low costs with minimal inputs. I visited Bradley's growing space on a long summer day. Inside the singular polytunnel from which he currently operates it was oppressively humid, despite the fans and cooling system. Bradley, along with a friend, built their hydroponic growing set-up from scratch on some land leased to them at a retail park on the edge of a village. Their integrated system included fish for the production of fertilising materials and, at the time of visiting, was producing a bounty of celery, onions, leafy greens. I was informed, using minimal inputs other than feed for the fish. Notably it was not a vertical farm and relied on solar light, but it was climate controlled to the greatest degree possible within their DIY system. I was impressed by the fact that they had set all this up, as well as a local distribution scheme whilst working other jobs part-time. Bradley told me that originally the focus was on fattening fish for sale to local angling ponds and that he would like to franchise his model out in the future. I had visions of my own of scores of similar set ups constructed throughout cities on patches of brownfields land, producing fresh vegetables for local communities. As Carolan (2016) points out it is important to be *affected* by prospective food futures and I was enthused by the energy and the space.

Beyond some uneasiness at the wellbeing of the fish within the system I struggled to see how this reality could materialise in practice for myriad reasons relating not least to

financing, land access, set-up, knowledge, and labour. These are, of course, the central reasons why so many new entrants to farming in England struggle to get a foothold in the first place. In fact, I find it hard to foresee small, urban controlled-environment agriculture sites or vertical farms operating in an any way significant fashion into the future beyond the operators of the more DIY growers with whom I spoke or worked like Patrick or Grant. Where the possibilities for these forms of growing remain viable, for example with microgreens, it is hard to foresee why these won't be centralised in larger facilities and form part of more established commodity supply chains. The market as a machine for rendering processes viable into the future works vociferously in societies defined by the mute compulsion towards wage labour (Mau, 2023) and the circulatory valorisation of money (Harvey, 1996). The pessimism of political economy highlighted by Carolan is difficult to resist here when talking about histories and futures of the probable (Büscher, 2021) rather than the open future horizon of possibility that Carolan appeals.

Vertical farming is an idea that creates a promissory future that appeals to both the pitfalls of the present and the uncertainties about future profitability and sustainability that those pitfalls generate. Such discussions of the openness of the future are linked with consideration of human relationships with plants in Chapter Two. This is an underdeveloped aspect of this chapter so far, given the distinct political ecological dynamics vertical farms create. It is those dynamics that the next section of this chapter explores in more detail, particularly as regards the balance of care for and control over plant life facilitated by these systems. I also ask how these dynamics interlink with the above framing of the sector's techno-scientific promise (Joly, 2010).

5.4 Care and Control within Vertical Vegetal Geographies

5.4.1 Controlling Environments for Agriculture

So far, this chapter has looked to the future orientations and socio-technical imaginaries associated with vertical farming's development, as well assessing, and describing the potential dynamics and current realities of the sector. It has acknowledged the extent to which envisioned and advocated futures extrapolate the potentialities and pitfalls of contemporary methods. It is necessary, however, to further consider the practice-based elements of vertical farming. Vertical farms are sites of agricultural production that host conflicting and overlapping political ecological temporalities created by the agricultural interactions between plants and people. This section relates such daily realities of cultivating plant life within vertical farms with the core theoretical concepts raised in Chapter Two of control, care, and futurity.

Making these connections is fundamental to my efforts to unpick how different approaches to the future permeate and shape trajectories of possible or real socio-technical change in agricultural systems. It also helps further flesh out the logics of vertical farming that make it a site of investment and interest, contextualising such practices within a historical trajectory of intensifying agricultural control and surplus alienation (Büscher, 2021). Recognition of this intensifying control as a motor for investment is nuanced, however, by connecting such control with approaches critical of industrial agriculture, of which vertical farming is perhaps the apotheosis, based on the promotion and valorisation of an 'ethic of care'. To make these arguments I draw further

on my empirical data, as well as beginning to integrate more of the theoretical framework introduced in Chapter Two.

To begin, it is worth briefly returning to the quote above from my interview with the data scientist Hugh about how maximising control is essential to vertical farming's development. This theme emerged consistently in interviews, within discursive materials and within my own broader efforts to contextualise vertical farming within CEA and contemporary agriculture in general. Vertical farming systems represent an opportunity for unprecedented levels of agricultural control over plant life and the minimisation of ecological uncertainty in the present. In theory, they should also be able to minimise commercial uncertainty given their capacity to exclude ecological uncertainties like seasonality, extreme weather, dwindling soil fertility or the presence of unwanted insect species. As I argue throughout this chapter, however, this is not yet the case despite the vaunted capacities of these systems given the economics currently inherent to their operation.

Through visiting sites and talking to practitioners I came to see how vertical farms represent the apex of agricultural efforts to shape plant life to capital-T *Time* (Kolinjivadi et al., 2020) and the clock, rather than the 'natural' rhythms of seasonality or diurnality. Spatially, this is facilitated by the infrastructure of exclusion afforded by technologies and architectures of environmental control: for example, the climate modulation, sealed doors, cleanable surfaces, hair nets and overcoats utilised by Oscar and Lucian. Here the work of Eva Giraud (2019) is relevant, who argues that in thinking multi-species politics, not all relationalities are desired. Where scissions or cuts are made or

attempted is a vital consideration for political ecological thought. Vertical farms create new ways of connecting with plant species and build on the developments of greenhouse CEA in working to exclude others. This is not a novel dynamic inherent to vertical farming; a spatial multi—species biopolitics of what forms of life are or are not welcome within agriculture operates across every form of farming. Vertical farming, as I encountered it, makes this logic particularly explicit. Spatial isolation from, for example, threats to plant health or insufficient sunlight also facilitates the intensified temporal rhythms discussed above, allowing the acceleration of crop development and more accurate anticipation about yields, helping to reconcile supply and demand, and attempting to disconnect agricultural production from the geological reality of hemispheric seasonality.

Maintaining control within the vertical farm, then, is based on a fundamental future-orientation wherein everything that could possibly go wrong for the rearing and harvesting of fragile vegetal lives must be mediated. This pessimistic agricultural futurity infiltrated my own experience of working with Grant and Stuart in the growing rooms. A sense of an overriding instrumental rationality pervades here, as Gunderson (2015) cites as central to an approach to environmental domination rooted in work of the Frankfurt School. With that brings a need to recognise the ways in which these systems are also concurrently looking to control plants as well as people, in both space and time. It is no coincidence, perhaps, that such growing operations are also known as ‘plant factories’, given their spatial orientation to subsuming human and more-than-human life to capitalist clock time. The encounters that I had with workers in such facilities were limited. Oscar described the work to me as repetitive and simple when I visited his workplace. Once suitable growing formulas have been delineated and control is

monitored and assured then systems may require little in the way of everyday plant observation and maintenance, with a focus instead on efficient sowing and harvesting. This is aided, of course, by increasing datafication and automation available to such farms. As Victor Muñoz Sanz (2022) has demonstrated in similar high-tech CEA spaces in the Netherlands, the introduction of digital technologies of monitoring and surveillance does not necessarily serve to free workers from drudgery, but rather creates new ways, via processes like gamification, of disciplining and motivating them to work productively.

Yet as this thesis set out in Chapter Two, I am looking to complicate the idea that people totally dominate and subsume plant life in agricultural systems. Resultantly, it is also necessary to acknowledge the ways in which plants control their environment, given how vertical farms are, in reality, tailored responsively to their needs. As Hugh told me and as I saw on a trip to a controlled environment growing facility at a university, image-recognition software that responds to perceived water shortages or developmental issues can adjust the growing environment via an arguably direct (but obviously algorithmically channelled) response. It is not only workers that are surveilled in these systems. This represents a new digitally mediated twist on Levins' and Lewontin's (1985) idea of organisms as both subject and object of their environment-making and, as such, how their future is shaped. Vertical farms can be seen, in fact, as a new historical nature (Moore, 2015a). However, it is a historical nature made possible by a logic of intensification unique to the current agricultural conjuncture but deeply bound with the capacities and qualities of agricultural plants. The extent to which plants are transformed and controlled in these spaces, however, for me points not a flat ontology

of mutual becoming but rather an intensification of surplus alienation (Büscher, 2021) which, ironically, involves the development of a deeper connection with and understanding of plants' needs on a certain level. Accordingly, I ask: how can these growing environments help us understand the complicated relationship between control and these forms of *care*? And what does that tell us about how humans and plant relate to the future with these systems? As a site of such intensities, vertical farming allows these linked concepts – control, care, and futurity – to be further explored together.

5.4.2 Caring for Plants

In some ways vertical farms could be understood as machines for optimising plant care. Yet the enhanced levels of control in these systems likely does not align with the forms of care associated with the sort of multi-species collaboration and conviviality advocated for by scholars like Puig de la Bellacasa or by advocates of degrowth or 'multi-species sustainability' (McGreevy et al., 2022; Rupprecht et al., 2020). Anthropologist Eben Kirksey (2015: 209) for example, calls for an ethic of care which '[allows] other life forms to flourish without utilitarian calculation'. Such calculation, and the suppression of undesired 'lively futures' (Adam and Groves, 2007) is intrinsic to vertical farming.

Yet, in my research with people involved with vertical farming, it was obvious that growers cared for the wellbeing and flourishing of their plants, even in this seemingly instrumental environment (cf. Chao, 2018). They were affected in embodied ways by the outcomes of the processes of cultivation and maintenance for plants throughout their life cycles. They were attentive to plants' vulnerabilities and the curation of a hospitable environment. Grant would be frustrated or pleased depending on the successful germination of

different seeds. Oscar and Lucian discussed the processes and repetitive steps taken to ensure that they were feeding their plants in the best way possible for their wellbeing. The improved and refinable health, vigour, and wellbeing of plants in these growing systems is essential to the entire epistemological and economic rubric of vertical farming. Yet environments producing any kind of multi-species conviviality are anathema to the ethos of vertical farming. Soil – a substance increasingly understood as immensely complex and a rich matrix of lifeforms and interactions – is often the first thing to go once growing moves indoors. It is too unpredictable, too latent, and too alive (cf. Krzywoszynska, 2019). This recognition speaks to the way that care and attention within vertical farming inform practices and processes oriented fundamentally to the removal of uncertainty and a legible, empty future which can be acted on via interventions via different variables. Each plant, if cared for sufficiently and correctly, offers the hope of healthier, quicker growth than that which came before.

This is not the typical ethic of care associated with a transformed agricultural world (cf. Puig de la Bellacasa, 2017; McGreevy et al., 2022). But it is, I argue, a form of teleo-affective and embodied care, nonetheless, with a distinct futural orientation and affective resonances. As such, it can also help us understand contemporary futurities emanating from and driving vertical farming. Centrally, I understand the variables which facilitate these future-oriented care and control practices as ‘vectors of perfectibility'. Diverse engagements with these means by which vertical farmers can exercise control – plant genetics, microbiome, water, nutrients, light levels, temperature, CO2 levels, pest control, tempos, staffing, and growing media - produce diverse ‘plant growth recipes’. Not all growers will have equal access to regulating these factors. Many of these vectors

are available via CEA in greenhouses and even conventional farming. However, the vertical farm represents a spatio-temporal matrix of control which allows the way plants to be carefully controlled in more diverse ways than ever before.

These ideas were encapsulated in encounters throughout my research. In one presentation at a conference on vertical farming, a young scientist set out how the start-up with which he was working were looking to quantify and alter the microbial landscapes within which plants in hydroponic operations like vertical farming grow. Appropriately here, efforts to suppress the uncertainty and vitality of vegetal agricultural ecologies become a weakness to be addressed via a new vector of control – in this instance the addition to growing media of 'the right microbes' that were otherwise vacant from these deliberately sterilized milieux (cf. Lorimer, 2016). In another telling discussion, in an interview on a podcast, the founder of a vertical farming business talks at length about the vectors of perfectibility involved with his efforts to produce tomatoes '*as they should be'*, with the need for greater development of temperature variation, tailored seeds, different varieties, and induced stress (Duran, 2021). Here, the extent to which plant life in agricultural systems is 'anthropo-ontogenetic' (Ingold & Hallam, 2014, as cited by Barua, 2023: 8) - formed and shaped according to the logic of human labour and capital - is amplified. But so too are affective resonances of perfectionism and the need for collaboration with, and listening to, plants. Growers constantly strive towards an imagined future of the perfect, totally controlled fruit or plant, inculcating their process and spaces of growth with affective atmospheres of possibility, anxiety, and hope (Bryant and Knight, 2019).

Such approaches to care for plants exemplify an understanding of plant agency typical of the sense of 'robotic' or 'machinic futurity' described by Rezvani (2021) and Gerber and Hiernaux (2022). Through the manipulation of variables an ideal process of phenotypic development of different plant types becomes possible. Plants 'perform', according to supporters at least, in new and unprecedented ways. The genetic potentiality within each seed is understood as being implicitly predisposed to certain spatio-temporal conditions within the growing space (cf. Chapter Four). There is an inherently linear, modernist temporality to this logic (Adam & Groves, 2007). Yet, these conceptualisations and processes, I would argue, can be understood as a form of care insofar as it resonates with the central aspects of care outlined by Puig de la Bellacasa (2017: 5), for whom 'care is understood as a concrete work of maintenance, with ethical and affective implications and as a vital politics in interdependent worlds'. To cultivate plants in such a fashion *is* a concrete work of maintenance with affective and embodied resonance for practitioners for whom the wellbeing of plant life *matters*.

As mentioned above, vertical farming mobilises a form of vital (bio)politics of cultivation and exclusion, as all agricultural systems do. It is, however, *not* a vital, multi-species politics that resonates with established understandings of such ideas within academic treatments of multi-species ethics of care. Yet it must be understood as 'vital' insofar as plant life emerges with speed, vigour, and vitality, with the anticipation and fulfilment of the needs of plants, at root, the foundation of vertical farming. This is never an entirely closed or finalised process, however. This was a reality I observed on Grant's flypaper or when I visited Bradley's growing space, his celery was swarming with leaf mining fly. To paraphrase what one researcher growing chillies and tomatoes during a site visit to a

university-based experimental CEA growing space told me about the pests they were trying to exclude: "*Once they're in, they're in*" (HE Interview, 26.10.2022). The question then, is how to improve growing systems over time to minimise these intrusions and maximise efficiency and control. This too, I argue, involves care.

5.4.3 Caring for Systems

In that direction this sub-section considers the care for the *materials and systems*, rather than plants, involved in vertical farming and their ongoing improvement and prospective future economic viability. Whereas Krzywoszynska (2019) and Puig de la Bellacasa (2017) discuss care for soil and agricultural life, instead we encounter the affectively charged maintenance of nutrient-packed hydroponic solutions or LED-lighting arrays. The electronic engineers, data scientists, plant pathologists and horticultural technicians involved with developing and running vertical farms are involved with ongoing acts of maintenance of not just plants, but also the technical systems upon which plant lives in these spaces are utterly dependent. This understanding of care is complicated further when considering the extent to which automation is increasingly involved in vertical farming, via, for example, the delivery via pre-programmed software of specific 'plant-growth recipes', the automatic surveillance and maintenance of variables like temperature or light levels or image-recognition software that identifies and responds to plant pathologies without human intervention. Workers, owners, and investors in an emergent sector like vertical farming are constantly striving for a future characterised by a very different formulation of an old agricultural idea: improvement (Emery, 2010).

Yet, in my research encounters with people and texts it was hard to unpick how different future orientations and affective registers shaped these processes of technical improvement and care. What was the *true* intention of efforts to better cultivate plant life via improving vertical farming systems? Were my research participants motivated by a desire to make money from this novel technology given the possibility of prosperity associated with start-ups and venture capital? As Patrick, one of the more explicitly critical and reflexive interviewees I spoke with admitted, his ideal future would be for franchised versions of his vertical farming systems to facilitate his early retirement to the Caribbean. This, of course, does not resonate so clearly with those who work as employees in enterprises, or as researchers in publicly funded endeavours across the country.

Or were these efforts unforeseeable without hope against or fear for the dire ecological and environmental futures which most interviewees seemed to share a recognition of. After all, when questioning interviewees about how they felt about the future of agriculture, many admitted anxiety or uncertainty about food production and security in the years to come. Although criticism of the ideological roots of eco-modernist or green capitalist approaches comes easily to a critical social scientist, the individuals' desires, motivations, and ideas about care for future generations, for example, were often multi-faceted, overdetermined, and complex.

Participants' relationships with the future as a site of technological improvement and environmental uncertainty co-existed in a way that, from my perspective, seemed irreconcilable. In fact, for political subjects with eco-modernist inclinations profit and

care for the environment are complementary. Such worldviews permeate the shared futures of the vertical farming sector and are articulated through diverse the media, institutions, and events that create the sector's international public sphere. In other words, the quotidian successes and failures of vertical farms are fed back into broader shared socio-technical imaginaries via technical collaborations, discursive spaces like podcasts or webinars, the publication of research or the displaying of prototypes or commercially available hardware at trade shows or other exhibitions. Thus, an uneven but discernible (and often digitally mediated) teleoaffective formation (Welch, 2017) emerges about what might and could be for the future of vertical farming and its materialities within which care for systems and the sector is shared and communicated by interested parties.

This analysis of caring for technology and systems, however, moves us away from foregrounding a post-instrumentalist ethic of multi-species care, as typified by Puig de la Bellacasa and others. In complicating this understanding of care, I look to assert the fact that changing forms of engagement with plants, and the embodied practices, socio-technical imaginaries and affects these generate, do not only flow naturally in one direction, against the current of the intensification of surplus alienation (Büscher, 2021) towards greater conviviality and inter-species justice. In other words, what I am trying to show is that people in England in 2022 *cared* for plants in vertical farming systems in ways which are profoundly implicated with the affective resonances of processes of innovation, the accrual of profit and other associated forms of social capital and prestige. These realities infuse our respective relationships with the more-than-human world and create logics of valuation and exclusion – as typified by the sealed ecology of

the vertical farm – which will shape how we continue to try to live practically in an age of worsening ecological crises. Instrumental and economic rationality *is* mediated here by the putative ecological gains of vertical growing systems, but, from my perspective, instrumentality certainly seemed to dominate the logic of the vertical farming sector, despite its window dressing.

This does not mean people do not care for plants in CEA systems. But we must consider how aspects of social life mediate people's capacity to care in different ways, for example via the temporal strictures of daily life. Addressing these temporal questions is vital to foreseeing a future agriculture defined by different forms of care in a way rooted in a transformational and materialist sensibility. As Johns-Putra (2013) reminds us, care is spatio-temporally variegated and cannot be used to privilege some imagined subject formation without attention to its temporal dynamics and subsequent shifting intensities. Yet whereas Johns-Putra tends towards Heideggerian abstraction to the extent that the approach to care therein is diluted, Kathleen Lynch (2022) more clearly asserts the significance of capitalisms varying tendencies towards subsuming or transforming care from a more empirical and sociological perspective.

The issue of care-for-plants here also comes into dialogue with the emergent field of digital ecologies (Turnbull et al., 2022) and a growing interest within the social sciences about the ways in which digital technologies and infrastructure mediate and facilitate intra-human care and agricultural care (Mol et al., 2015). Given the increasing reliance amongst conventional farmers on connected devices and other forms of algorithmic, data-driven ways of farming this is also relevant to critical approaches to terrestrial

farming. That said, as Parsons (2022) illustrates, these are processes of *intensification* rather than rupture, and this must be considered here too. This, again, opens up the necessity of considering these processes in broader historico-geographical processes of alienation and surplus alienation as advocated by Büscher (2021). Yet can this be considered *alienation* given the intimacy and intensity of these relations, albeit relations mediated through software, data, and infrastructure? Are these systems less indicative of surplus alienation than field horticulture that relies on precarious migrant labour? Turnbull et al. (2022) argue that digital technologies transform rather than suppress our relations with the more than human world. I argue, however that these systems are best understood historically-materially as shaped by an instrumental, if ambiguous, logic of intensification that *is* worthy of criticism in and of itself.

Finally, this discussion of care and vertical farms necessitates acknowledging a fundamental social fact within English agriculture and society more generally which shapes individual and societal futures in diffuse and elusive ways: market dependence. As Soren Mau (2023) reminds us in *Mute Compulsion,* we are compelled towards certain futures as a result, fundamentally, of a need to reproduce our respective and shared metabolic relationship with the world *via the market*. Questions of future profitability or viability and the future spectre of insufficient income affects farmers of all kinds (see Chapter Six). This reality affects the care and time taken, in the short-term, to successfully harvest another batch of microgreens as well as, over a longer temporal horizon, shaping hope and expectations about the sector into which people are investing their lives. These formations, of course, connect to techno-optimistic hopes and myths about the inevitability of overcoming vertical farming's problematic energy costs in the

coming years, for example. These realities also permeate care across all agricultural milieux, as Puig de la Bellacasa (2017) acknowledges in her treatment of productivist temporalities. But, I argue, the expectations about vertical farming tell us something more about CEA as a burgeoning sector, and the conjuncture of the food system more generally.

5.4.4 Vertical Farming in a Mutating Food Regime

To further establish why, I return to a central question which drives this thesis: why do some agricultural futures materialise over others? What political valences of different agricultural futures means they are cultivated or rejected? And where do plants (and the more-than-human world more broadly) fit within all this? To answer this first question in the context of vertical farming, it is the agrarian political economic currents within this thesis which come to the fore. That is because, I argue, there are multiple aspects associated with vertical farming which offer opportunities for the expansion, reproduction, and consolidation of power for various fractions of capital, both inside and outside of the agri-food sector. Understanding these tendencies helps build understanding of why the development of vertical farming infrastructures into relative permanences in the future is (or was) appealing, despite the present and future obstacles to the industry's drive for profitability and viability. These assessments exceed recent work of the likes of Carolan (2022) and Bomford (2023) in their analytical ambition.

Firstly, vertical farming (and CEA more generally) can be seen as a mode of maintaining or increasing opportunities for profitability along the agri-food chain given how it creates need of and markets for a range of novel material and knowledge-based inputs. This was

a reality I observed most starkly during participant observation at CEA conferences and trade events. In these spaces, CEA or 'industrial horticulture', operators can liaise with people developing and potentially source robots for picking, various types of environmental sensors, seeds, different materials for their structures, tailored hydroponic feed solutions, microbial supplements, integrated pest management products, biostimulants, and 'natural' growing media. Within non-solar vertical farms these possibilities increase even further to include elaborate interconnected LED arrays and other infrastructural components. If modernist industrial terrestrial farming is understood, in part, as characterised by a reliance on externally sourced inputs supplied by a small selection of increasingly consolidated agri-businesses, then one potential future resonance of vertical farming and CEA derives from the opportunities it creates for further value extraction and profit in food supply chains. At the moment, my research encounters suggest that in the English context these goods and services are produced by a range of small to medium-sized firms, with varying degrees of reliance on private capital or public and research adjacent investment. Yet, further corporate consolidation represents a very possible horizon in this sector given the oligopolistic dynamics across the agri-food chain (Fairbairn and Reisman, 2024; IPES-Food, 2017).

As discussed above, these endeavours and new products may be driven, in part, by an ecologically oriented tendency towards input substitution. Biostimulants and microbial cocktails may replace (to some extent) pesticides and fossil-fuel derived fertilizers as sources of profit for agri-business. Yet the likely reality for the future is probably 'both and' rather than 'either/or'. Harriet Friedmann's (2005) assertion that we are living within a shifting and evolving 'corporate-environmental food regime' is an obvious touchstone

here. These modes of growing reminding us that a certain understanding of environmentalism can be articulated with *further* industrialisation of agriculture, in the sense of the word deployed by Duncan (1996), for whom industrialisation means the replacement of biophysical processes of true circularity (e.g. the revolution of the sun) by the energy-intensive unidirectional conversion of abiotic matter (e.g. solar panels). In this sense, despite the contribution mentioned above of any food production to the production of life-sustaining use values, I argue vertical farming is not *really* about food security in the future in any true sense of the word, but rather about intensifying control and profits in the food chain, via intensifying control over plants and, ideally, removing as many people as possible.

I argue this also the case as a result of two further elective affinities I see between vertical farming and the contemporary food regime. The first tendency to be addressed – how vertical farming could facilitate greater possibilities for vertical integration – represent a continuation of a well-established dynamic in capitalist agriculture. The second aspect, around the future capacity for platform-derived rentierism, is a more novel phenomenon.

Starting with the former point, the role of (owner-operator) farmers and growers in contemporary capitalist food chains can be partly understood as a propertied class fraction to whom management of ecological risk and uncertainty is outsourced by agri-business. In this process, often facilitated by access to interest-laden credit, owner-operators become a source of profitability for 'productive' capitalists upstream who produce agricultural machinery, fertilizers, pesticides, and other inputs. They also become a site of extraction for processors and retailers along the food chain who can

‘add value’ to their products via agro-industrial chemistry or sell their produce at a loss given their capacity for profitability elsewhere in shops. In the meantime, and buttressed by insurance schemes and state-support, farmers face the contingencies of life at once on the market and at the social-ecological interface of agricultural production. The extent to which this is true obviously varies across space and time. For the purposes of comparison with vertical farming here, the best example is perhaps one often called upon to examine these systems: industrial poultry production, which Constance et. al (2013) argue is the basis for a global agri-food regime based on ‘flexible accumulation’ (cf. Harvey, 1989). Industrial poultry production has created opportunities on both sides of the farm for profit via upstream genetic inputs and and downstream via preserving, flavouring and other forms of transformation which ‘add value’.

Much like the vertical farm the contemporary poultry facility is a site of heightened environmental control, surveillance, and anthro-ontogenetic manifestations of (avian) life. Is the vertical farm an opportunity to move the production of plant-life further towards this model and facilitate even greater supply chain vertical integration in the production of plants? I would say it is. Firstly, the industrialisation of the plant factory increasingly relies on similar technologies to the distribution and sale of foodstuffs in terms of automated systems. The spatial-temporalities of the vertical farm increasingly resemble the forms of robotic predictability, partitioning and connection typical of the supermarket distribution network (Sumartojo et al., 2023). The investment Ocado, pioneers of these very technologies, has made in Jones Food Company speaks to this overlap. Further, the lesser land requirements of vertical farming and the capacity for concentrated peri-urban land acquisition also diminish the initial costs required to

branch out into production. In the English context at least, high land values mediate access to sufficient quantities of unpredictable rural acreage for those looking to begin profitably producing agricultural commodities at sufficient scale for integration with commercial supply chains. The capacity for automation also offsets the need to find reliable sources of horticultural labour. This is a reality increasingly being found difficult by producers in the United Kingdom, as is well documented by media coverage and governmental reports and statistics (Davies, 2022; House of Commons Environment Food and Rural Affairs Committee, 2022). The prospects, then, of future incursion by large food systems actors here into the 'own-operate' sector, as is already happening across the food chain according to Arboleda and Purcell (2022), is surely notable. The opportunities available for integration by processors and retailers to extract greater profit from vertical farming are, then, apparent.

I argue also vertical farming offers new opportunities for profitability to actors such as agro-chemical firms, seed breeders or, increasingly, more exclusively data-oriented players. This is as a result of what I see as the capacity for rentierism which vertical farming's reproducibility, uniformity, and attempted spatio-temporal neutrality facilitates. This is enhanced by the growing reality of remotely facilitated automation, cloud computing, machine learning and the processes of intellectual property management which associated with the realities of what is variously described as contemporary 'techno-feudalism' or 'platform capitalism' (Prause, Hackfirt and Lindgren, 2021; Rikap, 2023; Srnicek, 2017). As AeroFarms' website says: 'Every farmer is a data scientist, every plant is a data point'.

The reality of this synchronicity came to me in my discussion with Theo, a crop physiologist with an emergent business interest in producing small controlled growing spaces. Theo was generally sceptical of the prospects of current vertical farming systems, but the interview was particularly insightful regarding the scope for open-source approaches to vertical farming systems and the growing interest in forms of 'predictive plant biology' (TC Interview, 23.6.2022). In particular, Theo saw the smaller set-ups he was developing as contributing towards future efforts to refine 'plant growth recipes' for future use in controlled environment systems. Plant growth recipes could offer off-the-peg combinations of different vectors of perfectibility executable via digital integration with growing hardware, producing as uniform or reliable results as possible. The idea of the plant growth recipe as a potentially commodifiable knowledge-based input easily leads to speculation about greater intellectual enclosure and rentierism within the agri-food space. Comparisons arise with, for example, the current processes of patenting and controlling seed supplies.

These remain speculative theories about the tangents of these forms of growing. However, I argue they are rooted in material realities afforded by vertical farming in the present. It is necessary, given the abstraction involved so far and the uncertain future of vertical farming, to attempt to connect these dynamics to broader changes in the political economic/ecological conjuncture. As Prause, Hackfort and Lindgren (2021) demonstrate digital technologies like algorithmic management, cloud computing and associated platforms have been part of agricultural systems for some time now. They offer a variety of conclusions in line with the argument I set out here, including a recognition of the potential these technologies offer for consolidation by retailers

backwards along the food chain, the possibility of greater data enclosure and further precarity for agricultural labour. My treatment of emergent forms of vertical farming and CEA as future potential sites of further financialization and rentierism builds further in these directions with a focus on these novel approaches to growing, as well as beginning to attempt to articulate these emergent forms back into a critical analysis of food systems dynamics.

5.5 Conclusion

To conclude, I will first briefly reiterate the key arguments from each section before returning to the research questions from this work's introduction. This chapter has highlighted how future-oriented discourses associated with the promises and present of vertical farming have looked to construct its viability and attract investment. This is unpacked in Sections Two and Three. In Section Two I describe the different spatial forms vertical farming currently takes in England, charting its recent attraction to investors and asking why it has proved an influential vision of the future despite its pitfalls. This question is addressed in Section Three through an engagement with the socio-technical imaginaries associated with vertical farming as relayed to me in interviews with stakeholders in the sector and observed on site-visits. I argue that the spatialities and temporalities produced by vertical farms are constructed as appealing futures given how they articulate and reproduce existing aspects of the agri-food system in terms of both a putative environmental agenda and the capacity for the intensification of production on less land. I also addressed uncertainties and anxieties about the future of such growing

methods, given their energy demands and the limited profitability associated with plants that have any significant calorific content.

Section Four connected these observations with theoretical approaches established in Chapter Two. Firstly, it explored how the vertical farm can be seen as a site of intensified instrumental rationality and robotic futurity, given its emphasis on suppressing diverse ecological temporalities and emergence in the interest of predictability and capitalist clock-time. I complicated this trajectory, however, by considering how vertical farms are also always sites of future-oriented care via the embodied practices involved with facilitating plant growth and improving vertical farming systems. This led the argument back to the question in Section Two, asserting how these realities make vertical farming further appealing to investors given how such growing systems portend a possible future of profitable demand for new agricultural inputs, greater capacity for vertical integration of the plant-based food chain and opportunities for rentierism and intellectual property enclosure. I associated these dynamics with the digitalization of the existing food regime and platform capitalism in general. This analysis of vertical farming maps out key dimensions of the agricultural relations with the future inherent to the sector, thus addressing directly the first research question established in the Chapter One.

But what does this discussion tell us as regards the other two research questions established in this thesis's introduction? Firstly, what influence are the vegetal inhabitants of vertical farms having on such relations with the future in practice and at the level of the imaginary? And, finally, what does this consideration of vertical farming futures tell us about what the food system *should* be like?

As regards the second research question, the vertical farm represents an acute form of agricultural efforts to align more-than-human lives with capital-T *Time* (Kolinjivadi et al., 2020). I have shown how vertical farming is best read as an emergent function of the intensification of the instrumental rationalities which shape capitalist agriculture. This reality is intertwined with subjects' experiences of occupying a world where one's future is always already shaped by market dependence. This is not to say, however, that vegetal agencies and qualities of vegetal life do not co-produce the emergent spatio-temporalities of vertical farming. Via an ambivalent reading of care, it has been shown that the preferences and capacities of plants to *be well* are literally vital within vertical farming systems. Furthermore, the contingencies and complexities of plant life and the relational nature of plant-being stymies and will continue to stymie the capacity for total control over plants within these systems. Yet addressing this tension will also produce further opportunities for profiteering and industrialisation within agriculture, for example via new means of microbial management within hydroponic solutions. The quest for perfectibility will never be resolved and the complexity of plants as living creatures will serve to further shape the systems produced to attend to their needs and the futures of profitability which emerge from these efforts.

Vertical farms also help crystallise the approach set out in Chapter Two that looks to apply the ideas of Moore (2015a) in an empirical context without reproducing an ahistorical flat ontology, as criticised by Tilzey (2017), Büscher (2021) or Arboleda (2017). This is because we can understand the vertical farm as an emergent historical nature within the trajectory of capitalist agriculture, without recourse to romantic discourses of unnaturalness. In fact, recognising them as an example of an ecology wherein

agricultural practices look to balance the needs of plants with the needs of people in new ways helps nuance understandings of care and control across all agricultural landscapes. However, as I also set out above to recognise this fact is not to argue in favour of such socio-technical forms. Rather, I have demonstrated the extent to which the logic of the vertical farm can be understood as an appeal to investment and the potential for future profit rather than the production of use values in the form of food. The distinction between the allocative and authoritative moments of Tilzey's (2017) stratified ontology emerge here, given this seems to be an instance where the semiotic 'authoritative' cultural logic of capitalism exceeds the possible extant materialities of 'allocative' social reproduction. What I have shown, however, is the way in which that cultural logic is shaped and embodied in material engagement with, and care for, plants as part of these emergent social-ecological configurations. This is not to merely highlight the transhistorical or mutuality of such configurations, however, given how I argue that these agricultural forms are shaped by the intensification of surplus alienation outlined by Büscher (2021) in ways which sees plants instrumentalised in ways that are conducive to what I would say is an inherently undesirable future defined by energy-intensity, high material throughput and greater corporate power over our shared need for food production.

In that direction, as regards a normative approach to the future encouraged by this thesis's third research question, this chapter clearly aligns to an extent with the criticisms by the likes of Puig de la Bellacasa (2017) regarding industrial agricultural temporalities and their foreclosure of an ethic of care. Agricultural transformation is required that recognises the temporalities of the more-than-human world and mediates

our historically specific surplus alienation from them. However, on this note the realities – material and projected – of vertical farming serve to help us nuance calls for such an ethic of conviviality. In this vein I follow assertions made by Julie Guthman (2019) in her examination of the strawberry industry. As Guthman asserts, contra the writings of thinkers like Donna Haraway, agriculture is an innately anthropocentric process. In the face of environmental uncertainty, we increasingly need to find different ways to care for and work with plants that work along these 'vectors of perfectibility' via diverse means of agricultural practices all of which, in different ways, are predicated upon human intervention, environmental manipulation, the modulation of vegetal life-forms towards anticipated phenotypical ends and the biopolitical privileging of some forms of life over others. This is as true for swidden agriculture as it is for agroecology as it is for vertical farming. Fundamentally, David Harvey's critique (2000: 183) of Henri Lefebvre's open future outlined in Chapter Two resonates with this recognition of the necessity for control and closure over the future in any transformational societal project.

6. GROWING VIABILITY

6.1 Registering Scale in English Agriculture

6.1.1 Walking

During my journeys to visit farms I walked through dry paths in fields of wheat that seemed enormous by English standards but were, in the scheme of things, small. Perhaps as a result of familiarity, ideology, or its patchworked nature, English agriculture rarely felt 'big' or particularly 'industrial' during my fieldwork. These reflections foreshadow the question that shapes this chapter: what is the relationship between the future of food production and the way scale is discussed, conceived, manifested, and remade in English farming? And how can we integrate a political ecological approach into these ubiquitous discourses around agricultural scale and the future? Not least an approach sensitive to the *vegetal* political ecology which I have tried to mobilise in this thesis?

This chapter starts to explore these questions. In doing so it builds on previous references to scale and the scalar in this thesis, firstly, in the theoretical framework established in Chapter Two and, secondly, in the methodology in Chapter Three. This chapter complements these interventions and builds on them to make several interrelated arguments.

Firstly, discourses of scale in the agricultural sector refer to various elements of social-ecological agricultural processes that do not necessarily align with orthodox human geographical approaches to scale. Nevertheless, these discourses about scale, particularly when applied to future visions of agricultural systems, are influential and have real effects. These scale-oriented imaginaries take as a futural goal an endpoint or expression of agricultural systems – often the optimal or viable spatial extent of farms – in a way that is incongruent with a political ecological approach to futurity. Fundamentally, these mainstream discourses of agricultural scale fetishize the results of social processes rather than considering the processes themselves. Echoing the first point, this does not lead to a wholesale rejection of a scalar approach as understood in human geographical terms. In reality, what I look to show is that the processes which produce these outcomes – which are read in much agricultural discourse in England as to do with scale – are affected by scale insofar as they are mediated by political and ecological factors at the quotidian level of farming praxis in a way that reinforces my general approach to futurity. Plants, too, play a role in producing these outcomes and what 'scales' become achievable or manifest in agricultural systems. This is due to their materialities and their differences in form and development. These realities have been differentially overcome or modulated to facilitate what is understood as 'farming at scale' in different ways in horticulture and arable agriculture. Finally, a recognition of the need to focus on the processes which result in expressions of 'scale' within the relative permanences we delineate as farms is informed by and fleshes out the approach to the future mobilised by David Harvey in *Spaces of Hope* (2000).

This chapter does not purport to address the riddle of agricultural scale in a way that makes conclusive or total statements within long running debates on scale in human geography. Rather it builds consistently on the theoretical ideas established heretofore in order to address the inconsistencies and absences regarding how scale is perceived in diverse visions of agricultural or agroecological transformations and how these approaches relate to the future and the vegetal.

To begin to flesh out these directions, I will briefly unpack discourses of agricultural scale further in the rest of this introductory section. I then offer two empirical sections which are comparative in orientation. They deliberately look to draw out the differences and similarities between 'mainstream' or 'conventional' farmers and those looking to create an alternative agricultural future through discourse, imaginaries, institutions, and practices. They are based on ethnographic data gathered during visits to farms and discussions with farmers in the second half of 2022. The first focuses on 'conventional' farms looking to succeed according to agronomic orthodoxy and integrate with supply-chains 'at scale'. The second is concerned with my time on a farm that operationalises 'alternative' ways of farming at a different scale, predominantly a more 'local' or 'small' scale which also emphasises a more intimate engagement with vegetal life through agroecology. Across these sections, similar themes emerge regarding the capacity food producers have to bring about a different future, the way futurity impacts relations with plants and vice versa and the imbrication of these facets with discourses of, and the production of, scale.

These nuances and reflections are brought together in this chapter's fourth and fifth sections. The fourth section looks to apply the preceding discussion to a reading of the order of discourse associated with agricultural scale in both lay and academic circles, with a particular focus on the normative aspects about what scale of agriculture we '*should'* be advocating. In making these connections the arguments fleshed out above emerge more clearly. These are then distilled in this chapter's fifth concluding section, which also stitches these arguments into the broader fabric of this thesis via consideration of the research questions set out in the introduction.

6.1.2 Interrogating Scale

Discussions about scale have long permeated popular and academic discourses of possible and desirable agricultural transformation. These are *the discursive politics of agricultural scale*. They emerged frequently throughout my research in discussions with farmers or campaigners and at industry events or conferences. One need only look at how scalar concepts affect tropes ranging from advocacy for 'small farm futures' (Smaje, 2020) and 'short' supply chains to the influence of 'big tech' on 'global' food systems. Ideas about scale are pervasive but diffuse. Scepticism towards centring scale above other forms of socio-spatial relations inspired by the works of scholars like Jessop, Brenner, and Jones (2008) is nowhere to be found. As such, these discourses of scale serve as a vector in this chapter towards consideration of scale from a more political ecological perspective and a nuancing of such scalar-oriented thinking as it dominates visions of agricultural change. Yet these future-oriented discourses shape and are shaped by actual farming practices. As Cox (2020: 59) argues: 'reified notions of scale are used to discursive effect'.

This is also a necessary given how it addresses gaps and vagaries in the existing literature. These scale-first ways of thinking about the future do not just suffuse the popular order of discourse concerning agriculture and its transformation, but also affect and influence academic work in this field. This is typified in an article entitled '*Is less more … or is more less? Scaling the political ecologies of the future*' by Paul Robbins (2020). The article explores visions of agricultural transformation through the rubric of scale without ever reflecting on what scale *is*, how scale relates to other socio-spatial facets of a process like agriculture, what effects this has on agricultural production in practice and what ramifications this has for the prospect of transformative socio-ecological change in the future. The spatial and temporal questions which underpin the *production* of agricultural scales are overlooked and, as with many contributions, scale is considered as some kind of aim or objective, rather than something epiphenomenal to the food system and its governance.

Robbins' reflections start in a large Wisconsin dairy farm and go on to juxtapose imaginaries of future agricultural systems characterised by smaller farms, greater labour inputs and community-level management with farming futures reliant on technology 'at scale', automation and 'large scale planning'. Robbins explores approaches he considers transformative, the first paradigm being the degrowth movement (Kallis, 2018) and the second 'eco-modernist' socialism (Huber, 2022). Yet despite Robbins' mobilisation of foundational political ecological concepts, he does not stop to break down what constitutes 'highly technical and broadly scaled technologies' or 'local-scale organization and autonomy' beyond relying on (likely differentiated) common sense understandings of such invocations. This chapter looks to address this deficit whilst, like

Robbins, connecting such considerations with broader socio-technical imaginaries of change and transformation. Unlike Robbins, I draw on empirical observations from my research on farms in England in 2022. This chapter also explores the connection between these ideas and their mediation or power over vegetal life in farming systems.

But before moving to that section it is necessary to first clarify how I approach scale here, given the tensions discussed above and the conflicting conceptions of scale mobilised within agricultural discourses and by human geographers. This chapter is not necessarily oriented to making ground-breaking theoretical assertions about what scale is or isn't. In fact, it takes as its anchor longstanding theoretical approaches to scale and the politics of scale from critical geography, as typified in the work David Harvey (1996). This approach focuses on scale as governance or power dynamics across different spaces and places and scale as a vector or impediment to political transformation. Central also is the idea of the production of scale (Smith, 2008; Jones et al., 2017) and the impact of capitalism in these processes, a subject of vital consideration to discussions of agricultural scale. Recent work by Kevin R. Cox (2020) has looked to reaffirm this direction. Cox affirms where the fundamental link lies between human geographical approaches to scale and agricultural discourses of scale in asserting that when thinking through capitalism's impact on scale, we must consider that 'it is what seems to work, what can be put together and reworked so as to work at a particular time and in a particular place in advancing the accumulation process' (2020: 59). This is an important idea borne out in the discussion of empirical work below about what 'scales' of agriculture emerge in terms of the sizes of farms and the mediation of the processes that

produce these outcomes by factors across scales such as global markets, national governance, or the individual qualities of different forms of agricultural produce.

Both Cox's work and this thesis go against positions offered by Sarah Marston and others (2000; Marston et al., 2005). Marston, Jones, and Woodward (2005) argue against the utility and efficacy of an approach to socio-spatial theory that operationalises scale as a primary analytical lens. They dismiss past work by thinkers like David Harvey for imposing a scalar logic of verticality or nested hierarchy in their analysis which overemphasises the impact of the global and offers only 'pre-configured accounts of social life' (2005: 422). Instead, they offer an account inspired by the Schatzkian approach considered at length in Chapter Two, which prioritises sites of immediacy and interaction (and, by extension, practices) in its analysis. Marston et al. look to distance this approach to ahistorical flow-centric considerations that reproduce the kind of openness I also discount in Chapter Two through a recognition of the way in which blockages and assemblages or relative permanences come to be shaped by both 'endo-' and 'exo' events that affect sites unevenly. But, as Cox (2020) suggests, their approach can be seen to display the tendencies they claim to refute.

There are clearly overlaps here with the kind of thinking I argue against in Chapter Two that are worth exploring in more detail when approaching questions of scale. For example, there is a shared rejection of ahistorical and open flow-oriented approaches within Marston, Jones, and Woodward's work. Nevertheless, I still distance myself from their perspective for its embrace of a flat ontology, as again discussed above and in, for example, the work of Büscher (2021; 2022), Arboleda (2017) and Mau (2023). This thesis

has demonstrated an approach that recognises the impact that the 'more-than-life' effects of the social-ecological historical development of capitalism has on biotechnology and CEA. This is continued here in regard to conventional and 'alternative' agricultural futures.

This work also draws on political ecology. Approaches to scale in that discipline are best summarised by articles by Neumann (2009) and Sayre (2005). Both scholars argue that to think scale politically ecologically is to recognize the separateness and dialectical implication of the 'epistemological' and 'ontological' moment of scale. The former refers to the way in which we choose to see scale via research. My own decision to attempt to operate across scales via 'mid-range' ethnographic work is explored in Chapter Three. That manifests itself in this chapter in a focus on the farm-level or scale, which I acknowledge is not necessarily *ontological* but serves as a point through which the social-ecological processes of agricultural obviously flow in a concentrated fashion. Further it is a 'scale' which is reified and reproduced in agricultural discourses in ways central to the discussion to follow. The latter term refers to the spatial and temporal manifestations of material relations and ecological processes and how they change according to a real sense of scale. This biophysical moment of scale, they argue, has real ontological effects and is not just a construct. In the chapter below I attempt to consider the idea of scale in this regard via looking at the socio-ecological processes of agriculture as historical natures reliant on labour, technology, and different forms of vegetal life. Within that, I try to begin thinking about how different plants serve to co-produce agricultural scale. I attempt this via exploration of how different temporalities and materialities of plants and the historically-mediated technologies designed for their

growth and harvest come together to foreclose, enable, or reproduce certain understandings of and manifestations of agricultural scale.

The following sections look to empirical material I gathered across various sites during my fieldwork to demonstrate these tensions and arguments. The next section explores the production, valorisation, and governance of agricultural scale in spatially large 'conventional' farms which produce commodities for supply chains that end up in supermarkets or on global commodity markets. The subsequent section focuses more on the work of a farm which better typifies a 'small farm' imaginary, in doing so complicating and historicizing what that means in practice.

6.2 Overcoming Convention

6.2.1 A Mile to Shotley

I walked about a mile from the station in 32-degree heat to meet Spencer. At our agreed rendezvous point he picked me up in his tractor and we went back along narrow country roads in the same direction I had come from. Spencer apologised but told me excitedly that the harvest was starting today. It was early July, and the intense heat of the summer of 2022 meant barley and wheat were ready to go earlier than ever. We chatted throughout the journey. It took around fifteen minutes to get from where the grain was to be stored to the field where harvesting was taking place. Spencer was in his mid-twenties with a crisp upper-class accent. He met all my pre-conceived aesthetic stereotypes of an upper-class young English farmer. He was disarmingly open and friendly. We were

quickly engaged in a broad discussion about the past, present and future of farming in England. He had graduated from a top agricultural university a few years previously and was now assistant farm manager here at Shotley Farm in Kent. Shotley Farm is a misleading name because, in addition to the original Shotley Estate, the business was now responsible for contract farming hundreds of hectares of arable land in the local area. This necessitated the drive which gave me the chance to begin interviewing Spencer.

Our conversation quickly made connections between what was going on today and the politics of agricultural scale. Firstly, the heat was a natural topic of conversation and Spencer attempted to assert early in the conversation his concern about the impact of climate change now, and in the future. He voiced a firm belief in the 'regenerative' methods being championed across so much land by Shotley as the necessary response to the environmental and ecological crises he recognised as global in scope. Yet he also acknowledged the reality that their operation also needed to remain productive and profitable at the same time. After all, they were competing not just with neighbours, but with wheat producers worldwide in a networked global market. This includes farmers in Canada, or elsewhere, working on a massive spatial scale. This competition was enabled by the fungible and storable nature of what they were producing, a reality epitomised in Shotley's commercial relationship with an international grain marketing business.

When we arrived at the correct field, Spencer maintained an appropriate pace and line with the huge tractor to catch the grain being harvested by one of his colleagues in another vehicle. We proceeded up and down a long field on a gentle slope. Eventually we

headed back and once we had returned to where I had been picked up Spencer tested a small sample of the wheat for quality in advance of its entrance into the global supply chain. It seemed OK I was told, despite the very dry summer. One test acted as an appropriately representative sample of the whole trailer's contents. In fact, the grains of wheat seemed only comprehensible as a multitude, an aggregate or a population expressing a history of weather, soil fertility, and, vitally, varietal genetics at the molecular level.

These are qualities of grain that lend themselves to taxation and storage, as discussed by James Scott (2007). In reflecting on this, the spatio-temporal impacts that this mode of annual agriculture has had on human society loom into view. This is what Tim Morton (2017) would describe as the cultural legacy of 'Mesopotamian agri-logistics'. These are forms of agri-logistics which, in England, have been increasingly mechanised and depopulated in the last 80 years. Harvesting this quantity of grain at once without ever looking another person in the eye is an outcome of a long history of annual arable agriculture, the technologies developed to support it and their diffusion globally and differential adoption locally. These are historical phenomena which cannot be separated from the power dynamics and social relations which created them and the spatio-temporalities they facilitate. At that moment, as we awaited the results of that grain test, the present and its possible futures were touched by the Corn Laws, the colonisation of America, the Green Revolution and ever shifting food regime dynamics. These historical facts co-produced the extant scale and future viability of Shotley Farm and Spencer's work.

Yet this was not on Spencer's mind at that moment. Spencer's teleo-affective horizon was saturated by a desire for quality and results as manifest in the reading of the tested grain. It is possible to make further comparisons here, on a futural level, with Rezvani's (2021) description of seed-saving farmers in Brittany and how different farmers have different relationships with plants and time. Rezvani quotes a critical peasantist farmer ascribing a sense of the robotic or predetermined to how industrial farmers view seeds and plant development. In Spencer's actions there was certainly an anticipatory or calculating logic facilitated by the triumphs and techniques of a historically-produced industrial agricultural project. This was manifest in Spencer's work, even the more experimental or 'regenerative' aspects. Luck, mediated by chemistry, history, and finance, played a big part too of course.

But, despite the anonymity of each grain and the global market within which he was competing, Spencer seemed deeply invested in the quality of the product and the future of the farm and its ecology and landscapes, not least because he was still early in his career and eager to impress. He clearly deeply cared although this wasn't necessarily expressed practically in the sense that much contemporary social scientific literature on the subject might understand it (Chao, 2018). He told me he had been working with a few experiments in polycropping where multiple plants are grown at the same time. His enthusiasm for the diverse morphologies, rhythms and capacities of plants was clear, if coloured by an instrumentalism. He was ambitious about the possibility of getting more out of each field in the future, increasing the output of the farm not just across space but also intensifying it in time. Here, the processes which produce 'scale' as related to the quantity of production a singular agricultural space is capable of can be seen within

Spencer's plans for intensification and efficiency. Yet these ideas and their material manifestation are rooted in an understanding and harnessing of the differential capacities and rhythms of plants and how those preferences and processes could be utilised to better articulate the changing seasons with increasing profitability.

Spencer showed me some of these experimental fields on my second visit. He told me he was working with a farmer-led organisation to integrate livestock into crop rotations in order to improve soil fertility without recourse to artificial fertilizers. Yet, he was also working with what he described as 'big' businesses on trials too. There was a balance, typical of even the most conventional or industrial arable agriculture of intense environmental control over plant life and other implicated species wherever possible, weighed up against costs and in constant negotiation with chance over the large estate. As Spencer put it regarding his oilseed rape crop during that second visit:

> "*I basically put it in with a hundred kilos of nitrogen… and that's it. I will not touch it now until after Christmas. I will put on slug pellets to minimize the risk. I am now down to the Gods of farming, and I hope it takes off. I can't really do much else about it. I can keep spraying it but what does that achieve? I sit tight and hope."* (SS Interview, 9.9.2022)

This spoke to an atmosphere of hope which was palpable in Spencer's manner and energy. In their agronomic approach and supply chain connections, Shotley represents a paradigm of an emergent and optimistic form of 'regenerative agriculture'. This way of doing things is both looking to create change whilst also remaining articulated with

corporate agricultural interests (Tittonell et al., 2022), as manifested via discourses of precision farming (Clapp and Ruder, 2020). Some might call this 'regenerative farming at scale'. Scale here perhaps meaning that environmental goals can be realised through the subtle transformation of a historically produced and extant way of farming which occupies vast amounts of land and produced a significant proportion of global calories in ways which rely on little human labour. In other words, an idea of scale as an outcome of a socio-technical configuration dependent on inputs of labour and technology in order to ascertain what scale of farming becomes viable or possible.

6.2.2 Big Technology?

Although the machinery and infrastructure I saw around Shotley was far from brand new, this was still clearly a heavily capitalised operation in terms of their tractors, combine harvesters and other infrastructure. After all, for farmers, the right technology can facilitate working at a scale that can secure their futures in the face of land agglomeration, competition, and low consumer prices.

Spencer and I did not address the question of indebtedness explicitly, but the temporalities and futurities associated with taking on debts to acquire new technology or more land will be well known amongst the farming community. Taking on debt is obviously a central way in which farmers are able to 'scale up' their operations with new machinery or more land. In 2022 the average farm debt across England was £272,400, an increase of almost 10% on 2021 (Defra, 2023). As Soren Mau (2023), channelling Maurizio Lazzarato (2012), asserts in his recent work on the economic power of capitalism, debt has long served as a means to secure and reproduce the future of capital accumulation

(cf. Graeber, 2011). But debt is not the only way that the contemporary scale and mode of agriculture comes to reproduce or even intensify itself. Similarly recent critical work in agri-food scholarship has looked to point to the lock-ins and path dependencies that shape the future of agriculture in advance as a result of the strategic futurities which agri-businesses are able to embed in hardware and software alike. For example, as Sarah Hackfort (2023: 8) puts it: 'systemic, technological, data, legal and soft lock-in effects reinforce the already existing dependence of farmers'. This is, of course, not solely to be equated with the size, shape, and nature of technologies, but must be embedded in a historical materialist critique of the co-development of agricultural technologies, institutions, landscapes, and farming subjectivities (cf. Arboleda, 2017). The scale of farming now, and in the future, is determined by these realities.

Central to these historical dynamics of agricultural and socio-ecological transformation, as Robbins (2020) points out, has been a replacement of labour power with the embodied abundant energy provided by cheap fossil fuels. This was demonstrated on my visits to see Spencer. The only one of Spencer's colleagues I ever met in person was the company secretary with whom he shared a prefabricated cabin on the edge of his experimental field. When we were collecting the harvested grain, Spencer communicated with his two colleagues in separate large machines over a walkie-talkie. Ensuring sufficient future labour supplies worried him more than anything else, he told me. Without workers, how, after all, could they continue managing all this land?

Spencer's boss owned a significant estate which represented some, but not all of the land, farmed by the business. He sounded like a reasonable person to work for and

shared, it seemed, much of the energy and optimism about the future of regenerative agriculture that Spencer expressed. The rest of the area farmed had come as a result of his manager's own success and capacity for investment of time and money in methods and machines. This reality speaks to the professionalization of contracted arable farming in England over recent decades. Scale is complicated here by the relationship between land ownership and those who work the land, shape the landscape, and control its multi-species inhabitants. As regards this first idea, this professionalization, and the datafication allowed by novel machinery, is seen by many in the sector to be key to rendering the agricultural sector able to attract more young people and assuage the emergent labour issues (Henderson, 2022). Yet this is complicated by the fact that there are simply fewer and fewer farms and farmers in England. In the United Kingdom, as a whole, there were 222,000 agricultural holdings in 2010 (Defra, 2016), in 2021 that figure was down to 216,000 (Defra, 2022a).

The current processes of agri-environmental reform associated with the United Kingdom's departure from the EU can be expected to further this shake out, given how it removes the guarantee of subsidy provision through the Common Agricultural Policy for many farmers. As Spencer said the second time I visited:

> "*It's about survival at the moment really, trying to minimise risk … everyone's going to go through a period of consolidation… how can we adapt? That's the key thing we can do. The next two, three, four up to five years is going to be a bumpy ride*." (SS Interview, 9.9.2022)

These dynamics, which have been perpetuated both deliberately and unconsciously, have obviously shaped how farmers and labourers across different sizes of holdings envision the future of farming and also feel the present emotionally and affectively in the present via their practices.

Spencer, possibly as a result of his youth, relative privilege, and modest success, was optimistic about the ingenuity within the sector and saw promise in technological developments and discourses associated with so-called regenerative precision agriculture. However, other commercial farmers with whom I spoke operating at across large areas of land and integrated with conventional supply chains were much more circumspect about their future prospects. The existence of a so-called productivity treadmill (Cochrane, 1958; Levins and Cochrane, 1996) in farming has long been associated with these tendencies. Via my research I saw how such a temporality of competitiveness and expansion had inculcated the futurities of my interviewees in diverse ways. For example, the mental health toll of working as a farmer is increasingly well documented (Shortland et al., 2023). Now many, in response to this intensification, are likely searching for ways to either do more with less on their existing holdings or to increase their operational size. Given the spiralling cost of land in England, for many technological improvements offer the only route to maintaining the volume of their output (if not profits) whilst cutting costs and farming the same, or less, land.

6.2.3 Cruel Techno-optimism

This reality is also as true for the horticultural producers I spoke with operating in a ‘conventional’ fashion as it is for arable farmers. That said, the way in which scale is

produced in horticulture differs from the work done by their more mechanised arable counterparts, as do relations with and creations of vegetal political ecologies. During my fieldwork I attended a horticultural trade show for fruit producers in the South East of England where this was made apparent. On display at the show was a variety of products oriented towards increasing efficiency, output, and precision via the introduction of new agricultural technologies. The exhibition interventions purported to make a difference to how plants would or should develop in diverse ways. This included products like rockwool, a growing media used in hydroponic farming produced via high-energy processing of basaltic rock. There were automated arms for picking strawberries and robots that patrolled field of berries at night fighting mildew with UV light. There were large displays featuring glass panels and new types of greenhouse structure. Each of these interventions could, in theory, have an effect on what could be considered the scale at which a horticultural business is operating.

It was a hot day and people were activated and excited by what was on display. Desire for the new products circulated. In the case of many participants, it was likely a desire mediated by their financial realities and thus a desire masquerading as curiosity. People were chatty and many were drinking beer or eating ice cream. There was an atmosphere of sociability and enjoyment not typical of all the agricultural events I visited during my research. I chatted openly with an Eastern European farm manager and his landowning boss in the queue for some lunch. Their hopes for the future of their business coalesced around a belief that direct sales would guarantee viability in years to come.

I also bumped into Arthur, a previous interviewee whose orchard I had visited a few weeks previously. Arthur was perhaps typical of the individuals attending the event and although he was not in the mood to chat at the trade show, my previous interview with him had proved enlightening. He was in his late fifties and was the owner and manager of a family-run orchard about 25 miles away. In the interview I conducted with him he listed his anxieties about the future: inflation, lower demand for the specific variety of apple he grows, concerns about unprecedented temperature fluctuations, changing pest profiles and the growing difficulties recruiting the right sort of labourers. I did not get a chance to meet any of those workers, but they were vital to maintaining Arthur's operation given the still relatively limited capacity of automation in harvesting apples. Unlike wheat, apple trees cannot yet be harvested exclusively mechanically and horticulture in all its forms remains the most labour-intensive form of farming in England, with businesses employing needing seven workers on average compared to one or less for other types of farming (Defra, 2022a).

Ultimately, Arthur seemed weary and a touch cynical. But he also had a belief that via some of his connections and position within the market he would be able to increase efficiency and productivity and pass on his family business in a good state and at its current scale. As he put it:

> "*There will be challenges: climate change, lack of labour, withdrawal of chemicals and other things I don't even know about yet… but, yeah, I think we've got a really good niche here*." (AW Interview, 1.7.2022)

This was, however, not the case for his competitors, a view which hinged on a belief in the capacity of the market to generate futures efficiently, rationally and for the best:

> "*The traditional horticultural holding that produced some apples some pears some plums… is not going to exist anymore… I think you've got to let market forces sort it out. I'm a big believer in market forces*." (AW Interview, 1.7.2022)

The famous dictum of former American Secretary of Agriculture Earl Butz that farmers should "get big or get out" echoes here. And Arthur's faith in the future and the logic of the market was almost certainly buttressed by the fact that he owned a significant amount of land and was operating across that spatial extent via the work of several full - time employees. Other attendees at the trade event likely did not have quite as significant a holding, but many would have owned some land, and most would be either extracting profit from their waged labourers or overseeing that extraction on someone else's behalf. Further, the relationship most horticultural owner-operators have with the future, like Arthur and despite their class positional privilege, would be shaped by their relationship with the market in an abstract sense and, very likely, the supermarket in a more concrete one. Size of an owned holding, read by many as 'scale', is of course, inseparable from wealth and class position, although this often complicated by indebtedness and land ownership.

Another grower I talked with, Carl, was pessimistic about the future extent and output of his farm as he feared incoming ELMS policy would mean the end of the tenancy he had on land that could be put towards providing public goods. For Carl, the changes in policy

represented another layer of uncertainty between him and the horizon. He was good at growing vegetables, had been doing so for a long time and provided employment opportunities to young people from the nearby village. But perhaps some of this land would be afforested so the local landowner could get money for doing relatively little and no longer have to deal with pesky tenants? At this time of policy change, there was a general sense amongst commercial producers I spoke with during my research that there was a need to think strategically about the future as things were, in general, getting worse. The competitiveness and uncertainty associated with edible commodity production for the mass market infused the technologies on display with the prospect of a viable or profitable future for producers. According to the National Farmers' Union (NFU, 2022), in the year leading up to the end of 2022 horticultural production costs increased 27%. As discussed above, the prospect of greater input or energy efficiency through new materials and products or reduced labour costs through partial automation offers hope to producers facing the squeeze.

Such 'techno-optimism' is often invoked as a discourse associated with futuristic eco-modernist visions (Marquardt and Nasiritousi, 2022; Tutton, 2021) but it is also, undoubtedly, an aspect of the teleo-affective formation (Welch et al., 2020) and lived experience of many conventional farmers across England and beyond. Accordingly, atmospheres of technological expectation manifest themselves in the present both ideologically, in people's imaginaries or language, and materially in the agricultural landscapes we see changing according to expectations about future tech. Consider for example Gardezi and Arbuckle's (2020) work connecting a sense of techno-optimism amongst US farmers with diminished interest in climate change adaptation or mitigation

or, in a different direction, the changes made to the landscape and labour in New Zealand orchards described by Legun and Burch (2021). There, a faith in the impending arrival in automated picking technologies is already shaping landscapes and labour in the horticultural spaces. Scale is produced, in part, by expectations and, resultantly, gambles on the future.

These forms of futurity emerge amongst individuals with, in many cases, decades-long experience of the increasing intensification of their sector and the widely discussed reality of the agricultural 'treadmill' facing commercial producers of commodities (Cochrane, 1958; Levins and Cochrane, 1996). This urgent temporality of price pressures, competition, uneven technological advances, indebtedness and shifting trade relationships complicates and mediates experience of the futural and the futuristic. In addition, food producers now face the worsening realities of climate change and supply chain disruption in the present, as well as greater difficulty attracting and retaining horticultural workers. English farmers and growers are, of course, also losing, gradually, the guaranteed safety net of EU-administered area-based subsidy payments that have long served to shield many from the realities of producing for global commodity markets (although not so much in the horticultural sector). The scales of agriculture that emerge then, in conventional English farming are clearly mediated by the network that is the national or international supply chain.

Emanating from this nexus of circumstances, and apparent in many of my research encounters, is a sense of Lauren Berlant's influential understanding of 'cruel optimism' (2011): a futurity shaped by an 'attachment to compromised conditions of possibility'

(Berlant, 2007: 33). The artifacts farmers and growers see as ensuring their future viability are also those that will possibly put them out of business as debt spirals or they are unable to keep up with keeping prices down. In this regard, there is also definitely something of the 'mute compulsion' Soren Mau (2023) describes in his recent work on economic power and the logic of capital. Producers' futural experience are saturated by the horizontal relations of capitalism: the exigencies of competition and the precarity of profitability. Previous chapters have discussed how this is related to a heightened control over plant life. Within this consideration of scale, we can consider various understandings of scale, and changes in scale, as an outcome of changing ways in which agricultural processes manifest themselves as produced by efforts to ensure future profitability rooted in capacities at the present moment.

Technology is a vital factor in this equation. When Robbins talks about technology 'at scale', he is discussing the forms of technology that facilitate intensified production in the interest of competition. The development of such technologies of scale-as-output is imbricated, fundamentally, with the historical development of capitalist agriculture (Winner, 1980), histories of proletarianization and 'the agrarian question' in general. Whether such technologies 'at scale' can or should play a role in the future remains an empirical question, but recognising these histories and how they will shape the future is important. Further, the impact of agricultural technology on farming 'at scale' is connected with decreasing amounts of labour required to farm greater amounts of land, a reality particularly clear in the discussions of arable agriculture above. Greater outputs have required less labour, a significant cost for farmers, preserving a modicum of profitability for many enterprises amidst downward pressures on food costs and

increasing yields. Yet this reality is also contingent and could change in the future, given the anxieties voiced above about future labour availability and the need to attract young people into farming. This is particularly true for labour-intensive horticulture, hence, to return to technology the appeal of emergent tools for automating picking or pest control that might see horticulturalists able to ape the scaled-up technologies of their arable cousins. The relevance of this is particularly clear in Chapter Five of this very thesis on vertical farming and CEA.

So, given this relatively bleak picture of the pressure facing food producers and the difficulties of inducing change via national level policy, what of those looking to do things even more differently in terms of agricultural practice from the 'grassroots' who focus on the 'local'? And are their operations, to introduce another sense of the world, 'scalable' enough to create a more agroecological future or, failing that, at least grow the English horticultural sector?

6.3 Growing What's Good

6.3.1 Producing Scale at Nettle Bank Farm

The future prospect of a break never seemed further away than during the hours I spent stooped over harvesting tiny brightly-coloured chilli peppers by hand, in a polytunnel at Nettle Bank Farm. By contrast, the day I spent harvesting squash alongside around ten other people went by in the blink of an eye. This difference in the experience of time is possibly a result of the camaraderie engendered by working in a team. Or it could be

because I could look up and see fields, trees birds and hedges rather than plastic. Or it could be because the pace and rhythm of work was set by others. Within this comparison there are a few related entry points for exploring futures, labour, the vegetal and the production of space-times and the scalar. In this section I continue along these lines drawing on ethnographic reflections on my time at Nettle Bank Farm, a place oriented towards the transformation of agricultural production towards more 'regenerative' or 'agroecological' methods, 'small-scale' technologies, and short supply chains. In other words, a place trying to make real an 'alternative' agricultural future in the present.

Nettle Bank Farm encompasses about 20 hectares of highly productive land in the East of England. Compared to Spencer's arable farm this is small and, as horticultural operations go, it's about half the size of the British average of around 47 hectares (Defra, 2024). Yet, compared to many smallholdings sharing the agroecological principles being operationalised at Nettle Bank Farm it is a relatively large, commercialised operation, with notable packing and processing infrastructure, with a significant number of growers working on less than five hectares of land (Defra, 2024).

Accordingly, the three weeks of October 2022 I spent working at Nettle Bank Farm provided me with a different perspective on the future of farming to that gained speaking to people like Spencer, or the scientists and growers from previous chapters. During this time, I got an idea of the histories, rhythms, and futures of what is, in England, a relatively well-known and commercially viable regenerative horticulture business. Yet my experiences echoed in surprising ways with the discussions above, despite the different 'scale' at which we were working. As far as work went, I was one of around twelve people

involved with picking a wide selection of fruit and vegetables which were sold directly to local consumers and to restaurants in nearby cities. This ranged from tomatoes and peppers in polytunnels clustered around the farmyard to ornamental gourds, carrots, and Jerusalem artichokes in fields beyond. Although they grew some heritage wheat, the predominantly horticultural nature of the business dictated the spatio-temporality of Nettle Bank Farm as a place.

The farm was owned by someone from the local area named Robin, but everyday farming operations were managed by a man called James, who prided themselves on adopting such a relatively low-tech, labour intensive and pesticide-free approach to vegetable production. It was organic, I was told, but certification was too bureaucratic a process for them, and they operated on trust with their suppliers who were free to visit whenever they liked. Robin had a romantic vision of an agricultural future that integrated much from the past. In the recent past the farm had even been using horses to plough fields. Farming heritage was a wellspring for a socio-technical imaginary of how the future should be, yet we never talked in detail about agricultural history in the area or the theory of change underpinning such a vision. All of my work was undertaken with hand tools or just my hands. I spent a long afternoon harvesting a strip of carrots with a pitchfork. That small field felt like the prairie. This technological philosophy resonates strongly with long-running tendencies in the alternative agricultural movement, and more recently the degrowth movement (Gomiero, 2018), regarding the idea of the ‘conviviality of tools’, as influentially theorised in the 1970s by Ivan Illich (2009). Within this rubric, the materialities of industrial technology inevitably produce futures controlled and steered by designers rather than users of technologies. Hand tools, conversely, via their

conviviality restore autonomy to their users and allow them the capacity to determine their own, in this case, agricultural futures.

But using only hand tools produced space-time, and by extension scale, in a way that deeply mediated the future possibilities of Nettle Bank Farm in one crucial respect: the necessity of an accessible supply of horticultural labour and, by association, the need to provide the amount of *time* required to cover the *space* being farmed in the desired way to a sufficient degree to attend to the lifecycles of the vegetables being produced there. Work by the likes of Maria Puig de la Bellacasa (2015), for example, on farming with an ethic of care resonates here. Does more direct engagement with plants through embodied labour necessarily engender 'a smaller scale' of farming where care for plants is more immediate or organic? What are the relations between discourses of scale and daily praxis in a site such as this? And how is this mediated by non-human lifeforms like plants?

Labour is key to understanding scale in horticulture, in a way that has been mediated in arable agriculture due to the historical circumstances discussed above. Yet, in a situation where the end of capitalist wage labour relations looks unlikely in the near future, advocating for a return to labour-intensive small-scale farming wherever possible poses some serious problems. The rest of this section explores these tensions, in doing so further demonstrating the connections between scale, place, territory, and network at the farm (Jessop et al., 2008). Fundamentally, Nettle Bank Farm's affective atmosphere as a place was deeply shaped by the density of people around and working on different things. This presence of labourers also determined the boundaries and

configuration of what was possible on the farm and the territory it was able to cover and work to improve.

6.3.2 Labour and Land, Land and Labour

The farm always felt peopled. The workers involved on Nettle Bank Farm fit into three types: migrant workers from Eastern Europe living on the farm, people from the local area working part time, predominantly in packing and processing, and people, me included, keen to know more about agroecological methods and therefore working on a voluntary basis in exchange for food and board. At the time I was there were two Eastern Europeans living on the farm, a married couple called Józef and Kat. They had been working across a number of different horticultural sites in England and Scotland for the past 8 years or so. They told me that the working conditions at Nettle Bank Farm were probably the best they had experienced. In the near future they were looking forward to returning to the country where they grew up and buying land near their families. This ambition had suffused much of their activity over the past years. Given their anticipated departure in the next year or so James was worried about how replaceable they would be given ongoing discussions about labour shortages in British agriculture.

The departure from the EU has rescaled the supply of migrant labour to British horticulture. Efforts during the early stages of the COVID-19 pandemic to involve more British people in fruit and vegetable picking quickly proved a failure. And now recent NGO-led research shows people from Ukraine, Uzbekistan and Tajikistan participating in a new seasonal workers' scheme which, in many instances, traps them in indebtedness and poor working conditions (McAndrew et al., 2023). James's workers were different to

Spencer's, who employed men of various ages brought up in farming and involved with contracting on various farms or exclusively for Shotley. Yet the concern about future labour supplies weighed on them both.

During my stay I spent much of my time working with Jess and Tom, a young couple from England with aspirations to start a small agroecological farm or market garden in the years to come. For them small fruit and vegetable growing was their best option environmentally, but also the financial realities of accessing land in England meant that they would never likely be able to do anything beyond that. At Nettle Bank they were volunteering in order to gain experience and knowledge. By the end of my time there they were keen to move on. Like many aspiring small farmers and growers, it will be tough for them to access land in the future, given land values, and tough to make enough money selling their produce without external sources of income. The vision of an agroecological future within which more people work the land requires skilled and knowledgeable people familiar with forms of farming outside of the industrial paradigm taught at most agricultural universities in Britain. At the moment this is a difficult pathway for most people and volunteering, low wages and exploitation are markable amongst aspiring growers looking to work on smaller farms with limited capital inputs and to develop future localised production networks, as recently increasingly acknowledged by grassroots organising in the sector by groups like the Land Workers' Alliance and Solidarity Across Land Trades (SALT).

Land access was less of an issue, however, for Robin who leased the land occupied by Nettle Bank Farm from a family member at what was apparently a favourable rate. This

provided a relatively secure future horizon for the business, which had also taken on new fields and built new infrastructure on site with the intention of selling more directly to the public in the coming years. This relatively secure future is, of course, rooted in a deep history of class relations and land ownership that has moulded the changing size and shape of British farms in the last five hundred years (Wood, 2002; Duncan, 1996).

Security also came, to a degree, from the size of the holding accessible via this arrangement. Most producers growing in a similar fashion in England would be doing so on a much smaller scale. The size of the holding made possible growing green manures for composting and keeping horses, factors that increased the autonomy of the farm in terms of reducing inputs and boosting soil fertility. Such advantages would be very difficult for a smaller grower. Although 'small-scale' is often heralded as the future of farming by certain agricultural groups like the Land Workers' Alliance (Laughton, 2017) operating at this medium scale afforded advantages at Nettle Bank Farm, in turn providing some certainty regarding the future, ecological benefits and commercial resilience (Thompson and Stinnett, 2018). These on-farm operations, amongst other methods, will become sources of money through ELMS if Nettle Bank Farm choose to apply for such funds. There was minimal discussion, however, of governance or regulation during my time there, and Robin and James seemed to think that by doing their own thing they should be able to exist autonomously from policy, as they do from organic certification, in the future. The idea that national-level or local government policy should support their work did not seem to occur either. They were forging their future on-site. This resonates with my broader experiences of the political futurity of the 'alternative agriculture' movement in the United Kingdom, within which an anarchist or libertarian

sensibility suspicious of state-led change mediates attitudes towards the future and theories of change.

6.3.3 Careful Farming

The way things worked at Nettle Bank Farm allowed what some scholars might call a 'greater ethic of care' (McGreevy et al., 2022) for individual plants and their produce. This manifested itself in terms of a heightened attention to the aesthetic qualities of plants' phenotypical development, or an emphasis on taste and texture rather than the robustness or speed of growth of a variety. James in particular demonstrated a deep knowledge of the necessary approach to each plant and the readiness, ripeness, or suitability of individual specimens for harvesting or, alternatively, composting. The variety of crops possible at this scale also allowed for crop rotations which necessitated planning into the future to assure that crops could give and take what they could or needed from the rich loamy soils in which they grew. There was an openness to vegetal futures that was mirrored, to an extent, in Spencer's work, but which facilitated a much greater variety of on-farm agricultural and biological diversity. Relatedly, the certainty and control facilitated by spraying with pesticides was, however, eschewed in favour of a belief that an array of other life forms would help keep plant pests under control.

A dynamic of more targeted controlling interventions was, however, present in some respects, for example as typified by long plastic nets protecting cabbages, or the multiple enclosed polytunnels dense with tomatoes, peppers, and aubergines after the summer heat. Plastic matting prevents weed growth to minimise labour time. Plastic netting covers field vegetables to keep away crows and butterflies and boost yields. Plastic

covers the polytunnels that allow the growth of aubergines, peppers, and tomatoes. Countless plastic tags kept those tomatoes upright and easily harvestable. Plastic, like unpaid labour, facilitates profitability which allows continuity. Plastic is embodied time and energy. Here perhaps we can begin to make connections between discourses of scale and futurity via a reading of scale as an understanding of the relationship between labour, outputs, spatial extent, technology which, when read together, combine to form an idea of agricultural potentiality that can be enhanced or eschewed. Interventions like plastic allow operations at a larger 'scale' than access to labour will permit.

James admitted it was difficult to foresee a situation wherein the number of workers employed, or the type of produce demanded did not necessitate plastic usage. This is not to say that only in a plastic free world is a transformative future realised, nor that this would be immediately feasible, but rather to point out the long material and abiotic temporalities implicated within the current viability of more agroecological systems. In many instances biodegradable alternatives were available but simply remained unaffordable. Here change, and change which was genuinely desired, was fettered by the competitive realities of market production and the ongoing realities of the age of cheap oil. Again, discourses of scale as currently manifesting in agriculture become difficult to separate from commercial viability and the 'mute compulsion' (Mau, 2023) of production for the market. In turn, these shaped what sort of *place* it was through the inevitable junction of people and plastic that represents much contemporary horticultural production in England.

The scale and intensity at which Nettle Bank Farm could produce vegetables was also mediated by ecological factors. The record-breaking heat earlier in the summer, I was told, necessitated starting work before dawn. It also had effects on water supplies at a regional scale beyond but inclusive of the farm, resulting in the need for prioritisation of what crops to water and grow and what to abandon to fend for themselves in the future. Thirstier crops, like beetroot, were written off and failed. We talked about the governance of water in the area, and I was given a brief insight into the relationships between farms, the local authorities and water companies. But neither Sean nor Robin mentioned any engagement beyond that. Unlike Spencer they rarely connected their agricultural practices with global discourses of climate change or even a regenerative agriculture movement, nor did they seem to be much connected with national-level institutions or representative bodies. Most focus was on the daily work of growing and working with plants to satisfy their own standards and their customers, as well as, where possible, enhancing local biodiversity.

Continuing with the idea of the ecological mediation of how scale is understood or produced at these farm sites, it is necessary to ask how plants themselves impact discourses and realities of agricultural scale and what effect this has on imagining the future of agriculture. Here the question of plastic and control leads again to the idea of multi-species care and conviviality. What, I think, the presence of these materials within such arguably 'prefigurative' systems reminds us of is, again, the inevitability of multi-species control in agricultural systems. Growing plants such as tomatoes and chilli peppers efficiently necessitate higher temperatures and lower moisture and therefore polytunnels. Their material qualities and growth – soft, fleshy fruit appearing at sporadic

intervals on vines – necessitates the continued reliance on the guile and perception of the human eye and hand which separates horticulture from arable agriculture in practice. In addition to this need for human labour, the presence, intentions, and desires of more-than-human pests like crows or caterpillars necessitated metres and metres of plastic netting out in the fields. As discussed above, this plastic represents energy that offsets the need for human labour or agro-chemicals.

The idea of control over the future re-emerges here. Reliance on human labour allows greater control over individual fruits or vegetables, compared to the way in which Spencer's grain could be engaged with only really as a sample of a multitude. Efforts to automate activities like harvesting are ongoing and efforts are being made not just to produce robotic systems capable of image recognition and dexterity, but also the breeding of plants to meet the needs of these systems. As Chapter Five on CEA argues, such an approach represents diverse histories and continuities of intensification which creates problems and deepens surplus alienation. I argue that such control and the mediation of uncertainty must be understood as a spectrum of possibility where compromises are required in any transitional future. In this direction, Eva Giraud's (2019) assertion that we must also think necessarily about which relationalities need to be cut or mediated rather than remarking upon the entanglement of everything is significant. Is human labour the only way to achieve a non-alienated future for horticulture at a necessary 'scale'? And if so, how is this prefigured in relations between people at Nettle Bank Farm?

6.3.4 Careful Commerce

The variety and quality of Nettle Bank Farm's produce fetched a premium price, thanks also in part to social connections beyond the immediate locality into the wider catering sector of the region. This was, of course, despite their access to land at below market rates and some additional unpaid labour. Much of this produce went to upmarket restaurants in urban centres. The ethic of care oriented towards plants was, in all likelihood, mediated and driven by James and Robin's anticipation of the reception their uprooted plants would receive from discerning chefs at an unspecified but inevitable moment in the future. This can be contrasted to Spencer's grain which would be agglomerated with wheats of equivalent quality grown by producers who shared their major international buyer. It is easy to forget, waste notwithstanding, that the future of farming is often food in all its materiality and ultimate metabolization. Not all produce, however, went to restaurants and, increasingly, the vegetables grown were being sold to local consumers via subscription.

Here a classic scalar assertion and trope of the alternative food movement was apparent: local food is best. This was a discourse reproduced by many I spoke to during this part of my research. Most of Nettle Bank Farm's neighbours were producing arable crops for commodity markets, much of which would likely find it's way into animal feed, bread, or biscuits. Yet here was an effort to localise or rescale the food system through expensive vegetables sold to people living nearby. The question of scale in terms of local food systems is well explored by agri-food scholars (Hedberg, 2020; Mount, 2012). Along those lines, the presence of Eastern European labourers, coconut coir imported from South Asia and plastic polytunnels clearly open the idea of *locality* to critique given the

networks via which such people and things integral to vegetable growing move across the world.

But what of the future trajectories of localisation and expectations? And the possibility or likelihood of greater localisation as a result of, perhaps, enterprises like these 'scaling out'? Aspects of the approach taken on Nettle Bank Farm to localising food systems connected scale and networks via the establishment, for example, of processing facilities on site and a shop for local sales of produce from Nettle Bank Farm and other vendors. Localisation here is advocated for as a form of reterritorialization, of staking control over a local food system through the establishment of new nodes in the network and the *control* over prices and produce allowed by direct-sales on your own territory. Yet champions of localising food production often risk ahistoricism. After all, the circumstances on Nettle Bank Farm as a site of historical class privilege and land ownership render this a relatively unique case in the locality. This is demonstrated by the surrounding farms producing commodity crops at large scales. Crops which, as a result of their nature, do not facilitate direct sales without intermediary processing or may not even be considered fit for human consumption, ending up instead as 'feed' rather than 'food'.

On the contrary at Nettle Bank Farm, as has been mentioned above, the quality and aesthetic of the fruit and vegetables picked was always under great scrutiny. James would channel his culinary habitus towards ensuring that the fennel I harvested demonstrated the appropriate bulge at the shoulder or that the tomatoes picked had just the right give. Within this there was less of a sense of robotic futurity (Rezvani, 2021) or a

requirement of uniformity than I encountered in talking to Spencer or vertical farmers. It was expected that different individual plants would produce different results, and this was something to be careful about, rather than something that could be *controlled away*.

This did not mean our work as people was not controlled or overseen. The fruit and vegetables that we were harvesting commanded a high price, embodying the care, change and labour time that had gone towards their production. It is possible to reach a conclusion that the provision of organically grown relatively local vegetables as a form of luxurious consumption speaks to the sort of frugal abundance associated with 'post-growth living' and a transformed sense of abundance or prosperity (Soper, 2020). But, in the current circumstances, this of course belies the realities of both production and access. Although Robin and James may have been farming with an ethic of care towards their produce and, to an extent, their local ecology, this care, I would argue was to a great extent oriented towards maintenance of their existing supply chains, reputation, and customer base. Again, we encounter the ambiguity of care as a future-oriented logic. The work of Adeline Johns-Putra (2013) is relevant here, who argues that to valorise care as a beneficent universal force is reductive, unhelpful, and ahistorical. In an agricultural context I argue we need to connect discourses and practices of care with consideration of capitalist dynamics that mediate, supress, or suffuse extant demonstrations of care, including in more conventional or industrial systems, as Puig de la Bellacasa (2015) suggests.

In this direction, a more critical understanding of care also allows articulation with Leonie Guerrero Lara et al.'s (2023) encouragement to articulate recent degrowth-

inspired critical work on food systems with a more robust consideration of the capitalist dynamics of the agri-food system. Care and conviviality often become facets of a business model oriented towards facilitating elite consumption. In the alternative food movement, this often articulates with middle-class or bourgeois aspirations, as influentially recognised by Julie Guthman (2000) in the Californian context over 20 years ago. Guthman's work echoed around Nettle Bank Farm. Horizontal relations of competition also render scale relational and relative, both as a discursive construct, but also insofar as competing producers are capable of exercising impacts on the ability of somewhere like Nettle Bank Farm to continue operating in their extant fashion as understood as 'scale'.

It is perhaps common-sense to argue that food producers care about the way their success or failure serves to reproduce their own livelihood and class position into the future. Yet this is often overlooked in academic explorations of agricultural care and transformation. Further, this is not to say these commercial and economistic logics solely dictate all farming operations. In fact, as with the discussion of vertical farms the 'mute compulsion' of economic power (Mau, 2023) was often mediated, as well as suffused, at Nettle Bank Farm by a clear extra-economic attachment to the landscape and local ecology which served to suppress the scale-as-potentiality produced through agricultural processes there. Yet delineating the boundaries between economic compulsion, reputational positioning and ecological commitments is difficult, as I have remarked upon throughout this work. These ambiguities connect with a broader dimension of my research which interrogates and explores the intentionalities towards transformation of diverse stakeholders in the food chain, from plant scientists to

lobbyists, all of whom believe they are playing a part in making agriculture more regenerative and 'feeding the world'.

Yet, when Nettle Bank Farm started there was suspicion and doubt about the future of a site which was seen, in the eyes of one local I spoke to in then pub, to have been 'growing weeds' due to the unfamiliarity of a differential approach to environmental control. And, despite the way in which the business has been able to take advantage of land tenure at a scale that facilitates biodiversity, circularity, and autonomy relatively efficiently, decisions around technology and temporality mean that their produce is expensive. The gulf between extant production and a more localised food system remains significant. And, with this gap needing to be bridged, it is important also to remember at the present moment the teleo-affective compulsions of commercial production and competition amongst producers, not only of commodity crops but also of artisanal or agroecological goods. This, without a doubt, mediates and structures decision-making about the future of Nettle Bank Farm via various factors of production mentioned above. Despite their many advantages, Robin and James always seemed harried and uncertain, particularly regarding client retention and labour access.

With this in mind, the future of such efforts at localisation and connectivity can be seen to represent perhaps a tendency not towards a so-called 'agroecological lighthouse' (Nicholls and Altieri, 2018) but towards an aggregator or intermediary of local production in other sites driven by a compulsion towards growth as a vector of security. This is a fundamental tenet of capitalism increasingly coming under critique from degrowth scholars, including in the agri-food sector (Guerrero Lara et al., 2023). Yet where

degrowth scholars tend towards work exploring the prefigurative facets of alternative agricultural processes or 'nowtopias', I assert here the importance of historicizing these and, via a consideration of scale, the enormity of the transitional question under scrutiny, following Robbins, who asserts scepticism about the fetishism of the local in visions of transition. Contra this tendency, I have also explored the realities of more conventional, industrialised, and capitalised farming operations looking towards the future. I have tried to articulate this with the idea that any work towards theorising and manifesting transition must work across scales in space and aggregation, but also in time and start not in the future, but in the present.

These comparisons lead now, in the coming section, to a more abstract engagement with what I call the 'registers of agricultural scale' mobilised in the preceding discussion and in the sectoral discourse more generally.

6.4 The Discursive Politics of Agricultural Scale

6.4.1 Registers of Agricultural Scale

What I hope to have begun to show in this chapter is how what is often considered the 'scale' of farming is in fact a combination of factors being enacted through the social-ecological processes of farming. 'Scale' in agriculture should be considered an outcome of various dimensions which shape what farming is rather than an objective for the future it seemingly is for many. I build further on this idea in this section which connects this argument with broader discussions of scale in considerations of agricultural change and

future agricultural states in England. I do this in order to apply these ideas practically and to address a gap in the literature regarding what we actually talk about when we talk about farming and scale. In doing so I re-emphasise the difference between many agricultural discourses and more theoretically inclined approaches to scale and socio-spatial relations more generally. To do this I interrogate a number of what I call interconnected 'registers' of agricultural scale.

6.4.2 Scale as Spatial Extent

The most obvious register of scale that emerges in the discussions of desirable agricultural futures is the question of farm size or the spatial extent of farms. Neumann (2009) critiques approaches such as those of Marston et al. (2005) who conflate spatial extent and scale. Yet in the discursive politics of agricultural scale this is the norm. For some, transitioning towards smaller farming units is both an ethical imperative and an inevitable outcome for the future as a result of present dynamics. This tendency is epitomised in the work of academic turned smallholder Chris Smaje. In his book *Small Farm Future* (2020), Smaje argues that small kinship-based farms will likely emerge in a climate changed future and will be able to provide sufficient and nutritious food for the population of Britain. Similar perspectives manifest politically peasantist and smallholder movements of contrasting tendencies which produce scalar discourses in different national contexts. In England, this is primarily via organisations like the Land Workers' Alliance and the Real Farming Trust.

A small farm future is, of course, constructed in tension with the idea that farms in the future should be, and will become, increasingly large. This future would represent the

continuity of existing trends in England (Willis, 2017). Economies of scale seemingly make larger English farms more efficient, with Defra statistics showing 'a small number of economically large farms (8%) produced over half (57%) the agricultural output using just 33% of the total farmed land area' in England in 2017 (Defra, 2021c). Such putative efficiencies connect with a vision of the food future within which farming must be as intensive as possible where it does take place to free up 'space for nature' elsewhere. This vision, known as 'sustainable intensification' (Dicks et al., 2019) or 'land sparing' (Lamb et al., 2016) has been discussed above in both previous empirical chapters.

Central to my argument in this chapter is that imagining future agricultures in a way that foregrounds scale-as-size alone is a reductive view which is insufficient for envisioning a better farming future, despite its ubiquity as a discursive touchstone. 'Small farms' or 'big farms' are relative and are not necessarily good or bad in and of themselves. It is the system, methods and power dynamics which matter. Exploring the relationship between holding size, ownership, labour power, environmental impact and on-farm economic and ecological diversity helps to flesh out this point.

6.4.3 Labour and Supply Chains

This connects to another register of agricultural scale: workforce size. Scale means very different things for horticulturalists and arable farmers, yet this is rarely accounted for in the discursive politics of agricultural scale, inside and outside of academic circles. Take, for example, a report by for the Prince's Countryside Fund (Winter and Lobley, 2016) in which the authors suggest farms with one or two workers are 'small' farms. Yet according to agricultural statistics horticultural farms in the United Kingdom employ, on average,

seven people, including so-called ‘casual’ workers whereas cereal and grazing livestock farms employ, on average, less than one (Defra, 2022c). The average size of a horticultural holding in 2021 was 44 hectares, compared to 176 hectares for cereals (Defra, 2022d).

These comparisons resonate clearly in the above discussion, given the way the materialities of grain and the histories of global arable agriculture have produced the capacity for Spencer to advocate for a regenerative turn to a large-scale industrial agriculture. Equally, migrant labour remains essential to horticultural operations in England, with ramifications for on-farm working conditions, supply chains and costs. Yet this question is also often flattened, and one ‘scale’ is focussed on above all others: the ‘family farm’. Winter and Lobley’s focus on what they call ‘family farms’ or ‘family-owned businesses worked both managerially and largely operationally by family members’ (2016: 3). Here the inseparability of discourses of scale, ownership and territory in agriculture re-emerges.

Yet ideas which are perceived to threaten the autonomy of ‘family farms’ in the future in the interest of social and environmental justice are beyond the pale across much of Europe, as recent farmer protests in early 2024 have shown (Hancock and Bounds, 2024). For fruitful future analysis, considerations of farm size must be brought into relation with labour and ownership and how these contribute to farms’ capacity for value-generation, rents, and profitability within time; in other words, their ‘viability’ as permanences which reproduce and intensify social-ecological relations into the future. At the moment, based on my discussions above, for many farmers the pathway to

viability is not necessarily an increase in scale-as-size but an intensification in operations and a gamble on improving efficiency.

Thinking through scale in this way also necessitates critical engagement with supply chains. At Nettle Bank Farm, the aspirations of an agroecological business to reterritorialize food system power via local sales are also a history of class power and land ownership in the locale. For Spencer, the global market in which the value of his grain is determined plays a role in shaping his agronomic decisions and future options. Here, to follow from Jessop et al. (2008), scale is inseparable from the socio-spatial consideration of network, place (e.g. 'the local') and territorialization inherent in the governance and regulation of food supply chains. This is not to say that thinking about doing supply chains differently in the future is not important. However, I would argue a focus on the processes and power dynamics of supply chains is more important than their length, which such a focus being another example of the replacement of critical considerations of scale with a focus on spatial extent within the discursive politics of agricultural scale.

6.4.4. Governance

Scalar considerations of governance emerged in different ways throughout the empirical material discussed above too, from the impact the transition to ELMS has on farmers like Arthur, to the way in which Robin and James seemed disinterested in national-level policy or certifications schemes. Questions of governance concern much human geographical work on scale, particularly the much-maligned conception of a 'nested hierarchy of governance' and it's rejection (Brenner, 2001; Cox, 2020). In this regard, the

current moment in English farming is significant, with the reformulation of previous European Union agricultural policy very much an ongoing process of ‘rescaling’. This rescaling of agri-environmental governance has had diverse effects in a United Kingdom now fragmented in terms of approaches to farming support. It also removes a ‘level’ from the group of institutions via which farms are governed, with the changes to the national terrain of governance considered below.

Conversations in this area often ask what the appropriate scale for creating a different future is. Is it local or the national? Grassroots or top-down? Yet when we are talking about ‘levels’ of governance, what we are really talking about is differential institutional power over land use decision-making via regulation, the capacity for requisition and the escalation of capacities via inducements to direct change.

This clarification, nevertheless, reinforces a scalar trope reproduced throughout farming discourses which valorises the ‘level’ of the farmer or owner-operator as a unit of analysis above all else in terms of their control over decision-making about what is grown and where and for whom (Darnhofer, 2020). This abrogates consideration of the broader political ecological horizon and historical forces which mediate and structure these processes significantly. This manifests itself in academic knowledge production via the concept of ‘autonomy’ in the work of theorists like van der Ploeg (2008) and in the public sphere via tropes of farmers’ rugged individualism and proud independence (Jansen et al., 2022; Stock et al., 2014). In policy circles, programmes focusing on rendering farmers rational entrepreneurial subjects reproduce this dynamic and wilfully ignores the broader totality of the food system that sees some farmers inevitably go out of business,

given their longstanding reliance, in many cases, on public money delivered through agricultural subsidies. In this direction, ELMS will affect the future scale of agriculture by resulting in farms going out of business and, thus, land being concentrated and farms growing larger. Whether by chance or by design, critics of the policy like Wach (2018; 2020) estimate that this will contribute to the paradigm of sustainable intensification and land sparing, despite, perhaps, the intentionalities and discourses associated with the policies.

On the other hand, the CAP has long been associated with the agglomeration and domination of large farms across Europe and a powerful farm lobby. Bartolini and Viaggi (2013), for example, found a demonstrable connection between the receipt of CAP money and the desire and intention to expand farming operations in the future. Interventions from European Commissioners for Agriculture (Foote, 2021) and Friends of the Earth Europe (2021) alike have suggested the CAP has hurt small farms. Yet, my discussions with farmers portend a worse future for 'small' or 'family' farms outside the CAP given the loss of baseline income it offered even the least profitable farmers through the basic payment scheme.

The move towards ELMS, then, creates a moment about which speculation about the future of the scales of conventional English agriculture is rife. These discussions also illustrate how the viable operational extent of farms *in situ* is clearly shaped and structured by national policy or, in the case of the CAP, supranational policy. Fundamentally, to reiterate a recurrent argument made throughout this thesis, to ignore the way in which the mute and even sometimes coercive forms of historically-

determined capitalist power and hegemony shape these policies in favour of focussing on networks and flat ontologies is not advisable for anyone wishing to actually understand the system they wish to change.

6.4.5 Technology

Also worthy of brief consideration is the register of the scale of agricultural technology and the prospect of embracing technology 'at scale' as referenced by Robbins, who discusses 'scaled, intensive, and technical innovation' (2020: 4) as something opposed by advocates of the degrowth movement. It is easy to assume that this description covers the sort of robotic milking apparatus he discusses in the article. This machinery makes it possible to milk large numbers of cows with minimal human input and a degree of simultaneity. Yet what is meant by agricultural technology 'at scale' is murky in Robbins' work, and in much wider literature and discourse on the topic. A definition of scale reliant on widespread usage would recognise that technology 'at scale' could refer to things like shovels. Further, any delineation of technological forms based surely on spatial extent or popular usage crumbles very quickly when we acknowledge that the technology that has perhaps most attracted the ire of the alternative agriculture movement over the years are tiny genetically-modified seeds.

However, it is likely that what Robbins means is technological forms designed to maximise output whilst minimising labour inputs (whilst usually relying on fossil fuel inputs instead). I believe scale here stands in for a fossil-fuel underwritten and historically-produced form of agricultural 'efficiency'. That reality, however, points to another question of scale in terms of power and governance relevant here, however,

which Robbins does acknowledge: the commensurability of different technological forms with immediate democratic control and their propensity to reproduce capitalist social relations. Why the generic language of scale needs to be inserted into Robbins' consideration of these worthwhile and interlinked considerations is not apparent to me given his failure to engage empirically with such questions, as he acknowledges is necessary. I would also argue, from a perspective sympathetic to agroecological change, the promotion of horticulture and, to an extent degrowth, that these ideas of technology, scale, efficiency and, by association, complexity obscure the different forms of efficiency, knowledges, and intensity or intensification offered by labour-intensive forms of agroecological food production. Many of which rely on an intricate knowledge of working with plants to maximise outputs for mixed-cropping systems in ways which create different spatio-temporalities and human-environment relationships, as I experienced working at Nettle Bank Farm.

Further, the extent and uptake or spread of certain agricultural methods or technologies often also becomes a question of scal*ing*. For Wigboldus et al. (2016) 'scaling up means something similar to increasing (e.g. in terms of numbers, speed, size), whereas scaling out often relates to expanding, such as geographically spreading the use of a particular technology'. In this regard, it is possible to associate Robbins' idea of scale with the idea of 'scaling up', a process I would also associate with the idea of 'intensification' discussed at length in this thesis.

Conversely, the idea of scaling out is preferred by advocates of the agroecological and degrowth movements. For example, in Nicol's (2020), scaling up does not mean

intensification but rather the embedding of ‘grassroots’ change in a conception of a nested hierarchy of governance. Such scalar discourses unknowingly reproduce tensions from scalar debates in human geography, for example by uncritically reproducing a sense of the primacy of networks (Cox, 2020) or nested hierarchies of governance (Nicol, 2020; Brenner 2001). Yet they do not see agricultural scale as something produced in social-ecological life and maintained through power dynamics or viability, nor do they attend sufficiently to the historical-material factors which constrain or enable scaling up, out or across in different contexts, such as land ownership or class power.

6.4.6 The Vegetal Scale

The juxtaposition of arable agriculture and horticulture in the empirical sections of this chapter also demonstrated how critical approaches to agricultural scale must also attend to different forms of vegetal life and the socio-technical configurations developed to control them in various ways and at various scales. In other words, a relationship between plantiness (Fleming, 2017) and both the discursive politics of agricultural scale and the actual production of scale via agricultural processes becomes apparent. In *Fossil Capital,* Andreas Malm (2016) talks of how the advent of fossil capital was a means of producing energy at an intensity/scale beyond what was previously possible via harnessing photosynthesis. An escape from plantiness and a reliance on photosynthesis made economic growth possible at a scale then previously inconceivable. Yet, in contemporary agriculture the limits of plantiness have been overcome differently in different sectors, with effects on how technology has emerged, how labour is involved and disciplined and, ultimately, how scale is produced.

In the discussions above I tried to communicate how possibilities of scale, understood in the senses Robbins (2020) deploys it to mean efficiency and intensity, is conditioned by histories of working with and against the tendencies and qualities of plants. For example, arable farmers like Spencer can farm wheat as a multitude thanks to technical interventions that have created uniformity for ease of mass harvest and processing. This creates specific ways of relating to plants, space and time and conditions ecological outcomes associated with annual arable agriculture, regenerative or otherwise. Such farmers are likely expecting gene editing to aid their work 'at scale' in the future (cf. Chapter Four). Conversely, horticulture involves squishy, temporally, and spatially unpredictable, and high-value fruits and vegetables which necessitate hand-eye coordination and manual labour in their picking and packing, as well as fixed infrastructures of environmental control in their growth like polytunnels or vertical farms (cf. Chapter Five). This too creates relationships between plants and people, as well as between capital and labour.

Is this intimacy and 'small-scale' preferable for all agricultural forms in the future? In some ways, perhaps 'yes', in terms of addressing questions of surplus alienation through rebalancing human activity and care for plants with vegetal temporalities. In other ways 'no', given the reliance of so many humans on vast quantities of cereals for their daily sustenance at this present moment in time. Further, such a romantic view must also account for the working conditions of horticultural workers, most of whom are very much *alienated* from the products of their labour in the traditional Marxian fashion that likely mediates their relations with plants. Speculation aside, what I am trying to say here is to conflate different agricultural activities into one scalar imaginary (be that a 'small farm

future' or 'megafarms', vertical or otherwise) is to compare apples and oranges. A political ecological approach which considers plantiness makes this clear.

In this section I have addressed a number of common discursive 'registers' of agricultural scale, critiquing their logic and connecting to them to ideas around the production of scale in practice. What, then, does this chapter say to the three research questions established in the introduction? What import of this discussion for a political ecological approach to agricultural futures in England? In this chapter's concluding section, I briefly reiterate my argument before addressing these questions directly.

6.5 Conclusions

This thesis's first research question concerned how relations with the future are formed in practice by farmers. The current situation in agriculture creates a degree of freedom for farmers to forge their own future by choosing their agricultural methods. This moment of possibility is often taken as the lever or vector for change by advocates of a transformed farming future that relies only on changing farming methods via, for example, subsidies or educational programmes and 'scaling out' existing efforts. What I have hoped to demonstrate here is the matrix of factors which stymies the way on-farm decision making affects the production of scale and how this is not reflected in discourses about scale in agriculture. This matrix includes intertwined political ecological considerations: access to land, labour, appropriate technology, and credit, as well as the ecological, meteorological, and geological realities of wherever you may farm

and the vicissitudes, temporalities and materialities of the plant life you elect to produce, be that grass, annual cereals, tomatoes, or apples. The grammar that suffuses this entire rubric is, of course, horizontal relations of production – 'locally' or internationally - and the pressure to remain profitable via innovation, expansion, or efficiency. The configurations produce futurity differently for farmers, as they interlock with personal circumstances, broader socio-technical imaginaries, and the everyday affective atmospheres of the futural. Ultimately, I have argued that scale is an outcome of farming, rather than an objective or a choice and to acknowledge that is rooted in an understanding of the futural life of agricultural practice and the futuristic imagination of different agricultures. Nevertheless, it is unsurprising how scale becomes a focal point in an agricultural sector given its fundamental relationship with the quest to achieve viability.

This leads to consideration of the second research question shaping this thesis, regarding the extent to which more-than-human life shapes and is shaped by agricultural futurity. The juxtaposition above between arable agriculture at Shotley Farm and horticultural production at Nettle Bank Farm helps encapsulate this. Even though they are very different production systems, the different technologies available and the labour requirements between horticultural produce like tomatoes and arable grains like wheat show how the materialities of plants co-produce scales in agricultural settings and, thereby, foreclose or empower possible futures for farmers, workers, businesses, and the land. Here Chapter Five on vertical farms and CEA is also relevant given how it displays efforts to mediate these materialities via spatial and temporal intensification within vertical farms producing horticultural produce. Similar efforts are acknowledged

above regarding, for example, the automation of horticultural labour. Arguably, mobilising Robbins' understanding of scale, these are attempts to 'scale up' horticulture and make such methods more like how arable crops are produced by reducing labour inputs and cultivating greater uniformity and temporal predictability. Extant differences these efforts are attempting to overcome are underpinned by the material qualities of these crops – the calorific density, storability and uniformity of grain facilitating these configurations historically, contrary to the more variegated and perishable vegetal expression of fruit and vegetables.

Nevertheless, across all instances the choice of the plant any farmer chooses to grow impacts how the present can unfold and what futures might be expressed through the historical natures (Moore, 2015a) that are created in agricultural worlds. This is not to present English farms as sites of mutual becoming and entanglement between species outside of the rubric of history that has shaped both Spencer's expansive fields and the polytunnels of Nettle Bank Farm. I hope that this chapter, particularly when read in conjunction with the previous empirical chapters, demonstrates the historical nature of such social-ecological assemblages and the impact that the capitalist 'project' (Moore, 2015a) of nature-culture dualism and the pursuit of exchange value has had on these ways of producing food and the agricultural scales which emerge via these processes.

Finally, as regards the third research question and whether empowering forms of approaching the future are revealed here, the issue of the openness of the future re-emerges here. Further pushback against the idea of an open future and an ahistorical and network-centric conception of 'scaling out' agricultural transformation is asserted

above. The approach I take, oriented as it is to the analysis of processes in the present, rather than idealising future scalar states, also exemplifies a mode of thinking about the future attuned to David Harvey's dialectical utopianism as described in *Spaces of Hope* (2000; cf. Chapters Two and Three of this thesis). I have hoped to show that this approach, rather than one that takes scale in and of itself as a desired futures state, is the appropriate way to critique and build towards agricultural change.

I appreciate, however, this is an exercise in form rather than content, given how this effort to refute existing scalar discourses does not, in itself, make future-oriented assertions about what agriculture or agroecological should become and the forms of scale that would produce. As a result, many questions remained unanswered, including some with clear scalar connections like: 'what is the role of the state here? Or of farmers?'. Those are questions that must be addressed but cannot be answered here at length. However, in the next chapter, which is also this thesis's final chapter and conclusion, I attempt to offer some more concrete ramifications and directions whilst drawing the preceding materials together.

7. CONCLUSIONS: FROM ALIENATION TO RECALIBRATION?

7.1 Introduction

7.1.1 Recap

This thesis has looked to approach agricultural change in England in a way that integrates a theoretical concern with the future into an analysis of the present. In attempting this, it has also folded in an attention to historical specificity wherever possible. Equally, spatiality and temporality have re-emerged as keystones throughout my theoretical analysis and empirical observations. A connected focus on the ever-changing relationships between plants and humans in agricultural systems has added a further dimension to this work which ensures it speaks directly to contemporary debates in human geography, political ecology, and STS. In this sense, this research has looked to offer an interdisciplinary perspective on contemporary agrarian change in the Global North rooted in political ecology, following the call from Galt (2013) discussed in the introduction. And, although I acknowledged Galt's calls for an inclusive approach to post-structuralist thought, the arguments I have come to make in this thesis retain a distinctly political ecological quality. This has manifested itself in an interest in the power dynamics of capitalist agriculture and the changing relationships between humans and plants within these configurations, both now and in the future.

Fundamentally, I have attempted to combine an interest in geographical and political ecological work by scholars such as David Harvey and Jason W. Moore with qualitative, ethnographic research. This methodological foundation has allowed for an approach to futurity which makes this thesis an original contribution to the literature regarding the political ecology of agriculture in the Global North (Galt, 2013). This is due to the way I have worked across relations between scales of futurity, from the quotidian and affective futural register of daily practices in vertical farms or polytunnels, to the socio-technical imaginaries informing futuristic visions of automated English agricultures.

These reflections lead to a brief summarisation of the central arguments I make in this thesis below. These will be re-asserted in greater detail throughout this concluding chapter with reference to the preceding work. I offer these arguments now in distilled form for the sake of initial clarity:

1. The future of agriculture in England is not open. It is historically shaped and remains overdetermined by a range of structural factors. This does not mean, however, that it is totally foreclosed either. Nevertheless, an understanding of capitalist social dynamics and their intensification makes the future legible, if not foreseeable, in the present.

2. As such, the future is political. It is, of course, also ecological, given changing environmental circumstances and the ways in which agriculture is defined by the coming together of human and more-than-human life and the spatio-temporalities created by these configurations.

3. This includes everyday interactions between humans and plants in the agri-food chain, and the ever-intensifying efforts to shape how plants live and are capable of living in the interest of transforming agricultural production. These interventions will, however, never be total in their efficacy.

4. Attitudes to the future of agriculture in England affect decision-making in the present and are shaped by ecologically, historically, and ideologically determined understandings of possibility, desirability, and legitimacy.

5. This reality imbues people engaging with food production and agricultural change with an ambiguous political subjectivity that sees transformation as necessary and desirable but only within the confines of existing social relations. This may be as much the case for scientists as it is for conventional or agroecological farmers.

6. This ambiguous subjectivity is related to forms of future-oriented agricultural or biotechnological practices which are shaped by an inseparable logic of care and control.

7. These realities, and the empirical engagements which inform their theorisation, make foreseeing prefigurative forms of a radically different agriculture in the present difficult. But they also complicate or counterbalance efforts to dismiss certain aspects of contemporary agricultural practice as unnatural, anthropocentric, or inherently violent.

I will explore the political and practical ramifications of these assertions in greater detail later in this chapter with specific reference to the research questions established in Chapter One. Before then it is first necessary to further situate these arguments via a brief recap of each previous chapter. The final section of this chapter builds on these ideas to offer some potential directions for future research and concluding reflections.

7.1.2 Chapter Summaries

Chapter One, 'Introduction: Establishing Horizons', introduced the context this thesis was written in, setting out my intentions and the way my research changed over time. It also explained and justified this thesis's joint focus on the vegetal and the future. It argued that insufficient focus has been given to the relations between humans and plants in agricultural systems in the Global North. Further, it linked this concern with a desire to understand the future not exclusively as something imagined, but as something material which saturates the present. It established the political ecological roots of this work via the work of Galt (2013) mentioned above. It concluded by distilling these broad ambitions into three research questions. These will not be reiterated here as they are answered directly below.

Chapter Two, 'Literature Review: Towards a Political Ecology of the Future' further set out how I approach the future, building the theoretical framework which permeates the rest of the thesis. Firstly, it established, via consideration of the work of David Harvey, how I understand relations with the future to be linked to the spatio-temporalities which shape and are shaped by social-ecological processes like agriculture. It asserted how relationships with the future of agricultural systems are produced by contemporary

discourses, institutions, materialities, power dynamics and social relations. Further, it looked to both abstract and historicise these approaches to the future through the consideration of how some social processes become embedded in reality as relative permanences or formations.

This chapter then juxtaposed the work of Harvey on spatio-temporality (1996) with that of Theodore Schatzki (2010) on futurity and practice. Schatzki's critique of Harvey's work centres on the latter's perceived methodological abstraction and his lack of engagement with embodied social-ecological practice. Although I ultimately side with Harvey and critique Schatzki's ahistorical tendency towards a flat ontology, I also recognise the need to connect an attention with social space-times with the 'futural', as understood as the futurity of everyday practices. To make connections between these two registers I argue for the utility of the linked concepts of 'teleo-affective formations' (Welch et al., 2020) and 'socio-technical imaginaries' (Jasanoff and Kim, 2015), which are deployed consistently throughout the thesis. These concerns also animated my focus on emergent agricultural technological forms given the extent to which expectations about technology shape and are shaped by expectations about future agricultural landscapes.

Pursuant to my political ecological ambitions, the third section of Chapter Two brought in the diverse other species which are implicated by definition in agricultural systems. In particular, it connected the work in this thesis with 'vegetal political ecology' (Fleming, 2017) and an attendant concern with how human-plant relationships are historically produced. I argue against the sort of flat ontology favoured by Schatzki, linking my approach to Jason W. Moore's (2015) dialectical and historical consideration of humans

within nature. This leads to an explicit engagement with social scientific approaches to relations between humans and plants in agriculture that foregrounded the key concepts of labour, value, care, and control which suffuse the empirical chapters of this work. I concluded Chapter Two by arguing that the best way to understand how inter-species relationships make futures and shape futurities in agriculture is through an approach that follows Moore's idea of the double internality of humans in nature (2015), whilst recognising the need to add to such a theoretical basis by looking to further historicise the current conjuncture via a consideration of alienation (Büscher, 2021; 2022). This allows for an approach that engenders both historical specificity and causation, whilst still resisting dualism and anthropocentrism. In doing so I argue against approaches to the future which see the future as open or determined equally by multi-species agency, highlighting how the 'surplus alienation' associated with the capitalist mode of production must be accounted for in any political ecological consideration of agricultural futurity.

Chapter Three, 'Methodology: Between Theory and Practice', built on the theoretical ideas developed in the literature review and integrated them into my methodological approach towards conducting empirical research. This chapter first established how a political ecological approach to the future would operate, as opposed to existing social scientific approaches to the future. This leads to an elaboration of the methods and research I undertook in 2022. This can be summarised as an ethnographic methodology that attempted to make connections across scales of lived futurity through semi-structured interviews, participant observation and critical discourse analysis. This

culminated in the research as presented, which ultimately came to take the form of three interlinked case-studies presented as the three empirical chapters of this thesis.

The first of which was Chapter Four, ‘Phenotypic Intent’. This chapter explored how changing regulatory approaches to plant breeding technologies are implicated with both conceptualisations of plant life at the molecular level and understandings of the future of English agriculture at the landscape level. It does this by historicising claims about the potential of so-called ‘precision breeding technologies’, such as CRISPR-Cas9 gene editing, to revolutionise the production and cultivation of agricultural plants in England and beyond. Within this, consideration is given to the spatial forms, such as plant breeding facilities, which shape these technological developments and their epistemological underpinnings. Throughout, both scientific and legal efforts to define what plants do and what they are under certain circumstances are central. These knowledge practices are historicised as perspectives which represent dialectically opposed fragments of a specific ideological moment, in that they attempt to reconcile the unpredictability and vitality of plants with their regulation and control.

Ultimately, I made several key arguments. Firstly, that the socio-technical imaginaries which characterise expectations about the future of English agriculture must be assessed via consideration not just of ideas, but also of institutions and material practices like plant breeding. Next, I argued that ambiguity about what constitutes the ‘natural’ potential of plants is mobilised in contradictory discourses which have served to legitimate easing rules on techniques like gene editing. In other words, the genetic possibilities of plants are understood as both exceeding previous scientific

understanding *and* as fundamentally calculable and regulatable. This tension points to the mobilisation of forms of analytical or strategic nature-culture dualism within the 'capitalist project' (Moore, 2015a) itself. Rather, I argue that an approach that rejects naturality as a benchmark for legitimacy allows for a clearer analysis of these emergent technological forms. In this regard, the idea that precision-breeding in whatever form represents a ruptural moment in human-plant relations is rejected. Accordingly, I criticise the legislative approach taken in England as it reproduces this contradictory dualism, as well as forms of temporality reliant on a reductive modernist understanding of vegetal life (Adam and Groves, 2007).

Similar ideas underpinned Chapter Five, 'A Spectrum of Control', which explored emergent forms of 'vertical farming' in England. It looked, again, to contextualise the historical-material circumstances which have served to produce the financial, technical, and ideational capital required to assert that vertical farming can and should play a significant role in the future of English horticultural production. It argued that, despite growing concerns about the profitability and viability of vertical farming from an energetic perspective, a future within which vertical farming plays an increasing role coheres with historical trajectories of the intensification of control over plant life in agricultural or horticultural systems. I also argued that such systems offer novel opportunities for profitability, rentierism and corporate control over the food system. To make this argument, I drew on participant observation from my time working in and visiting these systems, as well as interviews with growers, technicians, and advocates of these methods.

I also combined future-oriented perspectives and futural practices with a concern for how plants themselves serve to produce the spatiality and temporality of these systems. I argued that these spaces are best understood as sites of heightened control over plant life in a way that also ambiguously represents an ethic of care for both plants and the material technical systems within which they are cultivated. I contextualised this by returning to questions of alienation, control, and care, arguing that, despite their pitfalls, vertical farms remind us of the intrinsic necessity in agriculture of human ecological steering and future-oriented forms of control. Nevertheless, I argued vertical farming represents an extreme form of such a reality given their ideational underpinnings and capital-intense logic.

The final empirical chapter, 'Growing Viability', applied the thematic and theoretical development established thus far to the question of farming more generally, in particular in relation to the production of scale in agriculture and the way scalar discourses shape expectations about the future of English farming. It did this by critiquing existing registers of scale which permeate transformational imaginaries of food systems change, ranging from those who fetishize small farming to those who believe only 'large scale' industrialized agriculture can deliver future food security. Using empirical data collected during my time spent visiting and working on farms, I argued that agricultural scale is a material corollary of lived future-oriented multi-species agricultural labour, as well as a facet of the various socio-technical imaginaries associated with agriculture. In arguing this I developed a perspective towards agricultural change and the future which acknowledged the political ecological considerations which make scale not just something that can be called for and engineered, but something that, in reality, is created

via relations with plants within historical structures, socio-technical configurations and pre-existing ecological conditions. Here, again, I hope to have argued for an approach that acknowledges the complexities of capitalist farming by humans within rather than on 'nature'. In doing so I linked such theoretical concerns to extant debates about what the future of agriculture should be like, arguing that the institutions and social relations which condition farming as it currently is must be transformed and, via that transformation, new relations between humans and plants will emerge, producing new spatio-temporal forms and, as a result, novel scales.

7.2 Research Questions

7.2.1 Returning to Research Question 1

The first research question posed in Chapter One asked 'how are peoples' relationships with the future formed in the present and how do those relations with the future impact agricultural change?'. There are three interlinked answers which emerge to this question in this thesis.

Firstly, I demonstrated how relationships with the future are produced via lived experiential practices, such as agricultural work or the development of agricultural technologies. Chapter Two set out how this works in the abstract, highlighting how spatio-temporalities are shaped by social processes, including the lived experiential and affective temporalities of daily life. Within agricultural production this includes the social-ecological interface created by caring and controlling other forms of life for the

purposes of human sustenance, as well as the ecological conditions which mediate the success of such activities. In laboratories for crop varietal development, however, the future is related to in a different way as a result of the different embodied knowledge practices involved, the temporalities with which they articulate and the spatial forms they engender. In this sense the relationships we have with the future of agriculture are rooted in the materiality of the present as social action.

However, it is a central argument of this thesis that these lived futurities do not simply combine to form 'big' futures as an aggregate of social experience. Rather, what I have tried to show is that these lived experiences of the future articulate with, shape and are shaped by broader social formations of futurity, be that understood as 'socio-technical imaginaries' or 'teleo-affective formations'. These represent some of the 'more-than-life' dimensions, to borrow again from Büscher (2021; 2022), of social reality under late capitalism, insofar as a 'highly uneven capitalist biopolitics comes to be experienced by humans as more-than-life, as a 'coercive external force'' (Büscher, 2021: 66). These iterative, shifting, and interrelated understandings *and* materialisations of what the future could or should be like have real effects on everyday experiences and relations with the future of agriculture, ranging from openness to utilising gene-edited crops, to the legitimation of investing public money in nascent forms of vertical farming.

Thirdly, both of these previous facets – lived experience and its 'more-than-life' resonances - are deeply shaped and mediated by historical trajectories that create relative permanences (Harvey, 1996) of materialities, imaginaries, institutions, discourses, social relations, and power dynamics which are then reproduced into the

future. In the context of English agriculture, as my research has shown, these are futures shaped by a past within which social relations of market dependence and an ever-increasing tendency to mediate the ecological and economic uncertainties of food production have become deeply embedded, with longstanding spatial, temporal, and ideological ramifications. These are futures mediated by a past within which institutions of agricultural technological development have been shaped and oriented towards the provision of cheap food, profitability, and chemical-aided simplicity. These are futures haunted by pasts within which farmer indebtedness and investment necessitate working towards maximising financial returns.

Within each chapter, breaking free of the structures which currently undergird and shape what the future of agricultural production will be like in England seems difficult (although it is worth noting that the majority of my focus has been on conventional rather than 'alternative' agricultures). For example, in Chapter Four, the lure of facilitating continued high-yield intensive monocultural arable agriculture through gene editing has proved irresistible to many farmers and scientists. In Chapter Five, long histories of controlling plants' environments lurch into the future on a wave of investment hype, regardless, in the first instance at least, of their material throughput and energy requirements. In Chapter Six, deep histories of market dependence, agricultural specialization and the concentration of land ownership combine to influence extant debates about the future desirable scale at which English agriculture could or should take place.

This is not, however, a story of unremitting continuity that will endure into the future, as is made clear throughout the thesis. Take, for example, the way within which the

ecological exigencies of climate change, water usage or reducing the use of agro-chemicals are mobilised to justify certain technological developments like gene editing or vertical farming. From this responsiveness to agricultural conditions, Polanyian tendencies towards offsetting the environmental impacts of market-driven food production or modulations in profitability emerge which integrate the logic of the agricultural present into a transformed future which remains pregnant with its own contradictions. This is echoed in the logic of technological development which supports and catalyses these shifts. NPBTs and CEA are both archetypal examples of this historical development of capitalist agriculture. Furthermore, these changes to agricultural practice and technologies facilitate and shape changing relationships with plants, understandings of vegetal life and the phenotypical manifestation of plants themselves and, as a result, their ecologies. Plants, of course, are accounted for in this change given what they can or cannot be made to do, leading us to a return to the second research question established in the introduction.

7.2.2 Returning to Research Question 2

This thesis's second research question asked: 'to what extent do plants, and humans' relations with plants, shape how the future is envisioned, practiced, and manifested within agriculture?'.

In Chapter Four, the capacity of plants to respond to the CRISPR-Cas9 process in ways that will shape the future of gene-edited landscapes was demonstrated. As was the way in which plant breeding processes are delayed by the need to evaluate plants' phenotypical development in real time. In Chapter Five, we encountered how the

materiality of plants determines the economic viability of vertical farms, given the differential energy requirements of, say, leafy greens and potatoes. The way in which removing plants from terrestrial soil-based ecologies may require the re-addition of microbial supplements to vertical farming systems was also highlighted as an example of the limits of ecological simplification. In Chapter Six, the realities of having to account for different plants' growth and forms was connected to a consideration of horticultural and agricultural labour and how this shapes the politics of agricultural scale. A tomato necessitates different forms of labour to wheat for reasons shaped by both the morphology of tomato plants and the histories of plant breeding and agricultural machinery which affect current practices.

The answer that emerges from these theoretical and empirical reflections is that plants fundamentally shape how the future is envisioned, practiced, and manifested within agriculture. However, they do so in a way that is historically modulated and is increasingly subject to novel and intensifying forms of human control. The work of Jason W. Moore (2015a) has been returned to throughout this work to establish a framework for thinking these ideas together. Capitalist agriculture produces 'historical-natures' within which both plants and humans are integral to the ecologies which result. These ecologies, of course, condition the kind of practices that take place therein, and the spatio-temporalities and futurities which are generated *in situ*. That takes different forms in plant breeding facilities as it does in an agroecological horticultural business. Nevertheless, the spatiality and temporalities of the sites I visited were clearly co-produced as a result of the way plants live and, so too, were shifting expectations about their futures.

Despite this, the work undertaken has not been as heavily influenced by post-structuralist or new materialist approaches as I had originally foreseen. This is because, despite arguments by critics like Tilzey (2017) or Kohei Saito (2023), I argue Moore's conceptual foundations can be combined with work by the likes of Harvey (1996) and Büscher (2021; 2022) in ways that do not lead inevitably to a vision of the world dictated by a flat ontology wherein 'agency' is promiscuous and diffusely distributed. In the situations discussed above, vegetal agency, as relationally emergent in agricultural systems, was constantly subject to suppression, mediation and harnessing for the purposes of profitable capitalist agriculture. This does not mean it was not present *per se*, nor efficacious. But rather, following Büscher (2021), that its consideration was best placed in an analytical rubric concerned with the diagnosis of, and resistance to, the intensification of surplus alienation within agricultural systems.

In each empirical chapter, plant lifeways necessitate human strategies to circumvent them in the hope of a more profitable agricultural future. In the case of vertical farms, this is done via growing leafy greens and tinkering with their 'vectors of perfectibility'. In the case of commercial horticulture, this is achieved by engaging precarious and low-paid workers to manipulate and work with plants that require more individual attention than fields of wheat or barley. In both cases, automation is touted as a future way to further overcome the limits to accumulation posed by vegetal beings. Whether or not that will be achieved is a point of speculation. What I argue *is* important, however, is how future agricultures and changing plant-society relations are best read as the intensifying striving towards such an end: the overcoming of the limits to accumulation posed by vegetal beings (cf. Mau, 2023).

As a result, following Büscher (2021; 2022), I argue the current moment is best analysed from a historical-material perspective interested in critiquing alienation, rather than championing the agency of the more-than-human world. The historical reality in England is that vertical farms *can* accelerate the maturation of basil significantly and that gene editing *will* have significant impacts on what plants are like and how they grow.

This thesis has often engaged with this reality through temporality and the need to engineer the predictability of plants and the synchronicity of their rhythms with the oscillations of capitalist accumulation both on farms and across the supply chain. This is not to say that agriculture and plants have been totally 'subsumed' by capitalist 'mute compulsion' (Mau, 2023). But efforts at subsumption as an ongoing 'capitalist project' are, I argue, the moment of social reality most necessary of examination in the interest of offsetting the unjust social and ecological consequences inherent to our way of producing food.

Yet, within this very thesis the idea of alienation itself is nuanced by acknowledging the novel forms of proximity, knowledge and care inherent to gene editing, vertical farming, or large-scale commercial yet 'regenerative' arable agriculture. The way in which this reality connects with considerations of care and control is discussed in further detail below, but the tensions between the two again highlight the complexities of thinking through alienation. Nevertheless, as I have argued throughout, I believe the questions of alienation and its intensification are highly pertinent to the historical-material moment of vegetal political ecology under consideration. This, to borrow again, from Moore

(2015a) is the 'capitalist project' of thinking and talking about nature as if our control or subsumption of it was not just never in doubt, but already achieved. The reality of actual 'capitalist process' as materially manifest is more complex than that. This is represented in the consideration above, on the one hand of NPBTs, technologies which look set to become widespread which rely on the vitality and potentiality of plant life to manifest desired outcomes through their genetic plasticity, and, on the other, vertical farms which try to control plants as much as possible, yet face an unpromising future in terms of their economic viability despite their elective affinities with an emergent food regime of digitalized capitalist agriculture. Both represent changing forms of plant-human relations sparked by uncertainty about the future and a desire to retain or reproduce existing power dynamics. These were the realities I encountered when considering this second research question throughout much of my research, with the exception of my time working at Nettle Bank Farm. Nevertheless, even there, where care was more *patient*, the working realities were shaped profoundly by historical power relations and market dynamics. What possibility, then, of new ways of relating to plants that would transform agriculture in the 21st century?

7.2.3 Returning to Research Question 3

That question leads to this thesis's final research question: 'How do different ways of conceptualising and materialising the future enable or constrain agricultural transformation in the present?'

Firstly, I argue that thinking about the future as 'open' and a site of radical experimental possibility (Carolan, 2016) does not resonate with the empirical examples I engage with

during the preceding chapters. In fact, in diverse circumstances, I highlight the need to understand what is shaping the future being created in the present. Although I understand the potential affective resonances of such an empowering idea as an 'open' future, to reject presentist structurally-sensitive critique in favour of a speculative openness is at best short-sighted and, at worst, naïve. We must conceive of the future as permeated by the ever-increasing weight of the permanences which are reproduced in the present by certain capitalist dynamics whilst also recognising how these permanences shift, offset and absorb novelty in the ways discussed in regard to the first research question.

To do so is not to reject the potential of the new or the transformed in the present. As I hope I have demonstrated in my examples, change is always happening. Farming has changed substantially in recent decades. However, much of this change, like the developments I point to in Chapter Four and Chapter Five, results from an intensification of existing dynamics of capitalist English agriculture, and efforts to offset or fix the problems and contradictions it generates. The scope of this empirical work limits the extent to which this thesis can point to concrete examples of affects, social relations, agricultural techniques, or emergent material infrastructures that carry hope of positive or radical transformations in the way that food is produced and distributed in England. Examples of such changes do exist, but as I have established earlier, I elected to focus, for the most part, on relatively 'conventional' or 'mainstream' farming. This approach was rooted in a position which acknowledges that, given the foundational nature of agricultural production to societal reproduction, we cannot dismiss the existing food system wholesale and start from scratch. This argumentation connects, again, with the

work of David Harvey on the need for a dialectical utopianism, as argued for in *Spaces of Hope* (2000). Contrary to this grounding, however, this thesis does not offer many hopeful seeds for agricultural change in the way the future is conceived and related with above.

It is worthwhile noting here the different ways to answer this question. The approach above refers to the approach we as social scientists and critical researchers should take towards considering transformative futures in conjunction with our research. But as I suggest above, the idea of an open horizon of possibility was only ever a hypothetical reality for my research participants. Food producers, plant scientists, technicians or campaigners recognise they are starting from a present moment characterised by extant material infrastructures, ecologies social relations and institutions. That has varying effects though, according to, for example, your commitment to creating change or your need to reproduce your farm as it is in order to continue to make money to buy food of your own. Yet, with this acknowledgement of market dependence, comes a reminder that throughout the research I present above the tendencies which I argued are producing futures of intensifying capitalist control over vegetal life were not often expressed directly by participants themselves. And, as the case of the scalar discourse in Chapter Six shows, the kind of approach I take to considering how futures are generated politically and ecologically is not shared by advocates for farming change, regardless of the size of their preferred future.

Yet there were forms of futurity which did emerge in my empirical research that I believe constrain rather than catalyse the possibility of transformative agricultural change.

Central within this are two recurrent concepts: techno-optimism and an understanding of plants as possessed by forms of 'robotic futurity' (Rezvani, 2021).

Techno-optimism consistently re-emerged in Chapters Four and Five as a defining ideological touchstone. This techno-optimism imbued advocates of gene editing and champions of vertical farming with a melioristic sensibility towards the future within which technical changes to material agronomic practices would be sufficient to offset and overcome the political ecological tensions of contemporary English agriculture in the present. Although this optimism is seemingly more justified as regards gene editing and NPBTs than vertical farming, in both cases I argue that this belief in technical fixes emerging in the future clearly delimits the way in which people conceive of and recognise the necessity of changes to the system which has created these problems in the first instance.

Within that intensification, the conception of plants as demonstrating a 'robotic futurity' wherein their development and manifestation can be forecasted and steered was another recurrent trope. I also argue that this way of conceiving of plants forecloses the imagination of different ways of relating to plants, given the hubristic belief it instils within scientists or farmers that agricultural plants and their ecologies can be seamlessly controlled, despite consistent reminders from plants and other species that this is never total. Even as recognition of the vital and relational nature of plants and agricultural ecologies develops amongst the scientists in Chapter Four, methods such as gene editing or vertical farming oriented towards an (impossible) suppression of this relationality as part of the capitalist *project* loom large.

This recognition brings us back to further consideration of the concepts of care and control. I would argue that the discussions above show that 'care' in and of itself as a way of relating to the future should not be read as intrinsically beneficent or transformative. This comes as a result of the ways in which care is rendered ambiguous as a result of its mediation within processes of capitalist agriculture and vegetal techno-science. Yet care should also be considered prefigurative given the reality of care as an unavoidable teleo-affective politics across agricultural forms. The question, however, becomes how we can create a situation within agricultural systems where a *slower care* can emerge (cf. Puig de la Bellacasa, 2017). There were hints of this in my ethnographic reflections at Nettle Bank Farm, but it is a question which could shape future research (see below). And if care is something about which I argue expectations should be tempered, I have actually argued for an acceptance and openness to the necessary reality of human control over plants in agricultural ecologies. This links back to the rejection of the idea of an open future. It is worth revisiting David Harvey's (2000) critique of Lefebvre's open futurity here. Materializing a future agricultural system through novel forms of control cannot be dismissed outright as totalitarian. Considerations of alienation, control and temporal disjuncture between humans and plants must be balanced against each other via new institutional arrangements. These are questions I take up further below in the next sub-section which explore the political implications of these arguments in more detail.

7.3 Final Reflections

7.3.1 Broader Political Ecological Implications

How can answering these research questions apply to any practical or political engagement with the agricultural future more broadly? Firstly, it should be abundantly clear that there is no blueprint here for a future agriculture. This is not a 'recipe for the cook-shops of the future' (Marx, 1990: 47). Nevertheless, there are applicable messages beyond critique that I think come from this research and represent interventions into the discourse on agriculture and nature-society relations more broadly.

Firstly, the intensification of alienation inherent to some of the agricultural approaches discussed above must be understood as a spectrum that can be mediated or resisted through alternative agricultural practices and the supply chains and institutions which render them more or less permanent. Through these practices we can develop different ways of relating to plants and, in doing so, different agricultural ecologies in the future. This is a reality best understood through an attention to temporality, as I have shown. Agroecological approaches to food production which produce, rather than resist, more consciously diverse synchronicities, and rhythms in agricultural timescapes must be sought. Yet these agricultural practices do not emerge simply from our imaginations or from convincing words. They must be produced in practices that create viable futures, not just islands that prefigure a different way of producing food.

As Chapter Six highlights, greater involvement of human labour in agriculture would also facilitate these changes and novel ways of relating to plants. But the vast majority of people in England do not work in agriculture or horticulture and do not want to. Failed efforts to attract British horticultural workers during the COVID-19 pandemic proved how distant a possibility for the future this remains. But recognition of this reality again reasserts a central argument of this thesis: the need for a holistic consideration of how agricultural outcomes come to produced that extends beyond agronomy and the imagination. Different farming methods, greater education of the public or novel imaginaries alone will not transform the food system, let alone reproduce change and create relative permanences.

Changes will have to articulate across social life, from addressing market dependence through decommodification to cultivating the institutions to produce, disseminate and cohere changes to physical and social infrastructures of food production, distribution, and consumption. But, as I argue, this will not just happen because we want it to. The future is not open in that way. This comes together in arguing for radical interventions into the governance of the food system which would begin to short-circuit market logic and gradually rebalance power over land-use decision making or food supply chains. This position is pursuant to the work of Harvey (2000) which recognises the need to start making the future in the present in a way that recognises the materialities and reproductive infrastructures of the present as something that cannot be dismissed or done away with in one fell swoop.

The scale of the need to work systemically, radically yet pragmatically is significant, but this thesis has hopefully made a coherent argument for this as a starting point. The importance of founding new institutions to create these possibilities is perhaps the most important facet that has emerged from my own thinking during this research process. Approaches that focus on agronomy and changes to the material basis of farming alone cannot produce viable agricultural permanences, nor can theories of change rooted in discourses or imaginaries, which take changing public opinion or farmers' mindsets as sufficient to changing the future. Discourses, materialities, power relations and social relations can, however, both be transformed and cohere via institutions, and I believe that, as such, they must represent a central dimension of any agricultural theory of change.

The question of institutions and institutional design brings us back to the topic of control, over both other humans and more-than-human life. To invite and accept new shared institutions in this instance is to invite and design new forms of diffuse control. This recognition connects to my scepticism towards the fabulation of futures premised upon an open futurity as typified by the work of Carolan (2016) and the anarchist or libertarian tendencies of the alternative food movement discussed in Chapter Six. This, to reiterate, is rooted in the need to consider social relations, history and power dynamics when theorising change. To borrow an appropriately vegetal metaphor: a desire solely to see a hundred flowers bloom may result in 99 flowers dying and one blooming which is incapable of drawing sufficient nutrition from the soil to further reproduce. This is a result of the growing media through which such a horticultural expression is being sought. This

is not to say that experimentation and voluntarism must be abandoned, but rather that efforts may be better focused on replenishing or even replacing the soil.

My conclusion from this is that such structural change, change to the social growing medium so to speak, necessitates an attention to the role of both the state and the institutions in its constellation which is often missing from alternative agricultural imaginaries in England and agri-food scholarship. I argue that to unlock or destabilise the relative permanences created in how food is produced now will require an engagement with these realities. This is particularly the case if we are to seek is a pre-emptive transition towards a future agriculture, rather than a reactionary disassembly into a small farm future (Smaje, 2020) in a significantly hotter world.

All told, I believe a strategic pessimism is required. This offers a way of relating to the future that does not totally foreclose change but recognises the way within which such possibilities are fundamentally political ecological whilst becoming increasingly sticky over time. There is also, perhaps, hope in the ways within which agricultural systems are renewing themselves in order to offset environmental uncertainty or social unrest. Within that the integration of novel forms may result in slippages that portend new forms of possibility. This is not necessarily evinced in my empirical material, but the frequency of agricultural change in order to retain or cultivate viability is. This is also a rejection of a futurity premised *entirely* on history: we cannot go backwards and look to farming heritage alone to solve these problems, although of course the past is a reservoir of what we might now call agroecological methods. Too many people are deracinated from food

production and reliant on food as commodity for this to be a defining strategy of any transformation and its technological philosophy (cf. Duncan, 1996).

This rejection also speaks to my argument that new relations with plants can be created by changing practices without rejecting the irrevocably anthropocentric nature of agriculture. We can develop new ways of caring for each other via our relations with plants through the provision and distribution of healthful food whilst acknowledging that new agroecological landscapes will require diverse forms of control and ecological discipline. This is reconcilable with an approach that sees humans within nature but with distinct qualities that can facilitate agroecological stewardship, rather than the sort of 'Good Anthropocene' logic for which Jason W. Moore's work is critiqued by the likes of Kohei Saito (2023). I am arguing that it is possible to reconceptualise the environmental and social logic of agriculture in a way that at once recognises the naturality of human agricultural forms, whilst at the same time sees the real capacity for temporal disjunctures or unnecessary ecological violence within that internality. These capacities derive from historical circumstance and power dynamics and can thus be overcome without totally threatening social reproduction. In overcoming, for example, the intensification of alienation, a specific and valorised form of inter-species care will be required, as too will be a slowing down of the temporalities of capitalist agriculture and a realignment with seasonal rhythms. It is no coincidence these suggestions may be anathema to a vertical farmer.

7.3.2 Future Research Direction

This work generated many avenues for possible future research. Firstly, as highlighted in Chapter Four, work that looks in greater ethnographic depth at the processes by which plants are bred, trialled, licensed, distributed, and discontinued in England or the United Kingdom would address an existing gap in the human geographical and STS literature. This would build on the work above in two important ways. Firstly, it could allow for a greater engagement in the way plant development is anticipated and evaluated by breeders, technicians, and farmers. This could connect to efforts towards a more situated attention to the way plants themselves succeed or fail under different circumstances according to agronomic criteria. It would also allow greater connection and engagement with these embodied practices and the histories of plant breeding in the United Kingdom. This could connect with agrarian political economy or critical political ecological literatures drawing on food regime theory (Tilzey, 2017) or metabolic rift theory (Saito, 2023).

Another direction that subsequent research could take concerns agricultural land use decision-making in England. In particular, further social scientific research is required on the idea of a 'land use framework' for England. I made some efforts late in my fieldwork to begin discussing this with participants as it increasingly became a focal point for policymakers and campaigners across the United Kingdom in 2022. In reality, the idea of an ambitious land use framework could serve as a conceptual foil for further consideration of some of the fundamental and underlying questions which reoccur throughout this thesis. These are questions around the role of the market in determining social outcomes and allocating and mediating land use, as well as questions about the

real autonomy of farmers as sovereign decision-makers of what agricultural produce is grown, where and how. It would also offer an opportunity to explore or envision alternative institutional forms which could create different agricultural futures through an emphasis on deliberation, collaboration and consensus amongst land managers, communities, and experts.

Finally, the third and final future direction for research which I believe would complement this thesis is action-research or participatory research that would look to understand and re-envision agricultural care and temporality in conventional farming systems whilst working with farmers. In order to avoid an attention solely on agronomy and farming practices, however, this would also require engaging actors across the food chain to see how changing agricultural forms of care could be facilitated and rendered institutionally viable. This could include exploration of structural interventions like a 'right to food' or ambitious societal visions such as degrowth. This is an ambitious methodological approach which would require a priori buy-in from key stakeholders to guarantee success and sufficient data collection. If done properly, it could serve as a living lab for an alternative food future, and better delineate the prefigurative practices and affects which resonate in the present, driven by a hunger for food systems change.

7.3.3 A Conclusion

In undertaking this research, I experienced a range of affective states in terms of how I related to both agriculture's future and my own. This was shaped and transformed by the COVID-19 pandemic, the cost-of-living crisis, and the ever-present background radiation of climate anxiety. At times I felt empowered and at others I felt hopeless. Sometimes

these affective states were triggered by the presence and thoughts of others and at other times I experienced them alone. What emerges from these turbulent years of introspection and engagement, however, is one final and certain conclusion: *the future will be different*. Current trajectories of global heating will have impacts on food production in the coming decades which will exceed our capacity to govern in an anticipatory fashion. And as this change happens and a drastically different future emerges, the factors that have allowed most people in a country like England to take the availability of foods for granted will be increasingly destabilised. It is very possible that the historical prioritisation of the accumulation of wealth over the equitable distribution and ecological production of healthful food will come to be seen as an epochal mistake. In the meantime, I hope that the growing presence of such a future in the present catalyses collective action before it is necessitated in more reactionary forms.

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APPENDICES

Appendix A: Excerpt from Field Notes

17.5.2022

Insightful trip to [the Institute]. I met [Jenny] at reception and we walked over to her office so I could finish my tea. Whilst we were in the office, we had a chat, and I learnt a bit about her background and some of her overall views. She has no degree or similar in plant science but has worked her way up to her current position as head of CEA and horticulture in a practical and vocational way. Within this explaining this she also demonstrated the disjunctures between those involved with plant breeding and those involved with the maintenance and daily interactions with plants within the facilities. This is something perhaps to be considered and taken forward in future given differing appreciations for futurities in situ and futurities in theory of seeds and cultivar development. [Jenny] talked of her understanding of plants and their development in an embodied/practical sense and the capacity of her and her staff to acknowledge emergent problems with the development of different cultivars. [Jenny] claimed she could notice, for example, when a batch of cultivars were not demonstrating certain aspects of phenotypical development that may be associated with their genetic profile.

We talked a bit about the institutional dynamics and oscillations between funding and resourcing different approaches. For example, [Jenny] was unhappy with the lack of resources and attention given to entomology and nematology in recent years. Things

tend to move in cycles as far as she was concerned, and whims are followed or prioritised according to varying institutional ebbs and flows. We also talked a bit about conjuncture and the general understanding of the role of [the Institute] and the intentions and objectives of the facility as is. Here we encounter similar arguments: we need to grow more food in Britain, we need to be more self-reliant, and we cannot rely on cheap imports produced to lower environmental and regulatory standards.

We then visited the facilities: the CEA rooms, the greenhouses, and the insectary.

The [Jenny] rooms were very interesting. Behind big bank vault style doors, a cluster of different varieties of wheat growing in pots. Only maybe 12 or 15 in total. She told me that as a result of the increased capacity to predict and engineer the outcomes of plants trials could now be constructed with fewer and fewer plants. Uncertainty has been significantly reduced. The atmosphere is rendered optimal for the growth of these plants according to a set timetable, there are no efforts to necessarily make things move more quickly. The lights were bright LED lights, with a little gentle wind from the occasional fan if I remember correctly. [Jenny] hypothesized about what it would be like if we could hear the plants scream. We continued through the facilities. I got some more conjunctural/imaginary horizons: for [Jenny] we are constantly playing catch up with pests and the growing population. We need to innovate and manipulate plants unless we fall behind this curve, which would result in suffering. She was also keen to point out what is, for her, a significant difference between plants and animals in terms of genetic editing. For [Jenny] the significant differences between plants and humans means the

risks of unforeseen circumstances are significantly reduced compared to tinkering with animal genetics. She also talked about the differentiation between various categories of GMO plants – and lamented the extent to which GMO development has been overlooked or chastised.

The greenhouse and insectary didn't yield much. The facility felt very quiet and there were only a few maintenance staff around. I guess the plant breeders and 'scientists' are all off in labs somewhere. I understand [redacted] *at the heart of new investment given renewed institutional interest in food and farming systems. [Jenny] seemed quite proud of the insectary. Insects being used to test plants resistance, but the cultures within are 'pure' and lineages which, as I understand it, have been there for quite a while.*

On the way back there were dried out stream beds between fields of light, golden wheat. Maybe we do need genetic editing, I thought. Maybe we are operating in difficult, time-pressured scenarios here. Yet what does an alternative [Institute] look like? Would many of the principles be the same? Working with plants to ensure the best outcome, exposing them to different conditions, stress-testing them… presumably yes. Or would it not be centralised at all like this

APPENDIX B: List of Interviewees

Interviewee	Interviews	Anonymised as:	Format
Agricultural Robotics Developer	1		Online
Environmental Farming Advisor	1		Online
Farming Policy Campaigner	1		Online
Pesticides Campaigner	1		Online
Farming Policy Campaigner	1		Online
Farmer & Campaigner	1		Online
Farmer & Campaigner	1		Online
Farming Policy Campaigner	1		Online
Agricultural Knowledge & Extension Professional	2	Gabriel (GM)	Online and in-person
Indoor Grower and Plant Technician	1	Jenny	In-person
Research and Innovation Policymaker	1	Lee (LN)	Online
Farming Policy Campaigner	1		Online
Agricultural Inputs Public Relations Professional	1	Nigel (NS)	Online
Farmer & Campaigner	1		Online
Agricultural Robotics Developer	1		Online
CEA technician/grower	1	Arnie (AF)	Online
CEA grower	1	Bradley	In-person
CEA Public Relations Professional	1	Jerome (JG)	Online
CEA grower	2	Oscar (OO)	Online and in-person
CEA technician	1	Kevin (KT)	Online
CEA grower	1	Will (WR)	Online
CEA grower	1	Lucian	In-person
CEA data scientist	1	Hugh (HG)	Online
Land use data scientist	1		Online
CEA technician	1	Theo (TC)	Online
CEA Grower	1	Patrick (PA)	In-person
CEA Grower/Horticulturalist	1	Grant	In-person
Farmer	2	Spencer (SS)	In-person
Farmer	1	Arthur (AW)	In-person
Farmer	1		In-person
Farmer/Horticulturalist	1	James	In-person

Local Authority Professional	1		Online
Farmer	1		In-person
Farmer	1		Online
Biotechnology Campaigner	1	Deborah (DY)	Online
Crop Scientist	1		Online
Biotechnology Campaigner	2		Online
Crop Breeder/Data Scientist	1	Dylan (DP)	Online
Industry Association Policy Professional	1	Kyle (KA)	Online
Biotechnology Public Relations Professional	1		Online
Biotechnology Public Relations Professional	1		Online
Land Use Campaigner	1		Online
Plant Breeding Public Relations Professional	1	Helen (HR)	Online
CEA technician	1	Henry (HE)	In-person
CEA grower	1		In-person
Crop Scientist	1	Clive (CB)	Online
Farmer	1		Online
Land Justice Campaigner	1		Online

APPENDIX C: Example Interview Schedules

1. Gene Editing Interview Schedule

1. **GDPR**
    a. Introduce yourself and ask if they have any questions prior to getting started.
    b. IN-PERSON: Explain confidentiality elements and ask them to sign the consent form.
    c. VIRTUAL: Explain confidentiality elements, start recording and then ask them to verbally agree on the record to the statement in the consent forms.

2. **Introduction & Icebreaker**
    a. Can you tell me a bit about your role(s) at [COMPANY NAME]?
    b. Do you have a scientific background? How does that inform your work?

3. **[COMPANY NAME]**
    a. Can you tell me a bit about the work [COMPANY NAME] are currently doing?
    b. Could you explain a bit your relationship with [SUPPORTING INSTITUTION]?
    c. Where do you see your position in the current biotechnology sector?
    d. Your website accentuates the role of speed in what you do – how much quicker are you capable of working than existing technologies?
    e. I was wondering if you could tell me what is meant by 'future-proofed' crops?
    f. The website also includes some wording I find interesting around [XXXX] could you explain a bit what that metaphor means in practice?
        i. Why was this potential previously inaccessible?
    g. Can you tell me a bit more about how machine learning facilitates new developments in gene-editing?
        i. How can it be understood to 'imagine' new cultivars?
    h. To what extent can we really control genomic expression?
    i. How is the commercial relevance of traits determined?

j. Vertical farming is something I am interested in more broadly – can you tell me a bit about how these technologies might benefit that sector?

4. <u>Gene Editing in General</u>

a. How comprehensive or conclusive is existing research in to gene editing?
b. Should we be less concerned about gene editing plants than animals?
c. Do you think that the metaphors we have around communicating what gene editing is effectively convey what it involves?
d. Why should we equate gene editing with traditional forms of mutagenesis?
e. How do you feel about the term 'precision breeding'?
f. Why is an absence of 'foreign DNA' significant in the safety of these processes?
g. Why does better genomic characterisation result in better risk assessment?
h. To what extent is 'traditional breeding' "semi-random"?

5. <u>Legislation, Consultation & Regulation</u>

a. Is it fair to say the existing legislation is 'out of date'?
b. What do you think of the term 'precision breeding'?
c. Why do you think there is such support for gene editing?
d. Do you sympathise with any of the criticisms of gene editing forwarded by campaign groups?
e. LEGISLATION:
    i. "A feature of an organism's genome is "stable" if it is capable of being propagated whenever the organism is reproduced, whether by sexual or asexual reproduction…"
    ii. "In determining whether a feature of an organism's genome could have resulted from natural transformation, no account is to be taken of genetic material which does not result in a functional protein…"

iii. How do you think regulators and government foresee being able to assess what is or isn't possible to be a result of 'traditional processes'?

f. Do you think this legislation 'follows the science'?

6. <u>Future Regulation, Policy & Investment</u>

a. As current processes towards gene editing becoming more widespread, do you have faith in regulators and government to effectively enforce the new rules?
b. Who do you think could benefit most from ongoing processes to deregulate gene editing?
c. Do you think we are on a pathway to deregulate genetic modification as well as gene editing?
d. Do you think other countries and the EU will follow suit in changing their regulatory approach?

7. <u>Ecology/Environment</u>

a. Is there confidence that gene editing can deliver on the prospective environmental benefits?
b. Do you think there will be sufficient economic incentives to produce ecologically beneficial cultivars using these technologies?
c. Do you agree with the ACRE assessment that gene-edited organisms are unlikely to persist outside of agricultural environments?
d. Should be more willing to accept unforeseen risks as a result of the environmental situation we find ourselves in?

8. <u>Affect/Experiential</u>

a. Are you worried about how humans will feed themselves in the future?
b. Can you describe how you feel when thinking about the future of vertical farming?

c. What about conventional agriculture?
d. Are you optimistic or pessimistic about the future of food production?

9. <u>Scenarios/Imaginaries</u>

Explain lots of the questions will be about expectations and theories about the future so feel free to think big!

a. What are your plans or objectives for 2023?
b. Can you tell me what impact you think gene editing will have on UK farming in 10 years time? What about 50?
c. What about on a global scale?
d. What's the best-case scenario for the development of gene editing?
e. What about the worst case?

10. <u>Concluding/Follow Up Comments</u>

a. Is there anything else you would like to discuss?
b. SNOWBALL
c. Would you be happy to be interviewed again later in the year to follow up on some of our discussions?

2. Vertical Farming Interview Schedule

1. <u>GDPR</u>

a. Introduce yourself and ask if they have any questions prior to getting started.
b. IN-PERSON: Explain confidentiality elements and ask them to sign the consent form.
c. VIRTUAL: Explain confidentiality elements, start recording and then ask them to verbally agree on the record to the statement in the consent forms.

2. <u>Introduction & Icebreaker</u>

a. Ask them to introduce themselves and to describe their role in relation to vertical farming.
b. How did you come to get involved with vertical farming?
c. Do you have a scientific background? How does that inform your work?

3. <u>Production</u>

a. What sort of crops are you currently producing?
b. Why are these crops chosen?
c. Where do you get your seeds?
d. How long from sowing to harvesting?
e. Can you tell me a bit about your hydroponic system?
f. How good are germination rates?
g. Are some crops more reliable than others?
h. Have you got the timing right?
i. Do you get any pests?
j. What are the main challenges?
k. How data driven is your production system?
l. How much time is spent with the plants?
m. Are you able to find a good balance between supply and demand?
n. How will vertical farming change the type of crops we grow?
o. What crops might be produced in vertical farming systems or similar arrangements in the future?
p. Are there any facets of agriculture that vertical farms will be unable to address?
q. Who is the current market for vertically farmed produce?
r. How might this change in the future?

4. <u>Staffing/Automation</u>

a. How many people currently work at your vertical farm?
b. Do you think this will increase or decrease in the future?

c. What role can robotics or automation play in the future of vertical farming?
d. What kind of jobs, if any, will vertical farming create if it is successfully scaled up?

5. **Policy/Regulation**
    a. How favourable is the current regulatory or policy environment to the advancement of vertical farming?
    b. What sort of policies would bolster the chances of the vertical farming sector growing?
    c. Are there any current efforts to regulate vertical farming in order to ensure it is environmentally sound? Or standardise certain elements?

6. **Spatiality/Scale**
    a. Is there anywhere that is particularly advanced in terms of developing vertical farming systems?
    b. Why should we relocalise food production?
    c. Do vertical farms have to be urban?
    d. What impact would the increased presence of vertical farming in urban environments have on cities and how urban residents live?
    e. Will vertical farming become a global phenomenon? Why/why not?

7. **Business/Profitability/Investment**
    a. Are vertical farms currently a profitable enterprise?
    b. Who are the main investors in vertical farming systems?
    c. Do you think it's fair to categorise some discussions around vertical farming as 'hype'?
    d. Is there a competitive environment in the sector? Or do people look to share knowledge?

e. Should vertical farming be a priority sector for investment?

8. **Ecology/Environment**
    a. What benefits will the advent of vertical farming systems have for the environment?
    b. Will vertical farming systems help reduce greenhouse gas emissions?
    c. What energy requirements will vertical farming systems of the future have and how will these be met?
    d. What impact will vertical farming systems have on urban environments?
    e. What impact might vertical farming systems have on biodiversity?
    f. Are there still pests to be controlled in vertical farming systems?

9. **Affect/Experiential**
    a. Are you worried about how humans will feed themselves in the future?
    b. Can you describe how you feel when thinking about the future of vertical farming?
    c. What about conventional agriculture?
    d. Are you optimistic or pessimistic about the future of food production?

10. **Scenarios/Imaginaries**

Explain lots of the questions will be about expectations and theories about the future so feel free to think big!

    a. What are your plans or objectives for 2022?
    b. Can you tell me how you think your vertical farm will look in 5 years time?
    c. What role do you think vertical farms will play in providing food to the average person in England in 10 years time? (And 50?)
    d. What about on a global scale?
    e. What's the best-case scenario for the development of vertical farming?
    f. What about the worst case? What could go wrong for the sector?

g. Who would a successful vertical farming sector help most?
h. Who might be opposed to its development?

11. <u>Concluding/Follow Up Comments</u>

a. Is there anything else you would like to discuss?
b. SNOWBALL
c. Would you be happy to be interviewed again later in the year to follow up on some of our discussions?

3. Farm Visit Interview Schedule

1. <u>Introduction</u>

a. Icebreaker: Can you tell me a bit more about your farm?
i. Size, ownership status, employment, family history, succession status?

2. <u>Practice</u>

a. Daily practices
i. What's taking up a lot of your time at the moment?
ii. About how many hours a week are you working at the moment?
iii. Do you feel in control of your time?
iv. Would you like to spend less time working?

b. Forward planning
i. How far ahead are you able to plan at the moment in terms of the operations of the farm?
ii. How much would you like to change?
iii. Has this changed much in recent years?
iv. Would you like to expand if the opportunity arose?

c. Risk & Innovation

i. How would you describe your attitude to risk?

ii. Are you trying anything new or running any trials on the farm at the moment? If not, why not?

iii. Have there been any big recent changes or innovations in the last 10 years or so?

iv. How much difference can small changes make?

3. <u>Ecologies</u>

a. Plants

i. What varieties are you currently growing? Why?

ii. Are they reliable/predictable?

iii. Have you experimented with different cultivars?

iv. Do you do any breeding or trials on site?

v. Where do your seeds/cuttings come from?

vi. Can you tell me a bit about your experience of working with your crops/fruit?

vii. How do you know when somethings not right?

viii. How was last year's crop?

ix. Are your yields improving year on year or quite stable?

b. Pests

i. What are the major pest issues you face here?

ii. Are you able to stay in control for the most part?

iii. Are there any emergent or novel threats that worry you?

iv. What control methods do you use? Are they remaining effective?

v. Have you considered alternative methods like IPM or biopesticides?

vi. Do you think the way pests are controlled in the future will change much?

vii. Some people advocate for a pesticide free future, do you think this is possible? Why/why not?

viii. Biodiversity is on the agenda – do you think it's improving or declining in the area? Why?

c. Soils

i. People talk a lot about soils these days, is this something that you've become increasingly interested in?

ii. Have you noticed any changes to your soils in recent years?

iii. Are you interested in the Soil Management aspect of ELMS?

iv. There are some who say quite worrying things about the future quality and fertility of British soils, is this something you're concerned about?

d. **Climate change and weather**

i. Do you worry about the impact climate change will have on your farm?

ii. Do you think the weather will get more unpredictable in coming years?

iii. Do you rely much on water from elsewhere?

iv. Do you think much about the future supply of water to your farm?

v. Are you concerned about your on-farm emissions?

e. Landscape

i. How do you think the landscape round here will look in 10 years time? What about 50 years time?

4. <u>Policies</u>

a. ELMS

i. How is the so-called agricultural transition period affecting your farm?

ii. What have you done to mitigate the uncertainty created during the last few years?

iii. Will the introduction of ELMS make things better or worse for your farm in the future?

iv. Taken the future into account?

b. Innovation

i. Are there any emerging technologies you think could benefit your farm?
ii. Have you followed the discussion around gene editing? Do you think this could be a good way forward?
iii. What about discussions about precision agriculture?
iv. And automation?
v. Have you heard much about Defra's farm innovation programme?
vi. Do you think can make gains in productivity over the coming years?
vii. What about farmers in general?

c. Prices

i. How have the current issues around prices and inflation affected you?
ii. Has it or will it make you make any changes to the way you farm?
iii. Will input prices continue to increase in the future? Which inputs specifically and why?
iv. When, if ever, will things go back to normal?

d. Land Use Framework

i. The recent food strategy suggests they will publish a land use framework. What do those words mean to you?
ii. What could be some advantages from a land use framework? What about negative effects?

e. Vision

i. Do you think Defra and government ministers have a clear vision about what farming should look like in the future?
ii. How significant is net zero for farmers currently?

iii. Who do you think farming policies ultimately benefit?
iv. And who is calling the shots? Who has the power when it comes to the big decisions?
v. How much power do farmers have?

5. Imagining Alternatives

a. Optimism/Pessimism

i. Are you optimistic about the future of your farm?
ii. What about farming in the country as a whole?

b. Cooperation

i. Do you talk much with friends or neighbours about the future of your farm?
ii. Some parts of Defra's new policy platform suggest farmers should be cooperating more on agricultural and environmental improvements – do you cooperate at all with others? Is this something you'd be interested in doing more of?

c. Change

i. What's your view or response to people across the political spectrum who think that farming needs a real change?
ii. How much change is required**?**
iii. Who is best positioned to deliver that change?
iv. Do you identify with any terms concerning different understandings of farming?
    1. Nudge with 'regenerative agriculture' and 'agroecology'

d. Imaginary 5/10/20

i. What do you think English farming will look like in 10/20/50 years time?