University of Reading

Challenging orthodoxies:

Essays on agri-food system transformation

Costanza Conti

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Under the Supervision of:

Giacomo Zanello & Andrew Hall

Declaration of original authorship

I confirm that this is my own work, and the use of all the material and all contributions from other sources have been properly and fully acknowledged.

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Costanza Conti,

April 2023.

Declaration of competing interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this thesis.

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To all the girls who are told to sit quiet:
stand up and change the world.

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Abstract

Today's agri-food systems are at a watershed. A bundle of environmental, social, and economic threats currently looms over agri-food systems – ranging from climate change to inequality. Thus, in recent years, several research, policy and civil society actors have recognised the need to fundamentally shift production and consumption patterns towards more viable directions of development. This is why an agri-food system "transformation to sustainability" is increasingly central in the global agenda, as the only way forward to ensure agri-food systems of the future are environmentally sound, economically viable, and socially just. However, transformation will be a highly complex and uncertain process that is expected to fundamentally reshape the structure and functions of agri-food systems as we know them, demanding a shift from the established beliefs and practices, processes, actor relationships, and outcomes that have underpinned them. Recognising the need for challenging some of the accepted practices and "ways of doing things" that might have, until now, contributed to upholding unsustainability, this thesis i) discusses how new approaches are needed to tackle the inherent complexity of agri-food systems as a prerequisite to navigating transformation; ii) acknowledges that concealed system elements might have ingrained, and over time, reinforced, unsustainability in current agri-food systems, creating resistance towards novel (and sustainable) directions of change; iii) recognises that some key features and enablers might come into play for making transformative initiatives able to challenge the *status quo*; iv) considers how present challenges raise novel and largely unanswered questions on how agricultural and food research organisations can respond to the transformation agenda. Structured as a collection of papers and employing different qualitative research methods, the thesis explores and addresses the abovementioned points. In particular, the thesis i) provides, through a comparative case study analysis, a set of novel principles that might be helpful for navigating agri-food systems complexity; ii) identifies, through a systematic literature review, a set of interconnected elements that create resistance to new sustainable directions in current agri-food systems, presenting a framework that can help uncover them in different contexts; iii) reveals, through a case study in South India, some essential features and enablers of transformative processes; iv) discusses, through a critical literature review, the possible novel roles that agricultural research organisation of the future might assume to support transformations, and the consequent implications that different organisational visions might have. As a whole, this body of work identifies some of the most critical orthodoxies (a linearity orthodoxy, a simplicity orthodoxy, and an orthodoxy in the role of agricultural research organisations) that currently hinder a sustainability transformation, to then provide critical suggestions on how they could be overcome. The thesis also reflects on the implications of this for policy, highlighting how policies might need to be re-

envisioned in a way that can better respond and adapt to the complexity and uncertainty of agri-food systems contexts (and their transformation). Besides, considerations emerging from different chapters suggest that more attention should be devoted to supporting novel, wide-ranging and even unconventional forms of innovation, while also ensuring that the directionality of transformative processes across the globe is maintained towards sustainability. The thesis emphasises that policy-making processes should become much more inclusive, ensuring that all voices can participate in deciding desirable (if negotiated) transformation pathways. As a final point, the thesis proposes some venues for future research.

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[1] All tables, boxes and figures are, unless otherwise specified, elaborated by the author of the thesis.

Abbreviations and acronyms

AFROs	Agriculture and Food Research Organisations
CEO	Executive director
CSA	Centre for Sustainable Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CWS	Centre for World Solidarity
EALB	East African Breweries Limited
ESA	Eastern and Southern Africa
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FPOs	Farmers' Producers' Organisations
GLDC	Grain Legumes and Dryland Cereals
GR	Green Revolution
HICs	High-Income Countries
HLPE	High-Level Panel of Experts on Food Security and Nutrition
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IMOD	Inclusive Market-Oriented Development
LMICs	Low and Middle-Income countries
M&E	Monitoring & Evaluation
NARS	National Agricultural Research Systems
NASFAM	National Farmers' Association of Malawi
NGO	Non-Governmental Organisation
NPM	Non-Pesticide Management
NZ	New Zealand
OECD	Organisation for Economic Co-operation and Development
R&D	Research & Development
RRI	Responsible Research and Innovation
SAPCO	Sahaja Aharam Producer Company
SDGs	Sustainable Development Goals
STEPS	Social, Technological and Environmental Pathways to Sustainability
UN	United Nations

1. Introduction

"FESTINA LENTE."

"HURRY CAUTIOUSLY."

CAESAR AUGUSTUS

Abstract:

This chapter provides an overarching introduction to the thesis, illustrating how the pressing challenges of our age have called for a novel agenda – the sustainability transformation agenda. Drawing from the literature, the chapter illustrates how this agenda raises key issues in current research debates and identifies some existing research gaps. These gaps then inform the research questions addressed in the four core chapters of the thesis, that are briefly summarised at the end of the chapter to illustrate their contribution.

1.1 Setting the scene: between pressing challenges and a novel agenda

Unpreceded challenges threaten to wreak havoc on agri-food systems (Barnhill and Fanzo, 2021). From pressing concerns over climate change, land degradation and a biodiversity crisis, to growing disparities in wealth distribution and market volatility, these systems are also exposed to more frequent and severe shocks that include natural disasters, geo-political crises and pandemics, often striking with particular force Low and Middle-Income countries (LMICs) (IPCC, 2019; FAO, 2020; GNR, 2020; Clapp, 2022) These challenges call for an equally unprecedented solution: the transformation of agri-food systems towards sustainability (Caron *et al.*, 2018; Willett *et al.*, 2019).

Originating in the acknowledgement that current agri-food systems have "failed humanity" (UNEP, 2021) in terms of delivering environmentally sound and equitable pathways of development (Dury *et al.*, 2019b), the debates around transformation have flourished over the last decade (El Bilali, 2019a; Melchior and Newig, 2021). The idea of transformation has been employed to indicate the need for a redesign in the structure of the current systems (van Bers *et al.*, 2019; Fanzo *et al.*, 2021) to ensure a shift from the unsustainable trajectory that these systems have followed in the past sixty years (De Schutter, 2017; Conti, Zanello and Hall, 2021), and instead open the way to novel pathways of development that accommodate novel concern over the need to protect "our common futures" (IPES-Food & ETC Group, 2021). This shift is increasingly considered indispensable to ensure agri-food systems deliver interconnected and radically different outcomes - well illustrated by the Sustainable Development Goals (SDGs). Balancing environmental, social, and economic sustainability, these outcomes include protecting and preserving natural resources, greener growth, social justice and social inclusion, economic prosperity and a fairer welfare (UN General Assembly, 2015; Schot and Kanger, 2018).

With the latest United Nations (UN) food system summit, the transformation of agri-food systems has become a global priority (UN, 2021)– further spurring the now crowded debates around the topic, and fostering investigation on how transformative processes can be designed and managed across the globe (van Bers *et al.*, 2019; Scoones *et al.*, 2020; Dornelles *et al.*, 2022).

However, much remains unknown on what will characterise transformation or how and by whom they could be enacted (Béné, 2022; Ingram and Thornton, 2022). With its systemic goals and long-term prospects that challenge the unsustainable *status quo*, the transformation agenda calls for a re-think of many accepted practices, theories, and more broadly "ways of doing things" (Thompson and Scoones, 2009, p. 387) (including, established power structures and actor relationships (Holt-Giménez, 2017)), that might be misaligned or unsuitable to meet sustainability objectives (Niewolny, 2022). Therefore, these need to be questioned and -possibly- supplanted by novel ones

that can support the shift of agri-food systems towards a radically different direction of development (i.e., towards sustainability).

This recognition guides the thesis which, after this overarching introductory chapter (**Chapter One**) and clarifications on the research design (**Chapter Two**), identifies and challenges orthodoxies in the ensuing four chapters (Chapters Three, Four, Five, Six). These chapters are structured as stand-alone but interconnected scientific papers.

Chapter Three recognises that agri-food systems are complex and highly dynamic systems (Foran *et al.*, 2014; Hall and Dijkman, 2019; Dekeyser *et al.*, 2020). Therefore, a prerequisite for enacting change (and consequently, transformation) within these systems resides in the ability to tackle this complexity and dynamicity (Pant, 2014; Pereira and Drimie, 2016; Marshall *et al.*, 2021; Ng'endo and Connor, 2022). However, until now, mainstream research has primarily relied on linear and simplistic conceptualisations to operate in the agriculture and food space (Mayne, Mcdougall and Paz-Ybarnegaray, 2017; Mausch, Hall and Hambloch, 2020; Hambloch *et al.*, 2022), which are poorly suited for an era of global environmental, economic, and social change (Thompson and Scoones, 2009). Through a comparative case study analysis, this paper offers a set of alternative principles that could enable to navigate and respond to complexity.

Chapter Four investigates how, over the past six decades, unsustainable patterns of development have become a historically legitimised orthodoxy that is now difficult to dislodge (De Schutter, 2017) because of a set of mutually reinforcing and concealed elements that, operating together, hamper a sustainability shift (Kuokkanen *et al.*, 2017; De Herde *et al.*, 2019). Through a systematic literature review, the chapter provides a novel framework that helps to identify these elements.

Chapter Five argues that a constellation of spontaneous processes and initiatives is currently surfacing across the globe to challenge the unsustainable *status quo* and offer new, more sustainability-oriented development pathways (Seyfang and Smith, 2007; Sage, Kropp and Antoni-Komar, 2020; Herrero *et al.*, 2021). However, what enables some of these initiatives to succeed remains unclear (Bui, 2021; Ojha and Hall, 2021). Therefore, the chapter examines a case study in South India to shed light on some key features and enablers for these initiatives to open the way to transformation.

Chapter Six recognises that while the global community increasingly calls upon agriculture and food research organisations (AFROs) to provide solutions to deeply systemic problems (IPES-Food & ETC Group, 2021), these organisations might be required to shift from their well-established role as technology providers to instead become much more proactive in supporting a global sustainability shift (Schot and Steinmueller, 2019; Klerkx *et al.*, 2022). Thus, the chapter highlights the possible roles and responsibilities of AFROs in an age of transformation (Hall and Dijkman, 2019) and explores the different visions of Research and Innovation for transformation through a critical literature review to produce four different scenarios of AFROs "prototypes" for an era of transformation, highlighting the advantages and possible pitfalls of each vision.

Finally, in the last chapter (**Chapter Seven**), cross-cutting issues emerging from this body of work, along with possible solutions and policy implications, are discussed. Through the analysis of the findings and considerations emerging from the different chapters, the thesis flags how a "linearity" and a "simplicity" orthodoxy in current conceptualisations *and* action for agri-food systems change and transformation currently hamper a sustainability shift. The thesis suggests that these two orthodoxies could be overcome through a more attentive system analysis, that no longer focuses on single system components, but rather understands change (and transformation) as a system level process. This system analysis would however need to be coupled with a more careful and purposeful mobilisation of knowledge *and* power that explicitly aims at disrupting these orthodoxies and open new and highly diverse sustainability pathways. Besides, the thesis reveals a third orthodoxy in the modus operandi and role of AFROs, which calls for a much more honest and inclusive discussion on how different worldviews underpin their organisational visions and priorities, and a careful evaluation of benefits, trade-offs and risks that these might entail in different contexts.

Chapter Seven also reflects on the critical policy implications emerging from the thesis, highlighting i) the need to re-envision policies in a way that embraces the complex, and highly uncertain, nature of agri-food systems change, and is much more flexible in terms of "visions of success"; ii) the need to become more attentive towards these non-conventional forms of diverse and wide-spanning innovations needed for transformative change, that are not solely technological but span across multiple system domains. This should, however, be accompanied by targeted efforts to address directionality so that a sustainable trajectory is maintained. Finally, iii) the need for more inclusive dialogue and democratic negotiation for collectively-agreed visions of transformation.

1.2 A brief outlook on the bundle of issues in the quest for transformation

The discourse around agri-food system transformation, or transitions, towards sustainability, has increasingly become central in the international arena (El Bilali, 2019a; Melchior and Newig, 2021). Even if the distinction between the idea of transformation and transition remains hazy, with sometimes overlapping and sometimes contrasting conceptualisations (Hölscher, Wittmayer and Loorbach, 2018), this thesis adopts the notion of transformation, rather than transition, following a distinction made by Stirling (2014a). He argues that whereas transition refers to a process "driven by technological innovation, managed under orderly control, by incumbent structures according to tightly-disciplined frameworks for knowledge, towards a specific known (presumptively shared) end", the idea of transformation is used in to describe "plural, emergent and unruly political re-alignments, involving social and technological innovations driven by diversely incommensurable knowledges, challenging incumbent structures and pursuing contending (even unknown) ends"(Stirling, 2014a). This latter conceptualisation better mirrors the wide-spanning, unpredictable, and novel socio-eco-technical processes that the researcher believes will be needed to reconfigure agri-food systems towards sustainability, and is therefore chosen as preferred terminology throughout the thesis.

Besides, "transformation" is widely employed in global agri-food systems sustainability debates. For instance, the High-Level Panel of Experts on Food Security and Nutrition (HLPE) report has recently called for an all-scale transformation in "what is produced and how it is produced, processed, transported and consumed" to ensure food security and nutrition and sustainable development worldwide (HLPE, 2019a). At the same time, the latest IPES-Food report highlighted the role of civil society in achieving food system transformation by 2045, moving away from (unsustainable) industrial agriculture towards food sovereignty and agroecology (IPES-Food & ETC Group, 2021). The CGIAR and the EAT-Lancet Commission also called for systemic and radical transformations in the food systems (Willett *et al.*, 2019; CGIAR, 2020b). Following the Covid-19 outbreak, FAO has flagged the possibility of long-term transformation, indicating the disruption caused by the pandemic as an opportunity to "build back better", working towards fundamentally different food systems "that are resilient to shocks, ensure individual health and well-being, promote inclusion and improve environmental and economic sustainability by increasing efficiency and reducing waste" (FAO, 2021). In late 2021, the UN Secretary-General stated that "transforming food systems is crucial for delivering all the Sustainable Development Goals" (UN, 2021, p. 1).

All these voices highlight, in their own way, a relatively uniform recognition that the current configuration and direction of food systems, or the modern agriculture paradigm deployed in the past century, is not fit for purpose to deliver wide-ranging sustainability goals (Caron et al., 2018b; IPES, 2016; Oliver et al., 2018a), especially at large scales and poverty-stricken countries (Thompson and Scoones, 2009). Transformation is thus broadly intended as a process where multiple, interconnected and pervasive changes across society reconfigure not just component parts of the system, such as technology, but the system as a whole (Hall and Dijkman, 2019; Barrett *et al.*, 2022) – its functions, the values that underpin actions and outcomes, the goals it seeks to achieve and the way the system's performance addresses different social, economic and environmental objectives (Patterson *et al.*, 2017; Barrett *et al.*, 2022).

As the attention shifts from the problem (unsustainability) to the solution (transformation) (Westley *et al.*, 2011; Abson *et al.*, 2017), multiple actors - international research organisations (Körner, Thornton and Klerkx, 2022), policymakers (Galli *et al.*, 2020) as well as civil society (Kropp, Antoni-Komar and Sage, 2020) – are attempting to stir transformative processes around the globe. Nevertheless, transformation remains incredibly complex, especially in the highly dynamic, uncertain, and power-laden agri-food systems context (Barrett *et al.*, 2020; Dekeyser *et al.*, 2020). It is undoubtedly expected to carry costs (Thornton *et al.*, 2023) and redraw food systems as we know them (Kennedy *et al.*, 2021). It will also be politically onerous (Kennedy *et al.*, 2021), as it will necessarily breach the unequal political economy of food systems to create new political realignments that redistribute power in a way that is informed by much more democratic principles (Stirling, 2014a; IPES-Food & ETC Group, 2021).

However, if, at present, the need for transformation is irrefutable (Webb *et al.*, 2020), how it can be designed and implemented remains a point of contingency (Cohen and Ilieva, 2015). Knowledge of what works to create a systemic disruption in current systems is still insufficient (Anderson and Leach, 2019; Köhler *et al.*, 2019). On the one side, the complexity of the agri-food systems *per se* poses a significant challenge (Gamboa *et al.*, 2016), while evidence of transformations in the agri-food sector is limited when compared to others, such as energy and mobility (Magrini *et al.*, 2016; El Bilali, 2019a; Ronningen *et al.*, 2021). Such evidence is particularly scarce in LMICs contexts, with a large majority of empirical evidence having its geographical focus in High-Income

Counties (HICs)(El Bilali, 2019a; Köhler *et al.*, 2019; Melchior and Newig, 2021)[2]. Overall, to date, limited knowledge is available to explain how transformative processes can be unlocked in the agri-food systems space, (Köhler *et al.*, 2019; Ojha and Hall, 2021), and equal ambiguity exists on the actors who could play a role in nurturing and navigating and supporting such process (Hall and Dijkman, 2019; Parker and Lundgren, 2021; Béné, 2022).

The following paragraphs shed light on some of the current issues for bringing about an agri-food systems transformation that, if urgent, still needs to be managed cautiously (or - *festina lente*). Without the pretence of being over-inclusive, as the issues for transformation are too many and too wide-spanning to be captured in a single thesis, the paragraphs do represent some major preoccupations that have surfaced in the relevant literature around transformation, namely: i) the inherent complexity of the agri-food systems space, ii) their historically- maintained trajectory of unsustainable development; iii) the features of some emergent transformative processes and their enablers; iv) the possible roles of AFROs for fostering this transformation.

1.2.1 Interconnected goals heighten an inherent complexity: the challenge of operating in agri-food systems

Referring to the "web of actors, processes, and interactions involved in growing, processing, distributing, consuming, and disposing of foods, from the provision of inputs and farmer training to product packaging and marketing, to waste recycling" (IPES, 2015) as well as the institutional and regulatory frameworks that influence them (Hall and Dijkman, 2019) and their socio-economic and environmental outcomes (HLPE, 2017), agri-food systems are increasingly recognised as complex adaptative systems (Hall and Clark, 2010)– or systems where many components learn, adapt and evolve through interaction (Holland, 2006). This makes them renowned for their complexity (Hall and Clark, 1995). Manifestations of complexity include, for example, non-linear dynamics. Shocks such as pandemics, volatile prices, and geo-political crises (e.g. the Ukraine grain crisis) act as a "Damocles' sword" on food systems, representing threats that could occur at any moment (Orr *et al.*, 2022). This uncertainty makes timelines uncertain in terms of the delivery of their outcomes (Hall and Dijkman, 2019). Besides, agri-food systems configurations are both

[2] It is important to remark that the purpose of the thesis is not to investigate what characterises transformation in LMICs contexts or clarify differences between agri-food system transformation in LMICs compared to HICs. This would demand extensive and cross-country comparisons that go beyond the purpose of the thesis. However, acknowledging this research gap, the thesis chooses, for two of its core papers, to explore LMICs rather than HICs contexts.

highly specific to each place and deeply interlinked across spatial and temporal scales, with local contexts both influencing and being influenced by national and international dynamics (Hall and Clark, 2010; Turner, Klerkx, White, *et al.*, 2017; Madzorera *et al.*, 2021). Simultaneously, path dependencies and concealed, often unequal, power relations (Clapp and Scrinis, 2016; Swinburn, 2019), shape both the interactions system actors - farmers, the private sector, policymakers, researchers, civil society among others (Cullen, Tucker and Homann-Kee Tui, 2013; Cardona, Carusi and Bell, 2021) – and system outcomes (Baker *et al.*, 2021; Hambloch, Kahwai and Mugonya, 2021).

As agri-food systems must be made to deliver increasingly systemic objectives (e.g. poverty alleviation, environmental soundness, equity)– well illustrated by the Sustainable Development Goals (Box 1.2.1) – tackling complexity has been flagged as a prerequisite to achieving transformative change (Monasterolo *et al.*, 2016; Fanzo *et al.*, 2021; Marshall *et al.*, 2021). Better understanding this complexity could, in fact, be critical for identifying critical leverage points (Abson *et al.*, 2017) in which even small changes could, if achieved "produce big changes in everything" (Meadows, 1999).

Box 1.2.1. Agri-food systems and the SDGs.

Tasked with feeding the world population in a way that is safe and nutritious, agri-food systems are responsible for zero hunger (SDG 2), good health and well-being (SDG 3) and responsible production and consumption (SDG 12). With more than 1/3 of the world population relying on agriculture for its survival, the agri-food sector has an enormous potential to contribute to poverty alleviation (SDG 1), decent work and economic growth (SDG 8) and reduced inequalities (SDG 10), particularly LMICs, where agriculture accounts for 29% of GDP and 65% of jobs (Convention on Biological Diversity, 2018). As 43% of this population is composed by women who often have differential access to opportunities (e.g. in terms of acquiring land, machinery etc. (Agarwal, 2018)) the sector could also become a driver of gender equality (SDG 5) (The World Bank, 2012; FAO, 2018a).

Besides, accounting for the destruction of approximately 75% of the world's agrobiodiversity, causing intensive deforestation and furthering global soil erosion (European Environment Agency, 2015; Gladek *et al.*, 2017) agri-food systems could play a central role for preserving life on land (SDG 15) and, with agriculture responsible for 70% of water withdrawal worldwide, and being a major polluter of both freshwater, seawater and underground water resources (FAO, 2017b, 2017a; Foster and Custodio, 2019), changes in water use patterns in agriculture would be critical for preserving life below water (SDG 14).

Finally, as every stage of the food production processes (e.g. storage, processing, packaging, transport, waste) releases GHGs in the atmosphere (European Environment Agency, 2015), more sustainable infrastructure (SDG 9) and a switch to affordable and clean energy sources (SDG 7), are critical to allow agriculture to act against climate change (SDG 13).

1.2.2 Historical insights on unsustainability – or the manufacturing of a global orthodoxy

"If you think that the food system is broken, it implies that it used to work well. When did it work so well? And for whom? It certainly didn't work well for the native peoples who lost their land, or the slaves and indentured servants who worked the plantations, and it hasn't worked well for immigrants who pick our crops in the U.S. today… [the food system] is working exactly as a capitalist food system is supposed to work. It overproduces, it concentrates power in capital in the hands of a few, and it leaves us with all of the externalities."

(Holt-Giménez, 2019, p. 9)

Present and increasingly evident unsustainability issues – from land degradation to unjust redistribution of profits amongst multiple system actors – have brought about the suggestion that agri-food systems are "broken" (Schmidt-Traub, Obersteiner and Mosnier, 2019; Shanks, Van Schalkwyk and McKee, 2020)and need urgent "fixing" (Clapp, 2017; Zepeda, 2021). However, at a closer look, these systems are working exactly as they are supposed to (Holt-Giménez, 2019). Built upon concerns over the mismatch between population growth and food availability after World War 2 (Friedmann, 1982; De Schutter, 2014) (Box 1.2.2), agri-food systems were designed to rapidly increase food production through the uptake of new technologies both in LMICs and HICs - e.g. the Green Revolution (GR) (Thompson *et al.*, 2007a; Giuliani, 2018). The overall modernisation of agriculture was seen as a straightforward route to long-term economic development and the solution to global food insecurity – or feeding a fast growing world population (Clinton, 1993; FAO, 2009a). The Post-World War 2 "modern/industrial"[3] agriculture entailed several benefits: it increased food production and food security, reduced rural poverty and malnutrition, and made many food-deficit countries food exporters, linking farmers in LMICs to global markets with the expectation of raising their incomes (Diao, Headey and Johnson, 2008; Djurfeldt *et al.*, 2009). If implemented with the intention of ending the "War on Hunger" (Wharton, 1969), the modernisation of agriculture also opened what Wharton called a "Pandora´s box" of other problems. It built up economies of scale that used external inputs (e.g. fertilisers,

[3] The terms can be used interchangeably.

pesticides) that, in the long run, would prove to be harmful for the environment (Ramanjaneyulu and Rao, 2008a). It also attempted to maximise production and reduce labour intensity, by establishing "more efficient planting and harvesting, fewer types of expensive equipment, fewer labourers with specialised knowledge of individual crops, and strengthened knowledge of one value chain and commercial market, including all its regulations and tariffs" (Balogh, 2021). Monoculture and large-scale agriculture was promoted, as a way for farmers (especially in LMICs) to access larger and more profitable markets. This went, however, at the detriment of more diversified cropping systems (Monsalve Suárez and Emanuelli, 2009; Balogh, 2021), and led to the production of a narrower number of commodities in larger volumes, mainly to supply the food industry with raw materials (de Schutter, 2019). This allowed the food industry to offer consumers cheap and abundant (if less diverse) foods, in what has been called " mass-retail driven supply chains" (IPES, 2016, p. 70). These highly production-oriented and globalised agricultural systems primarily benefitted big players in the agriculture and food sector (e.g. multinationals and big industries instead of small-farmers, who saw their profit margin considerably reduced, and their choices constrained in terms of what to grow and how to grow it (Murphy, Burch and Clapp, 2012; IPES, 2017). Besides, over the years, the availability of affordable, energy-dense foods, coupled with increasing urbanisation, not only encouraged consumerism (Jacobsen and Dulsrud, 2007) but equally entailed a shift away from traditional and nutrient-rich diets towards unhealthy, nutrient-poor diets and consequent issues of malnutrition (with the frequent coexistence of both undernutrition and overweight and obesity (Sutherland *et al.*, 2022; WHO, 2022)) in both LMICs and HICs.

It has been argued that the post-War prioritisation of economic growth and agricultural production increases ultimately set the *direction* of global agri-food systems towards unsustainability (Conti, Zanello and Hall, 2021). The idea of direction, which will frequently emerge throughout the thesis, was initially employed in the research community to refer to the purpose towards which technologies were directed (e.g. productivity over sustainability) (Bergek *et al.*, 2008; Markard and Truffer, 2008; Stirling *et al.*, 2008; Røpke, 2012). In the novel debates on agri-food systems transformation, the idea expanded to refer to the purposes towards which socio-eco-technical systems (i.e. systems where technology, society and environment interact and influence each other (Robaey and Simons, 2015)) move through the establishment and perpetration of certain historical choices, priorities and actions, routines and (formal and informal) rules (Geels, 2004; Schot and Kanger, 2018; Johnstone and McLeish, 2020; Duncan *et al.*, 2022). As "technologies, market structures, regulations, political support, infrastructure, and user practices" (Johnstone and McLeish, 2020) align towards a certain direction, this closes-down alternative pathways, which

become more and more difficult to pursue (Stirling *et al.*, 2008; Schot and Kanger, 2018). Currently, much attention has been given to directionality, specifically in terms of how agri-food systems outcomes can be cumulatively directed towards sustainability (Klerkx and Begemann, 2020), without however, a transparent acknowledgment on who decides which direction is most desirable (or feasible), and how and by whom it can be implemented. (Anderson and Leach, 2019). How new directions of development can be agreed amongst different stakeholders, with often contending interests, remains unclear, as well as the benefits, trade-offs and pitfalls that different directions might have for the many actors operating in and beyond agri-food systems (Hambloch *et al.*, 2022; Klerkx *et al.*, 2022).

Box 1.2.2 Green Revolution: between old and new debates.

The "Green Revolution" was based on the conviction that hunger and malnutrition were the result of a quantitative problem of production which public policies supporting farmers and technological improvements would be able to tackle (De Schutter, 2014). Food scarcity could always be traced back to a problem of production – rather than being caused by issues of unequal distribution or narrow focus on feed crops (as opposed to a mix of foods that engenders dietary diversity) (Potrykus, 2010a; Gliessman, Friedmann and Howard, 2019). Recent calls for a Green Revolution in Africa – where successes of this initiative were scarce compared to South Asia – is still framed as around this production-oriented narrative. The Rockefeller Foundation and the Bill and Melinda Gates Foundation founded the "Alliance for a Green Revolution in Africa (AGRA)" in 2006, with the objective of increasing "productivity, profitability, and sustainability" (Toenniessen, Adesina and Devries, 2008)of African farms through "greater access to affordable yield-enhancing inputs, including well-adapted seeds and new methods for integrated soil fertility management". Food insecurity and slow economic growth in the continent are still seen as the result of low performance of agriculture, clearly portraying the embeddedness of the production/growth framing in the international research and policy arena. This is clearly illustrated by a statement by (Toenniessen, Adesina and Devries, 2008): "The low performance of agriculture in Africa is at the heart of its food insecurity and slow economic growth. Despite periodic local progress, average yields for sub-Saharan Africa have not increased […] dire consequences for food security are projected. […] Africa will probably continue to be the "troubled region" in terms of imbalance between food demand and supply. Their projections suggest that Africa is the only region that will experience major food shortages and where malnutrition is projected to rise over the next 20 years. […] Clearly, much more needs to be done by African governments, the international community, and the private sector to

reverse these trends by stimulating gains in agricultural productivity as the basis for food security, poverty reduction, and economic growth" (the statement refers to Africa specifically but could be equally referred to other contexts).

1.2.3 How does transformation happen? Evidence of system innovation starting in niches

In truth, sustainability was never a priority, or even a concern, when the industrial agricultural model was established. It only emerged as a global preoccupation much later, in the late 80s/early 90s (Brown *et al.*, 1987; Dovers and Handmer, 1993) – or when the trajectory of agri-food systems had already been long-established. The transformation agenda suggests that a major overhaul is now necessary to now shift this entrenched unsustainable direction towards new outcomes – e.g. environmental viability, equity, food sovereignty, and justice (IPES-Food & ETC Group, 2021; Candel, 2022).

The idea of system innovation -also widely used in the thesis - is intertwined with the one of transformation (Baret, 2017; Grillitsch *et al.*, 2019). It has been used to describe changes in existing behaviours and knowledge, capabilities and skillsets, consumer practices and markets, as well as infrastructure, institutions and policies (OECD, 2015; Ojha and Hall, 2021). These changes would "open-up" alternative pathways of development by reformatting both component parts of the system and the system architecture itself (Hall and Dijkman, 2019; Stirling, 2014b) and, ultimately, enable a transformation. A key feature of these changes is that they are no longer incremental, but rather, transformational. Whereas the first are continuity-based and cumulatively follow the same trajectory of development (e.g. technologies or policies directed at increasing agricultural production), the latter are changes aligned to fundamentally different trajectories ones (Geels and Kemp, 2007; Geels, 2018; Novy, Barlow and Fankhauser, 2022) (Figure 1.2.3). Because they are not designed to shift the directionality of the system (instead being focused on the improvement of an already determined trajectory), incremental changes are now deemed insufficient to deliver a sustainability transformation (Lindner *et al.*, 2016; Rogge, Pfluger and Geels, 2020).

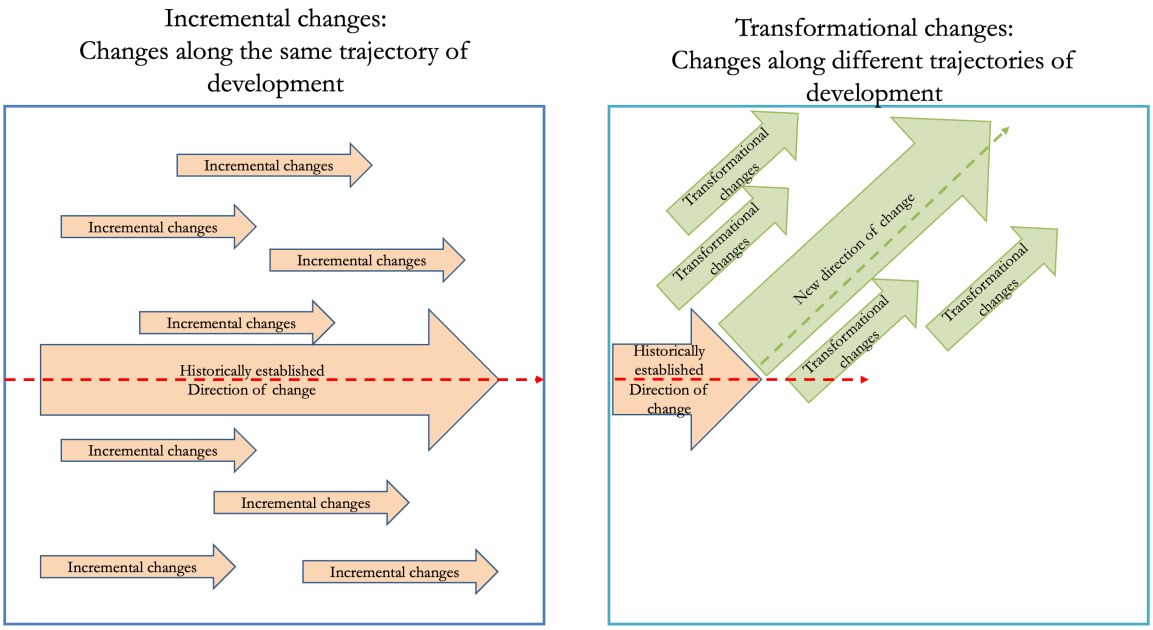

Figure 1.2.3. Incremental vs Transformational changes. The figure aims to capture the idea of directionality and, particularly, illustrate how shift from current historically-established directions of change is necessary to enable transformation. Small arrows indicate changes in the agri-food systems space (which could be either incremental or transformational). The "incremental change" arrows are parallel and point to the same trajectory of the bigger arrow, to represent a continuity with the historically established change trajectory. On the other hand, "transformational change" arrow point to the new trajectory of change needed for transformation.

However, which directions of development is appropriate to deliver sustainability over the long term is currently contested. Similarly, which transformational changes are needed to achieve these new directions, how they can be enacted, and who can support their simultaneous orchestration remains unknown (Leach, Scoones and Stirling, 2007; Kattel and Mazzucato, 2018; Klerkx and Begemann, 2020). With the blossoming of debates (and consequent investigation) around transformation, many have argued and found evidence across the globe, of such transformative changes and system innovation starting to happen in niches (Darnhofer, 2014; Chang *et al.*, 2017; Bui, 2021). Initially, niches were considered spaces where small networks of actors could experiment with novel technologies (and associated rules and practices) while being protected by market selection (Kemp, Schot and Hoogma, 1998; Rotmans, Loorbach and Kemp, 2007). More recently, the idea started being used to refer to spaces where innovation was not conceived as purely technological, but referred all novel practices and rules spanning across the technological, ecological, cultural, social and economic domains (Bui *et al.*, 2016b; Mawois *et al.*, 2019). It has been argued that as niches and their associated rules and practices gain recognition, they can

challenge the existing system[4] and generate alternative development models and pathways, opening the way for a sustainability transformation (Seyfang and Smith, 2007; Seyfang and Haxeltine, 2012; Sarabia, Peris and Segura, 2021). As a constellation of niches is currently emerging and gaining attention in both research and policy debates (Seyfang and Haxeltine, 2012; Bui *et al.*, 2016b; Meynard *et al.*, 2016; Chang *et al.*, 2017), these "may contribute to a fundamental overhaul of existing socio-technical systems and introduce a new set of sustainable and just directionalities" (Kanger and Schot, 2019, p. 8).

1.2.4 The unventured journey: the role of AFROs in transformation

A sustainability transformation will result in structurally different agri-food systems (Kennedy *et al.*, 2021). Some have argued that with its systemic goals and long-term goals, the transformation agenda requires both a rethink of roles and responsibilities that different actors (from formal and informal as well as from public and private sectors) have in the process (Béné *et al.*, 2019), and a much more explicit coordination of these actors' priorities and activities towards shared goals (Lindner *et al.*, 2016). In particular, as a number of challenges looms over agri-food systems, policymakers and other actors within and beyond the agri-food system space turn to AFROs to provide urgent solutions to looming problems (IPES-Food & ETC Group, 2021; Parker and Lundgren, 2021). However, until recently, research organisations have largely aligned with the industrial/modern agriculture agenda (Magrini, Béfort, *et al.*, 2018; Conti, Zanello and Hall, 2021) set after the War, providing technologies that would at once boost productivity and generate profits for industry (what is called as "the commercialisation of scientific discovery") (Schot and Steinmueller, 2018). This *modus operandi* has been increasingly questioned, as it seems to be falling short in terms of helping to design and deliver pervasive changes in current systems (Fazey *et al.*, 2018; Caniglia *et al.*, 2021). This is why suggestions have been made over the potential for AFROs (and research organisations more generally) to take up a new role and proactively attempt to go beyond their established technology-provider role (Hall and Dijkman, 2019; Körner, Thornton and Klerkx, 2022). To align with the transformative agenda, these organisations would need to respond to it through explicit efforts that address the directionality of the current systems (Lindner

[4] Also called the "regime" in the popular multi-level perspective proposed by Geels, which pioneered the idea of niches and illustrated how they can generate new pathways of development). Regimes are defined as "the deep structure that accounts for the stability of an existing socio-technical system. It refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011).

et al., 2016; Klerkx and Begemann, 2020) and be more proactive in promoting wide-spanning innovation that challenges existing knowledge, behaviours, infrastructures, industry structures, products, policies and regulation (Schot and Steinmueller, 2018). However, contrasting visions and worldviews currently exist in terms of AFRO's role in the 21st century (Klerkx *et al.*, 2022).

1.3 Gaps investigated by thesis – or questioned orthodoxies

The points discussed above shed light on four major research gaps[5]. These can also be considered as orthodoxies that need to be challenged "*as critical praxis for food systems transformation*" (Niewolny, 2022), and will therefore be addressed in the different thesis 'chapters. These gaps are:

A gap in terms of how complexity can be engaged with and navigated - or an orthodoxy in current conceptualisations of agri-food system dynamics as linear and static. The multiplicity of processes, actors, and interactions within and beyond agri-food systems and the increasingly interconnected issues that affect them make them complex systems to engage with (Jaradat, 2015). However, an orthodoxy exists in much of the mainstream research (Mayne, Mcdougall and Paz-Ybarnegaray, 2017), and consequent development intervention design and implementation, that anchors them to linear or static conceptualisations and provides "inadequate insight into the dynamic character of agri-food systems" (Thompson and Scoones, 2009, p. 387). These conceptualisations (and their practical implications) are no longer suitable to operate within food systems in an era of uncertainty and transformation (Thompson and Scoones, 2009; den Boer *et al.*, 2021). This gap calls for new and more complexity-aware approaches that can allow to successfully navigate complexity (Hall and Clark, 1995; Douthwaite and Hoffecker, 2017; Mausch, Hall and Hambloch, 2020; Govaerts *et al.*, 2021).

A gap in terms of the reasons that make a sustainability shift difficult – or a confusion over what maintains unsustainability as orthodoxy in current systems Despite many well-meaning efforts (Mausch, Hall and Hambloch, 2020) to implement sustainability in agri-food systems in the last three decades, a sustainability shift remains a distant prospect (Dorninger *et al.*, 2020). This is because current production and consumption patterns have become deeply embedded and seem to resist fundamental changes towards sustainability (De Schutter, 2017; Conti, Zanello and Hall,

[5] Clearly, more might be identified. However, for the purpose of this thesis, we focus on these four– which indeed represent major challenges according to much of the literature around transformation (De Schutter, 2017; Kok *et al.*, 2019; Dekeyser *et al.*, 2020; den Boer *et al.*, 2021).

2021). What exactly causes this resistance to change in direction remains, however, ambiguous and overlooked. Often, possible explanations of what is creating resistance are identified – for instance technologies (Pradhan and Mukherjee, 2018) , behaviours (Gonçalves *et al.*, 2015) or policies (Rutz, Dwyer and Schramek, 2014)) – but these factors are examined in isolation, or as manifesting under specific conditions or geographical locations (Fortier *et al.*, 2013; Feyereisen, Stassart and Mélard, 2017; Meynard *et al.*, 2018). This gap demands further questioning of the reasons that maintain and reinforce unsustainable trajectories of developments in current systems.

A gap in terms of the features and enablers of transformation – or an ambiguity on how orthodoxy can be challenged in practice. Transformative processes usually happen over long-time spans (20/30 years) and entail a many interconnected changes across institutions, behaviours, cultures, values, and technologies (Geels, 2002). It has been remarked that many of these processes of fundamental reconfiguration, in and beyond agri-food systems, have started to happen in niches (Darnhofer, 2014; Bui *et al.*, 2016b; Bui, 2021), where actors experiment with continuous, open-ended and place-specific (Walmsley, 2022) innovation, spanning across the technological, social and economic domains, to propose development pathways underpinned by fundamentally different values and aimed at delivering fundamentally different outcomes (Seyfang and Haxeltine, 2012). However, if niches often seem to be able to challenge the *status quo* -or the unsustainability orthodoxy - both the key features of transformative processes (Köhler *et al.*, 2019; Scoones *et al.*, 2020; Kirchherr, 2022) and the ways they can lead to successful transformation, remain elusive (Bui, 2021; Ojha and Hall, 2021), calling for further investigation.

A gap in the role of AFROs for supporting transformation – and an orthodoxy that relegates them to their 20th century role. Research & Development (R&D) – and consequently, AFROs - have an increasingly central role for fostering a sustainability shift worldwide (Fazey *et al.*, 2018; Kok *et al.*, 2021). As the transformative agenda mandates a transformational shift that re-formats current systems to sustainability (Kugelberg *et al.*, 2021), research organisations are in the spot-light for providing solutions to looming problems (Körner, Thornton and Klerkx, 2022). Until now, AFROs have played a role as technology provider, developing major technological breakthroughs (for example, in the case of the Green Revolution) (Giuliani, 2018; Schot and Steinmueller, 2019; Klerkx *et al.*, 2022). This is why some have suggested that the transformation agenda requires these organisations to become much more proactive in supporting or even managing transformative processes (Fazey *et al.*, 2018; Kok *et al.*, 2021; Körner, Thornton and Klerkx, 2022). Yet, contending views exist in the literature on what the novel agenda entails for

AFROs, creating disagreement on if and how their traditional role can be re-thought and reframed (Klerkx *et al.*, 2022). Besides, the implications of this(ese) new role(s), and its(their) possible benefits and pitfalls remain overlooked, for instance making it difficult for AFROs to pursue unconventional, non-tech innovation venues, which might however be critical for identifying and supporting novel transformation pathways (Hall and Dijkman, 2019).

Thus, the thesis will aim to explore and address the following points: i) an unclarity on how to engage with the complexity inherent to agri-food systems; ii) a lack of systematic evidence that explains what hampers a shift in the direction of current agri-food systems towards sustainability; iii) an ambiguity in terms of the key features and enablers of transformative processes challenging established agri-food systems; iv) a disagreement on the types and features of research organisations needing to respond to the global sustainability transformation agenda.

1.4 Research questions of the thesis

The stand-alone chapters of this thesis mirror the gaps identified in the previous paragraph.
In an attempt to answer the broad research question: **What are some of the current accepted practices, theories, and "ways of doing things" that might currently be hindering a sustainability transformation in agri-food systems, and how can they be challenged?**
This question is broken down into four sub-research questions that emerged from the analysis of the gaps explained above, namely:
Thus, the thesis proceeds to answer the resulting questions:

i. How does complexity manifest, and how can it be navigated in agri-food systems?
ii. What makes agri-food systems resistant to novel (and sustainable) directions of development?
iii. What characterises and enables transformative processes to challenge the *status quo*?
iv. What are the different visions of AFROs for supporting and engaging with transformation? And what are the implications of these?

The questions are addressed in separate chapters, that can either be read as stand-alone research articles, or as complementary investigations to answer the broader research questions.

1.5 Overview of the chapters

This section briefly describes the four papers in the thesis, summarised in Table 1.5.

Chapter 3, titled "Complexity at play: new principles for navigating agri-food systems dynamics and uncertainty" tackles current concerns over the engagement with agri-food systems complexity. The chapter seeks to answer the question: "How does complexity manifest, and how can it be navigated in agri-food systems?". The paper answers this question by conducting a comparative case study analysis, that purposefully selects and looks across six case studies of development interventions in LMICs - specifically in South Asia and Eastern and Southern Africa (ESA), namely: (i) one aimed at introducing sorghum beer in Kenya, (ii) one for controlling aflatoxins in Malawian groundnuts, (iii) one for promoting Smart Foods in India and Eastern Africa, (iv) one for exploiting sweet sorghum as biofuel in India, (v) one for introducing precooked beans in Uganda and Kenya and (vi) one for marketing pigeon pea in Eastern and Southern Africa.
The paper employs an agri-food systems perspective to understand how complexity manifests and how it could have been tackled. Then, it distils six principles that could help interventions navigate complexity in practice, and stresses the value of a much more reflexive and experimentation-oriented approach to interventions. Ultimately, it suggests the need to challenge and go beyond generally accepted assumptions in an era of growing uncertainty associated with agri-food system transformation.

Chapter 4, titled "Why are agri-food systems resistant to new directions of change? A systematic review", studies the factors creating resistance to a sustainability transformation in agri-food systems through a systematic literature review. The chapter seeks to answer the question: "What makes agri-food systems resistant to novel (and sustainable) directions of development?". This chapter recognises that even if agri-food systems are dynamic and continuously evolving, historically informed trajectories of agri-food system development have kept these systems stuck on unsustainable patterns, that now resist transformative changes towards more sustainable directions. This chapter digs deeper into the reasons that create resistance and investigates i) the way path dependencies in technology choice and use emerge and reproduce change trajectories (Kemp, 1994; Radulovic, 2005; Chhetri *et al.*, 2010); (ii) the way mutually supporting systems components create "lock-ins" that perpetuate existing directions of innovation (Kuokkanen *et al.*, 2017; Magrini, Béfort, *et al.*, 2018) (iii) and the way inertia in existing systems halts changes towards new directions (Dury *et al.*, 2019a; Leach *et al.*, 2020). The chapter then explains that the *status quo* is supported by different components of agri-food systems - technologies, behaviours, policies and institutions, infrastructure, power and politics and research priorities- which, co-evolving and becoming mutually supportive, keep a unsustainable trajectory of development in place. The paper

highlights that without re-designing the entirety of these components, re-directing them towards sustainability, a transformation will unlikely be achieved.

Chapter 5, titled "Path dependency disruption as starting point for agri-food system transformation? Insights from a case study in South India" conducts a qualitative case study to answer the question: "What characterises and enables transformative processes to challenge the *status quo*?". In response to the growing interest around the ability of niches and grassroots initiatives to stimulate agri-food system transformation worldwide (Bui, 2021), this chapter explores a case study of a Non-pesticide Management (NPM) initiative in South India. Over a time-span of 20 years, the initiative seemed to be able to build an alternative pathway that grants more environmentally sustainable, economically viable and just outcomes. The paper tests the framework presented in Chapter Four to assess whether a transformation is ongoing. Then, drawing from the case study history and going beyond the framework, the chapter discusses possible factors that might enable niches to open the way to alternative and sustainable production and consumption patterns, highlighting the importance of synchronising innovation in multiple system elements, navigating complexity, and leveraging agency for opening alternative and viable pathways to agri-food systems transformation.

Chapter 6, titled "What does the agri-food systems transformation agenda mean for agriculture and food research organisations? Exploring organisational prototypes for uncertain futures" conducts a critical literature review to investigate: "What are the different visions of AFROs for transformation? And what are the implications of these?". The chapter argues that research organisations are currently called to answer new and pressing demands for novel solutions to highly systemic and complex challenges, helping different actors in the global arena (from "panicking policymakers" to civil society organisations (IPES-Food & ETC Group, 2021)) achieve sustainability shifts. However, different visions exist for AFRO' s roles and responsibilities for aligning to the transformative agenda, each stemming from sometimes overlapping and sometimes contrasting research narratives and discourses (Schot and Steinmueller, 2018). These narratives are identified to then build four scenarios for AFROs of the future, namely: (i) Industry transition-oriented; (ii) Technology mission-oriented; (iii) Community innovation-oriented, (iv) Facilitating transformative innovation-oriented. The chapter discusses how each scenario has different strengths, trade-offs and risks to then raise attention to the alignments that these different scenarios have in terms of existing capabilities and mandates of AFROs. The paper discusses how decisions about AFROs can no longer be made unilaterally, but need to be negotiated among

multiple actors in and beyond the agri-food space. Finally, it reveals that different AFROs' roles have deep implications for the wider agricultural innovation system in which these organisations are embedded, which need to be made more explicit in current debates on AFROs for transformation.

Table 1.5. Thesis outline.

What are some of the current accepted practices, theories, and "ways of doing things" that might currently be hindering a sustainability transformation in agri-food systems, and how can they be challenged?				
Chapter	**Chapter 3** Complexity at play: new principles for navigating agri-food systems dynamics and uncertainty.	**Chapter 4** Why are agri-food systems resistant to new directions of change? A systematic review.	**Chapter 5** Path dependency disruption as starting point for agri-food system transformation? Insights from a case study in South India.	**Chapter 6** What does the agri-food systems transformation agenda mean for agriculture and food research organisations? Exploring organisational prototypes for uncertain futures.
The "orthodoxy" challenge	Mainstream research and interventions might be poorly equipped to engage with complexity in agri-food systems, thus calling for a novel approach.	Unsustainability is an orthodoxy which has become gradually embedded in agri-food systems, but the deeply embedded and interconnected factors maintaining it in place remain overlooked.	If grassroots initiatives have the potential to challenge the unsustainable *status quo*, the features of transformative processes and their enablers remain unclear.	The transformation agenda calls for a re-think of the traditional role of AFROs, who might need to go beyond their role of technology provider to instead become much more involved in supporting transformation processes across the globe.

The research question	How does complexity manifest, and how can it be navigated in agri-food systems?	What makes agri-food systems resistant to directionality changes towards sustainability?	What characterises and enables transformative processes to challenge the *status quo*?	What are the different visions of AFROs for supporting and engaging with transformation? And what are the implications of these?
Methodology	Comparative case study	Systematic literature review	Case study	Critical literature review
Contribution	The chapter challenges orthodoxy in mainstream research by providing a set of novel principles for navigating complexity.	The chapter uncovers the factors that keep the unsustainable (and orthodox) *status quo* into place, providing a framework that can help reveal them in different contexts.	The chapter uses the framework of Chapter Four as a way to identify the features of transformative processes, while going beyond the framework to discuss their possible enablers.	The chapter offers a set of scenarios that help portray the possible novel roles of AFROs of the future and generate a discussion on the implications that different organisational visions have.
Status at time of first thesis submission (April 2023)	In preparation for submission to Agriculture and Human Values.	Published in Global Food Security.	In preparation for submission in Innovation & Development.	Submitted to Global Food Security.

1.6 Disclosure Statement

This thesis has been supervised jointly by Giacomo Zanello, Deputy Director of the Graduate Institute for International Development, Agriculture and Economics at the University of Reading (UoR) (United Kingdom), and Andrew Hall, Senior Principle Research Scientist with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Agriculture and Food (Australia). Both supervisors contributed to the thesis, providing insightful comments, edits, suggestions and feedback on all chapters.

The stand-alone chapters (Chapters Three, Four, Five, Six) are co-authored as usual practice in scientific publications. In all chapters, the author of the thesis was the first author, with the responsibilities this entails. Other authors contributed in the following manner:

In Chapter Three, co-authors provided suggestions and insights. Andrew Hall provided major feedbacks and comments throughout the paper's write-up. One co-author (Alastair Orr) conducted the data collection for the case studies, published in a separate report. The other two co-authors (Kai Mausch and Caroline Hambloch), who were involved in the CGIAR's work pertaining the case studies, gave feedback on the final draft.

In Chapter Four, the co-authors (the PhD supervisors) contributed with comments and insights while helping the author of the thesis with suggestions to deal with manuscripts' reviewers' comments.

In Chapter Five, Andrew Hall provided feedback, corrections, and insights during the paper's write-up. The other co-authors (Giacomo Zanello and Tim G. Williams) provided comments on the final manuscript.

In Chapter Six, all the co-authors (Helen Percy, Samantha Stone-Jovicich, James Turner, Larelle McMillan, all part of the AgResearch New Zealand and CSIRO teams) participated (orally) in the discussion regarding the research scenarios developed in the paper. Andrew Hall (PhD supervisor) provided critical insights and corrections, as well as and continuous feedback throughout the paper's write-up. The final version of the paper was shared with all co-auhtors for comments and suggestions.

Feedback on the Introduction (Chapter One), Research Design (Chapter Two) and the Conclusions (Chapter Seven) was given by both supervisors.

2. Research Design

"THERE ARE NO IMPARTIAL *FACTS*."

REED, TURIEL AND BROWN, 1996

Abstract:

This chapter discusses the overarching research design of the thesis and is structured as follows: first, the researcher briefly highlights different ontological, epistemological, and theoretical positions, reflecting on the ones chosen for the study; second, the implications of these for the thesis are discussed. Third, the conceptual framework, methodology, and research methods are illustrated. Finally, a positionality statement is provided.

2.1 Introductory remarks

As social justice and equity concerns become increasingly important in the global transformation agenda, social sciences[6] assume a central role in tackling complex and multi-scale problems of culture, institutions and human behaviours (Shrivastava *et al.*, 2020; Sanborn and Jung, 2021). However, for social research to be meaningful and correctly interpreted, such research's underlying philosophical and theoretical assumptions need to be clarified (Moon and Blackman, 2014; Martin, 2016) This chapter thus provides clarification on the research design, illustrating the ontological, epistemological, theoretical perspective, conceptual framework, methodology and methods adopted by the researcher, to finally provide a positionality statement.

2.2 Ontology of the research

Ontology describes the beliefs one holds about reality and the kind and nature of reality and what exists (Richards, 2003). Ontology asks questions such as "what is there that can be known?" or "what is the nature of reality?" (Ahmed, 2008), with different ontological positions making different claims regarding the nature and structure of being (Rawnsley, 1998). In particular, the ontological position of the researcher reveals how his or her perceptions of human nature influence the approach they decide to adopt (Bracken, 2010), and are, therefore, a key aspect to be addressed explicitly prior to undertaking the research (Elder-Vass, 2007; Lauer, 2019).

Moon and Blackman (2014) determine a major distinction between two dichotomic ontological position: realism and relativism. Realism assumes that an external reality exists independently from individual knowledge of it. Relativism instead argues that the concept of "reality" hinges on those interpreting it (Lincoln, Lynham and Guba, 2018; Poucher *et al.*, 2020). Between these overarching and dichotomic ontological positions, others, more nuanced ones emerge, such as naïve, structural, critical realism, or cultural/bounded relativism.

Naïve realists believe that one true reality exists, which can be comprehended and explained when the appropriate methods are applied (Moon and Blackman, 2014; Michell, 2016; Beck, 2019), while structural realists believe one true reality exists, yet its structures (such as definitions, norms or technologies) that determine how reality is defined are subject to change, and thus, the nature of reality changes accordingly (Worrall, 1989; Moon and Blackman, 2014). Critical realists believe that if it is, in theory, possible to gather objective knowledge about this reality, the possibilities for this

[6] It has been argued that the aim of social science is "to understand the social reality as different people see it and to demonstrate how their views shape the action which they take within that reality" (Beck, 1979, quoted in (Anderson and Bennett, 2003, p. 153)

are limited, because of the individual's own subjective experiences of the world (Martin, 2016)– or the "basically flawed human intellectual mechanisms and the fundamentally intractable nature of phenomena" (Bryman, 2008, p. 14).

The author of this thesis (a social scientist) believes that there is not "one reality" that can be empirically, and "once-and-for-all" defined. She therefore adopts a cultural relativist (also called "bounded" (Moon and Blackman, 2014)) ontological position. Whereas relativists believe that reality is a finite subjective experience (i.e. reality cannot be separated from individuals' experience of it) and "nothing exists outside of our thoughts" (Levers, 2013), cultural relativists believe that truth is relative and belongs to the individual and her/his own culture, and thus all points of view are equally valuable (Reichert, 2015). More specifically, the bounded relativist position posits that "one shared reality exists within a bounded group (e.g., cultural, moral), but across groups different realities exist" (Moon and Blackman, 2014).

2.3 Epistemology of the research

Epistemological issues concern the issue of generation of knowledge – or how knowledge is acquired – while also looking at the relationship between the knowledge and the knower (Grix, 2002; Bracken, 2010; Chilisa and Kawulich, 2012). Thus, epistemological inquiry answers two questions: "what is knowledge?", "how is knowledge acquired?" and "whose knowledge counts?" (Brown and Dueñas, 2019). Three major epistemological views exist (Moon and Blackman, 2014): objectivism, subjectivism, and constructionism. Objectivism derives from a realist ontological position (Levers, 2013), and claims that reality exists independently of consciousness or experience, and objects within this reality have intrinsic meaning. This can be understood if the "right" methods are applied (Melles and Feast, 2010; Chilisa and Kawulich, 2012), making scientific research objective and neutral (in the sense of value-free) (Chileshe, 2005). In contrast, subjectivism draws more from relativism, rejecting the idea of "one" reality that can be known (Melles and Feast, 2010), as reality will always subject to perception. It is the individual who imposes meaning on the object (Moon and Blackman, 2014), with no "true" reality exists independent from perception (Melles and Feast, 2010).

Considering truth as intertwined with human experience but also strongly influenced by the individual cultural, historical and social background (Melles and Feast, 2010), the researcher adopts a constructionist epistemological position, which postulates that, if truth and meaning are constructed through the continuous engagement of the individual's mind with the world (Melles

and Feast, 2010), individual's knowledge is inevitably "filtered" through individual lenses dependent on social factors (e.g. social class, race, ethnicity) (Denzin and Lincoln, 2005; Levers, 2013) and often shaped by the individual's interactions with his/her community (Vygotsky, 1978; Moon and Blackman, 2014). Thus, knowledge is always "culture-bound, historically and context dependent" (Chilisa and Kawulich, 2012), making it difficult to create agreement amongst different groups. Different perspectives might be deeply embedded in fundamentally different historical, social, cultural, moral and contextual realities and perceptions (Renteln, 1988). This is, for instance, the case with the agri-food system transformation issue addressed in the thesis. Different transformation vision*s* exist, each underpinned by different perspectives, values and cultures. Whose knowledge count in deciding the "desirable" directions to pursue is consequently a contested matter, with different actors and groups in and beyond agri-food system contexts holding different beliefs and aspirations of what transformed agri-food systems should look like (Gliessman, 2023).

2.4 Theoretical perspective

The idea of theoretical perspective refers to the philosophical underpinning that guides research, informing the formulation of research questions and ways (new) knowledge will be processed (Collins and Stockton, 2018; Crossman, 2020). A wide array of theoretical perspectives exist.
For instance, on the one side of the spectrum and drawing from objectivism, positivism and post-positivism perspectives aim to predict reality. Positivism argues that scientific methods are the only way to accurately establish truth, and study an objective reality (Chilisa and Kawulich, 2012). Post-positivism - a less strict form of positivism (Chilisa and Kawulich, 2012) - highlights the value of a multiplicity of methods and recognises that all methods have flaws, but objective investigation is more likely to bring the researcher closer to the truth (Levers, 2013; Moon and Blackman, 2014). On the other side of the spectrum, theoretical perspectives that draw from subjectivism, such as postmodernism and poststructuralism aim to de-construct reality, studying how different languages or discourses divide the world and give it meaning (poststructuralism) or how truth claims are constructed in societies to ultimately benefit specific groups (postmodernism) (Moon and Blackman, 2014).

Drawing from constructivist epistemologies, the researcher of this thesis is guided by three major theoretical perspectives.

First, a constructivist perspective, which understands that individuals have subjective meanings of the reality around them, shaped by historical circumstances, cultural norms, and other

factors. This perspective is considered valuable because it helps the researcher to avoid narrowing the research on one single view or idea, and instead look for a "complexity of views" (Cresswell, 2014, p. 26).

Second, a critical theory perspective, which highlights the importance of challenging and critiquing existing assumptions, and the role of research (and action) for changing situations (Moon and Blackman, 2014). This perspective often takes an advocacy/participatory turn to account for the influences that politics and political agendas have for shaping actions of multiple social actors. Critical theory can be employed to shed light on how research inquiry can interlinked with political agendas (a topic that will be widely discussed over the different chapters of the thesis), stressing the urgent need for research to deal with societal issues of injustice and inequity (for instance, in the case of minorities or marginalised groups).

Third, a pragmatism perspective, which claims that all approaches are valid for understanding and solving a given research problem (Cresswell, 2014; Moon and Blackman, 2014; Popa, Guillermin and Dedeurwaerdere, 2015; Kelly and Cordeiro, 2020). Thus, it encourages pluralistic and transdisciplinary approaches to foster knowledge about the problem that needs to be understood or solved (Cresswell, 2014).

2.5 Implications of these perspectives for the thesis and for the choice of a conceptual framework

The previous sections have briefly outlined[7] the debates on some of the existent ontological, epistemological, and theoretical perspectives. This section explains the implications that these have for the research needs to be discussed more in detail.

Bounded relativism and constructionist positions are particularly valuable because they stress the need to acknowledge the existence of a diversity of perspectives, that might be shaped by individual's perceptions and belonging to a particular community and background. This is not only true in research debates, but also in the agri-food systems per se - for instance, multiple and unique agri-food systems contexts, shaped by different cultures, values and beliefs, which cannot be overlooked. Within the thesis, this translates into recurrent recommendations to always consider place-specific dynamics, behaviours, norms, cultures, political patterns. Even if some commonalities or elements might be identifiable across contexts, the researcher recognises that

[7] Without the pretence of being over-inclusive, as a multitude of perspectives currently exists and whose detailed description goes beyond the purpose of the study.

these need to be always carefully investigated with respect to the contextual conditions in which they manifest (this is the case especially for chapter three and five, which stress the importance of recognizing the specificity and uniqueness of different agri-food system spaces, and the diverse features that their transformation might have).

The choice of constructivism as theoretical perspective helps to highlight the role of historical circumstances (for instance, the Post-World-War 2 establishment of the productivist paradigm(Conti, Zanello and Hall, 2021)), cultural background and behaviours (for instance, consumerism (Jacobsen and Dulsrud, 2007) and established institutional structures (for instance, which legitimate the unsustainable *status quo* (Orderud and Polickova-Dobiasova, 2010; Frimpong Boamah and Sumberg, 2019) in creating a resistance towards a sustainability shift (Chapter Four). This perspective is complemented by critical theory, which allows the researcher to carefully consider and shed light on the political economy of present food system, and the power equilibria supporting it (these elements are particularly pronounced in chapter three and four).

Finally, the pragmatist perspective has implications in terms of the choice of a conceptual framework. Defining the "ways of thinking about a problem or a study, or ways of representing how complex things work the way they do" (Bordage, 2009), a conceptual framework illustrates the approach that a researcher uses to answer the given research question (Luft *et al.*, 2022). The questions of the thesis are -if interconnected- still highly diverse. Thus, acknowledging that all available approaches should be used to investigate the research problem (Cresswell, 2014, p. 28), the researcher consequently favors a "one size does not fit all" approach (Ng'endo and Connor, 2022), and does not apply an overarching conceptual framework, instead adopting different approaches to answer the thesis' questions.

2.6 Methodology and methods

The methodology refers to the "plan of action" (Melles and Feast, 2010) for carrying out research (Martin, 2016). It describes how knowledge is (or can be) acquired during the research (Brown and Dueñas, 2019). Methods instead refer to the specific procedures and techniques used to collect and analyze data for answering the research question (Crotty, 1998, p. 2).
As the researcher is set to study transformation – a process of fundamental societal change (Geels, 2002, 2006; Loorbach and Rotmans, 2010; Westley *et al.*, 2011; Wibeck, Eliasson and Neset, 2022) - the researcher adopts a qualitative approach that is suitable when aiming for a deep understanding of social contexts, and their high level of complexity and specificity. The researcher combines

different methods for answering the different questions (in a pragmatist perspective), while however recognised that no method is universally valid, and each has its own disadvantages, trade-offs and limitations (Kalof, Dan and Dietz, 2008; Kothari, 2012, p. 10)

In chapter three, the researcher adopts a comparative case study method. Whereas single case studies allow a comprehensive and in-dept understanding of the dynamics behind a given event or circumstance (Orum, Feagin and Sjoberg, 1991; Kaarbo and Beasley, 1999; Carter, 2020), comparative case studies help the researcher to look and compare across contexts to find shared patterns in an attempt to provide more generalizable knowledge about the studied topic (Sheridan *et al.*, 2014; Goodrick, 2017). This method allows to "trace across individuals, groups, sites, or states" (Bartlett and Vavrus, 2017) and discover how political, social, cultural, historical, and other circumstances (Denzin and Lincoln, 2005; Levers, 2013) can shape different agri-food systems contexts.

In chapter four, the researcher pragmatically adopts a systematic review method, originally mostly used in the medical field (Sargeant *et al.*, 2005; Farrukh *et al.*, 2020), to answer a broad research question which could hardly be captured through the lenses of single case studies (Dixon-Woods *et al.*, 2016). This is because the phenomena studied (path-dependencies, lock-in and inertia) do not always manifest in the same way in different contexts. With its comprehensiveness in terms of results and findings (Grant and Booth, 2009; Kelly, 2015), the selected method allows the researcher to navigate multiple and varied (geographical, social, political, and other) contexts, while simultaneously coming across a variety of perspectives and frameworks that have been used by other researchers in the selected studies.

Chapter five presents a qualitative case study, which explores a possible case of a transformation in the agri-food system. Case studies are a suitable method when investigating complex societal phenomena (Orum, Feagin and Sjoberg, 1991; Kaarbo and Beasley, 1999; Carter, 2020) -such as transformation. When conducting case studies, it often occurs that multiple interrelations and concealed patterns are brought to light (Fidel, 1984; Pearson, Albon and Hubball, 2015), demanding that the researcher adjusts his or her preliminary assumptions (Becker, 1970, p. 77). The author of the thesis, if initially adopting a framework for exploring the case study, however, remains open in acknowledging its limitations and openly discusses additional elements that unexpectedly emerged.

Finally, chapter six conducts a critical literature review, a suitable approach to take stock of different bodies of work and possibly resolve different schools of thought (Croom, Romano and Giannakis, 2000; Jesson and Lacey, 2006; Grant and Booth, 2009). Critical reviews present, analyse and synthesise material from diverse sources and different schools of thought, presenting diverse insights and research perspectives (Geels, 2004; Grant and Booth, 2009; Hambloch *et al.*, 2022), often trying to capture the context in which these generated. This method allows the researcher to draw insights from different disciplines and embody existing theory that helps to highlight the value of competing schools of thoughts (Grant and Booth, 2009). This approach will help the researcher to resolve these competing views, finding common points and acknowledging the value that lies in the diversity of each.

Table 2.6. Ontological, epistemological and theoretical perspectives of the researcher, and how they shape the research and methods used.

Ontology of the research	Epistemology of the research	Theoretical perspective
Cultural Relativist position. No "one reality" that can be empirically, and "once-and-for-all" defined. Truth is relative and belongs to the individual and her/his own culture, thus all points of view are equally valuable. More specifically, "one shared reality exists within a bounded group (e.g., cultural, moral), but across groups different realities exist" (Moon and Blackman, 2014).	**Constructionist Epistemological position.** Individual's knowledge is inevitably "filtered" through individual lenses dependent on social factors. Knowledge is always "culture-bound, historically and context dependent" (Chilisa and Kawulich, 2012).	• **Constructivist perspective.** Individuals have subjective meanings of the reality around them, shaped by historical circumstances, cultural norms, and other factors. • **Critical theory perspective.** Importance of challenging and critiquing existing assumptions • **Pragmatism perspective.** All approaches are valid for understanding and solving a given research problem.

Ontological and epistemological positions and theoretical perspectives, together, greatly influence the different chapters

General implications
• Help the researcher to look for a "complexity of views" instead of narrowing the research on one single view or idea. • Encourage the researcher to investigate the political economy of food systems, and reveal societal issues of injustice and inequity. • Make the researchers aware of the importance of pluralistic and transdisciplinary approaches.

Specific implications for methods used			
Chapter 3	**Chapter 4**	**Chapter 5**	**Chapter 6**
Comparative case study. Suitable method to shed light on the complex and highly diverse political, social, cultural, historical realities that characterize each place.	**Systematic literature review.** Method traditionally employed in medical sciences that is pragmatically adopted to navigate multiple and varied (geographical, social, and other) contexts to seek explanations of path-dependency (including, their highly political nature).	**Qualitative case study.** Method adopted to explore concealed interrelations that shape social phenomena, while remaining open to re-visiting initial assumptions.	**Critical literature review.** Method chosen to capture the diversity of (equally valuable) worldviews and perspectives around the research question.

2.7 Positionality statement

Positionality is a concept that has gained prominence in recent years to answer the question: "what role does the identity of the researcher play in the research?" (Castelló *et al.*, 2021). The idea of positionality is born from the recognition that even when research attempts to be objective, some subjective bias might always (unknowingly) appear in the research (Darwin Holmes, 2020; Hampton, Reeping and Ozkan, 2021). The researchers' own assumptions around the nature of nature of reality (i.e., ontological assumptions) and of knowledge (and the process of its acquisition - i.e., epistemological assumptions) are influenced by his/her experiences, values, cultural, ethical, political or religious background, the location in both time and space in which the researcher is situated, along with a multitude of other inextricable factors (Darwin Holmes, 2020; Robinson and Wilson, 2022). The researcher's position will therefore always shape her or his interpretation of the reality, understanding and beliefs (Smith *et al.*, 2021). Thus, explicitly addressing those, and how they might affect the research, helps ensuring transparency in the research process(Smith *et al.*, 2021). Below is the positionality statement of the researcher.

"The researcher is a citizen of the European Union and grew up in an environment which valued equity and democracy. Her studies and work experiences allowed her to live in multiple countries, both within the European Union – namely, in Ireland, Switzerland, the United Kingdom, Spain, Sweden– and outside it – namely, South Korea and India. This exposed her to different realities and taught her to value diversity, strengthening in her the belief that disagreements or contending visions are not to be considered an obstacle. Rather, they are an enrichment that enables people to dialogue, negotiate and co-create better solutions. The researcher also acknowledges her commitment to ensuring sustainability in current food systems, specifically addressing justice and intragenerational justice concerns. Her experiences and beliefs have implications in terms of her ontological and epistemological views (and consequent theoretical perspectives, methodologies, and methods), which tend to forefront the value of diversity and the importance of including different perspectives in and beyond research debates in an approach that does not prioritise or give primacy to one perspective over the others *a priori*, but instead tries to negotiate across different perspectives and experiences to reflexively find relevant solutions

Finally, the researcher acknowledges her standpoint as a European, educated white woman, and recognises that previous to undertaking the research, she held certain values and views (determined by her social, cultural, political context, gender and ethnicity, among others) that will implicitly shape the research -the questions it asks, and the answer it gives – to some extent. Despite her best efforts, known and unknown subjective bias might appear in the research."

3. Complexity at play: new principles for navigating agri-food systems dynamics and uncertainty

"USILOLE UDZIPHOGWA LOLA UDZIPHO HEREZA."

"DO NOT LOOK WHERE YOU FELL, LOOK WHERE YOU SLIPPED."

AFRICAN PROVERB

Abstract:

Complexity has long been recognised as a key feature of agri-food systems. Yet, it remains only theoretically acknowledged or poorly tackled in practice, hampering the potential of development projects to address agriculture and food-related challenges. The paper seeks to demonstrate the value of complexity principles embodied by an agri-food system perspective to help interventions navigate complexity. To do so, it uses six case studies of agriculture and food interventions in South Asia and Eastern and Southern Africa, to ground truth the way and implications of interventions encountering complexity, which often frustrates interventions' objectives. The paper demonstrates how an agri-food system perspective could have presented different project design options and alternative pathways once bottlenecks were encountered. The principles derived from this analysis stress the value of a much more reflexive and experimentation-oriented approach to interventions and suggest the need to challenge and go beyond generally accepted assumptions in an era of growing uncertainty associated with agri-food system transformation.[8]

[8] The complete case studies, and a few considerations around them, have been published in 2020 as a report, part of the CGIAR Research Program on Grain Legumes and Dryland Cereals (GLDC). The report is available at: http://oar.icrisat.org/11963/. This chapter is being prepared for publication in the "Agriculture and Human Values" scientific journal. The author of the thesis is the first author on the paper, followed by Andrew Hall, Kai Mausch, Alastair Orr, and Caroline Hambloch.

3.1 Introduction

Complexity is a core feature in agri-food systems (Foran *et al.*, 2014; Hall and Dijkman, 2019; Dekeyser *et al.*, 2020). A bundle of environmental and socio-economic issues– environmental hazards, market volatility, changes in climate, social issues and unexpected shocks (such as the Covid-19 Pandemic or the Ukraine grain crisis) (FAO, 2020; Parker, 2022) – have made this complexity even more sticking in recent years (Loring and Sanyal, 2021). Agri-food systems not only encompass all processes involved in growing, processing, distributing, consuming, and disposing of foods, but also the broad network of actors (and their often contrasting or conflicting interests and values) and the multiple ecological, social, economic, political interactions and institutional frameworks that shape these systems and operate at various scales (IPES, 2015; Blake *et al.*, 2019; Hall and Dijkman, 2019). It is the multiplicity of processes, actors, and interactions, coupled with unpredictable events, that cause agri-food systems to exhibit features of systems complexity. These include non-linearity of cause-and-effect relationships, emergent properties leading to unexpected behaviours of the system and unintended consequences and interconnected and multi-scale processes and outcomes (Pimentel, 1966; Falkenmark, 2007; Dekeyser *et al.*, 2020). The presence of historical and concealed path dependencies equally shapes agri-food systems development in unanticipated and intangible ways (Jaradat, 2015; Conti, Zanello and Hall, 2021).

This complexity has always been a distinguishing feature of agri-food systems (Douthwaite and Hoffecker, 2017). Since the 1960s, researchers have grappled with manifestations of agri-food system complexity in various contexts. For instance, interventions aimed to tackle malnutrition and food security in LMICs performed below expectations because of the systemic nature of these challenges (Pimentel, 1966; Robson, 1974) –which require a much deeper consideration of the forces and dynamics that govern these systems (Hambloch *et al.*, 2022). Rather than simply increasing yields, concerted actions were required across social, economic and political domains (Pimentel, 1966; Robson, 1974; Sen, 1981; Hay, 1986; Liang, 2019).

Over the years, further efforts have been made to understand and engage with the system dynamics of the agricultural and food sector, now recognised as being a complex adaptive system (Hall and Clark, 2010; Kampelmann, Kaethler and Hill, 2018; Oliver *et al.*, 2018; Ruiz-Almeida and Rivera-Ferre, 2019). Several system framings have been proposed and have evolved over the years to capture and engage with dynamics in the agricultural and food sector. For instance, from the 1970s onwards, research organisations such as the CGIAR adopted a farming system framing for agronomy research (Greenland, 1997; Pingali, 2001). Later, new framings emerged, such as the

food system framing or the agri-food system framing, to better capture the totality of processes, actors and interaction at multiple levels of scale in the agriculture and food space (Sobal, Khan and Bisogni, 1998; Thompson *et al.*, 2007; Ericksen, 2008; HLPE, 2017). These new, more encompassing framings are increasingly used in relation to the growing concerns over sustainability issues (Fraser, Mabee and Figge, 2005; Ingram and Brklacich, 2006; Ingram, 2011), and to date, they are still a critical point of discussion for research organisations trying to align and respond to the sustainability transformation agenda (HLPE, 2019b; CGIAR, 2020a; FAO, 2021). This novel agenda suggests that structural and concomitant changes in *all* elements of the agri-food system (e.g. technologies, patterns of practice, cultures and behaviours, infrastructure, policies and power dynamics) are needed to shift the direction of these systems from unsustainable patterns to long-term environmental viability, social justice and inclusion, and equity (Conti, Zanello and Hall, 2021; Herrero *et al.*, 2021).

However, despite the rhetoric and wide use of the terms food or agri-food system (Loorbach, Frantzeskaki and Thissen, 2011), complexity remains poorly understood and has yet to inform the emergence of a distinctive body of development practice (Kratli, 2008). Moreover, complexity-aware approaches remain largely unimplemented (Foran *et al.*, 2014; Mayne, Mcdougall and Paz-Ybarnegaray, 2017; Hambloch *et al.*, 2022) because they "challenge orthodoxy in much of mainstream research and evaluation" (Mayne, Mcdougall and Paz-Ybarnegaray, 2017). As a result, even if agri-food system complexity is widely recognised, it remains either only theoretically flagged or poorly tackled within interventions or even altogether forgotten (Douthwaite and Hoffecker, 2017; Turner, Klerkx, White, *et al.*, 2017; Govaerts *et al.*, 2021).

The purpose of this paper is to contribute to developing practical principles that can guide the implementation of complexity-aware approaches[9], specifically, principles for agricultural research for development interventions that have various food and nutrition security and improved farm income impact aspirations. What is common in these interventions is that their scope, by necessity, spans the production and consumption domain of the food system and, therefore, the broader social, economic, and political context in which these domains are embedded. The paper uses six case studies of these types of interventions to first illustrate and provide practical examples of how

[9] Complexity-aware approaches can be broadly defined as ones that are ready to continuously explore system dynamics, accommodate novelty, re-examining assumptions, and generally have an open, rather than a pre-defined, agenda (Douthwaite and Hoffecker, 2017; Hertz, Brattander and Rose, 2021).

complexity can manifest and frustrate the objectives of otherwise well-meaning interventions. The paper then suggests how an agri-food system perspective could be applied to identify ways the contingencies and consequences of complexity could have been addressed in these specific case studies. Finally, the paper distils principles from these experiences and analysis that could guide a complexity-aware approach in practice in the future. The paper begins in the next section by outlining the nature of complexity in agri-food systems and its implications for navigating change in the agriculture and food domains.

3.2 Complexity in agri-food systems

Complexity is a recurrent theme in literature around agri-food systems (Douthwaite and Hoffecker, 2017). Therefore, as a starting point of the paper, the literature around complexity was reviewed to identify recurrent themes in terms of explanations or "causes" of complexity in agri-food systems. Even if this search was not systematic, the authors of the paper attentively scrutinised the literature to identify recurrent preoccupations and issues regarding agri-food systems complexity. Consequently, six critical features of complexity, that seemed to be recurrent in the literature, could be identified: unpredictability of system dynamics, path dependency of systems dynamic, context-specific of system dynamics; power relations that affect system dynamics, temporal and special scales (Figure 3.2).

Unpredictability of agri-food system dynamics. The presence of "unknown unknowns" (Snowden and Boone, 2007) causes the effects and results of interventions sometimes to be sharply different from what is initially predicted (Thompson and Scoones, 2009). Unpredictability not only manifests in terms of unexpected *events* happening in agri-food systems (e.g. sudden shocks such as natural hazards) but also in the outcomes of interactions between actors and, more generally, between the multiple social, economic and environmental components (Holling and Meffe, 1996; Marshall, Haight and Homans, 1998; Ericksen, 2008). For interventions, this means unpredictability is a constant factor during projects as well as in unexpected trade-offs or synergies that might emerge (Jarvis *et al.*, 2011; Whitfield, Challinor and Rees, 2018; Mausch, Hall and Hambloch, 2020). However, linear conceptualisations of change that are still popular in mainstream interventions are poorly suited to deal with this unpredictability and rarely account - or openly discuss – trade-offs that might emerge (Nguyen, Renaud and Sebesvari, 2019; Mausch, Hall and Hambloch, 2020). For instance, interventions aiming to increase incomes by linking farmers to export markets might fail to acknowledge the changes in consumption patterns that

this can generate in the food system - as in the case of quinoa (Perez, Nicklin and Paz, 2011; Conti, Hall and Hambloch, 2021).

The path-dependencies dependencies of agri-food system dynamics. Consideration of path dependency is often a neglected aspect in intervention design and implementation (Conti, Zanello and Hall, 2021). And yet path dependency can significantly affect agri-food systems, covertly shaping their dynamics (Magrini *et al.*, 2016; Wigboldus *et al.*, 2016; Magrini *et al.*, 2018). In interventions, this might manifest as a concealed resistance of the agri-food system towards the changes that the intervention aims to achieve. For instance, the adoption of alternative technologies might be hampered by the dependency of the system on previously-established technologies, that over time led to the gradual build-up of certain patterns of use (e.g. knowledge and skills built around the technology, policies and infrastructure supporting these technologies), making them particularly difficult to alter (Cowan and Gunby, 1996; Hammond Wagner *et al.*, 2016).

Context specificity of agri-food system dynamics. Features of agri-food systems vary greatly across places. Interventions are thus faced with a variety of contexts that do not simply have different environmental features (e.g. different agro-ecological zones) (Fraser, Mabee and Figge, 2005; Ericksen, 2008) but also exhibit specific economic and social dynamics, which shape interactions and patterns of practice – for instance determining what is "acceptable" or "desirable" (Guenin *et al.*, 2022; Ng'endo and Connor, 2022), thus influencing actors' preferences and behaviours (Gonçalves *et al.*, 2015; Bruce and Spinardi, 2018).

Power relations. Actors in agri-food systems often attempt to protect their interests or expand their power (Bui *et al.*, 2016b; Díaz-Méndez and Lozano-Cabedo, 2020). This is particularly the case for influential players such as large food processors, traders and retailers and big input agribusiness (Clapp and Scrinis, 2016; Swinburn, 2019). Through their actions, these players might shape the direction of change of agri-food systems to adhere to their interests (Frimpong Boamah and Sumberg, 2019; Russell *et al.*, 2020). Players with vested interests might, for example, attempt to create obstacles for interventions that might adversely affect them, for instance, by suggesting that interventions aiming to reduce chemical inputs are unviable at scale as the reduction of chemical use would endanger their profits (IPES, 2015; Anderson and Leach, 2019). Despite the importance of these power relations, more in-depth political economy analysis that can reveal

power relations is rarely implemented in practice (Leeuwis and Wigboldus, 2018; Marsden and Rucinska, 2019).

Temporal scales. Interventions that aim to promote change within food systems have to engage with multiple elements, not only in terms of the food value chain (Dinesh *et al.*, 2021) but also in terms of the behavioural, technological, institutional and social drivers that interplay in the totality of the agricultural and food space (Woltering *et al.*, 2019; Conti, Zanello and Hall, 2021). Working through this can take extended time frames (Whitfield *et al.*, 2019). As a result, the impacts of interventions might demand longer time spans to take place (Wigboldus *et al.*, 2016; GLOPAN, 2020).

Spatial scales. Further complicating intervention design, implementation and impact are the by the multiple spatial scales that interlink in agri-food systems and create creating ambiguous boundaries (Halbe and Adamowski, 2019). For instance, interventions tackling local food-related challenges are in reality dealing with issues strongly interlinked across local, national and supra-national scales (Hebinck *et al.*, 2018; Marchetti *et al.*, 2020). This creates a mismatch with the frequently shorter-term and more linear objectives set by many Monitoring & Evaluation (M&E) frameworks (Leeuwis, Klerkx and Schut, 2018; Glover *et al.*, 2021; Govaerts *et al.*, 2021).

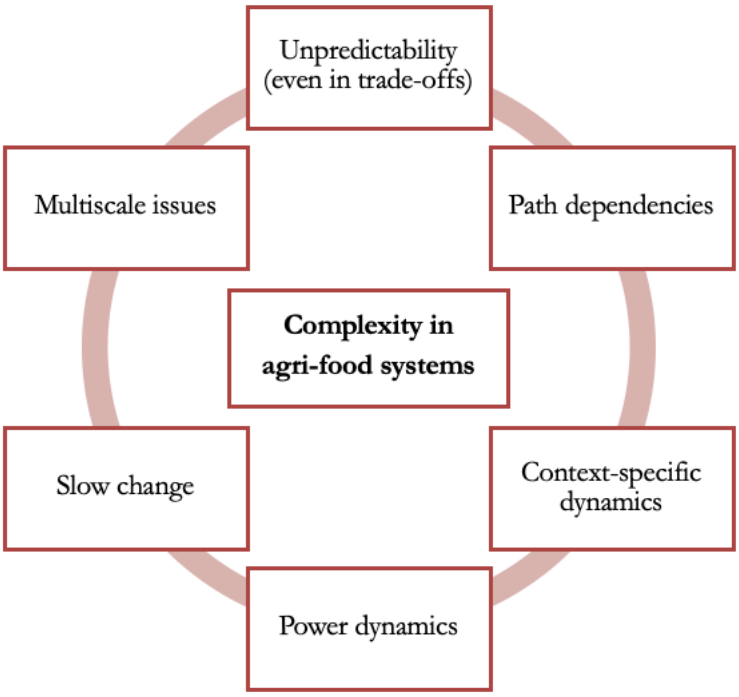

Figure 3.2. Some of the facets of complexity in agri-food systems.

Several authors have suggested that an agri-food system perspective could help deal with some of these features of complexity (Thompson and Scoones, 2009; Mausch, Hall and Hambloch, 2020). In contrast to food system research, where the focus has been on how systems can absorb perturbation and maintain their functions (Thompson and Scoones, 2009; Dekeyser *et al.*, 2020) the agri-food system perspective embraces uncertainty, suggesting disturbances can represent critical opportunities for doing new things and open new ways of innovation and experimentation (Thompson *et al.*, 2007; Thompson and Scoones, 2009). An agri-food systems perspective would also encourage the recognition that each place is unique and inherently diverse (Pimbert *et al.*, 2003; Thompson *et al.*, 2007) and thus demands the development and implementation of context-specific solutions (Leach, Scoones and Stirling, 2010; Hambloch *et al.*, 2022). Whereas much of today's policy and practice attempts to maintain the *status quo* or control change (Thompson and Scoones, 2009; Douthwaite and Hoffecker, 2017), the agri-food systems perspective forefronts the value of being able to respond, cope with and shape change (Thompson *et al.*, 2007; Hertz, Brattander and Rose, 2021). Table 3.2 compares and contrasts the principles of an agri-food system perspective with earlier framings of interventions.

Table 3.2. Elements of complexity, mainstream approaches, and features of an agri-food systems perspective.

Elements of complexity in agri-food systems	**How do mainstream interventions tackle this**	**Features of an agri-food systems perspective**
1. Unpredictability (even in trade-offs)	Pre-defined pathways of change that poorly accommodate unpredictability, no in-depth discussion of trade-offs.	Welcomes surprises and openly discussing trade-offs.
2. Path dependencies	Overlooked.	Shuns orthodoxies.
3. Context-specific dynamics	Frequent tendency to often do "more of the same, somewhere else".	Engages with context-specificity.

4. Political embeddedness	Political-economy analysis preceding interventions rarely conducted.	Exposes patterns of power.
5. Temporal scales	M&E frameworks demand evidence of quick change.	Embraces the lengthy nature of change.
6. Spatial scales	Ambiguous boundaries between multiple scales of agri-food systems.	Understands the multi-scale nature of agri-food systems contexts.

In summary, understanding that "surprises" are inevitable within agri-food systems interventions alerts us to the reality that causes, effects, and results might turn out to be sharply different from what was initially predicted (Millstone, Thompson and Brooks, 2009). Adopting an agri-food systems perspective (Table 3.2) might encourage the adoption of a much more open and flexible approach that seems extremely valuable in an era of growth uncertainty (Hall and Dijkman, 2019). However, the way that this lens can inform development practice remains, to date, highly conceptual (Rivera-Ferre, 2012; Forney and Dwiartama, 2022). To give this idea a strong grounding, we begin in the next section by using 6 case studies to illustrate how dimensions of complexity play out in interventions, frustrate impact ambitions, but also present missed impact opportunities.

3.3 Methodology

3.3.1 Justification of methodology

A comparative case study method is suitable for comparing and contrasting across contexts and, through an extensive degree of conceptual, analytical and synthesising work (Goodrick, 2017), finding patterns that can "trace across individuals, groups, sites, or states" (Bartlett and Vavrus, 2017, p. 11) – in this case, to reveal manifestations of complexity across contexts and draw broad principles for tackling it. The six case studies analysed in the paper are projects implemented by the CGIAR often in collaboration with local actors. Data for the case studies was collected as part of the CGIAR Research Program on Grain Legumes and Dryland Cereals (GLDC). The organisation has been working with agricultural and food system frameworks for decades (Greenland, 1997; Pingali, 2001; Leeuwis *et al.*, 2014; CGIAR, 2020a), and the case studies represented well-intentioned agri-food system interventions aimed either at increasing smallholder farmers' incomes or addressing food and nutrition security, or both. These six case studies were

specifically selected as they were all affected, in different ways, by some of the aspects of complexity, which ultimately hampered the achievement of their objectives. Thus, the case studies are remarkably relevant for identifying manifestations of complexity in practice, while at the same time reflect on possible strategies to respond to it. Besides, they are past rather than ongoing experiences. This helps us revisit them with a more informed perspective: looking at projects retrospectively can give us the benefit of hindsight, which cannot be obtained otherwise (Loorbach *et al.*, 2020; Ojha and Hall, 2021).

Through a thematic analysis conducted with the help of the aspects of complexity described in section 3.2, and the benefit of hindsight, manifestations of complexity, their implications and possible strategies to cope with these were identified and discussed.
The case studies are: aflatoxin control in groundnuts in Malawi (1), pigeonpea in Eastern and Southern Africa (ESA) (2), sorghum beer in Kenya (3), sweet sorghum for biofuel in India (4), precooked beans in Uganda and Kenya (5), Smart Foods in India and Eastern Africa (6). Our purpose is not to critique the interventions that form the case studies, which were not, after all, designed with an agri-food system perspective in mind. Rather, the purpose is to illustrate how complexity manifests within these interventions and develop general principles that could help future interventions tackle such complexity.

Our choice has, however, two limitations:

First, complexity is, by definition, impossible to capture in all its facets. New elements might always emerge. Therefore, our case study does not present *all the possible factors* of complexity, instead focusing on the ones highlighted in the literature review above.

Second, each case study will likely present *multiple* aspects of complexity (complexity manifests as a bundle of components rather than a stand-alone factor). Yet, to gain a deeper understanding of the elements highlighted in section 3.2, our analysis will focus on illustrating a maximum of two elements of complexity for each case - the one(s) that for us represents the major challenge the intervention encountered, even if this can be subject to interpretation- rather than more generally discussing at once a wider range of factors. More importantly, this paper does not mean to critique the theoretical efficacy of the interventions of the case studies but to use them as valuable system probes to reveal complex dynamics in agri-food systems.

3.3.2 Case study summaries

The case studies are now briefly summarised below:

Case study 1: Aflatoxin control in groundnuts in Malawi. The aflatoxin control for groundnuts in Malawi intervention attempted to increase smallholders' farmers' incomes by re-capturing EU markets for groundnuts, once Malawi's main source of exports.

The intervention was underpinned by the aim to re-enter recently lost export markets for Malawian groundnuts. These legumes were once one of Malawi's main sources of foreign exchange. However, in 1982, the European Union (EU) suddenly imposed a regulation on the maximum allowable limits of aflatoxin in foods (Nyondo, Nankhuni and Me-Nsope, 2016). The Malawian groundnut sector was not able to meet these new quality standards as the contamination of groundnuts by aflatoxins could occur at all stages of the value chain, making it a challenging issue to address (Orr *et al.*, 2022). As a consequence, smallholder groundnut producers who produced the majority of the Malawian exports were excluded from European groundnut markets (Natural Resource Institute, 2013). One of the CGIAR centres, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) wanted to ensure that farmers could again benefit from accessing these markets. In partnership with the National Farmers' Association of Malawi (NASFAM), the "Fairtrade model" was developed between 2002-2008 and aimed to develop a quality assurance system. By monitoring levels of aflatoxin using cheap test kits, farmers could again sell standard-compliant groundnuts in EU markets. Also, farmer groups certified for Fair Trade could obtain a premium price for their groundnuts. In 2003, NASFAM partnered with TWIN Trading, a London-based Fairtrade organisation, to promote sales of Malawian groundnuts in the UK. Based on consumers' willingness to pay a premium for 'ethical' products, Fairtrade did indeed enter into the UK market (between 2007 and 2011, the over 4,000 farmers involved generated an income of $527,000). Thus, in 2011, NASFAM and TWIN launched Afri-Nut, a groundnut processing business that could process 4000 t of nuts annually (Natural Resource Institute, 2013). However, only one of a total of 42 NASFAM associations obtained the Fairtrade certification (Orr *et al.*, 2022). This means that the Fairtrade model worked as a pilot, but could not be replicated at scale in Malawi.

Case study 2: pigeonpea in ESA. The pigeon pea in ESA (and particularly, in Malawi, Tanzania, Mozambique, Kenya and Uganda) aimed to produce varieties of pigeon pea and increase farmers income by taking advantage the demand of Indian markets for pigeon pea.

In fact, in India, pigeon pea is an integral part of many people's diet, and demand is often too high to be met by domestic markets. ESA is a major producer of pigeon pea[10]. ICRISAT aimed to capitalised on this opportunity by setting up a breeding program that produced improved varieties to supply to these export markets at the right time. Africa's harvest of pigeon pea is earlier than in India, allowing exports from ESA to benefit from peak prices between July – December before the Indian crop reaches the market. Varieties thus had to a) be suitable to be cultivated in ESA, b) have market traits favoured by Indian consumers, and c) reach India when prices were high. The program, which started in 1991, can be considered as an early example of market-led breeding inspired by the idea of market-led development. The breeding program was in the right place at the right time. In 2000, imports of pigeon pea to India were 44,000 t, and by 2015, imports had reached 450,000 t, with half coming from ESA (Rawal and Navarro, 2019). However, in 2017, the sudden imposition of an import quota for pulses to India caused an abrupt stop to these exports.

Case study 3: Sorghum beer in Kenya. The sorghum beer in Kenya aimed at raising smallholder farmers' incomes by introducing a novel beverage - the Senator Keg beer –, partly subsidised by the government as an alternative to illicit and harmful brews in the country. Producing this beer offered farmers higher prices for their sorghum production.

'Senator keg' was a sorghum beer produced and marketed in Kenya by East African Breweries Limited (EABL). The beer emerged as a response to two opportunities: one, the market for clear sorghum beer that had been growing in Africa, and the advantages such a market could present for smallholders (Orr, Mwema and Mulinge, 2014; Deutsche Bank, 2015). Two, a major health concern around deaths from illicit beers consumptions – which scandalised the public and challenged the government's legitimacy (Hesse, 2015). These beers were consumed by low-income consumers, who could not afford costlier but "safer" beers. Senator Keg would target poorer consumers and were offering farmers a substantially higher farmgate price for their sorghum (Orr, Mwema and Mulinge, 2014). However, the lower consumer price was based on government support. The Ministry of Finance agreed to waive the excise duty that it normally charged on beer to make Senator Keg competitive with illicit brews. Without this subsidy, the price of sorghum beer would have been higher than most illicit brews, and low-income consumers would not have been willing to switch (Orr, 2018). This tax break was critical to the success of sorghum beer.

[10]The biggest producer is Malawi (371,000 t), followed by Tanzania (252,000), Mozambique (200,000), Kenya (148,000), and Uganda (13,000) (Orr *et al.*, 2022).

However, in 2013, the subsidy was suddenly removed, Senator keg's price shot up, and its purchases fell by 75% (Orr *et al.*, 2022).

Case study 4: Sweet sorghum for biofuel in India. This case study aimed at introducing sweet sorghum as a new source of biofuel to raise the incomes of smallholders producing the crop while tapping into the potential of the biofuel market in the subcontinent. Demand for biofuels is particularly high in India due to the country's high crude-oil imports (Vinutha *et al.*, 2014).
In India, most biofuels are made by blending petrol and ethanol produced from molasses, a by-product of sugarcane (Ortiz *et al.*, 2006). However, sweet sorghums have a higher fermentable sugar content and can be used as biofuel (Basavaraj *et al.*, 2013; Pradhan and Ruysenaar, 2014). Sweet Sorghum also has a four times lower water requirement (Basavaraj et. al., 2012) and can be grown in semi-arid areas presented a significant opportunity to raise smallholder farmers' incomes. The waste product from sweet sorghum's processing into a biofuel can further be used as cattle feed. Leveraging its long history of genetic improvement of sorghum, ICRISAT switched some of its research programs to focus on sweet sorghum for biofuels. In 2007, it launched a BioPower Initiative in partnership with the Indian National Agricultural Research Systems (NARS). BioPower aimed at designing and testing a prototype value chain for sweet sorghum in the main sorghum-growing regions of India: Maharashtra, Uttar Pradesh, and Karnataka. The initiative trained farmers on how to manage the production of the new sweet sorghum varieties and was able to attract private investors, thus demonstrating the technical viability of the model of Sweet Sorghum for biofuels. However, sugarcane benefited not only from subsidies that reduce the cost of production but also from a Minimum Support Price(Orr *et al.*, 2022). Without similar government support sweet sorghum could not compete in the market (Basavaraj et al., 2013). A similar subsidy that would have put sweet sorghum into a competitive position and could have been justified by environmental benefits or by the income benefits to smallholder farmers was never implemented (Orr *et al.*, 2022)

Case study 5: precooked beans in Uganda and Kenya. The innovation of precooked beans in Uganda and Kenya tried to build a new value chain for iron-fortified, precooked beans to both improve nutrition and raise smallholder incomes (Ugen *et al.*, 2017).
Common bean is a staple food crop in Eastern Africa. Consumers usually buy dry, unprocessed beans, which have 2-3 hours of cooking time (UUFAS, 2014). This is a significant cost in terms of fuel and women's time (Nakazi *et al.*, 2017). The project thus focused on "precooked beans", which would be produced mainly by smallholder farmers. Precooked beans could be cooked in 15

minutes, saving consumers both time and money and being high in iron, they could tackle a widespread nutritional deficiency. For this, high-iron bean (HIB) varieties needed to be available (this was possible only because biofortification had long been a priority for bean breeding programs) (Dalberg, 2019). A supply chain had to be built ex novo to accommodate the novel product (Ugen *et al.*, 2017). Newly introduced HIB varieties required developing a seed system to supply farmers with these seeds. Ultimately, the novel product needed to be marketed successfully to create demand. If the precooked bean project successfully increased the supply of pre-cooked beans, it was labelled as one with "slow growth" (Orr *et al.*, 2022).

Case study 6: Smart Foods in India and Eastern Africa. The Smart Foods initiative in India and Eastern Africa undertook the challenge of changing consumption patterns in India and ESA using small-scale pilots to promote healthy diets, encouraging the consumption of millet and sorghum.

'Smart Food' was the brand name ICRISAT gave to consumer products made from its mandate crops. Launched in 2013, the initiative aimed at shifting consumption patterns in India and ESA, expanding the three primarily consumed staple foods (rice, maize, and wheat) to five by including millets and sorghum, considered to have better nutritional content than the others (Anitha *et al.*, 2020). They targeted urban, middle-class consumers at risk from lifestyle diseases such as obesity and diabetes and with high purchasing power as well as rural households to also improve their nutrition (Meier *et al.*, 2020). The Smart Food problem was framed as one of consumer demand – or the need to ensure consumers perceive and consequently buy and consume these "healthy foods" [11]. The initiative attempted this through a TV show (where contestants produced dishes using Smart Food ingredients that are judged by professional chefs) and by publishing books with novel recipes for cooking millets and sorghums. Both mainly targeted middle-class women, projecting a 'modern' image for millets (Finnis, 2012; Meier *et al.*, 2020). To include rural women, the Smart Food initiative used a 'home economics' model, developing partnerships with local governments and conducting workshops and participatory cooking classes. If the Smart Foods initiative created awareness and interest, changing eating habits is difficult and lengthy. The Smart Food initiative demonstrated the *potential* benefits of changing consumer behaviour, but any

[11] Smart Food was also marketed to attract to middle-class consumers in other ways, by appealing to global concerns about biodiversity and sustainability ('good for the planet, 'good for the farmer'), as well as decreasing culinary diversity and the need to preserve 'heritage' threatened by 'Western' diets (Finnis, 2012). In India, this marketing has capitalised on the recent shift in food policy from self-sufficiency in food to a greater emphasis on nutrition (Pingali 2017).

changes at scale in behaviour and demand for millets will be long-term and measured over generations (Pingali, Mittra and Rahman, 2017; Meier *et al.*, 2020).

3.4 Results

This section discusses the elements of complexity that have manifested within the different case study, to then highlight the consequences of these complexity elements, and discuss how an agri-food systems lens could have helped tackle them.

3.4.1 Unpredictability and path-dependencies in agri-food system interventions: Aflatoxin control for groundnuts in Malawi and pigeon pea in ESA

Within both the Aflatoxin control for groundnuts in Malawi (case study 1) and pigeon pea in ESA (case study 2) unpredictability, in both outcomes and trade-offs, and path dependencies emerged as elements of complexity.

The Aflatoxin control for groundnuts in Malawi intervention was set up to counter an unpredictable disturbance of aflatoxin regulation from the EU and regain entry into this market. This reflects well the tendency of interventions to try and counter change by trying to revert to a "known" state (Thompson and Scoones, 2009). It further highlights path dependency as it follows a long-back established approach to gain (or re-gaining) access to lucrative export markets as the best way forward to raise smallholder incomes[12] (Toenniessen, Adesina and Devries, 2008; Kay, 2015; Biénabe *et al.*, 2016; IPES, 2016; Koech, Jansen and Van Der Lee, 2016). Market linkages are generally considered the quickest and easiest way to alleviate poverty (Zeller, Diagne and Mataya, 1998; Calo *et al.*, 2005; Anitha *et al.*, 2019).

Instead of adopting the "export framing" the loss of export markets for the Malawian groundnuts could have opened the way to technical innovations. Rather than focusing on unprocessed nuts for export, the attention could have shifted to unleveraged opportunities in terms of groundnut oil, which is aflatoxin-free (contamination can be easily filtered out through a simple filtration process) and in high demand in African markets. If, on the one side, this would have demanded a quick change in priorities for plant breeding to respond to new circumstances, this might have solved the aflatoxin-control issue at a stoke (Orr *et al.*, 2022). On the other side, by framing control

[12] ICRISAT reports: "connections to markets are the most effective means for escaping poverty" (ICRISAT, 2010, p. 23). This is well-reflected in the narrative that dominated a later government summit held in Malawi: "Aflatoxin is locking Malawi out of lucrative export markets. Billions of kwacha – millions of dollars – are lost to Malawi every year. Yet with effective aflatoxin control, groundnut exports alone could grow tenfold, and account for an impressive 10% of the country's current exports" (Aflasafe, 2019).

of aflatoxin as an 'export issue' and not a broader issue of public health, this strategy has effectively re-directed toxins into domestic and regional markets (Orr *et al.*, 2022). Since aflatoxin regulations in these markets are not enforced, producers or exporters had no incentive to comply with them. By reframing the issue as a general public health concern rather than blaming outside forces for the lost markets, the public perception and incentives to control aflatoxin in groundnuts could have been anchored across the population.

Pigeon pea in ESA was very successful for over 15 years but was later hampered by the unanticipated imposition of an import quota for pulses in India. Similar to the case of groundnut exports from Malawi, this relatively unpredictable event was a fundamental disruption of the intervention logic, and the sector could neither prepare nor respond to this relatively unpredictable event. The intervention remained anchored to the well-established conviction that export markets are the quickest way to alleviate poverty (Toenniessen, Adesina and Devries, 2008; ICRISAT, 2010). Instead, one could have responded to the import quota by focusing on pigeon pea for domestic consumption – thus contributing to household food security and nutrition – instead of exporting it. Besides, the case study led to the institutionalisation of its approach, under the name of Inclusive Market-Oriented Development (IMOD) (Srinivas Rao, Bantilan and Parthasarathy Rao, 2014), highlighting the mainstream tendency of many development interventions to "find out what works and do more of the same somewhere else" (Wigboldus *et al.*, 2016). Being more aware of the importance of avoiding path-dependency might have helped prevent the later application of the IMOD indiscriminately - even when inappropriate (Orr and Muange, 2022; Orr *et al.*, 2022). By welcoming surprises, openly discussing trade-offs, and shunning orthodoxies, these interventions might have leveraged new opportunities and avoided certain drawbacks.

3.4.2 Context-specific dynamics and politics embeddedness in agri-food system interventions: Sweet sorghum as biofuel in India and sorghum beer in Kenya

Both sweet sorghum as biofuel in India (case study 3) and Sorghum beer in Kenya (case study 4) successfully identified emerging and promising opportunities. And yet, these interventions were challenged - in different ways - by the concealed context-specific and highly political dynamics that characterised the two regions.

Sorghum beer in Kenya tapped into the potential of East African beer markets, by making the price of the beer competitive with illicit brews and, at once, raising the incomes of farmers producing sorghum and increasing consumption of a local beer while decreasing consumption of a harmful brew (Mackintosh and Higgins, 2004). This competitive price was possible because of a government subsidy. Similarly, despite the potential of the sweet sorghum as biofuel innovation

to benefit farmers and the environment the government failed to adjust economic incentives for the innovation to be adopted at scale.

Why was the subsidy in Kenya suddenly removed? In the same manner, why did the government of India fail to subsidise sweet sorghum as it did with sugarcane when the innovation could demonstrate its potential benefits? The answer to both questions points at concealed elements of complexity: the place-specific and political nature of the Kenyan and Indian contexts (Orr *et al.*, 2022). In Kenya, the unforeseen removal of the indirect subsidy could be attributed to political dynamics. Eastern Kenya – the main region for sorghum production – was home to the Akamba tribe, which had voted overwhelmingly for the democratic party in 2002 (Hornsby, 2013). Promoting a market for sorghum would reward the Akamba for their political support (Orr, 2018). However, when the opposition party won the election in 2012, the Ambaka tribe could not expect "favours" from a political party that they had not supported (Orr *et al.*, 2022), and that had no incentive to maintain the subsidy (Orr, 2018). At the same time, the new party was under considerable pressure to reduce the high fiscal deficit, which made it critical to raise tax revenue. This policy decision left a legacy of uncertainty for the totality of the value chain (which depended on the subsidy), as Orr (2018) explains: "the success of sorghum beer in Kenya rested on fragile foundations that could crumble overnight if the government changed its mind" (Orr, 2018, p. 49). Even if the subsidy that was dropped in 2013 was re-established in 2015, frequent changes in tax policies over the years kept hanging as a "Damocles' sword" on the intervention[13], representing an uncertain threat that could unexpectedly strike at any moment (Orr *et al.*, 2022).

The failure of sweet sorghum as biofuel in India could also be attributed to the unaccounted political realities affecting the regions where sweet sorghum is grown. The states that presented suitable agroecological zones for the cultivation of sweet sorghum (Karnataka and Maharashtra) were the same states that have historically been strongholds of the sugar industry (Jitendra, 2019; Orr *et al.*, 2022). The absence of support can be attributed to the sugar lobby – which can be compared in terms of political power to the gun lobby in the US (Banerji, 2019). The lobby wants to preserve its interests and, through its close ties with political players, opposes subsidies to sweet sorghum that would endanger their revenue from sugarcane (Saravanan *et al.*, 2018; Orr *et al.*, 2022).

More carefully considering these dynamics before the set-up of the interventions might have helped find alternative or complementary strategies to address these contextual political issues. For

[13] After excise duty was reduced to 10 % in 2015, three years later it was raised to 20 %. In 2018 there were plans to raise it further to 40 %. EABL protested that this would cut demand by over 80 %.

Senator Keg, this might have involved novel business models that could make the beer competitive even without the tax break (Orr, Mwema and Mulinge, 2014), or create stronger national farmers' organisation that could lead a coalition of stakeholders and avoid the reversal of the policy (Orr, 2018). Similarly, recognising that sweet sorghum needed to be supported by a strong political coalition that could counter the influence of the sugar lobby might have helped the innovation gain essential political support (Raju *et al.*, 2001; Pradhan and Ruysenaar, 2014; Saravanan *et al.*, 2018).

These cases highlight the importance of recognising and acknowledging these issues as it will otherwise be impossible to solve them. The agri-food systems lens here sheds light on the importance of engaging with context-specificity and exposing concealed power relations.

3.4.3 Slow change and multiscale issues in agri-food system interventions: Smart Foods in India and Eastern Africa and precooked beans in Uganda and Kenya

The precooked beans in Uganda and Kenya (case study 5) and the Smart Foods in India (case study 6) projects embarked on an ambitious task of changing consumer behaviours by developing novel value chains or creating awareness of new healthier foods. However, both witnessed slow changes and encountered multiscale issues as elements of complexity.

Precooked beans were a promising innovation. The project set the bold goal of building a value chain for the product. This involved managing multiple and interconnected parts of the bean value chain and coordinating ten steps: i) screening and identifying suitable varieties; ii) multiplying seed using farmer groups; iii) producing grain through farmer groups; iv) aggregating grain and delivering to processors; v) establishing processing plants; vi) production and sale are profitable; vii) winning product approval from the Bureau of Standards; viii) identifying consumers willing to buy the product; ix) raising consumer awareness of nutrition benefits; x) ensuring a continuous supply to meet consumer demand. Tackling all these steps synchronously was challenging for the intervention and required time and effort for coordinating different actors and activities. Yet, the project was frequently criticised for its slow growth (Aseete *et al.*, 2018; CASA, 2020) – instead of praised for engaging in the challenging task of building a value chain "from scratch" (Orr *et al.*, 2022). Building a value chain is a long-term investment (and a critical objective for many development interventions (Staritz, 2012)), and a 2.5 years project time-span is inadequate to ensure harmonisation between a wide range of stakeholders and all the "moving parts" parts of the value chain (Orr *et al.*, 2022).

The lengthy nature of change also hampered the Smart Foods initiative. If the initiative could demonstrate the *potential* benefits of consuming these foods, it could not change consumption patterns at scale. If changes in consumption are relatively easier to witness in pilot projects (Obih and Baiyegunhi, 2017), ensuring that they are widespread requires much more concerted efforts – for instance, changing consumption patterns in India or ESA would require interconnected actions on several fronts, such as legislation, education, restrictions on advertising, and a public health campaign (Epstein *et al.*, 2012; Powell *et al.*, 2013). The expectation that these changes could be quickly achieved is unrealistic.

Even if it is increasingly being recognised that interventions aiming for shifts in production or consumption (or the value chain itself) cannot be achieved quickly (Leeuwis, Schut and Klerkx, 2017; Govaerts *et al.*, 2021), many M&E frameworks – and the donors' expectations underpinning them (IPES, 2016) - still look for proof of quick impacts (IPES, 2016; Leeuwis, Klerkx and Schut, 2018), underestimating the complexity of implementing deeper changes in agri-food systems (Govaerts *et al.*, 2021). Adopting an agri-food systems lens that embraces the lengthy nature of change, and its multiscale nature, would help better embed more long-term objectives in intervention logic and provide stronger backing and justification for interventions having more ambitious goals (e.g. building a value chain, changing behaviours) (IPES, 2016; Glover *et al.*, 2021; Govaerts *et al.*, 2021).

Table 3.4. Case study summary: complexity elements and encounters, possible strategies to tackle it, and some overarching principles.

Complexity element	Case studies	Complexity encounters	Possible strategies to tackle complexity elements	Agri-food systems principle(s)
Unpredictability (during the project and in trade-offs) and path dependencies	Aflatoxin control for groundnuts in Malawi Pigeonpea in ESA	1. Unpredictable changes in policies: • imposition of new safety standards for aflatoxins in the EU; • imposition of import quota for pulses. 2. Unacknowledged trade-offs: • aflatoxins redirected to domestic markets; • pigeonpea used for exports instead of food security and nutrition. 3. Path dependencies:	1) Shocks can present opportunities to do new things: • Experimenting with a new product – groundnut oil, which is aflatoxin-free. 2) A more open acknowledgement of possible trade-offs is needed: • Framing the aflatoxin problem as a health issue might avoid the consumption of unsafe products in local/domestic markets; • Pigeonpea might be used for domestic food security and nutrition. 3) It is equally necessary to identify path dependencies and be mindful of not generating new ones:	Welcoming surprises, discussing trade-offs openly, and shunning orthodoxies

		• Intervention framed by the trope of lost markets; • Intervention generates an orthodoxy (invertedly)	• Export markets do not always present the best option for raising smallholder incomes. • Market-led approaches cannot be applied indiscriminately.	
<u>Context-specific dynamics and politics embeddedness</u>	Sorghum beer in Kenya Sweet; Sorghum as biofuel in India	1) Patterns of politics are highly specific • E.g. to the Kenya and Indian context and 2) Have a major impact on interventions: • removal of the subsidies made Senator Keg sales collapse • Sweet sorghum is discarded as possible source of biofuel	1) The context of the intervention needs to be better explored: • Understanding political realities might help interventions to be set-up accordingly (e.g. do not rely on policies when these might not be stable) 2) Political dynamics should be discussed and accounted for: • Creating coalitions of interests or political entrepreneurs might be important to open different venues for innovation.	3) Engaging with context-specificity and exposing patterns of power

<u>Slow change and multiscale issues</u>	Smart Foods; Precooked beans in Uganda and Kenya	1) Change takes time • In terms of building a value chain for a new product • So does scaling, especially in terms of changing consumers' behaviours beyond the pilot stage of the project.	1) Project that set ambitious goals (i.e., building value chain from scratch, changing behaviours) might take longer time-spans, but deliver longer-term changes: • Building a value chain involves managing many steps and avoiding many "causes of failure", rather than showcasing success. • Changing consumer habits will take time but might entail important benefits. 2) Rethinking M&E: • Current M&E do often do not account for the length nature of change	3) Embracing the lengthy nature of change… and its multi-scale nature

3.5 Discussion and conclusion: the value of an agri-food system perspective

The case studies show that interventions rarely go as planned, and elements of complexity might always emerge and shape their dynamics and outcomes. The case studies show how an agri-food systems perspective could be used within intervention designs to possibly navigate emerging issues from agri-food system complexity, thus revealing its diagnostics and intervention framing power (also summarised in table 3.4).

The importance of welcoming surprises emerges in the aflatoxin control for groundnuts in Malawi and pigeon pea in ESA case. Moving away from attempts to "combat" change and cling to pre-set objectives (i.e. accessing export markets), a more flexible approach that welcomes disturbances as new ways of doing things could have opened the way for opportunities in more lucrative domestic markets (Orr *et al.*, 2022). This is in line with more recent literature, which highlights that shocks or perturbations in agri-food systems can rarely be controlled or predicted (Thompson and Scoones, 2009), and therefore, there is a need to move away from static and linear theories of change (Wigboldus *et al.*, 2016; van Tulder and Keen, 2018). Instead, it is more useful to embrace a more flexible approach that can enable interventions to respond (rather than control) to the always dynamic and evolving context. At the same time, these two case studies draw attention to the need to shun orthodoxies (i.e. accepted practices and routines) in the way interventions are designed and implemented (IPES, 2016; Conti, Zanello and Hall, 2021). For example, this would have helped question the export-oriented logic in which aflatoxin control for groundnuts in Malawi and pigeonpea in ESA were rooted (Kaoneka *et al.*, 2016; Aflasafe, 2019). Instead of narrowing the focus on only one solution (i.e. access export markets), a more open and critical approach that questions ubiquitous assumptions that might not, in truth, be always relevant or beneficial for to interventions (Borrella, Mataix and Carrasco-Gallego, 2015; Liverpool-Tasie *et al.*, 2020; Mausch, Hall and Hambloch, 2020).

A more open and flexible mindset could also contribute to identifying and clearly discussing trade-offs. The focus on export markets for groundnuts re-directed aflatoxins into domestic markets, while in the case of pigeon pea, this ruled out the possibility of exploring ways of expanding domestic consumption. Even if not all trade-offs can be predicted when intervening in agri-food systems (Dekeyser *et al.*, 2020), an upfront and honest discussion of possible trade-offs could be important for encouraging reflection on possibly different pathways (for instance, acknowledging the risks of linking farmers to export markets (Gill, 2019; Conti, Hall and Hambloch, 2021)) that

more carefully evaluate and weight out a broader range of options (Mausch, Hall and Hambloch, 2020).

A key feature of an agri-food system perspective is its recognition that each place has its own unique dynamics, which inevitably play out in and beyond the intervention. This is particularly so in terms of power relations playing out in different agri-food system contexts (Swinburn, 2019; Clapp and Ruder, 2020). For example, the sweet sorghum as biofuel in India and sorghum beer in Kenya case illustrated how embedded political patterns shaped the intervention implementation and its outcomes. It could be argued that changing such patterns is an extremely ambitious task, that goes beyond single interventions and requires much more systemic action (Fanzo *et al.*, 2021; Béné, 2022). However, it could also be argued that pre-emptively studying and understanding the political economy dynamics of different contexts might be a critical first step in intervention design (Hambloch *et al.*, 2022). Similarly, exploring how these dynamics might shape and direct actors' behaviours and the way this affect intervention outcomes provides a way to identify mitigation strategies (Anderson and Leach, 2019). For example, this includes strategies that alter contextual bottlenecks, such as by building stronger networks or leveraging the influence of policy entrepreneurs or, alternatively, strategies that circumvent possible bottlenecks, such as ensuring interventions are not dependent on fickle policies.

Finally, the case studies' experiences confirm that emerges that agri-food system change has both spatial and temporal scales, the latter of which is usually over looked (Conti, Zanello and Hall, 2021). This means understanding that change does not always happen synchronously between spatial scales, nor it adheres to fixed and often short-term deadlines (Beck *et al.*, 2021; Glover *et al.*, 2021; Sarabia, Peris and Segura, 2021). For example, in the Smart Food intervention case study, changes at the project scale could be demonstrated relatively quickly, but the broader desired changes (i.e. a shift in consumption patterns to include millets and sorghum) will require much more concerted action to happen at scale (regionally or nationally in India and ESA). Such changes need to be harmonised with other changes at the broader level, such as, for instance, policies that subsidise these crops to be consumed by the poor (Thow, Downs and Jan, 2014), or multiple behavioural change interventions that can over time alter purchasing and eating habits (Taufik *et al.*, 2019; Andreyeva *et al.*, 2022). As the pre-cooked been case demonstrated, building a value chain for a new product takes considerable periods of time as it requires innovation that ensures multiple value chain components (and inherent actors) can work together. Whereas many M&E frameworks used for evaluating agri-food systems interventions have short time-spans, which are

justified by donors' own priorities and preoccupation in terms of achieving "success" without deviating from the established or "desired" intervention's course (Govaerts *et al.*, 2021), the agri-food systems perspective invites a more realistic and accepting vision. This vision acknowledges the possible limitations in scale beyond the pilot interventions, or the longer time-spans required for interventions to explore and implement new pathways of change at multiple scales (Jagustović *et al.*, 2019; Woltering and Boa-Alvardo, 2021).

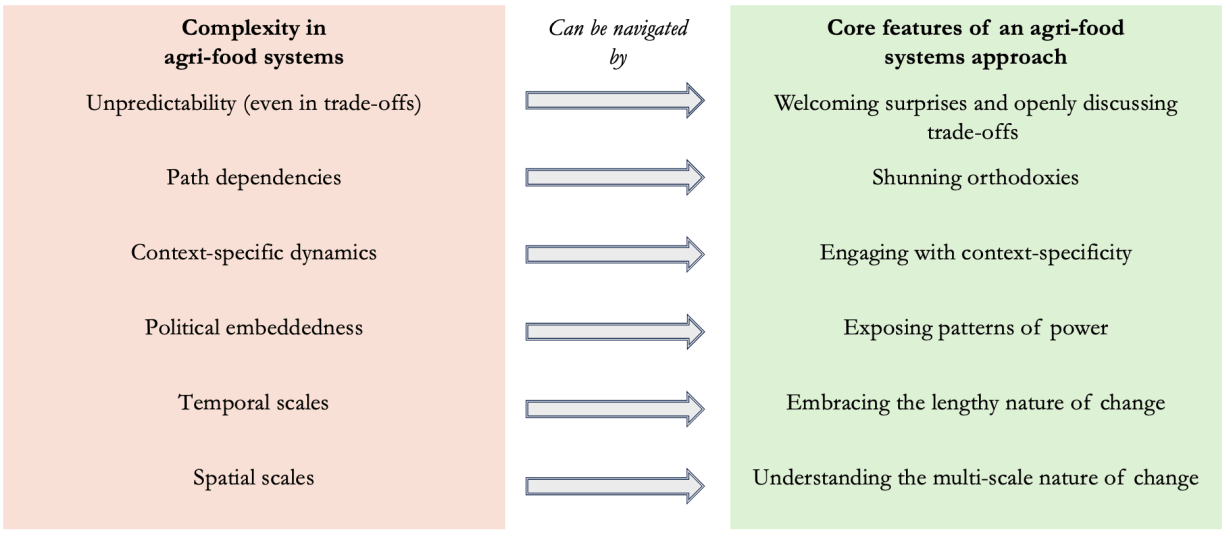

Figure 3.5. Core principles for operating in agri-food systems, from an agri-food systems perspective. It is important to note that elements of complexity can manifest differently in different contexts, either singularly or together, combine in unexpected ways and with unexpected outcomes. Thus, an agri-food systems approach should not be adopted as an inflexible or prescriptive manner but instead, should always be adapted and revisited as needed.

As a whole, these six principles highlight the value of a novel way of approaching interventions in agri-food systems that is not governed by generally accepted assumptions (Niewolny, 2022). Rather, it is open to reflexive and critical (re-)evaluation that prompts continuous experimentation and learning (Caniglia *et al.*, 2021; Schlüter *et al.*, 2022) as essential to embrace and navigate through complexity (re-setting the route when needed). In the case of the case studies, we would argue that a lack of reflexive evaluation and mid-course corrections hampered the ability of the interventions studies to navigate and respond to the complexity of contexts in which they were situated.

The implication here is that intervention should not that attempt to control or shy away from complexity (Thompson and Scoones, 2009). Nor should they adhere to what is "known to work" (Folke, 2006; Manyise and Dentoni, 2021), following pre-defined pathways of change that often respond to "established notions of accountability"(Hertz, Brattander and Rose, 2021, p. 35).

Instead, the principles that our case studies seem to confirm is the importance of being open to unpredictable developments, and seizing them as opportunities to venture into different (and possibly more suitable) pathways of change (Thompson and Scoones, 2009). This may require interventions to be iteratively (re)defined with multiple stakeholders, including donors, who might need to be convinced of the value of a more flexible and open approach to change, which might lead to different and possibly unknown outcomes (Stirling, 2014a; Hertz, Brattander and Rose, 2021).

3.6 Conclusions

The paper aimed to better understand complexity, its manifestations, and possible ways to respond to it within development interventions. It did so by revisiting six case studies from LMICs, which allowed us to shed light on how complexity plays out in practice, and discuss the value of a set of six principles that could help interventions be more aware and prepared to engage with this complexity. Notwithstanding the need for further testing and refinement, these principles could be particularly relevant in light of the agri-food system transformation agenda, as this is an agenda deeply involved in complex system dynamics and change processes. As this agenda becomes ever more urgent, there is no time to waste in mobilising already existing ideas about complexity. Paying serious attention to these ideas and wrapping them into a complexity-aware set of approaches to envisioning, designing, implementing and evaluating agri-food interventions. This could make a vital contribution to our collective, sustainable future.

4. Why are agri-food systems resistant to new directions of change? A systematic review

"IT IS SOMETIMES NOT POSSIBLE TO UNCOVER THE LOGIC (OR ILLOGIC) OF THE WORLD AROUND US EXCEPT BY UNDERSTANDING HOW IT GOT THAT WAY."

PAUL A. DAVID

Abstract:

A central concern about achieving global food security is reconfiguring agri-food systems towards sustainability. However, historically-informed trajectories of agri-food system development remain resistant to a change in direction. Through a systematic literature review, we identify three research domains exploring this phenomenon and six explanations of resistance: embedded nature of technologies, misaligned institutional settings, individual attitudes, political economy factors, infrastructural rigidities, research and innovation priorities. We find ambiguities in the use of the terms lock-in and path-dependency, which often weaken the analysis. We suggest a framing that deals with interdependencies and temporal dynamics of causes of resistance. Finally, we discuss implications for framing innovation for transformational change and other research gaps.[14]

[14] This paper was published in Global Food Security in September 2021:

Conti, C., Zanello, G., Hall, A., 2021. Why are agri-food systems resistant to new directions of change? A systematic review. Global Food Security 31, 100576. https://doi.org/10.1016/j.gfs.2021.100576. No edits, aside from formatting, have been made to the published article.

4.1 Introduction

It is increasingly clear that agri-food systems have evolved in unsustainable directions over the last fifty years (De Schutter, 2017). A central concern in recent debates about achieving global food security is the need to reconfigure and transform agri-food systems in a way that is better aligned with aspirations for sustainable and socially inclusive patterns of food production and consumption (Caron *et al.*, 2018; FAO, 2018b; Fanzo *et al.*, 2020; Herrero *et al.*, 2021). The need for new directions is evidenced by the persistence of environmentally damaging agriculture and food practices (Kopittke *et al.*, 2019; CCAFS, 2020) and by the prevalence of food insecurity, and malnutrition, particularly in low- and middle-income countries (LMICs) (Oliver et al., 2018; Roser and Ritchie, 2019; Global Nutrition Report, 2020). Shocks ranging from unpredictable changes in climate and unforeseen events such as the Covid-19 pandemic add urgency to the call for new directions. LMICs suffer most acutely from the inadequacy of current agri-food systems (Thompson and Scoones, 2009; HLPE, 2017).

Agri-food systems are not static but are dynamic and continuously evolving. Yet, a shift in the direction of agri-food systems change towards sustainability remains a distant prospect (Dorninger *et al.*, 2020). Different components of agri-food systems have co-evolved over time, becoming mutually supportive, keeping current production and consumption patterns solidly established and deeply embedded (Lamine et al., 2012). It is the resistance of agri-food systems to detach themselves from the past and change in new directions that is the concern (De Schutter, 2017). This implies a shift from incremental changes within the existing format of agri-food systems to a reformatting of the system itself in order to pursue new objectives such as sustainability, underpinned by new trajectories of innovation and development (Foster, McMeekin and Mylan, 2012; Kuokkanen *et al.*, 2017; van Bers *et al.*, 2019). At the same time, there are concerns that incumbent actors in agri-food systems (in particular powerful players in the global food chains such as large food processors, traders and retailers and big input agribusiness) may maintain, defend, and incrementally improve the existing agri-food system, caring little for sustainability objectives that might question the established, and highly profitable industrial food and farming model (De Schutter, 2017; Geels et al., 2017; IPES, 2017, 2016).

A large body of theory has addressed the question of why domains of economic and social activity tend to proceed along established pathways and directions, and how changes in direction take place (Kemp, 1994; Elzen, Geels and Green, 2004; Geels, 2004; Geels and Kemp, 2007; Magrini et al., 2016). This literature has provided theoretical explanations of (i) the way path dependencies in

technology choice and use emerge and reproduce change trajectories (Kemp, 1994; Radulovic, 2005; Chhetri *et al.*, 2010); (ii) the way mutually supporting systems components create "lock-ins" that perpetuate existing directions of innovation (Kuokkanen *et al.*, 2017; Magrini, Béfort, *et al.*, 2018) (iii) and the way inertia in existing systems halts changes towards new directions (Dury *et al.*, 2019a; Leach *et al.*, 2020). These ideas have manifested themselves in the socio-technical transition literature (Geels, 2002 and 2004; Geels and Kemp, 2007), and more recently, in the sustainability transition literature (Magrini *et al.*, 2018; De Herde *et al.*, 2019; Mawois *et al.*, 2019).

More recently there has been a rapid growth in the application of these "transitions" perspectives to sustainability concerns in agri-food systems (El Bilali, 2019b). This analysis has stressed the need for agri-food systems to undergo fundamental changes to tackle incumbent challenges (El Bilali, 2019b;. Melchior and Newig, 2021). However, debates on resistance of the agri-food system to change in new directions has a longer history in agricultural/farming systems and food policy literature that pre-dates the current upswing in interest in sustainability transitions in agri-food systems. In this literature the focus of attention has been on how changes in production and consumption at farm and other scales can be triggered to achieve different aims – improved productivity, environmental sustainability, food security etc. (Cowan and Gunby, 1996; Ruttan, 1996). This literature has a variety of explanations of resistance to change that range from human-ecology interactions through to more socio-political framings. Even in the contemporary sustainable development literature, there are different views on how resistance to change in direction and nature of the change agenda should be framed (Stirling, 2014a; De Schutter, 2017). For example, some reject the idea of transition as an appropriate metaphor for change (in agri-food systems and beyond), taking issues with its perceived focus on technological change presided over by incumbent interests and preferring the metaphor of social transformation, based around wider innovations in social practices as well as technologies, involving more diverse, emergent and unruly political re-alignments that challenge incumbent structures pursuing contending (even unknown) ends (Stirling, 2014a). This point of view also underpins a more diverse and pluralistic vision of future agri-food systems with multiple change pathways that reflect the values of diverse sets of societal interests (Leach *et al.*, 2007; Leach, Scoones and Stirling, 2010; IPES-Food & ETC Group, 2021). Building on the tradition of research on the power and politics of food systems (and development more generally), it proposes a critique of the role of dominant voices and expertise in shaping development trajectories that excludes socially and economically disadvantaged members of society (Thompson et al., 2007; Thompson and Scoones, 2009; van Bers et al., 2019).

These diverse fields of study have much to say about the nature of resistance to directional change in agri-food systems. However, a clear picture of explanations of resistance to change appears diffuse and even contested. This leaves unanswered questions about how resistance to change in new directions can best be understood and ultimately resolved. To take stock of these debates, old and new, this paper uses a systematic review approach. Its purpose is three-fold. Firstly, to map different domains of research in the agricultural and food research field, to understand how the question of resistance to change is conceptualised. Secondly, to identify different explanations of resistance to change in agri-food systems that emerge across the different bodies of literature. Thirdly, the review is used to identify critical research weaknesses and gaps that would benefit from further attention.

4.2 Conceptualising resistance to change in systems terms

The idea of resistance to change as a systemic phenomenon has its origins in the early 1980s, in the attempt to explain how apparently inferior designs (such as the QWERTY keyboard) (David, 1985) or unsustainable modes of production (Arthur, 1988) became dominant within a society. Studies show that, once historic circumstances and preliminary strategic choices lead to the establishment of a certain trajectory, a set of coevolving factors builds around and reinforces these choices (e.g. sunk investments costs in certain technologies, capabilities, infrastructural adjustment, institutional and policy conditions – see example in Box 4.2) (Nelson and Winter, 1982; David, 1985; Arthur, 1988). Thus, the initially set trajectory becomes extremely difficult to dislodge. To describe this phenomenon, researchers employed the concepts of path-dependency and lock-in (David, 1985; Liebowitz and Margolis, 1995; McGuire, 2008; Jacquet, Butault and Guichard, 2011). Lock-ins are "blockages" that lead to the exclusion of competing views and practices, making the system "blind" to possible alternatives and keeping it moving on the established trajectory (Feyereisen, Stassart and Mélard, 2017; Della Rossa *et al.*, 2020; Messner, Johnson and Richards, 2021). Path- dependency is used to express that "history matters", describing how initial choices in the past influence present decisions – or "initial moves in one direction elicit further moves in that same direction" (Kay, 2003). More recently, the term "inertia" has also surfaced in social sciences (Stål, 2015), to describe a disinclination towards change in agri-food. It is used in a complementary and overlapping manner to the idea of lock-in and path-dependency: at the individual level, it is used interchangeably with "lock-in" to describe individuals' disinclination towards change (Tonkin *et al.*, 2018; Yen, 2018); at the system level, it is often used as a synonym of path-dependency, to indicate how routines, social habits, infrastructure, organisational logics etc. slow or sometimes halt a change in direction in agri-food systems (Dury *et al.*, 2019a; Leach *et*

al., 2020). Over the years, these three terms became more popular in the literature, to explain systemic resistances in the agriculture and food sector (Baret, 2017; Oliver et al., 2018b; Rønningen et al., 2021). Yet, to date, these phenomena remain ill-defined and under-investigated in the agri-food sectors compared to others (such as energy and transport) (Ronningen *et al.*, 2021). This provides a rationale for conducting this systematic review.

Box 4.2. Pesticides: between technology lock-in, path dependency and inertia.

A common example that is useful to see how these three phenomena play out in systems is the high pesticide use in agricultural systems (Cowan and Gunby, 1996; Wilson and Tisdell, 2001; Vanloqueren and Baret, 2008; Grovermann *et al.*, 2017; Desquilbet, Bullock and D'Arcangelo, 2019; Flor *et al.*, 2019, 2020; Horgan and Kudavidanage, 2020).

The historical choice. Synthetic pesticides initially faced competition with more environmentally friendly practices (e.g. the precursor of what is today organic agriculture) (Wagner, Cox and Bazo Robles, 2016). However, their effectiveness in eliminating pests and helping increase productivity made them a preferred choice (ibid.).

The lock-in. Over time, limited appreciation of environmental externalities and consumer expectations for low-cost food, left unquestioned the probity of pesticide use, while social acceptability and permissive government policies (Bakker et al., 2020; Vanloqueren and Baret, 2008), powerful agri-chemical companies developed highly profitable business models that promoted pesticide use through "low prices, ease of access, and availability of technological support to farmers" (Wagner, Cox and Bazo Robles, 2016).

The path-dependency. In the meanwhile, private R&D investments in a wider range of products such as herbicide-resistant crops, encouraged incremental changes on the same trajectory, fitting both incumbent agrichemical company business models and farms practices, and further entrenching pesticide use (Vanloqueren and Baret, 2008).

The inertia. The uptake of alternatives has been slow as it would demand changes in the system at all levels: from overcoming farmers' inertia and enable change in farm level production patterns to fundamental changes in direction of research and innovation investments and priorities (IPES, 2016).

4.3 Methodology

This research adopts a systemic review approach to map old and new debates around resistance to change in agri-food system. We chose 1970 as starting year for our systematic review, for two reasons: i) the literature around the sustainability of agriculture and food production and

consumption emerged in the 1970s (and around sustainability more in general) (Yeh, 2019) and ii) the first conceptualisations of path-dependencies, lock-ins and inertia started taking roots in the 1980s (David, 1985; Liebowitz and Margolis, 1995; McGuire, 2008). The flowchart below (Figure 4.3) outlines the key choices (keywords, databases, type of publications, language and start year) and steps for our systematic review. The full protocol can be found in Annex I.

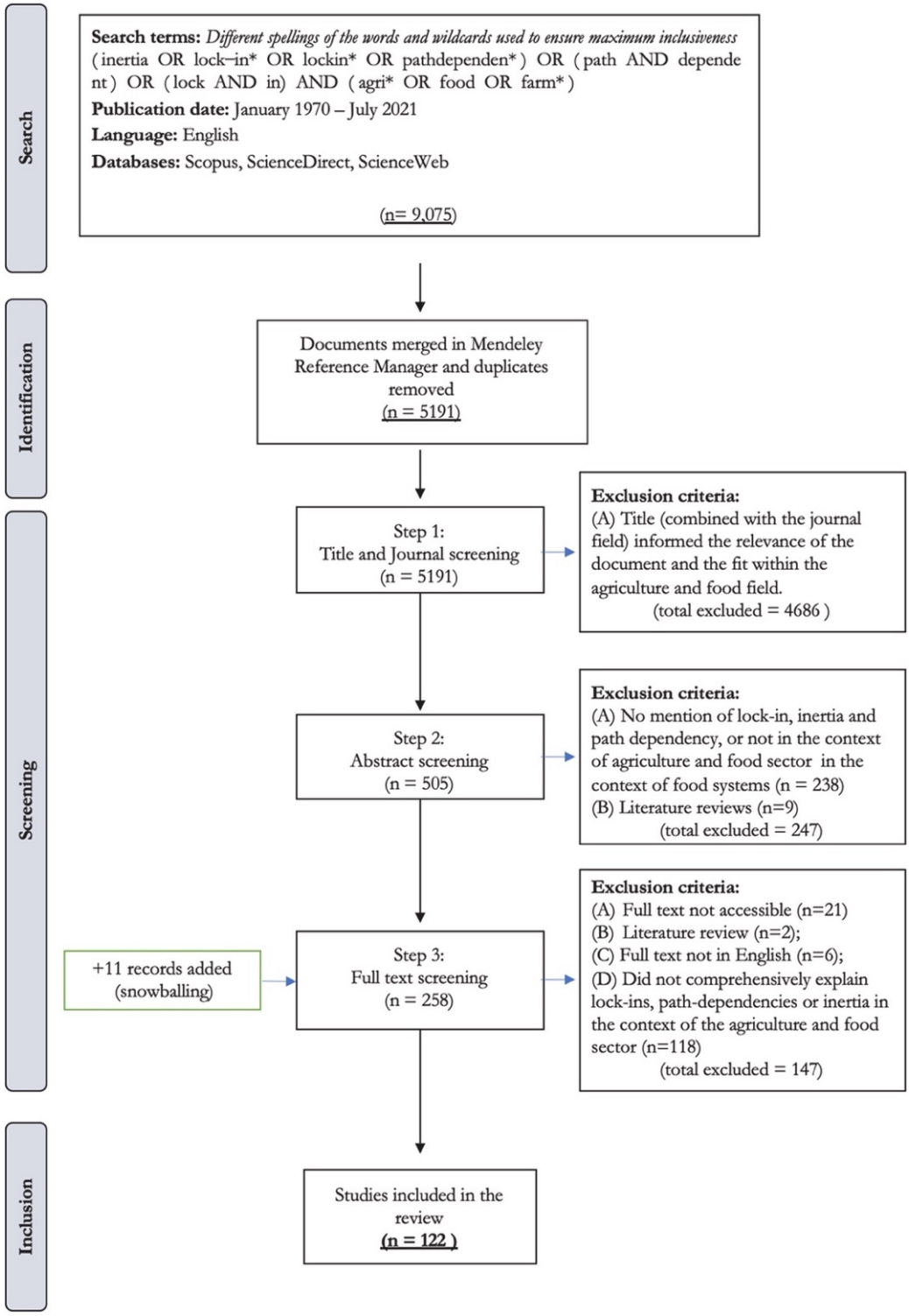

Figure 4.3 Flowchart illustrating the systematic review process.

4.4 Results

4.4.1 The literature landscape

From the systematic screening of the literature, 122 publications were selected. Most of the publications are peer-reviewed journal articles (108), 7 are reports, 3 are books or book chapters, 3 are conference papers, and 1 is a working paper. The review reveals that there has been a gradual increase in interest towards the study's topic over the years, with more than 70% of the total papers published after January 2015. The two oldest publication dated to 1996 (Cowan and Gunby, 1996; Ruttan, 1996). If this finding seemingly contradicted our initial assumption implying that the discourse around path-dependencies, lock-ins and inertia started in the 80s (David, 1985; Liebowitz and Margolis, 1995; McGuire, 2008), this was however, explained by the fact that these concepts were initially employed to refer to the industry or energy sector, and only a decade later appeared in the agricultural context (Huyghe and Brummer, 2014). Several sources among the shortlisted publication confirmed this finding (Jacquet, Butault and Guichard, 2011; Le Velly, Goulet and Vinck, 2020; Morel *et al.*, 2020). Besides, of the publications having a specific geographical focus (25 have none), almost 75% investigates path-dependencies, lock-ins and inertia in HICs.

Another point worthy of notice was the use of the keywords in the selected documents. 'Inertia' was, overall, usually referred mostly to consumers' attitudes and purchasing patterns (Yen, 2018) (Chen *et al.*, 2021). The term was only marginally used to describe resistance to change at the system level (Dury *et al.*, 2019b). In this case, it was mostly referred to policies (e.g. policy inertia) (Thow *et al.*, 2016; Henke *et al.*, 2018; Ng *et al.*, 2021). More ambiguous was however the use of 'path-dependencies' and 'lock-ins'. The two terms were used almost interchangeably (Berkhout and Carrillo-Hermosilla, 2002; Kay, 2003; Chhetri *et al.*, 2010). Despite the existence of clear definitions discussed in Section 2, it remained unclear in the literature reviewed whether lock-ins are a result of path dependency, or whether path dependency is a type of lock-in[15]. This finding will be further explored in the discussion. For the analysis of the results, we attempted to keep the terminology used in the original cited document whenever possible.

Research domains around resistance to change in direction agri-food systems. The review reveals that the debate around resistance to change in agri-food systems resides in three distinct

[15] For instance, (Morel *et al.*, 2020) explains how different elements of food systems have co-evolved historically and reinforce one another, arguing that they result "in the system's perpetuation and stability (lock-in)". In contrast, an IPES report categorizes path-dependency as a particular type of lock-in (IPES, 2016, p. 45). Many similar examples can be found in the literature.

research domains: the agricultural systems (AS), the food system (FS), and the socio-technical systems (STS) research domain. Despite complimentary and sometimes overlapping interests, these domains have distinct differences in terms of i) conceptual underpinnings; ii) scope and focus; iii) methodological approaches and iv) the core objectives of change explored. These distinctions are illustrated in Table 4.4.1, together with key references identified for each research domain. The explanations of resistance as mentioned in the different domains are detailed in Table 4.4.2.

The agricultural systems research domain. The focus in this research domain is understanding how agricultural systems can be adapted to achieve different goals. Building on various stands of systems theory, its core conceptual proposition is that changes in agricultural production patterns are determined by a set of interconnected elements, namely: ecological processes and resources, knowledge and technology processes and resources (including, extension services and agricultural research, input suppliers, but also farmer knowledge), market processes and resources (input and outputs markets and patterns of demand) and policies and regulations. Farmers' behaviour and farm-scale processes in relation to technological change are often central to the analysis. Initially, the primary concern of this research domain focused on how to increase agricultural production (mainly through technological improvements). However, the purpose of systems adaptation has expanded to include environmentally sustainable patterns of practice and adapting systems to better cope with unpredictable shocks (e.g. climate-related hazards). Within this research domain, the main explanation of resistance to change focuses on patterns of technology (Table 2) as the cause of lock-ins that, by favouring established production patterns, create path dependencies. Technological change is a core object of interest, but increasingly this is seen as an issue of co-innovation with farmers rather than technology transfer from research.

The food systems research domain. The focus of this domain is understanding the macro-level factors that shape food-related challenges and the way policy, governance and other institutional reforms can be better aligned to address challenges. Building on political economy and systems theories, its core conceptual proposition is that (i) food security and nutritional outcomes emerge from the (inter)relations between agriculture, industries, economies, ecology and society, and health (Sobal, Khan and Bisogni, 1998); and (ii) issues of power and politics tend to skew food production and consumption outcome in favour of incumbent interests to the detriment of the most disadvantaged in society. The analysis adopts a systems boundaries approach that encompasses both production and consumption dynamics at national and even global scales. Understanding factors that reinforce the unsustainable direction of agri-food systems development

is a core concern as are enquiries that explore how agri-food systems governance and policy can become more inclusive and democratic (Thompson *et al.*, 2007; IPES, 2015, 2016; Oliver *et al.*, 2018). Within this research domain, explanations of resistance to change focus on patterns of power and politics as lock-ins. The main explanation of resistance discussed in this research domain points out how patterns of politics and power engender a lock-in that, by favouring established food production and consumption patterns, creates path dependency in agri-food systems. Technology and innovation are recognised as important, but do not take centre stage (Table 4.4.2).

The socio-technical systems research domain. The focus of this domain revolves around the question of how to enable the profound changes in systems needed to lead societies to transition -or transform- towards different (more sustainable) social and economic objectives. This research domain stems from evolutionary economics and complex systems approach, but finds its deepest roots in science, technology and innovation studies, and in the empirical research on infrastructures and system provisions (Geels, 2002; Grin, Rotmans and Schot, 2010). Its core conceptual proposition is the idea that the embedding and co-evolution of technology with its social, institutional, infrastructural, policy and political context in a "socio-technological regime[16]" causes path dependencies in technology choice and innovation trajectories. A key framework is the Multi-Level Perspective (Geels, 2002, 2004), that frame changes in innovation direction as a process where niche level innovations (protected spaces where innovation initially emerges) can disrupt incumbent regimes as part of a transition process. This perspective also places great emphasis on the centrality of agency to open the way to alternative paths of development, (see for instance (Wiskerke and Roep, 2007; Lamine *et al.*, 2012; De Herde, Maréchal and Baret, 2019). Within this research domain, the main explanation of resistance to change focuses on multiple lock-ins that interplay at multiple levels, create innovation path-dependencies misaligned to sustainability and other unmet development aspirations. Technological change is a core object of interest but is understood to be part of a much less bounded social and political change process.

[16] A socio-technical regime has been defined by Geels as "the deep structure that accounts for the stability of an existing socio-technical system. It refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011).

Table 4.4.1. Characteristics of each research domain and key references.

	Conceptual underpinning	Scope and focus	Methodological approach	Core objectives of change explored	Key references
Agricultural system research domain	System thinking. Agricultural systems understood as a set of interconnected elements ecological processes and resources, knowledge and technology processes and resources (including, extension services and agricultural research, input suppliers, but also farmer knowledge) market processes and resources (input and outputs markets and patterns of demand) and policies and regulations). Together, these drive production modes towards a certain trajectory	**Scope:** Understand how to change patterns of production, mostly at the farm level, to achieve better performing (e.g. in terms of production, sustainability, resilience etc.) agricultural systems. **Main actor focus:** farmers (actor discussed in 96% of the sources)	Case studies: 30% Mixed Methods: 9% Qualitative: 4% Quantitative: 30% Theoretical: 13%	Changes in technology as a key element that enables or constrains change	(Anastasiadis and Chukova, 2019; Bacon et al., 2017; Bakker et al., 2020; Bardsley et al., 2018; A. Barnes et al., 2016; Chantre et al., 2015; Chhetri et al., 2010; Clar and Pinilla, 2011; Cowan and Gunby, 1996; Cox et al., 2019; Desquilbet et al., 2019; Flor et al., 2019, 2020; Gonçalves et al., 2015; Gowdy and Baveye, 2018; Hammond Wagner et al., 2016b; Louah et al., 2017; Mortensen and Smith, 2020; Newton et al., 2020; Pradhan and Mukherjee, 2018; Roesch-McNally et al., 2018; Wilson and Tisdell, 2001)

Food system research domain	Analysis of the political economy which shapes food systems, in particular the analysis of the power and politics dynamics that create unsustainability at the global level	**Scope:** explore how agri-food systems governance and policy can become more inclusive and democratic **Main actor focus:** institutions (94% of the sources)	Case studies: 32% Theoretical: 32% Qualitative: 29% Quantitative: 3%	Importance of (re)aligning policies and patterns of governance towards sustainability, while also tackling power imbalances in global value chains; how governance can become more inclusive and democratic	(Radulovic, 2005; Thompson *et al.*, 2007; Thompson and Scoones, 2009; Murphy, Burch and Clapp, 2012; Beilin, Sysak and Hill, 2012; Fortier *et al.*, 2013; Rutz, Dwyer and Schramek, 2014; IPES, 2016, 2017, 2015; Kimmich, 2016; Baret, 2017; Klimek and Hansen, 2017; Benoit and Patsias, 2017; De Schutter, 2017; Alpha and Fouilleux, 2018; Oliver *et al.*, 2018; TEEB, 2018; Termeer *et al.*, 2018; Swinburn, 2019; de Krom and Muilwijk, 2019; Frimpong Boamah and Sumberg, 2019; Russell *et al.*, 2020; Clapp and Ruder, 2020)
Socio-Technical transitions	Evolutionary economics, science and innovation studies to understand how multiple elements in socio-technical systems co-evolve	**Scope:** Role of individual agency and niches for creating a disruption in the regime	Case studies: 62% Qualitative: 14% Theoretical: 10%	It is the whole food system regime that has an unsustainable trajectory, and thus needs to be	(Wiskerke and Roep, 2007; Vanloqueren and Baret, 2008, 2009; Lamine *et al.*, 2012; Huyghe and Brummer, 2014; Magrini *et al.*, 2016; Kuokkanen *et al.*, 2017; Meynard *et al.*, 2018; Plumecocq *et al.*, 2018; Magrini

		Main actor focus: farmers and institutions (respectively, actor discussed in 76% and 72% of the sources)		changed. Tackling the directionality of innovation a key concern	*et al.*, 2018; Magrini, Béfort and Nieddu, 2018; De Herde *et al.*, 2019; Mawois *et al.*, 2019; De Herde, Baret and Maréchal, 2020; Morel *et al.*, 2020; Hale, Schipanski and Carolan, 2020; Messner, Johnson and Richards, 2021; Drottberger, Melin and Lundgren, 2021)

Note: the references are allocated to different domains after the analysis carried out by the authors. However, this allocation is not rigid, and could be subject to interpretation.

4.4.2 Explanations of resistance to directionality changes in agri-food systems

The analysis of the research domains reveals the existence of different explanations of resistance to a change in direction in agri-food systems. Through careful analysis of the selected literature, six thematic explanations of resistance emerged with considerable frequency, becoming critical themes of investigation and interest for the analysis conducted in this paper: (i) technological persistence; (ii) misaligned institutional settings, policies and incentives; (iii) attitudes and cultures that cause aversion to change; (iv) political economy factors that skew the direction of change; (v) infrastructure rigidities; and (vi) research priorities, practices and dominant innovation narratives misaligned to the transformational change agenda (Table 4.4.2). Its is acknowledged these 6 themes are presented explanations of resistance, these can also be considered as objects of change that can lead to better system performance: i.e. changes in technology can lead to sustainable innovation, and so on. Understanding how these different factors cause resistance to change is a foundation for addressing these as objectives of change.

Table 4.4.2 Explanations of resistance as mentioned within the different research perspectives.

		Research domains		
		Agricultural systems (AS)	Food systems (FS)	Socio-technical systems (STS)
Explanations of resistance to change	Persistence of dominant technologies	83%	42%	72%
	Misaligned institutional settings, policies and incentives	17%	84%	55%
	Attitudinal and cultural aversion to change	48%	13%	83%
	Political economy factors that skew the direction of change	0%	52%	41%

	Infrastructural rigidities	4%	26%	52%
	Research and innovation priorities practices and narratives misaligned to transformation	13%	23%	41%

Note: Each shortlisted publication was scanned to identify the explanations of resistance mentioned. A publication might focus on multiple explanations thus the overall total within research domains is not 100%. Colors are based on percentiles, from red (0) to green (100%).

4.4.2.1 Dominant technologies persist at the expense of better alternatives because they are socially embedded

77 publications discuss the role of technology in explaining resistance to change in agri-food systems. This is a frequent theme within the AS and STS domain, and relatively less in the FS literature. This literature discusses why technologies persist in agri-food systems even when alternatives better aligned with sustainability and other economic and social development outcomes exist (Ruttan, 1996; Wilson and Tisdell, 2001; Sutherland *et al.*, 2012; Farstad *et al.*, 2020). This phenomena is described using the terminology of "technology lock-in", denoting the way that once established, technology can block alternative technologies and development pathways and induce path dependency (Jacquet, Butault and Guichard, 2011; Pradhan and Mukherjee, 2018; Desquilbet, Bullock and D'Arcangelo, 2019; Bonke and Musshoff, 2020; Luna, 2020; Newton, Nettle and Pryce, 2020). The explanation of the causes of this phenomena is that, once a technology is chosen, farmers and other agri-food system players develop new skills and knowledge that allows them to employ the technology, creating a mutually reinforcing mechanism in which cognitive routines, practices, learning patterns and experiences become entrenched with the technology, making it a deeply socially embedded practice (Bruce and Spinardi, 2018; Bonke and Musshoff, 2020; Burton and Farstad, 2020). At the same time, policy and institutional settings adapt to support the use of technology and infrastructure and production modes build around it, thus making patterns of technology use a reinforcing factor for its continuous use (Huyghe and Brummer, 2014; Farstad *et al.*, 2020; Morel *et al.*, 2020). For example, chemical control of pests, weeds and diseases has become a well-established and persistent practice enabled by input supply chains, patterns of regulation and trust, and market acceptability. Alternatives such as integrated pest management exist, but barriers to adoption include acquiring new skills, the adaptation of existing farming practices, investment in new equipment and misaligned regulatory and price

incentives (Wilson and Tisdell, 2001; Barnes *et al.*, 2016; Hammond Wagner *et al.*, 2016; Bardsley, Palazzo and Pütz, 2018; Magrini, Béfort, *et al.*, 2018; Flor *et al.*, 2019, 2020; Bakker *et al.*, 2020).

4.4.2.2 Institutions and policies create incentives misaligned to new change directions

65 shortlisted publications explore the role of institutions[17] as an explanation of resistance to change in the direction in agri-food systems. This explanation, mostly explored within the FS and STS research domain, hinges on the recognition that institutions form a broad array of formal and informal rules, practices and norms that shape individual and organisational behaviour (Zukauskaite and Moodysson, 2016; Alpha and Fouilleux, 2018; Leta *et al.*, 2020; Messner, Johnson and Richards, 2021). Specific institutions, such Intellectual Property rights or food labelling regulations, are examples of institutions as lock-ins, incentivising certain forms of behaviour (IPES, 2016, 2017; Feyereisen, Stassart and Mélard, 2017; Russell *et al.*, 2020; Ng *et al.*, 2021) More often the institutional setting comprising of a cluster of policies, regulations and norms that block (lock-in) agri-food systems from pursuing new directions (Zukauskaite and Moodysson, 2016; Turner, Klerkx, Rijswijk, *et al.*, 2017; van Bers *et al.*, 2019; Messner, Johnson and Richards, 2021). For example, a paper investigating the diversification of cropping systems in France shows how a shift from major crops such as wheat, corn, and soy to more diversified cropping systems -which would enhance ecosystem services - is hampered by institutional settings. These settings do not support diversification as they have i) historically supported wheat prices (instead of, for instance, legumes prices) and ii) established different tariffs barriers for different species (favouring wheat) and iii) provided stable, clear and legible collective rules for major crop species to the detriment of minor ones (Magrini *et al.*, 2018).

Institutional explanations also explore the phenomena of path dependency of broader institutional settings themselves, which in turn causes the persistence of lock-in of the type discussed above and, in so doing, causes the path dependency of agri-food systems. This is discussed in terms of path-dependency and inertia to depict how once certain institutions are in place, they co-evolve with the system – and system actors- to support the initially established trajectory of development (Van Assche *et al.*, 2014; Kimmich, 2016; Thow *et al.*, 2016; Zukauskaite and Moodysson, 2016; Klimek and Hansen, 2017; Oliver *et al.*, 2018; Leta *et al.*, 2020). For example, a case study in the

[17] The term institutions is used here to refer to costumes and norms as well as formal rules. Formal institutions are rules designed and enforced by the government (such as constitutions, laws, property rights). Informal institutions are traditions or cultural and social norms that influence/constrain individual behaviours (Williamson, 2000, 2009; Leta *et al.*, 2020).

Czech Republic offered important insights to understand how path-dependencies in the institutions are at the same time long-lasting and deeply concealed. The study described how the institutional set-up established while the country still belonged to the Soviet bloc, has engendered a deeply concealed path-dependency that remains even now that the country is part of the European Union (Orderud and Polickova-Dobiasova, 2010). The authors showed how environmentally damaging farming practices, previously legitimated by the achievement of production targets set by the state, are now legitimated by profitability targets. Thus, even if the institutional set-up has changed, this change was incremental, as it built on the existing trajectories of development (e.g. based on non-sustainable practices) instead of promoting a directionality shift (e.g. towards sustainable production modes). Path-dependency depicts how the "new" institutions are in truth built on the old ones, which still linger on but are *"wrapped in new clothing"*.

Several studies analysed path-dependencies in policies (Engström *et al.*, 2008; Kickert and van der Meer, 2011; Rutz, Dwyer and Schramek, 2014; Thow *et al.*, 2016; Baret, 2017; Benoit and Patsias, 2017; de Krom and Muilwijk, 2019; Ng *et al.*, 2021). The studies highlighted how "today's policy issues find their origin in critical historical moments that create their own path-dependent political processes that are resistant to change" (van Bers et al., 2019). It is argued that " past policy adoption explain future plans as evidence of path dependency" (Chavez and Perz, 2013) with policies that tend to follow the path set at their creation (Lăşan, 2012). Ample attention was also given to the European Common Agricultural Policy (CAP), as a policy that suffers from persistent path-dependencies which hampers major policy shifts to different production trajectories (Kay, 2003; Lăşan, 2012; Rutz, Dwyer and Schramek, 2014; Benoit and Patsias, 2017; Henke *et al.*, 2018; Kuhmonen, 2018; Rac, Erjavec and Erjavec, 2020). A recent study from Rac et al. (2020) showed that the decision-making processes within the 2018 CAP reform is "too strongly influenced by agricultural stakeholders who favour the *status quo"* and thus fails to meet the call from the public for an environmentally stronger policy.

4.4.2.3 Attitudes and cultures that cause aversion to change

59 publications discuss how attitudinal and cultural factors are a key determinant in the propensity of individuals to behave and act differently in relation to technology adoption, food consumption habits, and their willingness to ignore or proactively address negative environmental externalities of agri-food systems. This explanation appears most frequently in publications belonging to the AS and STS research domains, arguing that values, attitudes, cultures create a lock-in that keeps actors stuck in certain production and consumption modes (Stassart and Jamar, 2008; Wilson, 2008; Beilin, Sysak and Hill, 2012; Reenberg, Rasmussen and Nielsen, 2012; Gonçalves *et al.*, 2015;

Barnes *et al.*, 2016; IPES, 2016; De Herde *et al.*, 2019; Renwick *et al.*, 2019; Bonke and Musshoff, 2020). For example, for farmers, this means that after the initial adoption of a certain cropping practice, the practice becomes part of the family tradition, and thus is automatically labelled as the "best" one – even when it endangers negative externalities (Gonçalves *et al.*, 2015). A study in Brazil revealed how field burning practices in are still employed in spite of their negative environmental externalities, as they have become part of the family history, and thus farmers do not want to detach from them.

Attitudes as a lock-in are also discussed as a cause of path dependency, particularly in relation to risk attitudes of farmers. For example, in the case of resource-poor farmers in developing countries, an initial decision (such as technology adoption) that led to failure can generate path dependency by making the farmer more reluctant to take risks in the future (Yesuf and Bluffstone, 2009). Similarly, when a shock (e.g. a natural hazard) occurs, this can both influence how the farmers will respond to a future shock (Bacon et al., 2017), but also shape later decisions in other matters, as the farmer will be affected by the shock for some time after it happened, and even more so if the farmer is resource poor (Molla, Beuving and Ruben, 2020).

Findings also show how attitudinal and cultural drivers create inertia among consumers (Jacobsen and Dulsrud, 2007; Webb and Byrd-Bredbenner, 2015; Obih and Baiyegunhi, 2017; Yen, 2018; Chen *et al.*, 2021), keeping them "stuck" along certain patterns of consumption. For example, the decision to purchase and consume food is influenced by "cultural understandings" (Messner, Johnson and Richards, 2021), values and habits which are part of the individual's lifestyle – creating patterns of purchase that align and reinforce a particular trajectory (i.e. consumerism) of production and consumption (Jacobsen and Dulsrud, 2007). Consumers' attitudes exert influence across the agri-food system as demands often reinforce the industrial agriculture, production-oriented development, demanding that cheap varied food should be made available all year round (IPES, 2016; Messner, Johnson and Richards, 2021), and often preferring processed, imported foods (e.g. snacks and exotic fruits) to locally available, more sustainable alternatives (Obih and Baiyegunhi, 2017; Yen, 2018).

4.4.2.4 Political economy factors that skew the direction of change

Explanations of resistance relating to the political economy of agri-food systems are a central theme within the FS research domain. Central to this explanation is the argument that the political economy of food systems creates a lock-in whereby "powerful actors" (Bui *et al.*, 2019), "power imbalances" (Hale, Schipanski and Carolan, 2020) and "concentrate corporate power" (Clapp and Ruder, 2020) shape the direction of change in ways that support their interests and values and

maintain the *status quo*, and that is often misaligned with the transformation of the agri-food system towards more sustainable and inclusive outcomes (Foster, McMeekin and Mylan, 2012; IPES, 2015, 2016, 2017; Oliver *et al.*, 2018; Swinburn, 2019) At a global scale, it is argued that the historical "ascendancy of a corporate food regime" ingrained power imbalances in global supply chains (De Schutter, 2017), and set the global food systems on a path-dependent trajectory where sustainability is far from being the primary concern (Murphy, Burch and Clapp, 2012; IPES, 2016, 2017; De Schutter, 2017; van Bers *et al.*, 2019). Part of this argument suggests that a "concentration of power lock-in" (IPES, 2016) is kept in place through multiple mechanisms. On the one side, the presence of large firms dominating the market increases farmers' reliance on a narrow range of suppliers and buyers, generating a lock-in that i) constrains their choices in terms of what to grow and how to grow, ii) increases their reliance on a given set of available commercial inputs (such as fertilizers or feedstock) and iii) limits their access only to certain sources of energy and financing (IPES, 2016). On the other hand, large corporations can undermine political priorities and regulatory interventions (Foster, McMeekin and Mylan, 2012; Bui *et al.*, 2019; Russell *et al.*, 2020). For example, as almost 90% of the global grain trade is controlled by four agribusiness firms – a change in sourcing policy by a big corporation might entail a change in regulation across the sector (Murphy, Burch and Clapp, 2012; IPES, 2015). Besides, big agribusinesses investments in R&D provide these players with a way to grow their influence in framing global problems (i.e. global productivity challenges) and then provide a solution which in turn raise demand for their products (i.e. input-responsive crops and breeds). At the same time, political actors also have a role in the process of change, as they are rarely willing to propose transformational policies. Gains from such policies might not be observed in the short term (i.e. within the election cycle) or politicians do not want to jeopardize their chances of (re-)election by proposing measures that "row against" the established culture and beliefs (IPES, 2016; Frimpong Boamah and Sumberg, 2019; Radulovic, 2005).

4.4.2.5 Infrastructure rigidities

With food and feed markets develop around specific crops, infrastructures and inherent logistics are set up to accommodate the collection, processing, storage, and marketing of these crops, to the potential detriment of others. Yet, infrastructure was rarely termed as a "lock-in" per se and was rather discussed on the sidelines (34 papers), and almost solely in the STS research domain, which recognises the importance of infrastructural arrangements for switching to different production and consumption pathways. For example, Meynard et al. (2017), argue that even when there is evidence that grain-legumes would contribute to cutting down GHGs emissions, adoption

and diffusion of these crops is faced with critical infrastructural barriers at all level of the value chain, from collection to food and feed processing firms, which would face higher transaction costs for minor species than for dominant ones. A similar case is presented by Magrini, Béfort and Nieddu (2018). Several sources mention infrastructural developments (or lack of) as a factor that hampers change within agri-food systems (Thompson and Scoones, 2009; Clar and Pinilla, 2011; Pradhan and Mukherjee, 2018; Hale, Schipanski and Carolan, 2020), without however discussing the wider implications of this. Infrastructural rigidities cross the boundaries of the agri-food sectors, as they also involve transport and energy systems. In this view, it is argued that the use of renewable energy sources in the food value chain is key to meet sustainability targets (see for instance (Radulovic, 2005; Beilin, Sysak and Hill, 2012; Kimmich, 2016). However, this issue remains mostly overlooked in the selected publications.

4.4.2.6 Agricultural research priorities, practices and dominant innovation narratives misaligned to the transformational change agenda

Research and innovation priorities have a crucial role in shaping agri-food innovation and policy trajectories (IPES, 2016). This theme appears mainly in the STS and FS domain, even though it still remains marginal compared to other explanations. Central to the explanation of resistance to change in research priorities, practices and innovation narratives, is the argument that the institutional setting of (particularly) public agricultural research create a lock-in that supports (path dependant) research trajectories misaligned to the transformation of agri-food systems (Hall and Dijkman, 2019; Klerkx and Rose, 2020). This institutional setting includes: the way priorities are set and research capabilities built; professional reward systems for scientists; a low-risk attitude by research funders; inappropriate patterns of partnership; a lack of complexity aware evaluation practices; and disciplinary fragmentation poorly aligned with transformational challenges (Turner, Klerkx, Rijswijk, *et al.*, 2017; Hall and Dijkman, 2019; Glover *et al.*, 2021). This manifests in: short-cycle projects developing incremental solutions (IPES, 2016; Hall and Dijkman, 2019); legacy plant breeding programmes misaligned to current development priorities (McGuire, 2008); the reluctance of researchers to switch to new topics (Vanloqueren and Baret, 2009); public research strategies, driven by funders, adopt private sector market demand principles at the expense of a portfolio approach adapted to the uncertainties of agri-food system transformation (Glover *et al.*, 2021) and a lack of consideration of the directionality of agriculture and food innovation and its relevance to societal grand challenges (Herrero *et al.*, 2021).

The existence of more concealed dynamics in the setting of research and innovation trajectories – and how they support the *status quo* – is also offered as an explanation to resistance to change. For

example, it is argued that, stemming from the Green Revolution, the "modernisation" of agriculture-thinking has gradually taken over in the research for development discourse, with a steady body of research developing around "production-innovation" and "growth" narratives (Thompson and Scoones, 2009). In these narratives, technology-driven economic growth is presented as the way forward to feed the world and has gradually become systemically embedded, shaping monitoring and evaluation frameworks that measure success in terms of "total yields of specific crops, productivity per worker, and total factor productivity" (IPES, 2016), investment and funding allocations, and production-oriented research agendas (Thompson *et al.*, 2007; IPES, 2016). These dominant research and innovation narratives create lock-ins blocking alternative research narratives, labelling them as "micro-project scale" and relegating them to a background shelf (Flor *et al.*, 2020; Anderson and Maughan, 2021). This argument is also supported by Hall and Dijkman (2019) who discuss how productivist and technology-centric approaches keeps the current agri-food system transformation narrative stuck into "linear and component change logics".

The progressive privatization of agricultural research, which aims to secure returns on investment and focuses on a small number of tradable crops and technological innovation (especially the ones for input-responsive agriculture) further secures the production profitability narrative (IPES, 2016) at the expense of sustainability concerns. As governments' funding to research institutions decreases, these need to rely on the private sector, whose investments oftentimes aim to recover the cost in terms of production volume, rather than to deliver global food security or sustainability (IPES, 2016). Thus, even if alternative discourses (e.g. agroecology, integrated pest management) are gaining increasing attention, current research trajectories are still locked-in the historically established, industrial/modern agriculture model that ranks productivity goals above sustainability ones (IPES, 2016; Baret, 2017; Anderson and Maughan, 2021).

4.5 Discussion: towards an explanation of resistance to change of agri-food systems

This systematic review showed how different research domains understand and explain the phenomenon of resistance to change. It also identified different six explanations of resistance that emerged as recurrent themes in the selected literature. This section identifies i) research gaps within the selected literature; ii) it offers insights into the causes of resistance to change in direction of change of agri-food systems are presented above; iii) it discusses the implication for future research on directionality changes in agri-food systems.

4.5.1 Research gaps in the selected literature

The three research domains, namely the AS, FS and STS discuss different aspects of resistance to change. The AS mostly provides insights on dynamics of change at the farm level of scale, mostly showcasing how technology choices and individual behaviours hamper the switch to more sustainable production patterns (Wilson and Tisdell, 2001; Gonçalves *et al.*, 2015). By contrast, the FS captures the patterns of power and politics that shape food system trajectories at the global level. The STS adopts a more holistic approach, highlighting the interplay of different factors creating resistance at multiple levels of scale and amongst a variety of actors. Yet, this literature could be that it focuses majorly at the regional and country-level, giving relatively less attention to the macro-level forces and players that shape global agri-food systems (which are, however, well discussed in the FS research domain). The argument that the STS literature needs to give more attention to the power and politics dimension is well present in the literature (Markard, Raven and Truffer, 2012; Hinrichs, 2014; El Bilali, 2019b).

Thus, the analysis showed that each research domain has inherent research gaps (more or less pronounced)– this calls for more transdisciplinary dialogue between different research domains, already well acknowledged in the research community but only partially implemented in practice (Markard, Raven and Truffer, 2012; Hinrichs, 2014).

Another gap concerned the geographical focus of the publication. A large portion of the studies is set in HIC. Even if this might be caused to the specific keywords used (i.e. a wider search might have found similar concepts expressed through different terminology), this finding aligns with previous studies that highlighted how there is still limited evidence and understanding of how change happens in LMICs (Köhler *et al.*, 2019; Ojha and Hall, 2021), and is mirrored in recent reviews in relations to the topic of transition and transformation in food systems, that seems to be predominantly studied in HIC (El Bilali, 2019b; Melchior and Newig, 2021). Still, needs further study to better evaluate whether this bias is simply an issue due to the keyword choice or rather is a symptom of an existing gap around our understanding of processes of change in LMICs.

Besides, it emerged from the literature that certain explanations of resistance remain under-investigated, in particular infrastructure and research and innovation priorities. This needs more attention. As an additional point, even though agri-food systems clearly have interlinkages with the transport and energy sector, which impact their overall sustainability, these interlinkages are neglected in the literature. Despite extensive evidence that path-dependencies and lock-ins are well present in these two sectors energy and (Unruh, 2000; Barter, 2004; Klitkou *et al.*, 2015; Seto *et al.*, 2016; Trencher *et al.*, 2020), how these dependencies intertwine with agriculture and food and contribute to deepening resistance to change is a neglected topic.

4.5.2 Insights into the causes of resistance to change in direction of change of agri-food systems

While the has surfaced six thematic explanations of resistance to change, a degree of ambiguity with the terms lock-ins and path dependency means that a clear picture of cause-effect relations in the resistance process is muddied. So, for example, some analysis argues that institutional settings are a lock-in, shaping the behaviour of farmers, consumers or research organisations etc. (Zukauskaite and Moodysson, 2016; Leta *et al.*, 2020). However, the analysis also discusses path dependencies in institutional settings, where policies and other incentives persist to, for example, encourage production at the expense of environmental and other considerations (Orderud and Polickova-Dobiasova, 2010). Yet the persistence (path-dependency) of the institutional setting means that institutional setting also act as lock-ins to other areas perpetuating path dependency in the development of the agri-food system in its existing direction. In the same fashion, technology can be viewed as a lock-in, blocking out alternative technologies (Hammond Wagner *et al.*, 2016). At the same time the skills, capability and institutions that build up around technology create a path dependency in technology choice and in doing so reinforce the path dependency of the agri-food system as a whole (Magrini *et al.*, 2018).

This is the inability of the concepts of lock-in and path dependency to clarify cause-effect relationships. It part, this is due to the ambiguous way these terms are used in much of the analysis of agri-food systems. However, it is also partially a result of the inability of these terms to represent the dynamic interplay and interdependence between lock-ins and path dependencies that take place at different physical and temporal scales and domains of the agri-food system. For example, analyses do not make a clear distinction between the historically remote causes of path dependency (a resistance to change in direction) (for example, establishment of the industrial agriculture model in the period following the Second World War (De Schutter, 2014)) from the more immediate proximate causes (lock-ins) which contribute to the perpetuation of the direction of change such the consumers expectations of cheap food round or the concentration of power in agro-industries (Clapp and Ruder, 2020; Foster et al., 2012; IPES, 2016, 2017; Swinburn, 2019) that are themselves path-dependent. In other words, the way these concepts are used struggles to distinguish whether factors reinforcing the current direction of change are a cause of resistance or an effect of other historical and proximate factors. This seems unsatisfactory.

It would be much more useful to conceptualise the six thematic explanations of resistance to change that this review has identified as sub-domains of path dependency, recognising that they

are interdependent and co-evolving and that they simultaneously manifest as an effect (a path-dependency) as well as cause (lock-in). This helps to reveal that it is the collective, reinforcing nature of these sub-domains of path-dependency that cause resistance to change in the agri-food system as a whole. Based on our exploration of the explanations of resistance to change in direction of agri-food systems, we believe these sub-domains of path dependency are: technology choices, institutions and policies, attitudes and cultures, infrastructure, power and politics, infrastructure, research and innovation priorities, practices and narratives (Figure 4.5.2).

This whole system reconceptualization of resistance to change shares much in common with the STS concept of a socio-technical regime (Geels, 2004; Lamine *et al.*, 2012; De Herde *et al.*, 2019; Morel *et al.*, 2020). It also aligns with calls for the reframing of innovation for transformation as a whole of system endeavour rather than a task of individual stand-alone technical, institutional or other innovations (Schot and Steinmueller, 2018), and with current perspective suggesting the bundling of innovations to progress agri-food system transformation (Barrett *et al.*, 2020b).

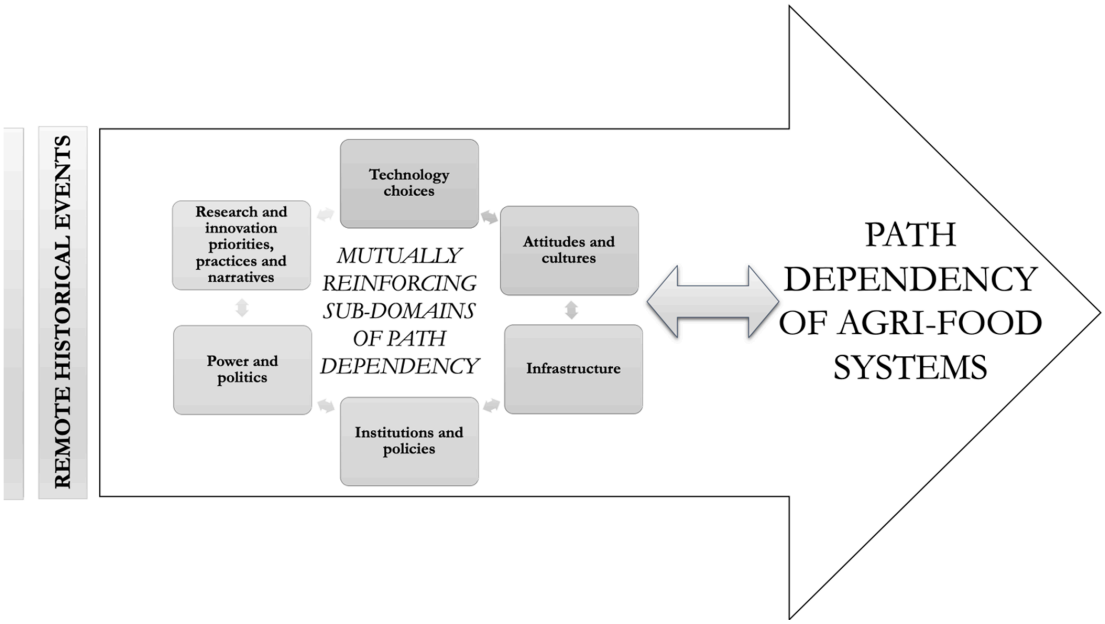

Figure 4.5.2. Explanations of resistance conceptualized as sub-domains of path dependency. Double-headed arrows represent the self-reinforcing nature of these phenomena.

4.5.3 Implication for research on directionality changes in agri-food systems

Recent literature has highlighted that our understanding of processes of change remains largely theoretical (Oliver *et al.*, 2018), and that our knowledge on how transformative processes can be designed and managed in practice remains a much-contested interrogative (Cohen and Ilieva, 2015). It has been argued that to enable a directionality change we need to tackle the feedback mechanisms that keep the system in its current unsustainable state (Oliver *et al.*, 2018), and that we

need much more inter- and trans-disciplinary approaches (Francis *et al.*, 2008; Hinrichs, 2014, 2016).

The systematic review revealed that we need a much more profound and systemic understanding of how directionality changes can be unlocked in agri-food systems. On the one side -as discussed in the previous paragraph – we need deeper analysis to unravel the proxy and remote causes that anchor us to an unsustainable trajectory of development. On the other, it demands the recognition that technology or policy fixes are -if enacted in isolation- insufficient to tackle today's challenges (Drottberger, Melin and Lundgren, 2021). The interconnected and self-reinforcing nature of the factors that create resistance to change, highlighted in the review, requires a reframing of innovation as a systemic process, where innovation does not merely refer to innovation in *all* components of the system (technologies, infrastructure, institutions, individual behaviours, research and innovation priorities, patterns of politics and power) at multiple geographical scales (local, national, global). However, the analysis of lock-ins, path-dependencies and inertia highlighted a much more concealed issue in the way we frame change: an issue of the *temporality* of change. The path-dependent nature of agri-food system ensures that until a directionality change is attempted on a single component of the system – the others, self-reinforcing factors, ensure that the impact of this change is limited, and cannot alter the overall system trajectory. For instance, despite increasing advocacy for implementing agroecology, this research narrative is kept at bay by all other factors – not only dominant research priorities that support industrial agriculture, but also behavioural preferences (that also involve technology choices) towards historically established production modes, infrastructure that supports the most profitable crops (such as wheat), institutional settings and policies that still favour industrial agriculture, and power players that ensure the dismissal of agroecology as a micro-scale project (Thompson *et al.*, 2007a; IPES, 2016).

The issue of temporality is thus crucial when aiming for directionality changes – yet still largely overlooked. The systematic review shed light on the need for multiple changes (i.e., in policies, technologies etc.) to happen on the same temporal scale – or on the need for all the factors reinforcing unsustainability to be re-directed towards a sustainable trajectory *simultaneously.*
However, how this new framing of innovation can be implemented in both theory and practice requires further attention, especially in light of the current path-dependency of research priorities to still conceive change as a short-term and linear process.

5. Path dependency disruption as starting point for agri-food system transformation? Insights from a case study in South India

"MALUM CONSILIUM QUOD MUTARI NON POTEST."-
"BAD IS THE PLAN THAT CANNOT CHANGE."
PUBLIUS SYRIUS

Abstract:

In response to the growing interest around the ability of niches and grassroots initiatives to stimulate agri-food system transformation worldwide, this chapter explores a case study of a Non-Pesticide Management initiative in South India, that the researchers believe might be an example of an ongoing transformation. Over a time-span of 20 years, the initiative seemed to be able to build an alternative pathway that grants more environmentally sustainable, economically viable and just outcomes. The chapter attempts to clarify the often ambiguous features that characterise transformation by employing a path dependency framework (presented in Chapter Four). Then, drawing from the case study history and going beyond the framework, the chapter discusses possible factors that might enable niches to open the way to alternative and sustainable production and consumption patterns, to finally highlight some venues for future research[18].

[18] This chapter is being prepared for submission in the "Innovation and Development" journal. Expected edits will mainly include shortening the case study section to reduce word count. The thesis'author will be first author in the paper, followed by Andrew Hall, Giacomo Zanello, and Tim G. Williams.

5.1 Introduction

The recognition that a shift to sustainable production and consumption patterns worldwide is the only way forward to "protect our common futures" (IPES-Food & ETC Group, 2021) has become increasingly central in research and policy debates over the past ten years (Barrett *et al.*, 2020a; Webb *et al.*, 2020). While the topic of "sustainability transitions" or "transformations" in agri-food systems (and beyond) (El Bilali, 2019a; Melchior and Newig, 2021) is receiving growing attention, a constellation of place-specific, highly diverse, and often spontaneous initiatives across the globe has started to blossom, all attempting to move, in their own and place-specific way, towards more sustainable system states (Bennett *et al.*, 2019; Michel-Villarreal *et al.*, 2019). Frequently driven by until-now marginalised actors (Pereira, Frantzeskaki, *et al.*, 2020; Anderson and Maughan, 2021), such as local communities, grassroots movements, and Indigenous Peoples, these processes are challenging the unsustainable direction of development of current systems in favour of fundamentally different pathways rooted in principles of environmental viability, social justice, food sovereignty and equity (Pereira, Frantzeskaki, *et al.*, 2020; Sage, Kropp and Antoni-Komar, 2020; Anderson and Maughan, 2021).

It has been remarked that many of these transformative processes have been happening in niches (Darnhofer, 2014; Bui *et al.*, 2016b; Bui, 2021), protected spaces where innovation can emerge and be experimented with. When discourses around transformation initially surfaced, niches were considered spaces where small networks of actors could experiment with novel technologies (and associated rules and practices) while being protected by market selection (Kemp, Schot and Hoogma, 1998; Rotmans, Loorbach and Kemp, 2007). In recent years, however, the idea of niches expanded to refer to spaces where innovation was not conceived as purely technological, but also, as all novel practices and rules spanning across not only technological but also ecological, cultural, social and economic domains (Bui *et al.*, 2016a; Hall and Dijkman, 2019; Mawois *et al.*, 2019). A "signature feature" of transformation seems, in fact, to be the presence of innovation in *all* elements of the system (Ojha and Hall, 2021). Such innovation would manifest as interconnected shifts in existing behaviours and knowledge, capabilities and skillsets, consumer practices and markets, as well as infrastructure, institutions and policies (OECD, 2015).

However, to date, how an ongoing transformation can be detected in practice, and how niches can trigger such transformation remains an unknown (Berkhout, Smith and Stirling, 2004; Bui, 2021).

On the one hand, initiatives that are cited as transformational examples often do not in truth exhibit the core features of a sustainability transformation (Ojha and Hall, 2021; Kirchherr,

2022) – creating ambiguity in what transformation actually indicates and raising the risk of voiding the term of its meaning (Feola, 2015; Scoones *et al.*, 2020). This creates a "fuzziness" for identifying ongoing transformational shifts.

On the other, subject to unpredictable, non-linear dynamics, as well as unforeseeable shocks (FAO, 2021; Parker, 2022), the agri-food system space is an extremely difficult space for niches to navigate and unlock change in (Fares et al., 2012; Magrini et al., 2018; Sutherland et al., 2012). What factors and enablers can allow niches to start unlocking a transformation -and thus, challenge the unsustainable status quo – remains uncertain (Köhler *et al.*, 2019; Bui, 2021).

This paper uses a novel path-dependency framework by Conti et al. (2021) to investigate a case study of a Non-Pesticide Management (NPM) initiative in South India (Box 5.3) - specifically, in the Andhra Pradesh and Telangana states. The authors believe that the NPM initiative, and the two organisations associated with it, the Centre for Sustainable Agriculture (CSA) and its commercial offspring, the Sahaja Aharam Producer Company (SAPCO), might be an example of an ongoing agri-food systems transformation in the states. The paper is structured as follows: after briefly describing the framework and the methodology, the paper presents the case study. The framework is used to trace the history of the NPM's initiative, as well as a tool to assess whether a transformational shift is ongoing. Then, the paper discusses how the niche could trigger an agri-food systems transformation, not only by using the framework but also going beyond it to observe and identify key events and actions that have enabled the initiative to establish different production and consumption patterns. Finally, the implications of the case study for the broader debates and action for transformation are discussed.

5.2 Transformation as path-dependency disruption: a framework

That a sustainability shift in agri-food systems would imply more than simple policy or technology fixes within existing development trajectories is now well-recognized (Drottberger, Melin and Lundgren, 2021; Barrett *et al.*, 2022). Whereas over the past 50/60 years, global agri-food systems have been oriented towards the delivery of economic growth - often favouring incumbent players and poorly tackling justice and environmental preservation concerns (Thompson *et al.*, 2007; Swinburn, 2019)- the new century agenda has demanded that agri-food systems are made to deliver fundamentally different outcomes, well-illustrated by the Sustainable Development Goals (SDGs) (Barnhill and Fanzo, 2021; Willetts, 2022, 2023). This implies fundamentally redrawing current systems to ensure that all systems are cumulatively directed towards the delivery of sustainability (Scrase *et al.*, 2009; Sen, 2014; Bui *et al.*, 2016a; Diercks, Larsen and Steward, 2019;

Mawois *et al.*, 2019). For this, the concept of "system innovation" (Hall and Dijkman, 2019) has been increasingly employed to describe how transformative changes (i.e., changes along different trajectories of development) are needed to reshape the architecture of the system itself - its functions, the values that underpin actions and outcomes, and the way the system's performance addresses different social, economic and environmental objectives (Leach *et al.*, 2012; Patterson *et al.*, 2017; Barrett *et al.*, 2020a; Klerkx and Begemann, 2020). The path-dependency framework proposed by Conti et al. (2021) (Figure 4.5.2) is useful to illustrate this idea, as it shows how system innovation can be understood as the disruption and consequent innovation in path-dependency elements perpetrating unsustainability. The framework shows that transformative changes in multiple path-dependent system elements (labelled as "sub-domains of path-dependency" – i.e., technologies, behaviours, policies, R&D activities, infrastructure – see box 5.2) are indispensable to redesign the system (or achieve system innovation). The framework stresses that without changes in *all* these elements path-dependency at the system level will unlikely be breached, impeding the re-direction of this system towards sustainable outcomes.

It is important to note that the framework contains an inherent temporal component. This means that, for instance, the adoption of novel technologies might hinge on changes in behaviours that build the skills and capabilities to use the technology, or infrastructural changes that allow to deploy it (e.g., in the case of renewable energy use). Differently, initial policy changes (e.g., towards sustainable production) might spur Research and Development of new technologies, while nudging behavioural changes at the farm scale. Thus, pathways of path-dependency reformation may unfold differently in different contexts, making "temporality of change" key to understanding transformation. Besides, some path dependencies may be easier to disrupt than others (e.g., due to the political power of vested interests), so transformative change can be instigated by the progressive disruption of path dependencies, with earlier disruptions creating momentum for subsequent disruption in other elements (Conti, Zanello and Hall, 2021).

Box 5.2. The Path-dependency framework: an overview.

The idea of path dependency employed in the framework is used to illustrate the idea that initial choices in the past influence present decisions – or "initial moves in one direction elicit further moves in that same direction" (Kay, 2003). The framework thus suggests that with the post-World-War 2 choice to "industrialize" agriculture, a set of interlocking elements in the agricultural and food system space was oriented towards the maximising production instead of pursuing sustainability (at that point, not a major concern). Thus, technology and technologies

choices, attitudes and behaviours, policies and institutions, infrastructure, patterns of power and politics, and research priorities were built to fulfil that outcome and, over time, became "sub-domains of path dependency", became mutually reinforcing and ingrained unsustainability in agri-food systems, which is now difficult to dislodge. These sub-domains of path-dependency are:

Technology Choices. Once a technology is chosen, agri-food system players develop new skills and knowledge that allows them to employ the technology, creating a mutually reinforcing mechanism in which cognitive routines, practices, learning patterns and experiences become entrenched with the technology, making it a socially embedded practice.

Attitudes and Cultures. Once certain behavioural patterns become established, they are difficult to dislodge. For instance, farmers might adopt certain cropping patterns and be reluctant to change them, while consumers can who become accustomed to certain buying and consumption (e.g., cheap junk food).

Infrastructural rigidities. With food and feed markets develop around specific foods, infrastructures and inherent logistics are set up to accommodate the production, processing, distribution, and marketing of these foods, to the potential detriment of others.

Policies and Institutions. On the one side, policies tend to be set on the same lines as the previously established ones – with past policy adoption explaining future as evidence of path dependency. On the other, institutional settings, once established, form a set of norms, laws, formal and informal rules that tend to persist over time.

Power and politics (or the political economy of agri-food systems). Powerful actors in the food system have considerable interests in maintaining the current, profit-oriented direction of food systems, and therefore use their power and influence to shape the direction of change in ways that support their interests and values and maintain the *status quo*.

Research and innovation priorities, practices, and narratives. Once certain research priorities and innovation trajectories are set, a system develops around them, including professional reward systems for scientists, patterns of partnerships, funding modes among others. These keep shaping research agendas towards certain directions of change.

5.3 Methodology

Complex socio-technical and ecological change processes (specifically, of transformation) can hardly be computed in quantitative terms (Hall, Sulaiman and Bezkorowajnyj, 2007; Hall and Clark, 2010). Instead, they have many facets and causal links between multiple phenomena are not immediately apparent (Yin, 1994; Baxter and Jack, 2008; Royer, Bijman and Abebe, 2017; Vilas-Boas, Klerkx and Lie, 2022). Therefore, the paper conducts a qualitative case study (Baxter and Jack, 2008) to gain an in-depth understanding (Fidel, 1984; Baxter and Jack, 2008) of the events that, over more than 30 years, led to deep changes in production and consumption in South India.

The paper thus combines a purposive search for relevant information and semi-structured interviews. The purposive search includes published documents that provide information on CSA and SAPCO such as journal articles, reports, government documents, academic and technical literature, following a strategy similar to Glover *et al.* (2021). The search for relevant publications was conducted on ScienceDirect, Google Scholar, and Scopus, using "Non-pesticide management", "India", "Centre for Sustainable Agriculture", "Sahaja Aharam Producer Company" as keywords. The organisation´s websites (https://csa-india.org/; https://www.sahajaaharam.com/) were also searched for relevant documents and information.
Semi-structured interviews were conducted with members of CSA and SAPCO who, based on their involvement in the organisation, could provide relevant information about the initiative. These include: the Executive director (CEO) of SAPCO, the funder of CSA (who is also SAPCO executive director), six directors of farmers' producers' organisations (FPOs) composing SAPCO and two FPO CEO, the program officer for the Organic certification released by CSA, the procurement and packaging managers, the SAPCO store manager, as well as farmers and consumers (who often are the farmers adopting NPM methods themselves). Data was collected after the obtention of the Ethical Clearance by the University of Reading (UoR) (Ethical clearance number: 001827). Semi-structured, in-person interviews were conducted with the selected participants, who were insured that their identity would be kept anonymous. The interviews begun with an explanation of the study, to then proceed with asking the interviewees the pre-decided questions. If these questions were decided *a priori*, however, the interviewees were encouraged to expand on answers to talk about what they deemed relevant, and were sometimes probed by the interviewer to provide additional comments, insights or explanations on elements that were deemed relevant for the case study (such as possible elements of path-dependency, and how they were overcome).

The full list of questions used in the interview can be found in Annex II, together with the granted ethical clearance form, the summary of all interview transcripts, extensive case study summary and image reproduction permissions (for Figure 5.4.5).

Data was then analysed thematically, using the sub-dependency domains presented in Box 5.2 as guiding themes for the analysis (Braun and Clarke, 2006). During the interviews, specific attention was paid to whether the interviewees would mention one of the sub-dependency domains, i.e., technologies, behaviours, policies, R&D activities, infrastructure. Besides, the interviewer remained aware and open to discovering and investigating of possible other elements that might emerge from the interviewees' experiences and observations beyond these pre-defined domains.

5.3.1 Case study summary

This case study documents the progress development of a sustainable approach to food production and consumption. As a bundle of issues caused by the GR plagued the Andhra Pradesh and Telangana states, CSA, a grassroots farmer empowerment agency, and, later, its commercial offspring SAPCO, promoted a technological innovation (NPM, box 5.4) as a solution to address interconnected environmental, social and economic problems.

These two organisations over time altered behaviours both in terms of farmers 'production practices and consumers´ purchasing and eating habits. They also prompted considerable infrastructural and institutional innovations. By acquiring their own infrastructure, they ensured more equitable distribution of profits (with increased profit margins for farmers), while empowering farmers through the set-up of democratic cooperative structures. CSA and SAPCO evolved in response to a continuously changing context, taking advantage of multiple opportunities, such as the attention of media or the State´s government new needs for sustainable solutions, as a way to expand their outreach. These two organisations gradually became (i) a profit-making venture that remains democratic and socially just; and (ii) a regulatory body that can provide formal certifications for food and other products, and an organisation capable of altering the existing infrastructure to accommodate sustainability and equity concerns.

Thus, from counting only a few small villages under NPM in the early 2000s, CSA and SAPCO are now engaging with more than 50'000 farmers directly while reaching more than 200,000 farmers through their services (http://csa-india.org/programs/). They helped more than 600 villages transition towards organic agriculture and supported the set-up of more than 400 cooperatives in Andhra Pradesh and Telangana. CSA and SAPCO have opened three shops and a franchise selling more than 200 different products to respond to increasing consumer demands – to date, one of the main issues is supplying enough products to meet the fast-growing demand.

Currently, state governments frequently consult CSA for possible R&D activities to promote organic farming. Apart from Andhra Pradesh and Telangana, CSA's action in supporting NPM extends to 10 other states: Maharashtra, Tamil Nadu, Karnataka, Punjab, Himachal Pradesh, Sikkim, Manipur, Nagaland, Chhattisgarh and Odisha. Recently, CSA has been actively involved in the drafting of an Organic Farming Policy in Kerala, Odisha and Madhya Pradesh. CSA and SAPCO's primary mission has become to help the government (nationally and at the state level) "in transitioning towards economically viable and ecologically sustainable agriculture" (https://fpohub.com/about/).

Box 5.3 NPM: an overview.

NPM has been defined by Ramanjaneyulu and Rao (2008a) as an "ecological approach to pest management using knowledge and skill based practices to prevent insects from reaching damaging stages and damaging proportions by making best use of local resources, natural processes and community action". It is based on:

- Understanding the crop ecosystem and modifying it by adopting suitable cropping systems and crop production practices that enhance soil and plant health;
- Understanding insect biology and ecosystem cycles, while adopting suitable preventive measures to reduce pest numbers.
- Building farmers' knowledge and skills in a way that allows them to make the best use of local resources and natural processes so that it secures present and future environmental viability
- Promoting community action as a way to ensure fair distribution of profits and benefits, especially amongst marginalised communities (Ramanjaneyulu *et al.*, 2009).

These principles seem to be closely aligned to what IFOAM Organic International has recently flagged as key principles of organic agriculture – or the principle of health, the principle of ecology, the principle of fairness and the principle of care (IFOAM, 2020).

5.4 Results

This section illustrates how the path-dependency sub-domains identified in the Conti et al. (2021) framework were (if implicitly) identified by CSA and SAPCO as structural problems (e.g. land degradation due to intensive chemical use, policy and infrastructure shifts, urbanisation and consumption changes) health (section 5.4.1). Then, by retracing CSA and SAPCO history, the case study proceeds by highlighting how these different path-dependency domains were gradually

disrupted over the years. In particular, the framework's lens retraces the case study history and allows to capture:

i. The initial technology and behavioural changes that CSA prompted (section 5.4.2);
ii. The infrastructural and institutional changes that were critical to break out of infrastructural rigidities and a lack of more democratic stractures for farmers (section 5.4.3);
iii. The leveraging of behavioural changes (and more widespread awareness) as a way to overcome a path-dependency in policy (5.4.4);
iv. New regulatory, policy and behavioural changes as a way to foster CSA and SAPCO´s outreach (5.4.5).

5.4.1 Path-dependencies (and their consequences) in Andhra Pradesh and Telangana

In the early 60s, geopolitical conditions promoted the Green Revolution (GR) in India. This initial historical choice, motivated by concerns over both economic growth and possibly insufficient food supply for a fast-growing population, promoted the modernisation of agriculture through technologies such as high-yielding varieties/hybrids and chemical inputs (Ramanjaneyulu *et al.*, 2009). The GR aimed to alleviate poverty and raise food security by providing rural farmers higher income and production using these new technologies. However, in the South Indian study area, like many other locations in South Asia, the GR also had unexpected and negative consequences:

A shift in farmers' practices (and knowledge of those) towards intensive chemical input use. While farm productivity initially increasing, farmers gradually lost knowledge around natural farming practices that had been used for centuries (Kumbamu and Stone, 2015). However, chemical inputs started to have environmental consequences (e.g., damaging soils, polluting the water) ultimately making farmland less fertile. Besides, pesticides created health issues for farmers spraying the them as well as for people consuming the crops (Ramanjaneyulu and Rao, 2008a). These issues ranged from mild symptoms such as rashes and coughs to more serious health problems that would emerge years later, such as cancers, immunotoxicity and disruption of the endocrine systems (Roberts and Reigart, 2013).

A shift in policy and infrastructure. Initially supporting the GR through, for instance, integrated food grain price support, storage and public distribution system, in the 1990s onward policy further accommodated this mode of "modern" agricultural development. For example, India's economic liberalisation in 1991 promoted several changes (in trade, private and foreign investment, taxation,

and fiscal discipline) to boost economic growth (Vaditya, 2017). These changes resulted in cuts to farmers' profits by around 40%, due to increased chemical input costs. While R&D investments were directed towards the development of new, high-yielding varieties (Kumbamu and Stone, 2015), this shift to industrial and chemical inputs concentrated the power in the hands of big agribusinesses in the post-economic liberalisation era where state owned agricultural input agencies where replaced by private enterprises.

Progressive urbanisation and consumption changes. While the urban poor suffered from a lack of access to (healthy) food, the availability and increasing popularity of junk and fast foods, coupled with limited awareness of nutrition, led middle and higher-class consumers to shift from traditional diets (rich in pulses, vegetables and fruits) to overconsumption of nutrient-poor food (Rajendran, 2022).

These issues prompted the establishment in the late 1980s of the Centre for World Solidarity (CWS), a Hyderabad-based Non-Governmental Organisation (NGO). Its objective at that time was to help farmers respond to increasingly persistent pests and weed problems[19] and at the same time reduce their reliance on costly chemicals by applying principles of NPM. This was at a time when the concept of "organic agriculture" was at the very margins of consumer and political consciousness. CWS encouraged and supported farmers in one village to shift from chemical inputs to NPM by trialling the new techniques on small patches of their land and later expanding this area. Initial successes built credibility for NPM, encouraging more villages to adopt the new practices (Nair, 2009). However, CWS was not an agriculture-focused NGO and had no solid research background in agriculture (Vicziany and Plahe, 2017). Soon after beginning, it had to wind down its agricultural operations to focus on other domains of rural development.

5.4.2 Changes in technology choices and behaviours (2004-2008)

In 2004, a major shock affected Andhra Pradesh and Telangana[20]. An acute water shortage coupled with continuous and diverse pest attacks caused huge losses for already indebted farmers and led to 1,200 farmer suicides in less than three months (June-August (Ramanjaneyulu and Rao, 2008a;

[19] Mainly in terms of controlling red hairy caterpillars. These are a pest of rainfed crops like castor, groundnut, cotton, etc. These used to invade farms in large numbers, despite the use of chemical pesticides, and caused huge losses. The red hairy caterpillars were brought under control, without using chemical pesticides, through effective interventions such as bonfires, trap crops, etc.

[20] The two states separated in 2014. Before that, Telangana was part of Andhra Pradesh.

Nair, 2009). As a response, an agricultural scientist previously involved with CWS saw the potential of NPM to help farmers respond to interconnected environmental hazards and established CSA as an NGO dedicated to expanding NPM. He recovered pre-GR knowledge of traditional and environmentally sound agricultural practices and integrated them with his scientific background to improve and further develop NPM techniques. To leverage NPM's potential to the fullest, the scientist understood the need for immediate changes in both technology choices (i.e., costly and environmentally damaging chemical inputs) and behaviours, both farm-level adoption of new practices and changes to consumption practices. He also recognised the need for consistent funding to run CSA.

CSA took a three-pronged approach which combined supporting the use of new production techniques, leveraged added value in products, and secured financial sustainability.

CSA took a three-pronged approach:

Supporting the use of new production techniques. CSA started to provide technical support and carry out capacity-building programmes. NPM is more knowledge-intensive than chemical-intensive production. Techniques such as farmers' field schools (FFS) were used to train farmers to understand pest infestations so that they could tailor their responses to the specific pest issues in their own fields, and test the efficiency of different non-pesticide treatments. Farmers who practised NPM often shared their successes with other farmers, thus contributing to the awareness of CSA's actions and novel practices.

Leveraging added value in products. NPM is knowledge and labour intensive. However CSA recognised that food produced in this way had added value both in terms of their sustainability credentials as well as potential health benefits to consumers. This added value had to be reflected in the price of the product. demanding a higher price required building awareness among consumers about the dangers of consuming foods produced with pesticides and the benefits of healthier diets. This awareness was scarce in the early 2000s. CSA's solution for this was the establishment of a "special" market for vegetables and fruits (initially, only these products were produced under NPM). Twice a week, farmers would come to the market in Hyderabad and talk directly with consumers, explaining how food was produced without pesticides. Gradually, this created awareness and encouraged changes in some consumers' food purchasing and consumption habits, although the scale was relatively limited. These foods would also be consumed by farmers and their families. CSA conducted no formal advertisement. However, urban consumers would also indirectly boost sales by spreading the word to friends, neighbours, and acquaintances, raising awareness about the benefits of pesticide-free products.

Securing financial sustainability. CSA needed funds to conduct research, experiment with NPM techniques and run farmer field schools. The initial solution was to involve policymakers. Following a visit by the local state Minister for agriculture in 2004, the government partnered with CSA, providing funding to bring 3 million acres under NPM, a target met five years later (in 2010). CSA was also able to obtain international funding from Hivos (Klaver *et al.*, 2015), a Dutch-based international development organisation that helps build social movements that strive for just, inclusive and sustainable societies (https://hivos.org/). These two collaborations helped CSA financially and increased its credibility and outreach.

From 2005 to 2008, CSA involved increasing numbers of farmers in NPM, "re-skilling" them to move away from the high-input agricultural model. As awareness spread and NPM solutions demonstrated their potential, many villages converted *in toto* to NPM.

5.4.3 Changes in institutions and infrastructure

By 2008, both the State and the National governments were explicitly recognising the environmental and socio-economic damages of the GR and the importance of organic agriculture. For example, a the Government of Andhra Pradesh states "*the need of change in farming system approach [towards organic agriculture]"* (Government of Andhra Pradesh, 2008). However, a change in the ruling party in the government of Andhra Pradesh in 2008 ended the collaboration and funding between the state and CSA. CSA continued training and technical support to farmers by using its own staff, but withdrawal of government funding created financial limits to the expansion of NPM. At this point CSA realised that the dependency on uncertain government support was not an appropriate way to pursue long term goals and that CSA needed to be self-sustaining financially. The NGO identified two measures to achieve this.

First, the creation of farmers' cooperatives and Farmer Producer Organisations (FPOs)[21], run by the farmers themselves. The first advantage of cooperatives was that each would have its own staff (which would be trained by CSA) to conduct NPM training and advise farmers. This increased accountability, as the cooperative would be responsible for its personnel and the efficient running

[21] Both co-operatives and FPOs operate under cooperative principles. The difference between the two is a legal rather than a conceptual difference: cooperatives are conventionally registered under the Cooperative Act, which is a state act. FPOs are registered under the Producer Companies Act, which is a national level act. Thus, FPOs can operate across state boundaries and government intervention is minimal. A discussion between the differences or the advantages of each goes beyond the purpose of the paper, and for simplicity, we use the term "cooperative" to indicate both.

of operations. It also reduced the load on CSA, who would only train the cooperative staff and thus less frequently need to visit the expanding number of (often remote) villages under NPM. In 2008, the co-operatives united to create a farmer producer company – the SAPCO, which is a federation of 23 FPOs and cooperatives, where each has a democratically elected chairperson. This process of institutionalisation ensured that decisions around SAPCO's operations would be taken collectively and democratically.

Second, creating new infrastructure to better market NPM products and grant higher financial independence for CSA and SAPCO. To operate under their own funding, both organisations needed to increase production volumes – and thus profit. This was achieved through changes in the value chain, specifically concerning processing and transport infrastructure. Before CSA, farmers used to sell their produce to intermediaries (who would take a large profit margin). After CSA's intervention, farmers still had to bring their produce to the market themselves. This was not a marketing strategy that could work at scale. Cooperatives could ensure that larger production volumes would be achieved, and that produce would be uniform in terms of quality and production modalities. Cooperatives became "hubs" where farmers could bring their produce without having to transport it to the market. Besides, CSA wanted to ensure that 50 per cent of the retail price of the food sold is returned to the farmers, compared to 20-30 % that the farmer gets on the mainstream market (Vicziany and Plahe, 2017) (Figure 3). The expansion of CSA's work also led to new crops produced under NPM, such as cereals, millets, pulses, oils, and spice. These had to be stored, processed, and packaged[22]. Progressively, CSA acquired processing facilities (e.g., flour and oil mills; previously, these operations were outsourced to third parties) managed by SAPCO.

With the opening in 2009 of its first retail store selling organic products in Hyderabad, SAPCO (with the help of CSA) had managed to build a democratically controlled value chain in which the farmers agreed collectively about their production and other strategies through their representatives in SAPCO. The retail store allowed farmers and consumers a more stable outlet for selling and buying NPM products.

[22] Specifically in the case of cereals and pulses, storage was a big problem for farmers. In the rainy season, they would not know where to store their produce. SAPCO storage facility helped farmers overcome this challenge.

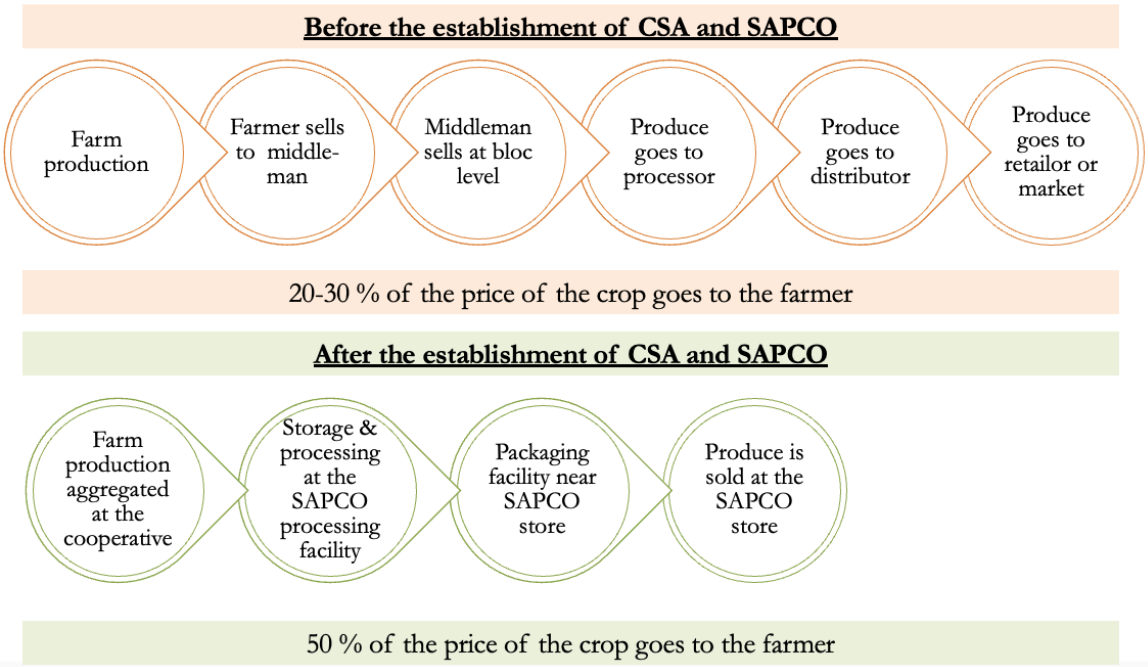

Figure 5.4.3. Value chain before and after SAPCO.

5.4.4 Changes in consumers ´attitudes and regulations (2012-2016)

The growing outreach of CSA led the organisation's work to be featured in a nationally streamed and extremely popular TV show, Satyamev Jayate[23], which aimed to raise awareness about environmental issues. The show shed light on the dangers of pesticides and the benefits of consuming pesticide-free products. Soon after, and in part as a consequence of such media attention, the Food Safety and Standards Authority of India (FSSAI) analysed common food items and found that they contained pesticides in quantities 1,000 times higher than permissible limits (Prasher, 2013; Satyamev Jayate, 2013a).

Thus, several Indian States called for urgent solutions. Organic agriculture was deemed as a solution that could mitigate environmental degradation (mostly due to monocropping patterns and chemical use), health issues (linked with exposure to pesticides) and poverty issues (by generating higher or more stable incomes for farmers). Thus, several government schemes were set up, such as the Capital Investment Subsidy Scheme, the National Project on Organic Farming, and the National Paramparagat Krishi Vikas Yojana Scheme (Government of India, 2010c, 2010a). Several

[23] The title's literal translation from Hindi means "Truth alone Triumphs". The TV show "discusses and provides possible solutions to address social issues in India" (http://www.satyamevjayate.in/smj3-about-us.aspx). Aamir Khan, a beloved Bollywood celebrity, brought to the public the dangers of pesticides and presented CSA as a lead example of healthy products while explaining the benefits of NPM.

states asked CSA to provide its sustainability expertise and support changes in both technologies and production methods, usually in collaboration with local NGOs.

Research started being conducted on CSA; scholars from both Indian and international institutions came to observe their practices and business model, increasing its visibility. At the same time, CSA continued expanding its work by further exploring NPM to include new crops and adapting practices to specific agroecological conditions in each state.

Concomitantly, CSA received recognition for its efforts in terms of farmers' empowerment. SAPCO had a democratic structure, which made the government aware of the potential of cooperative models to further farmers' rights and reduce the vulnerability of rural livelihoods. In 2013, the government changed its regulations to favour cooperatives. Before 2013, the legislation for setting up cooperatives was muddled, making it difficult for farmers to apply. New regulations simplified the process to ensure more farmers could form cooperatives.

The success of CSA was confirmed when the NGO won two national prizes: one for the "Best Rural Innovation" and one for the "Best Community Management Model". This symbolised how both the technology and the institutions received a prize.

5.4.5 More regulatory, policy, behavioural changes (2016-2022)

In 2016, the CSA funder and SAPCO executive director was invited to a TED talk on the importance of consuming organic foods. The talk went viral. The growing concerns over the danger of consuming foods produced with pesticides seemed to be the new norm in consumers' minds. Consumers demanded food that was organically produced and could prove to be so. Thus, the government was pressured for more regulatory changes. Particularly, it made efforts to improve an existing "Participatory Guarantee System" (PGS), a system set up as early as 2006 to certify crops produced under organic principles. Until 2016, the PGS was dysfunctional: the implementation of the legislation had been scattered, and even if 327 PGS centres were allowed to certify, the process was slow, the quality controls weak and corruption frequent. Overall, the certification was unreliable. In 2016, the government started to scrutinise different centres, cutting their number to 65. CSA applied to become one of these centres, and its new regulatory role allowed it to make NPM more credible - and thus more marketable. With the certification, farmers could sell at a premium price.

In parallel, CSA kept expanding awareness about NPM, partnering with the Grameen Academy to create "FPOhub" and mentor farmers so that they could independently set-up and manage

cooperatives[24]. Consumers were equally involved: SAPCO continued to set up consumer-targeted initiatives, such as nutritional counselling sessions, urban gardening, household waste management and composting, water harvesting and recycling activities, along with periodic cooking festivals and exhibitions. SAPCO also started running activities in schools to create awareness in children about healthy consumption (Ramanjaneyulu, 2019) (figure 5.4.5).

In 2020, the pandemic threatened the functioning of the retail stores, as lockdowns made it hard for the products to move from remote locations to the stores, while the processing hubs had to initially halt production. However, CSA and SAPCO quickly resolved these issues by making several transport and storage adjustments and, ultimately, selling even more products to consumers who were more than ever aware of the importance of nutrition for better health. Besides, the success of the cooperatives in empowering smallholder livelihoods ensured the support of the government in terms of cooperative-friendly policy measures, such as i) an income tax exemption on cooperatives (2019); ii) a guarantee of subsidies for the first three years of a cooperation's operation (in particular, covering administration costs) (2020) and iii) the set-up of a National Ministry solely dedicated to cooperatives (the Ministry of Cooperatives) (2022).

Figure 5.4.5 The SAPCO official webpage detailing some of the services they offer. https://sahajaaharam.com/. Permission to reproduce the image granted (Annex II).

[24] The program includes mentoring support to develop viable business strategies, promoting market linkages, setting up infrastructure facilities for FPOs, input and digital services and legal compliances support (https://fpohub.com/).

5.5 Discussion

Evolving and changing over a time-span of 20 years, the case study is an illustration of the importance of bundling different forms of innovation in the system's transformation process (Barrett *et al.*, 2020b). It also shows and way innovation needs to be wide-ranging *and* context-appropriate. This is in both spatial sense, for example innovation suitable to the specific Andhra Pradesh and Telangana condition, and in a temporal sense for example, at the right time to exploit certain opportunities, but also acknowledging the length of time some elements require to undergo change and disrupt path-dependencies and open the way to system innovation.

While the framework helps clarify the features of transformation, and assess whether one is ongoing (or less so), in order to identify the enablers of transformation it is critical to look at the totality of the history of the case study – which goes beyond the framework – to understand what could enable the niche to enable structural changes in production and consumption patterns. To address the following discussion firstly uses the framework as a "checklist" to understand whether a transformation is underway and secondly discusses the enablers of such transformation within and beyond the framework.

5.5.1 The path-dependency framework: is a sustainability transformation underway?

The framework helps us evaluate whether a disruption and consequent innovation (either social, economic, technological, or institutional) in different system elements is underway:

Technology Choices. The first element that stated changing was technology choices. Through CSA's work, farmers started switching from traditional and high-input production methods towards environmentally sustainable NPM methods, building knowledge and skill around the innovation which, over the years, kept developing, for instance, by expanding to other crops or adapting to new agroecological areas.

Attitudes and Cultures. If, on the one side, technology choices implied behavioural changes at the farm level, another major achievement for CSA was the ability to generate changes in consumers' attitudes – in terms of their purchasing and consumption patterns. From eating pesticide-loaded foods, consumers started acquiring awareness over the dangers of consuming these – which consequently created, over the years, new attitudes (and resulting interest) towards NPM products.

Infrastructural rigidities. With the acquisition of collectively managed infrastructure, which allowed alternative ways to store, process, package, and sell the foods, CSA and SAPCO were able to build alternative value chains for their products – which also ensured fairer profit distribution (i.e., farmers got a higher margin, figure 5.4.3 above).

Policies and Institutions. While encountering mild or null political support the beginning, CSA initially received little support from the government, which withdrew its support after the four initial years. However, a few years later, as awareness over sustainability and healthy consumption increased nationally, policymakers were prompted to look at NPM as a possible mainstream solution (instead of a side-line alternative) and thus started undertaking actions for supporting both NPM/organic production, while calling on CSA to provide expertise. At the same time, cooperatives set up by SAPCO shed light on the potential of alternative farmers' institutions that were socially more inclusive and just. Favourable policies thus increasingly facilitated cooperative structures.

Power and politics (or the political economy of agri-food systems). In India, powerful actors shape the food system (see for instance, in the case of the sugar industry (Lee *et al.*, 2020; Orr *et al.*, 2022). SAPCO and CSA managed to partially rebalance, if in a limited manner, shift the political economy of the food system by providing farmers technologies that made them self-reliant (i.e. as opposed to high-inputs supplied by big industries), while building more just value chains that allowed higher profits for farmers and more democratically controlled structures (i.e. as opposed to industrial value chains) – ultimately contributing to their empowerment. However, altering the political economy of the food system remains an enormous task, involving many players and many contending interests (Oliver *et al.*, 2018; Swinburn, 2019; Hambloch, Kahwai and Mugonya, 2021).

Research and innovation priorities, practices, and narratives. In India, funding for research is scarce (Pal, 2008; Sen, 2019) and in the past 40 years, it has mainly been directed towards modernising agriculture, improving existent chemical inputs and focusing on producing higher-yielding crop varieties (Government of Andhra Pradesh, 2008; Government of India, 2010c; Glover *et al.*, 2021; Jaacks *et al.*, 2022). Even if a shift to new R&D that can prioritise novel production (and other) practices that are more sustainability-oriented has yet to take place (Klaver *et al.*, 2015), it is, however, interesting to remark that CSA has captured the government's attention for their NPM research. The initiative might, therefore, have helped increase the acceptability among policymakers for alternative practices (and inherent research) that emerge from grassroots

rather than traditional research. In terms of R&D, this might therefore be, in the long run, a critical turning point. It could demonstrate the value of alternative and non-mainstream knowledge and research, and that this can deliver equally sound solutions for policymakers facing the new century's challenge (Anderson and Maughan, 2021)

What can be seen from the above application of the framework is the presence of innovation in different system elements, that confirm that CSA has tackled a number of path dependencies and has indeed initiated an alternative -and viable– development pathway aligned to sustainability and social justice as follows:

a) environmentally viable, as it cuts on chemical inputs and promotes natural solutions;
b) more socially just and inclusive, as it empowers small farmers, who "by default command, a smaller voice than industry" (Morin, 2016) to control their value chain democratically (through their elected representatives in SAPCO); and
c) promote more equitable economic growth by granting fairer profit distribution on decreasing reliance on big industry players.

Thus, the CSA story exhibits an ongoing system innovation that if not yet complete -- political economy dynamics and the R&D priorities seem slower to change – is, however, opening the way for a sustainability transformation. It remains uncertain what would be the scalability of this type of initiatives: further research is needed to assess their potential in terms of being economically, socially and environmentally sustainable pathways at scale - for instance, determining to what extent they can respond to food security and nutrition concerns). Yet, the case study undoubtedly calls for much more attention to be given to these unconventional bottom-up and emergent pathways towards more sustainable futures.

Figure 5.5. presents a heuristic that illustrates the progression from initial path-dependencies, the types of innovation to disrupt them, and the shift to an alternative agri-food system. Yet the case study tells us much more, giving insights into how innovation in these different system elements has taken place. This is discussed in the next section.

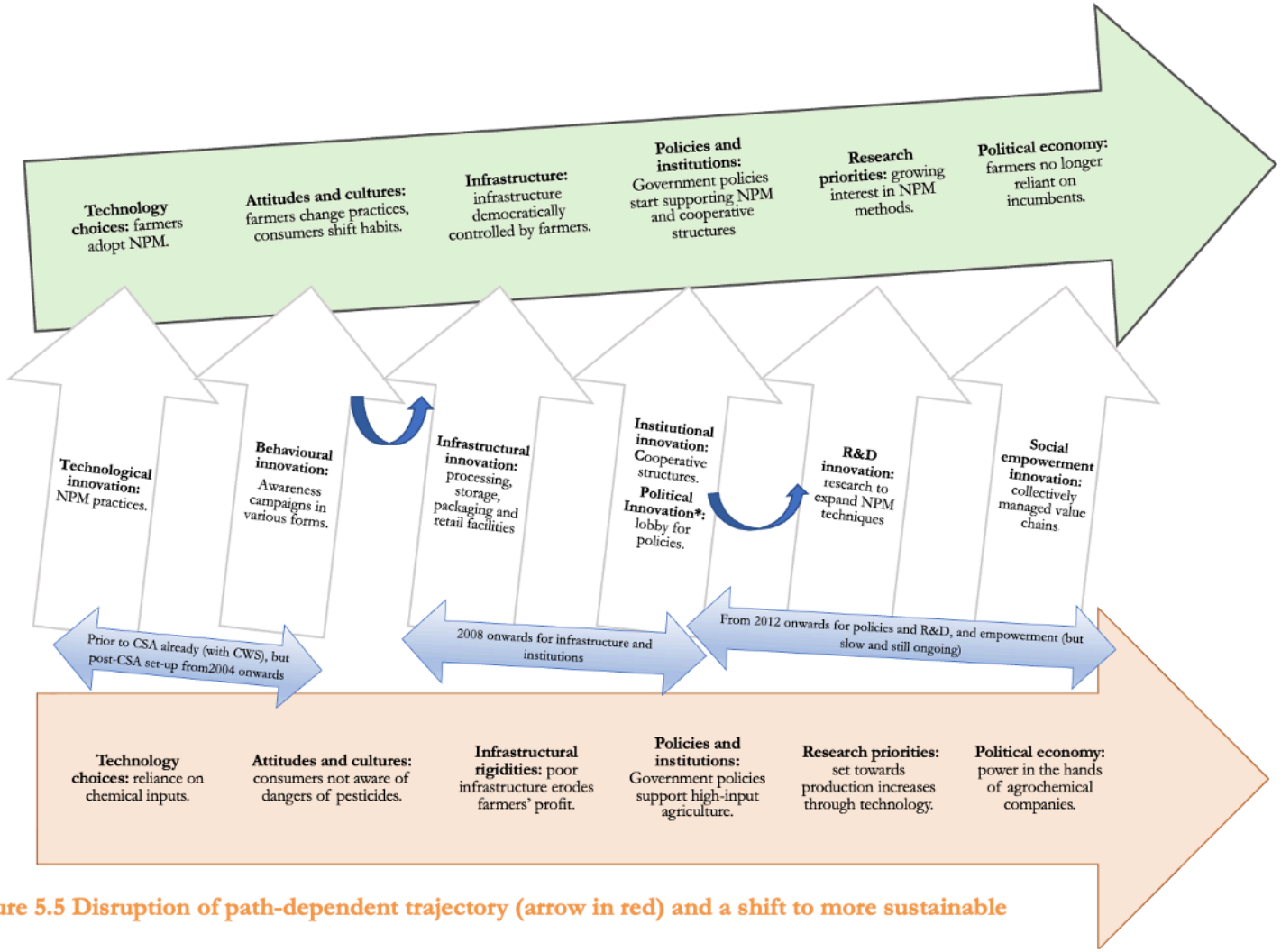

Figure 5.5 Disruption of path-dependent trajectory (arrow in red) and a shift to more sustainable trajectory (arrow in green). The arrows outlined in gray represent innovations in all different sub-domains of path-dependency. The double-headed arrows represent simultaneous changes. The curved/ C-shaped arrows represent consecutive changes. Institutional and political innovations are represented together in the original framework. However, in the NPM story, they happened at different times. The two separate "successive change" arrows pointing one at "institutional innovation", and one at "political innovation" represent that.

5.5.2 Insights on how transformation takes place

The case study also provides insights into how transformation takes place. These insights are partly supported by the framework, but also flag the need to consider additional issues.

5.5.2.1 Synchronising innovation in multiple system elements

Besides, the development of the framework discussed by Conti et al (2021) highlighted that these components might take different timespans to change. This was indeed the case for the NPM initiative. As illustrated in figure 5.4, technological and behavioural innovation seemed to happen relatively more quickly, whereas, for instance, changes in the political landscape only started to happen 8-10 years after CSA was established (if initially, the government manifested interest, this interest was short-lived when fundings were withdrawn). Credibility at the political level was only gained after CSA could prove its viability and received national media coverage – signalling the increasing importance of media for promoting sustainability awareness and action in recent years (Lockie, 2006; Stevens *et al.*, 2016). Even longer time spans were required for changes at the political economy level, and within R&D priority setting. Previous research had already highlighted the difficulty of shifting these elements towards new directions of development, highlighting how undermining unjust political power patterns (Anderson and Leach, 2019) and shifting research trajectories (McGuire, 2008; Vanloqueren and Baret, 2008) is a long-term process that might be both financially onerous (e.g. new investments for fundamentally different R&D activities (Magrini *et al.*, 2018) and politically costly (e.g political players might forsake the support of financially and politically powerful actors when "rowing against" existent practices (Radulovic, 2005; IPES, 2016; Frimpong Boamah and Sumberg, 2019).

What this temporality issue also highlights is that innovation in multiple system elements might need to be better synchronised: within the NPM initiative, this meant ensuring that changes in technological choices could be complemented by changes in behaviour, while institutional innovation (i.e. the set-up of cooperative structure) could be coupled with infrastructural innovation (i.e. the cooperatives could manage the new infrastructures set-up for accommodating processing, storage, packaging and retail of NPM crops). This then led to increasing recognition at the policy and within the innovation narrative of relevant government agencies.

Therefore, a key suggestion to enable transformation emerging from the case study is the need to couple multiple innovations "with the right timing". This could be critical for niches to succeed in triggering broader disruptions of incumbent systems by ensuring their capacity to challenge the

system under multiple aspects simultaneously, so multiple innovations reinforce each other in the dismantling of path dependency and in the consequent opening-up of alternative pathways.
However, the framework alone could not capture two elements of what seemed to enable transformative change.

5.5.2.2 Navigating complexity and leveraging "unknowns" as opportunities for transformation

The complexity of the agri-food systems space is widely discussed in the literature (Foran *et al.*, 2014; Gamboa *et al.*, 2016; Hall and Dijkman, 2019). However, what the framework cannot help explaining is the ability of the CSA to turn unpredictable shocks and challenges in to opportunities for experimenting with different and more sustainable pathways of development. For example, it was the water shortage and farmers' suicides that initially spurred CSA into action. The sudden withdrawal of government funding (due to a change in the government), that instead of causing collapse, created an opportunity for CSA to build its infrastructure from scratch and set up its own institutions. Later, CSA leveraged the FSSAI report on pesticides, the invitation to participate in the Satyamev Jayate TV show, and the TED talk to exponentially increase its reach and boost consumer awareness. Following the government's reform of the PGS system, CSA seized the opportunity to become itself a certifying body for organic agriculture. Finally, the Covid-19 outbreak could have truncated its operation and put at risk hundreds of farming livelihoods (as it had happened in other parts of the country), CSA and SAPCO were once again able to turn the sudden disruption into an opportunity to make NPM even more appealing to consumers more than ever concerned about their health and the importance of healthy nutrition (Das *et al.*, 2020; Dhiman, 2020).
Therefore, an equally critical enabler for initiatives to successfully operate and consequently transform the agri-food system seems to hinge on their ability to respond and continuously adapt to the always dynamic and evolving agri-food system context (Dorninger *et al.*, 2020; Conti, Zanello and Hall, 2021). This observation is supported by a growing body of literature that suggests the importance of moving beyond efforts stir change towards pre-established directions and "combating" shocks (Thompson *et al.*, 2007; Wigboldus *et al.*, 2016; Dinesh *et al.*, 2021). Instead, in an era of fast-paced environmental and social change (Feola, 2015; Dekeyser *et al.*, 2020), it is critical to welcome unpredictable events (advantageous or less so) and "disturbances" as ways to "to create opportunities for doing new things" (Thompson and Scoones, 2009) and leverage wide-spanning innovation that can lead towards unexplored alternative pathways (Leach, Scoones and Stirling, 2007; Stirling *et al.*, 2008; Pereira, Hichert, *et al.*, 2018). Capitalising on serendipitous

opportunities while proactively engaging and experimenting with "unknown unknowns" might be a critical ingredient for initiatives to thrive under uncertainty (Scoones and Stirling, 2020)

5.5.2.3 The role of agency for transformation

The role of agency in transformative processes is increasingly regarded as a critical component for transformative processes worldwide (Feyereisen, Stassart and Mélard, 2017; Kok *et al.*, 2021; Grzymala-Kazlowska and O'Farrell, 2023). From the NPM initiative, it emerges how the actions and efforts of CSA (and later SAPCO) staff were critical, as were the efforts of farmers to experimenting with new techniques and risking implementing them, while also participating and becoming proactive within cooperatives. Similarly, consumers' willingness and efforts in both switching to novel consumption patterns (several studies have proven that frequently, awareness alone does not lead to changes in behaviour (Wood and Neal, 2016; Balmford *et al.*, 2017), and spread awareness around CSA and SAPCO's work, was critical. Finally, the later involvement of media and government actors was important to create awareness and help CSA gain recognition at scale while facilitating its efforts to promote both NPM and cooperative structures (e.g., implementation of PGS and legislation to facilitate cooperative set-up). Relating to the point above, the capacity of organisations and networks to navigate and work with (rather than act against (Thompson and Scoones, 2009)) complexity might be the way forward. This would, however, require clear efforts to implement a novel approach to operating in the food system space, which moves away from pre-established change pathways and objectives set *a priori* (Hertz, Brattander and Rose, 2021) to instead propose a flexible approach (Leach, Scoones and Andy Stirling, 2010) that can capitalise on opportunities, openly experimenting with a broad range of innovation (Stirling, 2009, 2014b) to evolve and respond to an ever-changing context (Pereira, Frantzeskaki, *et al.*, 2020), and reflexively evaluate when new and possibly more suitable solutions might emerge. If the importance of such an approach is increasingly flagged for research and action towards transformation (Fazey *et al.*, 2018), its practical implementation remains limited (Mayne, Mcdougall and Paz-Ybarnegaray, 2017).

5.6 Conclusions and recommendations for future research

The paper presented a case study presents of an on-going sustainable transformation that has been ongoing in South India from the early 2000s till date. Initially emerged as a response to a historical path-dependency (originated in the GR), the initiative challenged this path dependency by implementing fundamentally different modes of production and consumption. CSA and SAPCO prompted innovation in multiple domains as a way to move towards environmental soundness,

economic viability, and social justice. The paper applied a novel framework to explore innovation in systems elements that signal that path dependencies have been broken and explored other enablers of transformation. The framework proved useful as a "checklist" to evaluate the level of transformation that an initiative might showcase. This makes it a valuable tool for development practitioners and researchers engaging with transformative processes, as there is currently much ambiguity – and lack of tools (Cohen and Ilieva, 2015) – to assess whether a transformation is ongoing, and what might be its extent (Feola, 2015; Scoones *et al.*, 2020; Truffer *et al.*, 2022).

Besides, by leveraging case study evidence, the paper also suggested that, for addressing path dependencies, it is useful for organisations and actors in the transformation space to reflectively experiment with multiple, interconnected, and context-adapted innovations in different system elements, but that innovation in these elements takes place over different timeframes. If the case study suggested that synchronisation of these innovations could speed transformation[25].

This idea of synchronisation is fairly challenging for policy, as systems elements such as culture and political economy are not amenable to existing policy and practice instruments (Ingram and Thornton, 2022; Ptak, Graversgaard and Dalgaard, 2023). This could be a fruitful topic of future research, and could be a critical point of reflection for policymakers and research for making more proactive and targeted efforts to ensure innovation in different domains could be successfully nurtured (e.g. through supportive policy and action) and orchestrated for increasing initiatives' (either top-down or bottom-up) potential to challenge the status quo. This is why temporality needs to further explored to understand *how* to practically trigger system innovation -in and beyond niches - in multiple system elements, and in particular accelerate it in system elements that seem more resistant to change towards sustainable directions of development. Tackling temporality might have critical implications for policymakers, who might need to proactively engage to prompt system changes where they are most needed to open the way to the increasingly urgent transformation of agri-food systems. Thus, the NPM initiative presents some powerful lessons and calls for further research to understand the many unknowns of transformative processes and their broader implications for practice, research, and policy, while also highlighting critical research gaps.

[25] As this is a single case study, it does not have the pretense to make overarching recommendations, especially on a point that remains so overlooked.

6. What does the agri-food systems transformation agenda mean for agriculture and food research organisations? Exploring organisational prototypes for uncertain futures

"Η ΚΑΜΗΛΑ ΔΕ ΒΛΈΠΕΙ ΤΗΝ ΚΑΜΠΟΥΡΑ ΤΗΣ."

" THE CAMEL CAN'T SEE HER OWN HUMP"

GREEK PROVERB

Abstract:

Agriculture and food research organisations (AFROs) are currently called to answer new and pressing demands for urgent solutions for interconnected challenges associated with the agri-food system transformation agenda. Contrasting visions exist for how transformation should be achieved, particularly the role of technology, creating difficult choices for AFROs. To assist in navigating this complex decision space, this paper reviews key research and innovation narratives that exist in the transformation debate. This is used to build four scenarios for AFROs of the future, namely: i) Industry transition-oriented; ii) Technology mission-oriented; iii) Community innovation-oriented, iv) Facilitating transformative innovation-oriented. The paper then discusses the likely concerns each scenario raises and will need to be discussed in on-going deliberation. Concerns include alignment with existing roles, mandates and capabilities, trade-offs and risks, and feasibility. Conclusions emphasise that AFROs cannot make unilateral choices on ways forward. Rather this will need to be negotiated among multiple actors in and beyond the agri-food system space. This needs to be connected to similar debates on the implications of the agri-food systems transformation agenda for reforming the agricultural innovation system in which these organisations are embedded.[26]

[26] This chapter will be submitted, over the next few weeks, to the Agricultural Systems or Global Food Security journal. No major edits are expected before submission. The thesis'author is the first author, followed by Andrew Hall, Helen Percy**,** Samantha Stone-Jovicich, James Turner, Larelle McMillan.

6.1 Introduction

As the need to transform food systems becomes increasingly central in global sustainability debates, a critical and still largely unanswered question revolves around the present and future roles of Agriculture and Food Research Organisations (AFROs)[27] (Klerkx *et al.*, 2022; Körner, Thornton and Klerkx, 2022). These organisations are at a critical point of inflexion as they are called upon to respond to new and pressing demands for solutions to highly systemic and complex challenges that span environmental (e.g. climate change and land degradation), economic (e.g. inequitable wealth distribution and persistent poverty) and social (e.g. inclusion of marginalised groups, issues of human rights, democracy and participation) domains (Shrivastava *et al.*, 2020; Den Boer, Broerse and Regeer, 2021).

Yet, while it is widely agreed upon that research and innovation will play a central role in helping design and manage food system transformative processes across the globe (Fazey *et al.*, 2018; Herrero *et al.*, 2020; Kok *et al.*, 2021), the novel agenda calls for a rethink of how AFROs function and their role and responsibilities for supporting – or even enabling - a shift towards more sustainable trajectories of development (Béné *et al.*, 2019). This task of rethinking AFROs is made even more difficult because, in the broader debates about food system transformation, there are different views on how this should be achieved, particularly in terms of the role of technology. Klerkx et al. (2022) highlight two opposing points of view. On the one hand, the "techno-optimists" argue that transformation can be achieved through the right technologies (Carolan, 2020; Di Vaio *et al.*, 2020; Lajoie-O'Malley *et al.*, 2020). On the other hand, the "techno-pessimists" argue that incremental and component technological innovations (e.g. agriculture 4.0, digitalisation of food value chains etc.) alone will unlikely be sufficient to respond to the transformation agenda (Klerkx and Rose, 2020; Klerkx *et al.*, 2022). Rather it is argued, transformation requires system-level innovation as a precondition to reframing innovation action and (re)directing technological innovation toward sustainability objectives (Hall and Dijkman, 2019; Klerkx and Rose, 2020).

These contrasting views play out in the societal and political arena in which AFROs operate. On the one side, policymakers are turning to research for silver bullet solutions and technological fixes for meeting sustainability targets (e.g., the SDGs by 2030, zero net emissions by 2050) (Bruce *et*

[27] For AFROs, we intend national and international publicly funded research organisations that have historically played a critical role in resolving agriculture challenges through technology development as well as systems, social and economic analysis.

al., 2018; Deutch, 2020; Costa *et al.*, 2022; Mengis *et al.*, 2022). On the other side of the spectrum, civil society is becoming increasingly involved in the quest for sustainability, urging research organisations to become more open and inclusive of alternative and bottom-up forms of innovation that have both technical, social and institutional change dimensions and which target structural and historical inequities of food systems (Berthet, Hickey and Klerkx, 2018; Pereira, Frantzeskaki, *et al.*, 2020).

Some authors argue that research organisations (including but beyond AFROs) should move away from their traditional role as technology provider and assume a much more proactive role in designing or even managing transformative processes (Fazey *et al.*, 2018; Kok *et al.*, 2021; Parker and Lundgren, 2021). As research communities start to engage with the sustainability agenda and respond to the new demands it places on research and researchers, a diverse set of "research for sustainability and transformation" practices has started to emerge with experimentation, reflexivity, transdisciplinarity and plurality as key features (Popa, Guillermin and Dedeurwaerdere, 2015; Caniglia *et al.*, 2021; Kugelberg *et al.*, 2021). Examples of these practices include responsible research and innovation (Stilgoe, Owen and Macnaghten, 2013; van der Burg, Bogaardt and Wolfert, 2019; Carolan, 2020), sustainability science (Clark and Harley, 2020; Horcea-Milcu *et al.*, 2020), human centres design (Veling, 2014; Bason, 2017) and mission-oriented innovation (Pigford, Hickey and Klerkx, 2018; Klerkx and Begemann, 2020; Loos, 2021).

Given the diversity of views on how technology should be harnessed for food system transformation and the expanding set of prescribed research and innovation approaches, AFROs face a difficult set of choices that must be made while simultaneously navigating the contested nature of the food system transformation process. This paper aims to contribute to the debate on the relative merits of different choices and approaches by structuring a discussion of the benefits and trade-offs of four hypothetical AFRO organisational prototypes or scenarios. To do this, we first review and contrast research and innovation narratives and prescribed "research for sustainability and transformation" practices that are associated with these. This is used to illustrate how research and innovation narratives are rooted in fundamentally different assumptions and imply very different visions of the role and *modus operandi* of AFROs and their core research practices. Second, based on the review of these different innovation narratives, we construct four scenarios of AFROs of the future: an industry transition-oriented scenario; a technology mission oriented-scenario; a community innovation-oriented scenario; and a facilitating transformative innovation scenario.

The purpose of the scenarios is not to predict or prescribe what AFROs will look like in the coming years: rather, these are used to highlight implications and adaptation considerations that need to be made and the benefits, trade-offs and risks that AFROs will need to navigate.

In conclusion, we highlight two issues. Firstly, choices about adapting the role and focus of AFROs need to be carefully considered by these organisations as these decisions cannot be made unilaterally and will require ongoing consultation and reflexivity as part of a process of continuous organisational refinement. Second, the issue of reimagining AFROs cannot be done in isolation from a complimentary process of reimaging the wider agricultural innovation system in which these organisations are situated. As with the first point, broad consultation and reflexivity will be required to reform and redirect the innovation system towards sustainability. Moving forward, we believe that the organisational prototypes represented by our scenarios could be a valuable boundary object to stimulate this consultation and to explore the perspectives of a range of interested and affected actors within the research and innovation system.

6.2 Methods

Several narratives have emerged to suggest how research and innovation could support and enable transformational changes in food systems. The idea of "narratives" is specifically used here to indicate the constructed nature that each view has in terms of certain issues, how they are problematised, the associated socio-technical solutions and the implied role of key actors in the process (Thompson *et al.*, 2007; Anderson and Rivera-Ferre, 2021). Narratives are rarely codified, but persist and evolve in organisational cultures and practices through written and oral artefacts that reinforce the dominant narrative by legitimising certain forms of practice and behaviour (Moezzi, Janda and Rotmann, 2017).

To explore narratives, a critical literature review approach is adopted to embody existing theories and conceptual contributions in the current research landscape (Grant and Booth, 2009). This approach implies a higher degree of analysis compared to traditional reviews (Grant and Booth, 2009), and is appropriate to identify the core features of both older and more recent views on research and innovation for transformation. Thus, the narratives are not to be intended as fully comprehensive or entirely discrete categories[28], but are instead useful to highlight fundamentally

[28] These narratives are a result of an analysis made by the authors. They are therefore not rigid and could be subject to interpretation. Besides, the purpose of the narratives is not to capture the entirety of the

different visions for research and action around sustainability transformation (see also a summary in Table 6.2.4). We present them here as foundation to imagine four different scenarios for AFRO of the future. The table below (Table 6.2) provides more details on the adopted methodology, and how it helped structure and inform the different sections of the paper.

From the critical literature review, four research and innovation narratives can be discerned, namely: i) the "silver-bullet technologies for transformation" narrative; ii) the "directing innovation for tackling grand challenges" narrative; iii) the "system replacement from the margins" narrative and iv) the "system innovation for transformation". In presenting these narratives below, emphasis is given to their core propositions about the role of research and innovation (and technology) in transformation, the major research debates and research approaches used, how change for sustainability is understood to take place (impact logic), who are the principal actors, and what success looks like. Key references for each narrative are organised in Table 6.2.

literature relating to these debates: the narratives are not all-inclusive, but rather attempt to capture critical points of debate emerging from a broad literature landscape.

Table 6.2 Approach used in the critical review and how it informed the derivation of scenarios and their implications.

Paper structure	*1. Critical literature review (Section 6.2)*	*2. Identification of axes of debate and cross-cutting issues (Section 6.3)*	*3. Scenarios (Section 6.4)*	*4. Implications of the scenarios (Section 6.5)*
How it was done	Methods used (SALSA), drawing from Grant and Booth (2009) • **S**earch: facilitated by a systematic search on several databases to identify significant publications in the field. ○ Databases searched are: Scopus, ScienceDirect, Google Scholar. ○ Keyword search: (transformation OR transition AND sustainability) AND (agri OR food) AND (research OR innovation)[29] **A**ppraisa**L**: no formal quality assessment. Publications screened	Through the analysis of the narratives in Section 2.	Drawing from the narratives (Section 2) and reflecting on axes of debates and cross-cutting issues (Section 3).	Drawing on the previous three sections.

[29] Search string adapted for different databases. The systematic search helped identify relevant publications. However, the aim of the paper is not to systematically appraise all existent theories, but rather embody existing theories and reveal different conceptual contributions made by different schools of thought around AFROs role and responsibilities for responding to the transformation agenda. Thus, the search is not over-inclusive.

	according to their relevance to the topic. **S**ynthesis: narrative (development of scenarios) **A**nalysis: seeks to understand and explore how different research narratives stem into different views on AFROs role and responsibilities and reveals the implications these might have.			
Resulted in	**Four Narratives**	**Two axes of debates and two cross-cutting issues**	**Four Scenarios**	**Implications on**
	i) The "silver-bullet technologies for transformation" narrative; ii) The "directing innovation for tackling grand challenges" narrative; iii) The "directing innovation for tackling grand challenges" narrative; iv) The "system innovation for transformation" narrative	a. Role of technologies b. Scope of interests c. Bottom-up or top-down type of approaches d. Level of reconfiguration	1. The Industry transition-oriented AFRO; 2. The Technology mission-oriented AFRO; 3. The Community innovation-oriented AFRO 4. The Facilitating transformative innovation-oriented AFRO	• Core strengths, contradictions, and trade-offs • Alignment with existing capability • Alignment with existing roles and mandate of AFRO • Risks for AFROs under different scenarios

6.2.1 The "silver-bullet technologies for transformation" narrative

The most long-standing narrative is "technology for transformation". The core proposition of this narrative is that novel technologies can deliver economic growth *and* sustainability. AFROs' role is here critical in delivering these technological breakthroughs and in doing so, propel (technological) change for sustainability. This narrative has historically conceptualised food system transformation as a process of using research and innovation to substantially increase agricultural productivity, in what has been defined as productivist/modernisation of agriculture-type approach (Cabral and Sumberg, 2022). This has played out in the development of food systems around the world driven by both public R&D and agri-business R&D and has been firmly in what has been defined as an "innovation for growth" (Schot and Steinmueller, 2018) framing of innovation.

The origin of the narrative can be traced back to post-World War Two concerns over the need for food production increases, particularly in LMICS, to meet the needs of a growing world population (Thompson and Scoones, 2009; De Schutter, 2014). A core approach has been to identify isolatable technical problems, such as pests and diseases or low yields, and develop technological fixes to resolve them. The approach is typified by the success of the high-yield cereal varieties that revolutionised food production in South Asia in the last quarter of the 20th century (FAO, 2009b; Sumberg *et al.*, 2013). The so-called Green Revolution (GR) was and continues to be closely associated with many of the CGIAR centres[30] which developed these varieties (Greenland, 1997; Pingali, 2001). Poverty and hunger were reduced, but there were significant environmental externalities, and in some cases, the new technologies exacerbated existing inequities. As the GR example suggests, this narrative sees technological and scientific discovery (and its commercialisation) as a motor for economic growth (Giuliani, 2018; Schot and Steinmueller, 2018) and is still alive in the innovation narrative of the CGIAR, even if this narrative has evolved during the years to become more encompassing of alternative and wider forms of innovation (Fredenburg, 2011; Cabral and Sumberg, 2022).

This long-standing narrative has recently responded to the transformation agenda by once again presenting technological breakthroughs as not simple accelerators for economic prosperity, but as a way to succeed in delivering sustainability (Potrykus, 2010a; Maclennan *et al.*, 2018; Davis *et al.*,

[30] The CGIAR Research Centres are non-profit research organizations, member of the CGIAR Consortium that, in collaboration with national and regional research organisations, academia, the private sector civil society and other actors operate globally to disseminate knowledge, technologies, and policies for agricultural development (https://eatforum.org/partner/cgiar/).

2019). This has justified renewed R&D investments from the public and private sectors in R&D to provide technologies with better environmental performance, for example, digitally enabled precision agriculture (Oliver, Bishop and Marchant, 2013), and improve food availability and nutrition worldwide, for example, foods with functional properties (Regis, 2020; Conti, Hall and Hambloch, 2021). The narrative legitimises the idea that stand-alone technology continues to be aligned with the business model of public AFRO and the private sector.

6.2.2 The "directing innovation for tackling grand challenges" narrative

Unlike the previous narrative that saw technologies' contribution to transformation through a general economic growth lens, this narrative explicitly articulates the need to purposefully direct innovation toward delivering sustainability, greener economic growth, and social inclusion. Often, this proposition is accompanied by an unequivocal mandate to disrupt the direction and structure of existing innovation systems (Schomberg, 2011; Bogner and Torgersen, 2018; Rose and Chilvers, 2018; van der Burg, Bogaardt and Wolfert, 2019; Klerkx and Begemann, 2020). This narrative is underpinned by the understanding that innovation has both a pace and a direction (the purposes to which it is deployed) (Duncan *et al.*, 2022). While AFROs have a critical role in stimulating innovation through R&D that can meet these objectives, public policy is also a key player in de-risking uncertain innovation ventures and safeguarding the preservation of the established directionality (Schot and Steinmueller, 2016; Wanzenböck *et al.*, 2020; Loos, 2021).

Over the years, two major approaches have emerged in the literature as a way forward for this. Responsible Research and Innovation (RRI) recognises that technological innovations are key to addressing societal challenges but can also have adverse societal consequences (Gremmen, Blok and Bovenkerk, 2019). To balance the economic, sociocultural and environmental aspects of innovation processes, RRI encourages stakeholder involvement (in agri-food systems and beyond) from an early stage (European Commission, 2011; Bronson, 2018). The logic is that multiple actors can be accountable and mutually responsive for the acceptability, sustainability and societal desirability of the innovation process and its marketable products (Bronson, 2018, 2019; Rose and Chilvers, 2018). However, others argue that RRI approaches may reinforce perceptions that novel technology will be the main driver for transformation, excluding other forms of innovation that may also be required (Eastwood *et al.*, 2019).

The second approach is Mission-Oriented innovation policy. Mission approaches are premised on the idea that time-bound public investments to tackle tightly specified societal challenges can act as a way of marshalling and redirecting research and innovation across the innovation system,

establishing new innovation capacities and trajectories (Mazzucato, 2018a). It is argued that, once established, these innovation trajectories de-risk private investment in products, services and business value propositions aligned with sustainable development objectives. (Mazzucato, 2016; Kattel and Mazzucato, 2018; Hekkert *et al.*, 2020; Klerkx and Begemann, 2020). Explicit in this prospect is the desire to catalyse disruption in the innovation system, creating new capacities for directed innovation (Boorman, Jackson and Burkett, 2023). Mission approaches are at a relatively early stage of development (Wanzenböck *et al.*, 2019). However, there are already concerns emerging that the path dependency of incumbent systems (for policy and sector silos, entrenched research practices and associated performance measures) may yet frustrate a potentially powerful approach (Björk *et al.*, 2022).

6.2.3 The "system replacement from the margins" narrative

A narrative that is becoming increasingly prominent originates in concerns that the current global food system is driven by, and result of a capitalist logic and that this consolidates injustices and unsustainability (Gahman *et al.*, 2022; Borras, 2023). This narrative suggests that the only way to achieve just and sustainable outcomes is to introduce or develop entirely new systems. To do this, it is suggested that previously marginalised players, such as civil society movements and indigenous and local communities need to be placed in the centre of the innovation and reconfiguration process of the food system (Putnam *et al.*, 2014; Gliessman, 2023). In this way, it is argued that transformation involves fundamentally restructuring the food system from the bottom-up, with previously marginalised players holding power to dismantle current structures and re-build these to comply with (locally envisioned) principles of equity, justice, and democracy (IPES-Food & ETC Group, 2021; Domptail, Hirsch and Nuppenau, 2023). This narrative stresses the need for diverse, grassroots and democratically driven transformation*s* from below, which, if underpinned by different sustainability visions unique to each place, succeed in breaching the industrial food system and replacing it with transformed and place-specific ones (Martínez-Torres and Rosset, 2010; Pimbert, 2017, 2022). This narrative has manifested itself through the emergence of several "alternative" or replacement agricultural systems ideas. For example, agroecology perspectives advocate for a shift to fundamentally re-designed food systems governed by principles of human rights and food sovereignty (De Schutter, 2010). Regenerative agriculture movements and advocacy is another example of the growing prominence of "alternative" or replacement agricultural systems ideas that are founded on ecological and social justice principles (Gosnell, Gill and Voyer, 2019; Breier *et al.*, 2023).

However, the way that AFROs should engage with the system replacement narrative is less clear (Sumberg and Giller, 2022). Transdisciplinary sustainability science and co-production research and innovation approaches are emerging as a suite of practices that enable the inclusion of a diversity of knowledges, values and beliefs into research and innovation practice (Clark and Harley, 2020; Wibeck, Eliasson and Neset, 2022). Prominent in such approaches is the recognition that this is not simply "assimilating" local and indigenous knowledge systems into western science but rather be considered as equally valuable for opening sustainable development pathways (McAllister *et al.*, 2019; Leventon, Duşe and Horcea-Milcu, 2021; Reid *et al.*, 2021). On-farm experimentation is another example of developing ways to support farmers in engaging with "alternative" farming systems practices to frame and undertake experiments driven by their own values and physical and temporal scales (Cook *et al.*, 2013; Lacoste *et al.*, 2021). Differently, citizen science challenges "traditional" science structure and research by stressing the need for public participation for a more democratic research process (Bonney *et al.*, 2016; Steinke, van Etten and Zelan, 2017). With all the research and innovation approaches associated with this narrative, there is a recognition that significant capability and capacity development efforts are going to be needed to equip AFRO to effectively engage in these more bottom-up and democratic innovation processes (Hall and Nahdy, 1999; Lacoste *et al.*, 2021).

6.2.4 The "system innovation for transformation" narrative

This narrative recognises that all elements of the current agri-food systems - existing behaviours and knowledge, capabilities and skillsets, consumer practices and markets, as well as infrastructure, institutions and policies- are not only unfit to purpose to meet sustainability objectives (OECD, 2015; Ojha and Hall, 2021). They also act as mutually-reinforcing factors of unsustainability (de Schutter, 2019; Conti, Zanello and Hall, 2021). The narrative frames transformation as a process of system-level innovation that fundamentally redesigns the system, orienting it towards delivering outcomes valued by society (Weber and Rohracher, 2012). The narrative recognises such system-level innovation will be not only costly and politically onerous, undermining incumbents' interests (Kennedy *et al.*, 2021), but also highly uncertain, with the quest for sustainable pathways possibly leading to unknown ends (Stirling, 2014a). This narrative further recognises that transformation will likely be both bottom-up and top-down. For instance, flourishing research debates on sustainability transitions have stressed the role of niches (protected spaces where innovation can emerge and be experimented with) to challenge the existing system (Bui, 2021). Other debates emphasise how a transformation to sustainability will be a negotiated process between all food system actors and largely driven and incentivised by policy and regulation (Grillitsch *et al.*, 2019).

One research and innovation approach suggested to engage with this understanding of transformation is the "pathway" approach, which understands that achieving sustainability will entail broad consultations that acknowledge the existence of "diverse sustainability goals and tackle the associated trade-offs" (Leach, Scoones and Stirling, 2007; Leach, Scoones and Stirling, 2010). Similarly, debates around transformative innovation policy and approaches (Diercks, Larsen and Steward, 2019; Haddad *et al.*, 2022), such as working in transformative spaces (Pereira, Karpouzoglou, *et al.*, 2018), propose collaborative environments that promote dialogue and reflexive learning among multiple stakeholders for elaborating solutions and strategies for achieving sustainability (Pereira, Frantzeskaki, *et al.*, 2020). The emphasis in both is experimentation and learning in both policy and practice and fostering the learning connections between these two domains. The role of AFROs in this process has yet to be definitively defined. One role could in supporting niche-level experimentation (Gamache *et al.*, 2020). This could imply convening and facilitating collective visioning, learning and innovation processes among stakeholders. It could also involve brokering between contending interests and opposing values and creating broader coalitions needed to prompt a transformation at scale towards collectively agreed visions of sustainability (Klerkx *et al.*, 2017; Hainzelin *et al.*, 2023). Different again, it could be about undertaking analysis to alter policy to unintended consequences of transformation or alternatively analysis that supports learning about how transformation can be accelerated into to achieve societal goals (Turner, Klerkx, Rijswijk, *et al.*, 2017). The narrative stress the importance of highly experimental, transdisciplinary, and reflexive approaches that can embrace the complexity and uncertainty of agri-food system transformation (Stirling *et al.*, 2008; Beck *et al.*, 2021).

Table 6.2.4

Narratives emerging from the literature, theory of innovation for transformation, school of thought, core research and innovation practices and key references.

Narrative	Theory of innovation for transformation	School of thought	Core Research and innovation practices	References
Technology for transformation	Technological innovations can be the way to achieve both economic growth and address sustainability concerns.	Commodity oriented R&D	High investments on promising scientific discoveries that can have economic returns.	(Greenland, 1997; Pingali, 2001; Bongiovanni and Lowenberg-Deboer, 2004; Scrinis and Lyons, 2007; FAO, 2009b; Potrykus, 2010b; Fredenburg, 2011; Oliver, Bishop and Marchant, 2013; Sreewongcha and Nakasathien, 2015; Patrício and Rieder, 2018; Smith and Smith, 2018; World Economic Forum, 2018; Maru *et al.*, 2018; Palazzi *et al.*, 2019; Shepherd *et al.*, 2020; Voytovych, Smolynets and Hirniak, 2020; Di Vaio *et al.*, 2020; Lajoie-O'Malley *et al.*, 2020; Zhang *et al.*, 2021; Fleming *et al.*, 2021; Goh and Vinuesa, 2021; Cabral and Sumberg, 2022)
Technologies directed to the public good	Technological innovations are essential for meeting sustainability target, but they	RRI	Targeted efforts to ensure stakeholder involvement and openly discuss ethical issues and social desirability of technologies.	(Schomberg, 2011; Von Schomberg, 2011, 2019; European Commission, 2011; von Schomberg, 2012; Owen, Bessant and Heintz, 2013; Bronson, 2018; Rose and Chilvers, 2018; Bronson, 2019; Eastwood *et al.*, 2019; Gremmen, Blok and

	need to be carefully directed to avoid adverse outcomes.			Bovenkerk, 2019; Owen, von Schomberg and Macnaghten, 2021; Simelton and McCampbell, 2021; Wakunuma *et al.*, 2021; Eastwood, Edwards and Turner, 2021; Bellon-Maurel *et al.*, 2022; Tabarés *et al.*, 2022; Kuzma, 2022; Craigon *et al.*, 2023)
		Missions	Time bound efforts that can drive markets and innovation systems to tackle grand challenges.	(Mowery, 2009; Mazzucato, 2018a, 2018b, 2016; Mendonça, van Aduard de Macedo-Soares and Fonseca, 2018; Kattel and Mazzucato, 2018; Wanzenböck *et al.*, 2020; Brown, 2020; Cappellano and Kurowska-Pysz, 2020; Hekkert *et al.*, 2020; Klerkx and Begemann, 2020; Bugge, Andersen and Steen, 2021; Björk *et al.*, 2022; Boorman, Jackson and Burkett, 2023; Nylén, Johanson and Vakkuri, 2023; Eastwood *et al.*, 2023)
Diversity for transformation from the margins	It is necessary to shift to much more plural, bottom up, participatory forms of research for addressing	Agroecology and regenerative agriculture	Substitutive system to the industrial agriculture one, rooted on human rights, social justice, food sovereignty and diversity.	(Pimbert *et al.*, 2001; Francis *et al.*, 2003; Martínez-Torres and Rosset, 2010; De Schutter, 2010; Gliessman, 2013, 2023; Putnam *et al.*, 2014; Pimbert, 2017, 2022; Mier y Terán Giménez Cacho *et al.*, 2018; Anderson *et al.*, 2019; Gosnell, Gill and Voyer, 2019; Ryschawy *et al.*, 2019; Tornaghi and Dehaene, 2020; Anderson and Maughan, 2021; IPES-Food & ETC Group, 2021; Quintas-Soriano, López-

	equity and inclusion concerns.			Rodríguez and Wilkes, 2022; Gahman *et al.*, 2022; Guerrero Lara *et al.*, 2023; Borras, 2023; Breier *et al.*, 2023; Domptail, Hirsch and Nuppenau, 2023)
		Sustainability science	Importance of knowledge co-production, need to include plural, tacit and until-now marginalised knowledge(s) into a anti-elitist, inclusive and transdisciplinary quest for sustainability.	(Clark, 2007; Kajikawa, 2008; Jerneck *et al.*, 2011; Kates, 2011; Whyte, Brewer and Johnson, 2016; Smith *et al.*, 2018; Messerli *et al.*, 2019; Schneider *et al.*, 2019; Clark and Harley, 2020)
		Citizen science	Public participation in scientific research, in particular, with members of the public partnering with professional scientists.	(Irwin, 1995; Bonney *et al.*, 2016; Dehnen-Schmutz *et al.*, 2016; Beza *et al.*, 2017, 2018; Pollard, Roetman and Ward, 2017; Steinke, van Etten and Zelan, 2017; Ryan *et al.*, 2018; van de Gevel, van Etten and Deterding, 2020; Mourad, Hosseini and Avery, 2020; Ebitu *et al.*, 2021)
		Plural knowledge systems	Need to address historical issues such as (de)colonisation, and de-westernize science to include indigenous and traditional knowledge.	(Hoppers, 2002; Pimbert, 2017; Díaz *et al.*, 2018; McAllister *et al.*, 2019; Zafra-Calvo *et al.*, 2020; Zanotti *et al.*, 2020; Hill *et al.*, 2020; Jacobs *et al.*, 2020; Chakraborty *et al.*, 2021; Reid *et al.*, 2021; Stevens, Paul-Burke and Russell, 2021; Leventon, Duşe and Horcea-Milcu, 2021; Delgado *et al.*, 2022; Suarez *et al.*, 2022; Rarai *et al.*, 2022)

Transforming innovation	Transformation requires system level innovation to deliver broad outcomes of social, environmental, and economic viability.	Transformative innovation	Search for transformative opportunities, under uncertain and unpredictable conditions (no established end).	(Stirling *et al.*, 2008; Scrase *et al.*, 2009; Weber and Rohracher, 2012; Stirling, 2014a; OECD, 2015; Schot and Steinmueller, 2019; Fagerberg, 2018; Schot and Steinmueller, 2018; Diercks, Larsen and Steward, 2019; Grillitsch *et al.*, 2019; Scoones *et al.*, 2020; Beck *et al.*, 2021; Ghosh *et al.*, 2021; Ojha and Hall, 2021; Haddad *et al.*, 2022; Parks, 2022)
		Pathways and transformative spaces	New more plural and democratic approaches to development and/or sustainability. Sustainability highly context specific and political.	(Geels, 2011; Fares, Magrini and Triboulet, 2012; Hinrichs, 2014; Darnhofer, 2014; Meynard *et al.*, 2016; Pereira and Drimie, 2016; Bui *et al.*, 2016b, 2019; Baret, 2017; Feyereisen, Stassart and Mélard, 2017; Magrini *et al.*, 2018; Pereira, Hichert, *et al.*, 2018; De Herde *et al.*, 2019; El Bilali, 2019a, 2019c; Farstad *et al.*, 2020; Pereira, Drimie, *et al.*, 2020; De Herde, Baret and Maréchal, 2020; Della Rossa *et al.*, 2020; Bui, 2021; Truffer *et al.*, 2022)
		Sustainability transitions	Science and innovation to support socio-technical reconfigurations toward more sustainable systems.	(Geels, 2011; Fares, Magrini and Triboulet, 2012; Hinrichs, 2014; Darnhofer, 2014; Meynard *et al.*, 2016; Pereira and Drimie, 2016; Bui *et al.*, 2016b, 2019; Baret, 2017; Feyereisen, Stassart and Mélard, 2017; Magrini *et al.*, 2018; Pereira, Hichert, *et al.*, 2018; De Herde *et al.*, 2019; El Bilali, 2019c, 2019a;

				Farstad *et al.*, 2020; Gamache *et al.*, 2020; Pereira, Drimie, *et al.*, 2020; De Herde, Baret and Maréchal, 2020; Della Rossa *et al.*, 2020; Bui, 2021; Truffer *et al.*, 2022)

6.3 Key Points of difference across the narratives: a framework for developing scenarios for AFROs of the future

By presenting the narratives, the paper demonstrates the existence of sometimes very different, sometimes overlapping, axes of perspectives regarding the role of AFROs in supporting a sustainability shift. In particular, two major axes of debate emerge from the literature, representing recurrent themes in the selected publications.

Axis 1. Technological potential for transformation. The first axis revolves around the role of technology in transformation. In some narratives, the development of new technologies plays a central role in achieving a sustainability shift, whereas in others, this role is more marginal. The "silver-bullet technologies for transformation" and the "directing innovation for tackling grand challenges" highly rely on the potential of technological innovation for responding to present challenges, and believe AFROs have a critical role in this in terms of producing and, particularly in the "directing innovation for tackling grand challenges" narrative, help to harness these technologies. Whereas these two narratives are technology "optimists" (Klerkx et al., 2022), the other two do not put particular emphasis on this, instead advocating for a much broader system reframing to ensure all elements (not only technologies, but also behaviours, institutions, political and power patterns) are redesigned to deliver sustainability, and technology will only be one part of this.

Axis 2. The scope of interests covered. The "silver-bullet technologies for transformation" and, ironically, the "system replacement from the margins" have relatively narrow interests in view. In the first, transformation is seen as a process where AFROs mainly deliver technological breakthroughs that, if contributing to sustainability, largely profit to powerful food system players (e.g., industries) deploying (and generating economic returns) from them. This leaves power relations undisturbed, with many actors (such as civil society) left out of the "sustainability" debates. The other narrative takes a seemingly diametrically opposite position, advocating for the primacy of marginalised actors in the sustainability debates. However, if underpinned by good intentions, this narrative, in truth, equally excludes incumbent actors from the debates in favour of the interests of communities wanting to replace the current systems. Instead, the "directing innovation for tackling grand challenges" and the "system innovation for transformation" understand that transformation will be a huge collective effort that by necessity will involve large coalitions working together towards the realisation of a common sustainability vision.

Two additional considerations cut across these axes.

One is around the **bottom-up or top-down type of approaches** that transformation that needs to be deployed for transformation. Both the silver-bullet technologies for transformation and directing innovation for tackling grand challenges narratives see transformation as a mainly top-down process. For the first narrative, this is driven by incumbents investing in research and innovation activities for producing new technologies; for the first, this is driven by a public sector which de-risks "risky" innovation venues and ensures the directionality of the process. On the contrary, for the system replacement from the margins narrative, transformation is largely bottom-up, with communities and marginal actors actively disrupting power structures, and AFROs focusing on nurturing niches willing to experiment with novel and largely local alternative pathways that can challenge the *status quo*. The system innovation for transformation narrative takes a middle-way stand on this, recognising both the importance of bottom-up disruption and the need for top-down support for transforming food systems.

The other element, more controversial to assess, is the **level of system reformatting** proposed by each narrative. The silver-bullet technologies for transformation narrative has ambitions to change the performance of specific parts of the system (productivity, farming system sustainability) without fundamentally altering its present configuration. Differently, the directing innovation for tackling grand challenges understands the need to alter the system direction through some form of coordinated changes across different elements, a recognition even more explicit in the system replacement from the margins and system innovation for transformation narratives that, if in different ways, aim for fundamentally reconfigured systems.

We now use these axes (summarised in Table 6.3) and elements of debates to build scenarios for AFROs of the future.

Table 6.3 Key points of difference across the narratives

	Silver-bullet technologies for transformation	**Directing innovation for tackling grand challenges**	**System replacement from the margins**	**System innovation for transformation**
Technology	Optimist	Optimist	Pessimist	Pessimist
Scope of interests	Narrow	Broad	Narrow	Broad

Approaches	Top-down	Top-down	Bottom-up	Top-down & Bottom-up
Level of reformatting	Low	Medium	High	High

6.4 Scenarios

The narratives help to highlight fundamentally different worldviews on the visions of future AFROs, underpinned by fundamentally different priorities, type of actions, actor involvement and visions of success for AFROs. Based on the analysis of the axes and considerations above, we now describe four scenarios: An industry transition-oriented scenario (scenario one); A technology mission-oriented scenario (scenario two); A community innovation-oriented scenario (scenario three); and a facilitating transformative innovation-oriented scenario (scenario four).

6.4.1 Scenario One: Industry transition-oriented

In this scenario, agri-food system transformation is understood as a process by which existing industries transition to more sustainable pathways through the adoption of new technology. AFROs are thus embedded in an R&D-centric agricultural innovation system that is geared towards market mechanisms allocating R&D resources and set innovation directions.

The central role of AFROs in this scenario is as an R&D agency that develops and supplies technology. AFROs have a strong partnership with industries, which co-invest in R&D and provide demand signals for Research and Innovation. Public policy is focused on allowing the market to allocate R&D funding and drive innovation aligned to sustainability objectives. The main role of public policy is to address market failures in funding allocation. Impact planning and technology choice mechanisms are articulated in strategic plans developed by AFROs. However, impact ambitions of AFROs are ultimately influenced by funding relationships with industries. In some cases, this might be powerful philanthropic funding bodies associated with major global industry players. While AFRO's track their impact performance, metrics around technology commercialisation and revenue achieved are also prominent. Core features of the organisational culture include entrepreneurship, customer focus and IP capture, although there may be tensions in these organisations with more traditional public science values and culture. Capability mixes for this type of AFROS include applied science and technology, engineering, economics and market engagement. Economic and social scientists have a less prominent role and focus on *ex-ante* and *ex-post* impact appraisal of technology options.

6.4.2 Scenario Two: Technology mission oriented.

This scenario shares the belief of the above in terms of the importance of technologies for delivering sustainability but recognizes that this will be part of a process of disrupting existing industries and creating new industries. Public policy is proactive in ensuring that innovation is directed towards sustainability by giving high priority to novel technological solutions for social challenges such as emissions reduction, waste reduction, food and nutritional security and so forth. AFROs are embedded in an R&D-centric innovation system that integrates agricultural innovation with innovation in allied sector. The system is geared towards the assimilation (deployment and use) of novel sustainability technologies through regulation and incentives, including investment in technological capability in incumbent and new industries.

The central role of AFROs in this scenario is as an R&D agency that develops and supplies technology. AFROs are mainly publicly funded with priorities purposefully aligned with national and international sustainability goals. Public funding is justified not just on market failure arguments, but also on systems failure arguments and the value of shaping innovation trajectories towards new social goals. AFROs establish networks and collaborations with the national and international scientific communities to access frontier knowledge to drive novel technology development. The is focus on the on the intersection agriculture of agriculture and food challenges, with scientists drawing on science and technology in other sectors and disciplinary fields (energy, transport, artificial intelligence and so forth). Technology missions are a key approach for focusing and accelerating research and innovation in defined challenge spaces. Responsible research and innovation approaches are routinely used to build social licence for contentions or disruptive technology solutions. The culture of the organisation is problem-solving spurred by scientific curiosity. The fast-paced production of these new technologies is motivated by a quest to respond to society's grand challenges rather than serving the interest of individual industries or stakeholder groups. The main accountability and performance measures include science metrics and science reviews, but these are combined public value impact assessments, for example, contributions to emissions reduction or improvements in food security. Capability mixes include applied science and technology and eengineering and economic and social sciences, but often clustered in multi-disciplinary groups. Economic and social science undertake *ex-ante* and *ex-post* impact assessment. Particular attention is given to brokering partnerships and diagnosing and designing effective innovation processes.

6.4.3 Scenario Three: Community innovation-oriented

In this scenario, the transformation agenda is framed specifically to achieve more democratic and just agri-food systems. The focus is on addressing complex societal and often place-based issues such as inequality, injustice, decolonisation, and food sovereignty. AFROs are embedded in a co-design and people-centred innovation system, geared towards supporting highly decentralised innovation processes with a strong role of local actors in governance arrangements.

The central role of AFROs is to provide research support to civil society and grassroots movements in their efforts to develop solutions local sustainability and inclusion issues. With public policy focusing on regional social development outcomes, publicly-funded AFROs structure themselves as a geographically decentralised network of local research centres, as part of a wider strategy of strengthening local innovation capacities. Working from the bottom-up, AFROs establish novel partnerships with civil society organisations and networks, as well as universities and other research centres, to co-develop context-relevant, applied science advances. Research priorities are demand-led by local communities and are often funded through regional development initiatives. Research approaches are highly applied and use co-innovation and co-production methods to build inclusive innovation processes to address structural and often cross-sectoral challenges (e.g., agriculture, food, nutrition, energy, health etc.). A highly democratised research culture applies sustainability science in place-based research to generate local solutions, and the innovation system becomes a mosaic of local/regional networks with strong community governance and leadership. Innovation performance is measured in terms of impacts on community-level issues. Research organisations are highly accountable to the community and associated governance mechanisms. Capability mixes are weighted towards the social and ecological sciences and organised in transdisciplinary teams and are often focused on bridging local and scientific knowledge systems and values.

6.4.4 Scenario Four: Facilitating transformative innovation-oriented

In this scenario, the transformation agenda if framed by the recognition that transformation will be complex, highly uncertain, and politically challenging and as such will need to be approached experimentally. Innovation is likely to be social rather purely technical involving brokering and negotiation of contending interests in society, as well as facilitation of the development and testing of solutions along uncertain innovation pathways. In this scenario, AFROs are embedded in experimentation-centric innovation systems geared towards plurality of innovation pathways, with a diversity of sources of innovation including, but beyond, R&D and with collaborative/top down bottom up governance arrangements.

The role of AFROs is as transformative innovation facilitation agencies highly networked into the broader innovation system, where they play an intermediary function. This function involves stimulating the reflexivity, evaluation, learning, and adaptive management processes that supports innovation. AFROs have core public funding to maintain critical research infrastructure and capability where "everybody likes an innovation broker, but nobody wants to pay for one". This is part of a wider public value justification premised on system failure arguments. However, AFROs rely on a consulting business model advising and facilitating innovation and change processes that industry and civil society groups are navigating and experimenting with. AFRO priorities emerge from their interaction with their broad network and in part are driven by demands from a market for sustainability innovation facilitation services. AFROs supports both top-down (policy driven) and bottom-up (community and industry driven) approaches to experiment with sustainability solutions. An important part of AFROs role is supporting innovation connections between agriculture and other sectors to address cross-sectoral challenges. AFROs culture centres around the value of collaborative approaches as well as reflexivity and experimentation, what works where how and for whom, rather than emphasising particular technological solutions or disciplinary approaches. AFROs mandate is focused on the reconfiguration of food systems and part of this mandate is providing evidence and advising public policy on sustainability. Key performance measures include both public value impacts, such as emissions reduction and food security, as well as outcomes related to the emergence of more democratic direction and steering arrangements aligned to sustainability. Capability mixes are weighted towards social and ecological sciences that are organised in transdisciplinary teams, and use facilitation and complexity-aware innovation process design approaches.

6.5 What issues do the scenarios reveal for further consideration

All the scenarios above present a vision for the role AFRO could play in the transformation of agri-food systems towards more environmentally and socially inclusive pathways. Each scenario attempts to encapsulate a particular worldview of how transformation could be achieved (Reilly and Willenbockel, 2010). The purpose of this paper is not to argue that any one of these presents an ideal option, as each has its own strengths and drawbacks. Rather the purpose is to help reveal the issues at stake that will need to be considered in deliberations about the role and *modus operandi* going forward. We discuss these issues by exploring six themes.

6.5.1 Core strengths, contradictions, and trade-offs.

Scenario One, industry transition-oriented, places technology at the centre of the transformation agenda. This exploits the traditional strength of AFROs in leveraging the power of science and technology to solve pressing problems (Schot and Steinmueller, 2018). However, this scenario would leave the responsibility for tackling other non-technical dimensions of the transformation process to other players. This would mean, for instance, that new capabilities and regulations to enable the use of new technology would need considerable industry and policy attention (Ptak, Graversgaard and Dalgaard, 2023). The need to break existing path dependencies and deal with the contested nature of change would probably need additional and purposeful governance arrangements to be in place that specifically address this dimension (Fesenfeld *et al.*, 2020; Dobermann *et al.*, 2022). This would need to be handled outside the scope of what AFROs are responsible for.

The second scenario, technology mission-oriented, similarly places technology at the centre of the transformation process, equally playing on the traditional strengths of AFROs (Klerkx and Rose, 2020). The scenario also exploits public policy's power to set new directions for innovation through missions and similar ways of targeting innovation towards transformation (Kattel and Mazzucato, 2018; Mazzucato, 2018a), exploiting existing relationship AFROs may have with industry (Hannon, 2016). However, the scenario's focus on top-down efforts to redirect innovation towards sustainability may overlook the potential of bottom-up and community-led innovation for sustainability (Diercks, Larsen and Steward, 2019), such as food movements, ecologically sensitive farming approaches and so forth. This could result in overlooking opportunities for AFROs to use research and technology to leverage and scale promising and often unconventional forms of innovation emerging from the margins. Instead it could carry forward a "naïve belief" that governments and public AFROs "knows best" in terms of what can enable transformation (Kirchherr, Hartley and Tukker, 2023).

The third scenario, *community innovation-oriented*, is an altogether new territory for AFROs that exploits the power of human-centred innovation processes (Biggeri and Ferrannini, 2014). While this could help with much-needed place-based solutions (Pereira, Frantzeskaki, *et al.*, 2020), other research and innovation mechanisms would need to be implemented to tackle issues at regional, sector or national scales. The fourth scenario, *facilitating transformative innovation-oriented,* presents a yet more radical vision of AFROs. It does, however, exploit the neutrality and legitimacy of AFRO's for broking and negotiating different visions and pathways to sustainability across

multiple food systems actors (Klerkx *et al.*, 2022). The risk, common perhaps with the third scenario, is that this type of AFRO might undervalue traditional skills and comparative advantage in research and technology that have served well in the past (Schot and Steinmueller, 2018). These capabilities might need to be housed elsewhere.

6.5.2 Alignment with existing capability

As already discussed, scenarios one and two are highly aligned with AFROs existing capability in science and technology development and would require complementary capability in topics such as responsible innovation or missions (Bugge, Andersen and Steen, 2021; Espig *et al.*, 2022), instead of proposing fundamental overhauls of these organisations (Wojtynia *et al.*, 2021). In contrast, scenarios three and four will require the development of radically new capabilities (Fazey *et al.*, 2017; Ministry of Business, 2021). In the case of scenario three, this will be capability in terms of community engagement, sustainability science and related forms for human-centred design approaches, on-farm experimentation, transdisciplinary, co-production and co-design approaches (discussed earlier in and in table 6.2) (Schneider *et al.*, 2021; Wibeck, Eliasson and Neset, 2022; Kok *et al.*, 2023). In the case of scenario four, this capability will need to be in areas such as visioning, foresight and coalition building (Den Boer, Broerse and Regeer, 2021; Leeuwis, Boogaard and Atta-Krah, 2021). While these types of skills are starting to appear in AFROs, scenarios three and four suggest that these would need to become core areas of expertise, rather than areas of capability that support core research and technology development capability (Caniglia *et al.*, 2021; Körner, Thornton and Klerkx, 2022). However, it is important to flag that considerable costs both in terms of time and financial investments will be required to develop different capabilities and skillsets that enable AFROs to pursue novel impact pathways and outcomes.

6.5.3 Alignment with existing roles and mandate of AFRO

As illustrated above, the four scenarios present progressively more radical visions of AFROs roles and mandates. This alerts us to the level of disruption and legitimation of AFROs' roles, that would need to be negotiated with sector stakeholders, policy and perhaps society as a whole. Scenario one is highly aligned with AFROs existing role of supporting agriculture and food production and the industry players associated with this agenda (Giuliani, 2018). As such it presents the path of least resistance in terms of social and political acceptance. In scenario two, the sector focus on agriculture and food industries remains, but the transformation agenda will demand more boundary work will allied sectors such as, for example, in the case of emissions reduction, energy, transport and manufacturing (Ghodsvali, Krishnamurthy and de Vries, 2019; Cappellano and

Kurowska-Pysz, 2020). In scenario three, the role and mandate of AFRO's will need to broaden out considerably to address a range of community issues in the rural sector that include agriculture and food industry, and go beyond these to include, for instance, dimensions regarding indigenous people, minorities, and food sovereignty (Kropp, Antoni-Komar and Sage, 2020; Espluga-Trenc *et al.*, 2021). This presents a considerable reframing of the role and mandate for most AFROs, challenging existing relationships and legitimacy to operate. Scenario four reframes the domain, mandate and impact aspirations of AFRO's from agri-food industry to agri-food system, as this scenario will inevitably encompass a much broader set of interests and pathways and will imply a fundamentally different way of engaging with sustainability challenges (Grillitsch *et al.*, 2019). As with scenario three, challenging existing relationships and legitimacy to operate might call for new alliances with both industries and the civil society (Weber and Rohracher, 2012; Herrero *et al.*, 2021).

A further issue for consideration is the way the scenarios align with the existing mandate of AFROs of balancing more immediate, demand-led, but often incremental research, with long-term and discovery research focused on creating more radical venues of innovation (Glover *et al.*, 2021; IPES-Food & ETC Group, 2021). Each of the scenario implies dealing with this in different ways. For example, scenario two explicitly shifts the balance of research and technology development focus towards the radical or transformative end of the spectrum. In contrast, scenario three with its focus on serving the needs of local communities, would seem to imply shifting the balance to the more demand led and incremental end of the spectrum. Ways of achieving this balance between serving todays sustainability needs and being prepared for the unpredictable research and innovation challenges that lay ahead is going to need careful consideration (Glover *et al.*, 2021).

6.5.4 Risks for AFROs under different scenarios

Many general risks associated with the scenarios have started to reveal themselves in the discussion above. However, each scenario is associated with specific risks. In the case of scenario one, existing relationships with major industry players may make it difficult to pursue new and disruptive pathways to sustainability in cases where these threaten incumbent interests (Anderson and Maughan, 2021; IPES-Food & ETC Group, 2021). This may also be a consideration in scenario two. A more important risk consideration for scenario two is that it might alienate existing and long-standing partnerships, particularly with industry players vulnerable to disruption (Hall and Dijkman, 2019). This might result in loss of political support and revenue from industry. Scenarios three and four may well encounter similar political and revenue loss risks. However, specific risks

for scenario three are that it will lead to the hollowing out of core capability in research and technology development. This could undermine the ability of a sector of country to absorb new science and technology from other countries and sources (Leitch and Harrison, 2005; Breznitz, O'Shea and Allen, 2008; Youtie and Shapira, 2008). Scenario four also risks this same hollowing out of research and technology capability. This might, in turn, create a risk in terms of undermining a sector or country's ability to collaborate in international research and innovation networks and influence the international agenda, for example on climate change.

There are of course ways a of mitigating these risks through adaptations in the broader innovation system to ensure capability gaps are filled, suitable funding mechanisms are in place, direction setting mechanisms are strong, and coordination is effective (Dinesh, Hegger, *et al.*, 2021; Körner, Thornton and Klerkx, 2022). However, just as the scenarios presents progressively more radical interpretation of the role, mandate and *modus operandi* of AFROs, each scenario will require an innovation system that is progressively going to embrace new minor to major adaptions (Koerner *et al.*, 2023). This raises a further risk associated with the urgency of the transformation agenda and need for AFROs to respond to it in a timely fashion. The major overhaul of the innovation system implied by scenarios three and four, even if they were politically feasible, could be a decades-long organisational and institutional reform project, as would the development of associated capabilities in the AFRO themselves. This temporal dimension will need to be given serious consideration (Weiser *et al.*, 2017; Conti, Zanello and Hall, 2021).

6.6 Conclusions

This paper illustrates different AFROs scenarios by conducting an analysis of current research narratives and identifying critical axes of debates within these. The scenarios of AFROs developed in this paper reflect a reality that there are divergent views on the role, *modus operandi* and contribution of research and innovation in the agri-food system transformation agenda (Klerkx *et al.*, 2022). None of these differences can be resolved by expert analysis as there are divergent yet legitimate political and philosophical viewpoints amongst stakeholders, that will have to be navigated (Scoones, 2016). As Foran et al. (2014) points out in respect to the notion of agri-food systems, not only can such differences not be reconciled, it also may not be useful to try and, instead, it would be better to embrace the diversity that these represent. The question remains, however, as to how this diversity of ideas can best be harnessed (Scoones, 2016; Kenter *et al.*, 2019). For AFROs, difficult and potentially contested choices lay ahead.

Given the broad industry, policy, and societal interests (and stake-holding) of AFROs, decisions about future pathways should not be made unilaterally and are likely to encounter opposition if they are. This seems to suggest that discussions and consultations will be need be inclusive of a variety of differ perspectives and interests. In reality, consensus is unlikely to be reached, but compromise on priority pathways for AFROs will be essential (Eakin *et al.*, 2017; de Cleene, 2019). The role of the scenarios presented in this paper could provide a boundary object (Morris *et al.*, 2021) to support reflection on what features of AFRO's operating model and objectives would be valued in relation to the agri-food system transformation agenda. The analysis of the scenarios in this paper identifies several issues that need to be considered in this reflection on the valued features of different AFRO prototypes. This analysis is not definitive but highlights the existence of strengths, weaknesses, trade-offs, risks and political challenges with different visions of AFROs. This could be a starting point to help structure broader discussion around the scenarios. However, it is important to highlight that the scenarios do not represent "discrete roles" that AFROs will have to assume. It is likely that, given the urgency of reconfiguring food systems, a more advantageous option would be a portfolio approach that combines different AFROs, based on the contextual relevance, feasibility, and short-term as well as long-term objectives that might vary across geographies and at different points of time.

A final point opened by the analysis of the different scenarios is that any discussion of the reframing and reorganisation of AFROs cannot be separated from a discussion about the nature of the agricultural innovation system and how this can be better aligned to the transformation agenda (Tomich *et al.*, 2019; Koerner *et al.*, 2023). The ability of AFROs to prosecute their role and mandate is always going to be mediated the "health" of the innovation systems. In most countries, the purpose for which the agricultural innovation systems is being developed (economic growth and or social inclusion and or food security) remains ambiguous. How the question of "innovation systems for what" is becoming an increasingly relevant policy concern (Frost *et al.*, 2019). This suggests that if AFROs are going to start and reflect with their stakeholders on possible organisational reforms and priority values, that this cannot be done in isolation from broader discussion of the future shape and aims of agricultural and even national innovation systems. Connecting these discussions and opening them up to as broad a participation that is practically possible is going to be critical in charting new research and innovation pathways towards agri-food system transformation (Stirling, 2008; Scoones, 2016).

7. Conclusions

"WE CAN'T SOLVE PROBLEMS BY USING THE SAME KIND OF THINKING WE USED WHEN WE CREATED THEM."

ALBERT EINSTEIN

Abstract:

This chapter provides an overarching conclusion to the thesis, illustrating the broader implications gained in the different chapters. After providing a summary of the four stand-alone chapters (Chapters Three, Four, Five, Six), this conclusive chapter pinpoints some of the existent orthodoxies that are currently hindering transformation and some suggestions on ways for challenging them that emerge across the different chapters. The implications of this for policy and practice are also discussed. As a final point, the thesis makes some remarks on research methods employed in the thesis, and suggests venues for future research.

7.1 An introduction to the conclusion

The thesis investigates agri-food systems transformation, seeking to answer the question:

"What are some of the current accepted practices, theories, and "ways of doing things" that might currently be hindering a sustainability transformation in agri-food systems, and how can they be challenged?"

This concluding chapter brings together the insights gained around this overarching research question. First, it provides a summary of the single chapters, to then discusses the cross-cutting insights that emerge across them relating to the research questions. Afterwards, the practice and policy implications of these insights are discussed. Finally, the chapter concludes by offering final reflections on the research methods employed and suggesting venues for further research.

7.2 Summary of chapters' findings

The four interconnected thesis chapters are summarised below.

Challenging the orthodoxy of mainstream research and practice that are still anchored to linear or static conceptualisations that are poorly equipped to operate agri-food systems in an era of transformation (Thompson and Scoones, 2009; Hall and Dijkman, 2019), **Chapter Three**, titled "Complexity at play: new principles for navigating agri-food systems dynamics and uncertainty" eexposes how complexity poses a constant challenge to interventions aiming to unlock change in current food systems (Marshall *et al.*, 2021), and suggests that addressing it is a prerequisite first step for then navigating transformation (Pereira and Drimie, 2016). The paper explores six case studies from LMICs through an agri-food systems perspective to help reveal how complexity manifests (often frustrating the objectives of well-meaning interventions) and explore how it can be navigated, highlighting the value of a set of novel principles for a more complexity-aware approach. This perspective sheds light on how unpredictability (also in trade-offs), path dependencies, context-specificity and patterns of power, as well as multiple spatial and temporal scales (all elements of complexity), manifest within the selected interventions, and the consequences of this. Then, the chapter discusses a set of principles that can help interventions navigate this complexity, namely: welcoming surprises and openly discussing trade-offs (1), shunning orthodoxies (2); engaging with context-specificity (3) and exposing patterns of power (4); embracing the lengthy nature of change (5) and understanding its multi-scale nature (6). The chapter stresses the value of an approach that remains flexible and open to respond and adapt to complexity instead of trying to predict and control change, altogether evading complexity (an orthodoxy in many of the current development interventions (Thompson *et al.*, 2007; Wigboldus

et al., 2016). This approach would need to go beyond generally accepted assumption and instead remain open to experimentation and iterative re-evaluation to navigate an era of growing uncertainty associated with agri-food system transformation.

After addressing the issue of complexity, **Chapter Four**, titled "Why are agri-food systems resistant to new directions of change? A systematic review" scans more than 9000 documents to identify 122 relevant publications to answer the question: "What makes agri-food systems resistant to directionality changes towards sustainability?". As starting point, the chapter examines the issue of path dependency to explain how once certain historical choices are made (such as the decision to implement modern/industrial agriculture after World War 2), shifting away from them is extremely challenging. By examining the publications, it then shows how three different domains of the literature, namely the agricultural system research domain, the food system research domain, and the socio-technical systems research domain, can help diagnose six major and interconnected explanations of path-dependency (or "sub-domains of path-dependency") that make a transformation to sustainability difficult, namely: embedded nature of technologies, misaligned institutional settings, individual attitudes, political economy factors, infrastructural rigidities, research and innovation priorities. The chapter explains how all these elements have become progressively self-reinforcing and now contribute to the maintenance and further embedding of unsustainability in present agri-food systems, making their transformation extremely challenging. The chapter illustrates that innovation in single system elements (e.g. changes in technologies) would be insufficient to shift the direction of the totality of the system towards sustainability, as all other elements (behaviours, political economy, infrastructural etc.) would ensure that the direction is maintained unaltered. The paper also reveals a largely under-investigated issue concerning the temporality of change, which hints at the need for *synchronised* (in temporal terms) innovation in *all* system elements to open the way to new sustainable development pathways.

Understanding the need to test these concepts and ideas in practice, the thesis employs the framework in the following **Chapter Five**, titled "Path dependency disruption as starting point for agri-food system transformation? Insights from a case study in South India", to probe a case study of a possible agri-food systems transformation in the South Indian context (specifically, in the Andhra Pradesh and Telangana states), that has been underway for over two decades. The case study analysis helps to answer the question: "What characterises and enables transformative processes to challenge the *status quo*?" by investigating a grassroots NPM initiative that began to counteract an historical path dependency (set in motion by the Green Revolution), and over time

was able to change technologies choices and behaviours, overcome infrastructural issues, gain attention from policies, raise attention to alternative research and innovation modes and priorities and partially disturb the political economy of the established agri-food systems. The framework proves a useful tool to evaluate whether a transformation is underway while also highlighting the importance of innovation in all system elements for enabling transformation, and the temporal dimension that this. The case study analysis also reveals some aspects not captured by the framework: i) the importance of navigating complexity and leveraging unknown, and ii) the role of agency, to then call for further research based on this findings.

Ultimately, **Chapter 6**, titled "What does the agri-food systems transformation agenda mean for agriculture and food research organisations? Exploring organisational prototypes for uncertain futures", recognises that, if AFROs are increasingly called upon to provide solutions to looming environmental, social and economic challenges, there are different visions of how these organisations could do so. The paper presents these different views by highlighting four research narratives around the role or research and innovation for transformation, namely: i) the "silver-bullet technologies for transformation"; ii) directing innovation for tackling grand challenges"; iii) system replacement from the margins and iv) system innovation for transformation narrative. The paper then proposes four resulting AFROs "prototypes" of the future scenarios: i) Industry transition-oriented; ii) Technology mission-oriented; iii) Community innovation-oriented, iv) Facilitating transformative innovation-oriented. Then, the chapter highlights that there is no "ideal scenario", and each has different strengths, trade-offs and risks. The paper argues that if some scenarios might be more aligned to the present capabilities and mandates of AFROs, the decisions about these different roles can no longer be made unilaterally, but will instead need to be negotiated among a wide range of stakeholders. Besides, the scenarios, together, invite to a much more explicit and careful discussion on the implications that their different visions have for the broader innovation system in which they are embedded.

7.3 Challenging orthodoxies: insights from the thesis

The thesis seeks to unveil some of the accepted practices, theories and "ways of doing things" that might be curbing agri-food systems transformation towards sustainability and discuss how they could be challenged, and the implications of this for policy and practice.

7.3.1 Three orthodoxies hindering transformation

Three interrelated and to some extent overlapping orthodoxies emerge from this body of work.

A "linearity orthodoxy". In Chapter Three, this orthodoxy relates to the design and implementation logic of development interventions which, still anchored to linear conceptualisation of change in agri-food systems, tend to consider change as a relatively straightforward, predictable, and largely controllable process. The chapter builds from considerations from previous literature (Thompson and Scoones, 2009; Wigboldus *et al.*, 2016) and explores six empirical and cross-country case studies, to show how this orthodoxy cripples interventions in practice, hampering their ability to deal with the complexity that necessarily characterizes new pathways of change (e.g. towards poverty alleviation or nutritional security). In particular, the chapter emphasizes how this linear logic might be particularly unsuitable for responding to recent calls for transformation, a process that will inevitably be unpredictable and non-linear (Stirling, 2014a). Chapter Four reveals that this problem goes much deeper, under two aspects.

First, through the systematic review, it identifies that indeed, linearity has become embedded in research and innovation priorities, that now are misaligned to the transformation agenda (one of the sub-domains of path dependency that the review identifies). This relates to the discussion in Chapter Six, which shows how this "linearity orthodoxy" is still prominent in some research narratives (and AFROs prototypes).

Second, Chapter Four demonstrates that linearity does not solely characterize research and innovation priorities (a system component), but rather, is an embedded feature of agri-food systems as a whole that, if dynamic and continuously evolving, are however set on the same (linear) trajectory of change that, reinforced by a set of interconnected elements, perpetrates unsustainability. In this sense, Chapter Five delineates, through the analysis of a case study from South India, how this linear direction of change can be overridden by niches and grassroots initiatives experimenting with new ways of doing things that challenge the *status quo*.

A "simplicity orthodoxy". If linked to the linearity orthodoxy illustrated below, the "simplicity orthodoxy" refers to a tendency in understanding change as a "system component" instead of a "system-level" process. This orthodoxy started to surface in Chapter Three, where changes in system components (e.g., technologies) seemed to fall short in delivering ambitious objectives such as poverty alleviation or food security. For instance, the chapter showed how a change in technology (e.g., sweet sorghum as biofuel) or in behaviours (e.g., consumption of Smart Foods) is in truth dependent and deeply interconnected to changes in other elements, such as policies and regulations, political economy dynamics, attitudes and habits, and so on.

This issue emerged more prominently in Chapter Four, which stemmed from the recognition that a shift agri-food systems towards sustainable patterns of production and consumption remains a distant prospect (Dorninger *et al.*, 2020). The Chapter reveals that until now, the majority of changes in agri-food systems have tackled isolated system components (e.g. technologies *or* behaviours *or* policies). This has turned out to be largely ineffective in delivering interconnected sustainability objectives (e.g. environmental viability, equity, justice). The reason for this is investigated through the analysis of path dependency in the current system. It reveals that the concealed reason for unsustainability in agri-food systems is to be found in the multiple and highly interconnected factors that, acting together, maintain the system on a certain trajectory. Therefore, the solution cannot be a "component" solution, but rather, has to be a "system-level" solution that addresses all these elements simultaneously. This makes the narrative of "simplicity" -if appealing for its straightforward potential – inadequate for delivering transformation.

This point is supported by the evidence presented in Chapter Five, where the system-level nature of transformation is illustrated through the story of NPM initiative. The initiative succeeded because, instead of focusing on single, if problematic, system elements (e.g., technologies that caused environmental problems), it could tackle multiple and interconnected system elements (e.g. technologies, behaviours, policies, infrastructure and so on) and reformat them in a synchronised manner. This sheds light on how system-level innovation -as opposed to system-component change - is an essential element for opening a viable transformative pathway.

And yet, Chapter Six hints at how this "component-change" focus is still predominant in some research narratives, in particular the ones that, as their core assumptions, have the belief that technology can be "silver-bullet" solutions for delivering a global sustainability shift (Klerkx *et al.*, 2022). This highlights a third orthodoxy emerging from this body of work:

An orthodoxy in the *modus operandi* and role of AFROs. The orthodoxy in their *modus operandi* is discussed in Chapter Three in terms of the AFROs' mainstream logic, which determines the way

interventions are designed and implemented. It is also pinpointed in Chapter Four, where it is argued that AFROs' present role as technology provider is shaped by historical post-war production concerns (i.e. mismatch between population growth and resources (Friedmann, 1982; De Schutter, 2014)) that consequently directed AFROs' Research and Innovation priorities towards technology developments that could quickly boost production and economic growth. Chapter Five is in a sense, a corroboration of this finding, highlighting how the grassroots initiative emerged as a response to the inability of traditional AFROs (within the Indian agri-food systems) to provide alternative solutions to an established development model (i.e., the GR) that was turning out as increasingly unviable both environmentally, socially and economically. This orthodoxy -and its implications – are more carefully explored in Chapter Six, which looks at how the "orthodox" role of AFROs is object of increasing debate and tensions. In particular, this chapter highlights that historically-established views on the role of these organisations are now countered with novel narratives, that argue that the "technology optimist" logic that AFROs have until now adhered to (Klerkx *et al.*, 2022) might be unsuitable for enabling these organisations to respond to the transformation agenda. These alternative narratives thus stress the need for much more wide-spanning and bottom-up innovation which would, however, imply a major rethink of AFROs as they are now (as well as the innovation system in which they are embedded).

7.3.2 How to challenge orthodoxies that hinder a sustainability transformation? A few suggestions on the way forward

The identification of these orthodoxies hindering transformation inevitably calls for solutions that can overcome them. Each chapter offers insights in this.

Drawing from real-world experiences, Chapter Three challenges the orthodoxy by proposing a set of novel principles that could shift interventions' logic (and thus, AFROs' *modus operandi*) towards alternative approaches. In particular, the principles identified in the chapter could inform project design and implementation in a way that can help them go beyond linearity and simplicity to instead embrace the unpredictability and complexity of the agri-food systems. This might help interventions become more effective in terms of opening new pathways of change, which is particularly important in an era of transformation.

Besides, Chapter Four provides a useful framework for at once revealing the systemic (as opposed to component) nature of transformation, while also shedding light on the specific system elements

(i.e. sub-domains of path dependency) that need to be tackled in tandem to open the way for a sustainability shift (including, a re-think of AFROs role and priorities).

However, insights provided by these two chapters should not be intended as "deus ex machina" solution for delivering transformation. In fact, moving away from orthodoxies cannot be achieved through by simply applying novel theoretical principles (which are, after all, widely available in the literature). Instead, moving away from orthodoxy will require the mobilisation of both knowledge *and* power. This emerges from the other two chapters.

Chapter Five certainly highlights the importance of changing and mobilising knowledge around transformation processes, which can hardly be predicted, directed, or controlled. This challenges orthodoxies of linear change to instead suggest a much more open approach that can adapt and respond to the unpredictable and capitalise on positive dynamics – which also means renouncing the definition of a priori objectives and time-spans. Besides, the case study challenges component-change notion, to highlight how transformation of simultaneous and possibly serendipitous reformatting of different system elements, and that requires engaging with broad-spanning environmental, social and economic innovation. These two points question traditional AFROs, suggesting that these organisations might need to revisit their mainstream operational modes and outlook (including, linear and component conceptualisations of change) to possibly support, nurture or even design and implement transformative processes.

The experience of the grassroots initiative, however, also talks to the power dimension. Alternative voices in sustainability debates have until now been largely marginalised, often being labelled as simple "micro-scale" projects (possibly because they endanger incumbents' interests) (Anderson and Maughan, 2021). Including these voices into the debates, ensuring that they can provide *equally valuable* evidence for informing and implementing transformative processes worldwide will be critical. As the NPM initiative suggests, these grassroots movements might indeed offer precious, if unconventional, solutions for delivering a system-level shift to sustainability (Bui, 2021; Gliessman, 2023).

Chapter Six reinforces this recognition. If one the one side, the chapter highlights that some scenarios demand a higher level of system reformatting and challenge AFROs *modus operandi* more than others (i.e., the community innovation-oriented and the facilitating transformative innovation-oriented scenarios), what the chapter also flags is the need for much more inclusive

dialogue to deliberate on desirable and diverse transformation pathways. These pathways will have to be equally acceptable to both incumbents *and* other actors. Wide-spanning forms of innovation (e.g., technological, social, cultural) stemming from multiple sources (e.g., the private sector as well as the civil society) will be essential to pursue these pathways (Stirling, 2014a; Herrero *et al.*, 2021). However, these pathways will be underpinned by fundamentally different worldviews (Reilly and Willenbockel, 2010), and this is likely to entail contestation and disagreements, possibly involving re-arrangements and shifts in current power configurations (Stirling, 2014b; Kennedy *et al.*, 2021). If consensus is unlikely to be reached, compromise can however be attained. Thus, this type of much more inclusive, democratic and open (especially, in terms of considering alternatives to what is "known") will both challenges orthodoxies of how things have been done till now -for instance, in terms of exclusion or marginalisation of certain stakeholders form debates (Anderson and Leach, 2019)- but could also be the way forward for truly challenging and finding viable alternative to overcoming the "global unsustainability orthodoxy" and deliver the transformation that agri-food systems desperately need.

7.3.3 Implications for policy

"What's really happening in the human world is politics, or morality, or religion, or aesthetics" "

(Churchman, 1979, p. 53)

Long before transformation debates, Churchman (1989) highlighted how the real world is problematic and mysterious, and characterized by clashing values and ideas. This recognition created a rift between what Churchman called "soft" and "hard" system thinking" (Checkland, 1989) which is, to date, of great relevance for the transformation agenda. Hard system thinking is a way of thinking about reality that is about prediction and control, with goals that are well-defined *a priori* (usually, by those in power), clearly established procedures, and quantifiable performances (Agnew, 1984). Therefore, this thinking is inadequate for operating in socio-eco-technical systems (Jackson, 1982), and even more inadequate for supporting their transformation. Instead, a "soft system thinking" approach understands the system in question (and the real world more generally) as messy and complex, and composed by individuals who act in different ways (Hernández-Orozco *et al.*, 2022). Thus, soft system thinking helps understand and navigate the diversity of human systems, and the conflicting world views, values and historical patterns underpinning them (Checkland and Poulter, 2006). In this view, each situation is unique, and no "standard" solution can be established. Solving problems in the system thus becomes a process of consultation and information exchange with "problem-owners" (i.e., all actors operating in the system). Democratic and inclusive dialogue would help accommodate "between (permanently) conflicting viewpoints

and interests" (Checkland and Haynes, 1994) and explore "desirable and culturally feasible solutions" (Checkland, 1999) rather than seeking to reach consensus on goals set *a priori*. This thinking has critical implications for the transformation agenda. Whereas much of current research and policy still considers some of the most critical unsustainability drivers as fixed system properties, or at least, as elements that can be tackled in isolation using disciplinary approaches, the transformation research and policy agenda will necessarily have to be inspired by (soft) system thinking (Abson *et al.*, 2017). This thinking would make room for much more careful consideration of the structures, values and goals that underpin unsustainability, and which need to be addressed as a set of "tightly interacting components" (Wiek and Lang, 2016) instead of isolatable system elements. More importantly, a system thinking approach would help understand solutions and actions for a sustainability transformation as long-term processes that involve continuous stakeholder dialogue, real-world experimentation, collective learning, and continuous (re) adaptation (Abson *et al.*, 2017).

These considerations are well-reflected in the thesis, which sought to underpin orthodoxies (including, one in which agri-food systems system components seem to still be tackled in isolation – a possible remnant of an "hard" system thinking tradition) in current action for sustainability transformation. Thus, it is now helpful to reflect on the "real-world" policy implications of challenging orthodoxies.

A first policy implication for engaging with transformative processes successfully seems to hinge on the need to acknowledge their uncertain and complex nature more openly. This requires a re-think on how success is envisioned (among policymakers but also among donors and the research community (IPES, 2016). It would be important to be more explicit – and realistic – in terms of scale of ambition, timelines, and outcomes within interventions. Understanding that in an age of high uncertainty, outcomes are often different from what previously envisioned (Stirling, 2014a), it would be important for policymakers to become aware that "unknown" ends does not always have to be intended with a negative connotation. However, more proactively and explicitly engaging with the directionality of (uncertain) transformative processes might be critical to ensure that this directionality remains towards sustainability (whatever might be its outlook) (Leach *et al.*, 2007; Duncan *et al.*, 2022).

Secondly, transformation will necessarily require experimenting with often bottom-up and wide-spanning innovation that touches to multiple domains (cultural, social, economic, environmental, technological). In this context, grassroots initiative might indeed be valuable for indicating viable

pathways of change (as seen in Chapter 5). Policymakers might want to become more attentive towards these non-conventional forms of innovation, being mindful of recognising the value of alternative knowledge*s*, perspectives, values and solutions (McAllister *et al.*, 2019; Ministry of Business, 2021; Stevens, Paul-Burke and Russell, 2021).

These first two policy implications emerging from the thesis have critical implications not only for policies *per se*, but also for funding mechanisms that underpin real-word interventions. Currently, many "funding narratives" are underpinned by specific performance indicators that often look for success in terms of performance of isolatable and easily quantifiable (e.g., in terms of costs and effectiveness) system components (e.g. "total yields of specific crops, productivity per worker, and total factor productivity" (IPES, 2016)). This neglects the much more systemic nature of today´s challenges, and fails to address the concealed and structural elements that underpin unsustainability (e.g., fundamental issues the political economy of markets that distorts food prices in a way that discourages shifts to healthier and more sustainable diets in low-income households (Phillips, 2017; Pancrazi, van Rens and Vukotić, 2022)). As a consequence, funding narratives often support the historically established production-oriented (IPES, 2016; Conti, Zanello and Hall, 2021), while being, at their core, poorly aligned to the system-transformation agenda (Hall and Dijkman, 2019; Conti, Zanello and Hall, 2021). Funding narratives should therefore be urgently revisited, acknowledging the need for much a more intentional and explicit system-level redirection of current systems towards sustainability. This would ensure that technological innovation (until now, frequently driven by profit rather than sustainability concerns (Schot and Steinmueller, 2018; Béné, 2022) is carefully directed towards sustainability (Kattel and Mazzucato, 2018), and is accompanied by innovation in other domains (e.g. social, cultural, economic) that can help redesign the totality of agri-food systems elements. As these novel forms of innovation will likely be unconventional and uncertain in nature, while requiring a re-envisioning of what "success" in interventions might look like, the public sector should take a much more proactive role in supporting them, for instance by funding (and thus, de-risking) uncertain pathways that might however be promising in terms of delivering sustainability (as seen in Chapter 5).

Another critical point emerging from the thesis is the value of dialogue and negotiation for envisioning and implementing transformative processes. No pathway will be without pitfalls or trade-offs. Pre-emptively discussing these among stakeholders might help transparently flagging them in a way that, if not making them more "predictable", can however more effectively identify strategies to circumvent or overcome them (de Cleene, 2019). Besides, different pathways to

transformation will likely be highly unique to each place, and underpinned by different worldviews that will consequently shape actions and priorities. Reflexive and inclusive dialogue among multiple and even unconventional stakeholders – driven by their diverse assumptions, knowledge and beliefs- might help find solutions where individual worldviews might find none.

Finally, the thesis raises a warning to "panicking" (IPES-Food & ETC Group, 2021) policymakers looking for silver-bullet solutions for looming global challenges (e.g. climate change). These solutions might indeed be valuable and promising in helping a shift towards more sustainable systems. However, policymakers should be aware that these solutions will unlikely lead to the overall system reformatting (for instance, in terms of the political economy of current food system, which keeps inequity deeply embedded (De Schutter, 2017; Conti, Zanello and Hall, 2021)) that might instead be needed for ensuring not only environmental soundness, but also equity and justice.

7.4 Final remarks on research methods

The constructivist and critical perspective adopted in the thesis enabled the researcher to challenge existing assumptions and explore a variety of perspectives that stem from different beliefs, norms and cultures, while the pragmatist perspective allowed her to remain open to a variety of approaches that "could work" (Moon and Blackman, 2014) for exploring the research questions. In particular, the variety of methods employed (comparative case study analysis, systematic review, qualitative case study, critical review) allowed the researcher to:

i. Explore a vast body of knowledge, spanning from early literature on agri-food system complexity (Pimentel, 1966; Wilson and Tisdell, 2001) or first conceptualizations of path dependence (Nelson and Winter, 1982; David, 1985; Arthur, 1988; Ruttan, 1996), to recent discourses on the systemic nature of transformation (Marshall, Dolley and Priya, 2018; Hall and Dijkman, 2019; Klerkx and Begemann, 2020; Vilas-Boas, Klerkx and Lie, 2022) and the need to include new and until-now-forgotten knowledges in the research debate (Whyte, Brewer and Johnson, 2016; Hill *et al.*, 2020; Reid *et al.*, 2021; Rarai *et al.*, 2022).

ii. Become aware of the diversity of agri-food systems contexts, both through the comparative analysis of case studies spanning from Kenya to India, and the systematic review that sheds light on extremely varied agri-food systems contexts and their evolution, carrying the researcher from Brazil (Gonçalves *et al.*, 2015) to Sweden (Zukauskaite and Moodysson, 2016), and Vietnam (Fortier *et al.*, 2013).

iii. Be open to revisit her own beliefs and assumptions, reflecting and openly acknowledging shortcomings and drawbacks in her research, in particular inviting her to recognize and address the limitations of her own path dependency framework (Chapter Four) that, tested through the case study in Chapter Five, fell short in capturing some aspects of the studied phenomenon (i.e. transformation).

iv. Challenge what she knows by exploring contending visions of transformation, to understand that none of these visions is "perfect". Instead, they all have pitfalls and trade-offs, that can only be understood and possibly circumvented through open transparent and collaborative dialogue.

The researcher however is aware that alternative methods could have been used to answer the same research question (White, 2017), and that the ones she chose will inevitably have (as all methods) their own flaws (Cresswell, 2014; Bonke and Musshoff, 2020).

7.5 Avenues for further research

A seemingly endless set of questions currently exist around sustainability transformation (Fazey *et al.*, 2017; Marshall *et al.*, 2021), making it impossible for the thesis to investigate their totality. The issues investigated in this body of work answer some pressing interrogatives but are also useful to highlight issues that need further research.

Chapter Three highlights a set of principles for more complexity-aware agri-food systems interventions. However, further testing might be needed in both LMICs and HICs contexts, thus refining these principles and possibly shedding light on others. Besides, it would be interesting to investigate how these principles could be incorporated in more recent projects aiming specifically for sustainability transformation.

Chapter Four presents a framework for identifying path-dependency. However, most of the studies selected through the systematic review are located in HICs contexts, and might not reveal specific path dependency factors that might exist in LMICs. These might include, for example, structural issues originating from decolonisation (Shiva, 2004; Coolsaet, 2016), or discriminations regarding ethnicity, gender or societal *status* (Frank, 1999; Kassie, Wagura Ndiritu and Shiferaw, 2012; Jensenius, 2017; Edwards, 2023). Thus, these might need to be further investigated.

Chapter Five presents a case study of a niche that has started to unlock transformation in South-Indian agri-food systems, drawing some implications on how transformative change might look like in practice, and how some grassroots initiatives can trigger it. However, the chapter findings stem from a single case study and thus need to be further tested, in both LMICs and HICs, possibly comparing multiple case studies and further demonstrating both enablers and possible reasons for

failure in transformative processes and formulating additional recommendations of this for policy and practice.

Besides, both Chapters Four and Five explore the issue of the temporality of change, which remains largely neglected in the research landscape around transformation. This critical research gap needs to be investigated further, as both papers suggest that the temporal synchronisation of innovation in multiple system elements might be critical to unlocking transformation. If this will be an undoubtedly difficult point to address, as system elements such as culture and political economy are not amenable to existing policy and practice instruments (Ingram and Thornton, 2022; Ptak, Graversgaard and Dalgaard, 2023), this should not be an excuse for inaction. Instead, further research and investigation on how innovation in until-now highly path-dependent system elements can be synchronised could be a critical starting point for implementing transformation in practice.

Finally, Chapter six presents four scenarios for AFROs of the future. Further testing them (e.g., through expert consultations, workshops, dialogue) could be critically important to shed light on additional elements and considerations, as well as practical implementation considerations. For instance, further exploration of the scenarios could reveal their desirability for different actors and in different contexts, highlight additional pitfalls and advantages, or even uncover that more scenarios exist for AFROs responding to the transformation agenda.

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Annex I

Systematic review process

- **Background**

Originally mostly used in the medical field, systematic reviews are now becoming increasingly popular in the agriculture and food research field (Sargeant *et al.*, 2005; Farrukh *et al.*, 2020). Despite presenting certain disadvantages - for instance, the keyword choice excludes a number of results, or some sources not be included in the search even if relevant, because of vague titles or abstracts that might not contain the search keywords (Mallett *et al.*, 2012)– systematic reviews provide a comprehensive, reproductible and unbiased search strategy (Sargeant *et al.*, 2005; Farrukh *et al.*, 2020). Whereas case studies taken in isolation might provide only a partial picture (Petticrew and Roberts, 2008, p. 11) of resistance, the advantage of a systematic review lies in the comprehensiveness of the results and findings it produces (Grant and Booth, 2009; Kelly, 2015). Synthetizing and appraising findings from a wide variety of study designs and settings will provide a deep understanding of how path-dependencies, lock-ins and inertia work together to create resistance to change, providing insights from a wide variety of publications set in different geographical contexts and using multiple frameworks and methods.

- **Systematic review protocol**

The systematic review included the Scopus, ScienceWeb and ScienceDirect databases. The systematic review conducted in this paper follows the PRISMA guidelines (Moher *et al.*, 2009). Prior to carrying out the systematic review, a protocol was implemented to ensure that only relevant sources are selected, while exclusion and inclusion criteria are clear and the methodology is replicable. The procedure followed in the systematic review is detailed below.

i) *Identification*The terms searched were as follows:(inertia OR lock-in* OR lockin* OR path-dependen*) OR (path AND dependent) OR (lock AND in) AND (agri* OR food OR farm*).

The multi-character wildcard "*" was used at the end of the words to ensure maximum inclusiveness of the results. The wildcard in fact ensures that different variations of the keywords

are captured in the search as it looks for the root word and alternative endings[31]. For instance, path-dependen* will include both path-dependecy and path-dependencies. Similarly, agri* will include agriculture, agricultural and so on.

The term "AND" was used to capture studies that captured inertia/lock-ins/path dependencies *only* within the context of agricultural and food systems. The term "OR" was used to indicate that at least one of the terms in the brackets should appear, and to search for variants of the same concept.

All databases were searched following the same search strategy for keywords in the abstract, paper title, or full text of the publication. The search included peer-reviewed journal articles, books, conferences and reports in English. As the literature around the sustainability of agriculture and food production and consumption emerged in the 1970s (and around sustainability more in general) (Yeh, 2019), whilst the first conceptualisations of path-dependencies, lock-ins and inertia started taking roots in the 1980s (David, 1985; McGuire, 2008), 1970 was chosen as cut-off point for our systematic review. One researcher led the screening of selected documents, and unclear cases were discussed within the team.

The search yielded the following results:

- On Scopus, 3,703 document results;
- On ScienceDirect, 400 document results;
- On Web of Science, 4,972 document results.

ii) Screening and eligibility check

All documents retrieved in the three different databases were then exported to Mendeley Reference Manager (https://www.mendeley.com/reference-management/reference-manager).

Duplicates were removed through the "Check for duplicates" tool. This tool checks for similarities in publication type (e.g. journal, book section, working paper, report), title, authors, publication year, journal name/book publisher and so on and in case to merge the document, asking for confirmation in case of conflicting fields. After checking and removing existing duplicates, the total was of 5191 documents. These documents underwent screening.

The systematic review then screened the articles through 3 steps.

[31] For more details: https://service.elsevier.com/app/answers/detail/a_id/15137/supporthub/scopus/; https://service.elsevier.com/app/answers/detail/a_id/11213/supporthub/scopus/#tips; https://clarivate.libguides.com/wosce/searchtips

STEP 1: Title and Journal screening

- Records were screened based on their title.
- Exclusion criteria: Records where the title (combined with the journal field) clearly informed that the document did not belong to the context of the agriculture and food sector (e.g. rather belonged to chemistry, biology, psychology etc.) were excluded.
- In case of doubt, the document was kept and passed to the second step.

At the end of this step, 4686 were excluded, and 505 were kept for abstract screening.

STEP 2: Abstract screening

- Records were screened based on their abstract.
- Exclusion criteria: each abstract was thoroughly read by the reviewer. Documents were excluded when:
    - (A) there was no mention of either lock-ins, or path-dependencies, or inertia, or the context of the document was not within the agriculture and food sector;
    - (B) Literature reviews were also excluded from the analysis, to only capture findings from original studies, as done in a recently published systematic review from Farrukh *et al.* (2020)
- In case of doubt, the document was kept and passed to the third step.

At the end of this step, 247 documents were excluded, of which 238 were excluded because not relevant to the topic (A), and 9 were excluded because they were literature reviews (B).
258 documents were kept for full-text screening.

STEP 3: Full-text screening

- The third step involved the analysis of the full text of each selected document.
- Exclusion criteria: each document was thoroughly read by the reviewer. Documents were excluded when:
    - (A) The full text was not accessible;
    - (B) They were literature review (this was sometimes unclear in the abstract);
    - (C) The full text was not in English (even if "English" was chosen as language of the sources, the fact that their abstract was in English might have led to their inclusion in the database);
    - (D) They did not comprehensively explain lock-ins, path-dependencies or inertia in the context of the agriculture and food sector (mentioning these concepts without a

clear explanation of their meaning and/or implications was not sufficient to make the source eligible)

At the end of this step, 147 documents were excluded: 21 were non accessible (of these 21, 17 were books or books chapter, and 4 were journal articles) not accessible (A); 2 were literature reviews (B); 6 were not available in English (C) and 118 were not relevant to the topic (D).

At this stage, 11 records were added through snowballing. Snowballing refers to pursuing relevant references cited in the selected documents and adding them to the search results. Snowballing is an alternative approach to discover additional evidence that was not retrieved through conventional search and is considered as a best practice when conducting systematic reviews.(Choong *et al.*, 2014). Records added through snowballing included five reports (Murphy, Burch and Clapp, 2012; IPES, 2016, 2017; Dury *et al.*, 2019b; Hall and Dijkman, 2019), which possibly did not come up in the systematic review process as their breadth of topic did not allow the inclusion of path-dependency, inertia and lock-in keywords in the abstract, title or keyword list. Six were a journal article which was relevant to the topic, but did not emerge from the systematic review (Kay, 2003; Murphy and Burch, 2012; Turner *et al.*, 2016; Klerkx and Rose, 2020; Anderson and Maughan, 2021; Glover *et al.*, 2021, forthcoming; Herrero *et al.*, 2021).
A total of 122 documents were thus selected for the analysis.

iii) Inclusion

Overall, a total of 122 documents was included in the analysis. To facilitate the analysis of these documents, reviewers created an Excel spreadsheet to the descriptive statistics of the selected publications: author, journal, year, affiliation of first author, continent of affiliation country focus, methodology, level of focus (macro/meso/micro). Then, all documents were attentively analyzed to identify patterns around our topic of study, and in particular pinpoint the existence of different research domain while enabling the clustering of explanation of resistance.

Annex II

1) Ethical Clearance Granted

School of Agriculture, Policy and Development

ETHICAL CLEARANCE GRANTED

University of Reading

Form 2. MSc PhD Staff Ethical Clearance Submission Form

PLEASE allow a minimum of 3 weeks for this process.
You must not begin your research until you have obtained consent as evidenced by this form returned from the APD student Office signed and dated. Ethical Clearance cannot be granted retrospectively.

This form can only be used if the application :

- Does not involve participants who are patients or clients of the health or social services
- Does not involve participants whose capacity to give free and informed consent may be impaired within the meaning of the Mental Capacity Act 2005
- Does not involve patients who are 'vulnerable'
- Does not involve any element of risk to the researchers or participants
- Does not involve any participants who have a special relationship to the researchers/investigators

If any of the above apply, please refer to the APD Ethics Chair to decide whether an application can be made through the APD review process or whether the application needs to be referred to the full University Committee.

It is the applicant's responsibility to check for any particular requirements of a funder regarding ethical review. Some funders may require that the application is reviewed by full University Committee and not the devolved School committee.

Full details of the University Research Ethics procedures are available at http://www.reading.ac.uk/internal/res/ResearchEthics/reas-REethicshomepage.aspx and you are encouraged to access these pages for a fuller understanding. Some helpful advice is available on this link http://www.reading.ac.uk/internal/res/ResearchEthics/reas-REwhatdoIneedtodo.aspx and the FAQs are particularly relevant.

ALL QUESTIONS MUST BE COMPLETED.

APD Ethical Clearance Application Reference Number : 001827

1. **APPLICANT DETAILS:**

Main applicant name:	Costanza Conti
Name of academic supervisor/project investigator:	Giacomo Zanello
Email Address (decision will be emailed here):	c.conti@pgr.reading.ac.uk
MSc Student	☐
PhD Student	☒
Staff Member	☐
Other (please specify)	Click here to enter text.

2. **PROJECT DETAILS:**

Title of project: Lessons for agri-food system transformatiotion: A case study of the Centre for Sustainable Agriculture and the Sahaja Aharam Producer Company Ldt. In Andhra Pradesh and Talengana state, India

Please provide a lay summary of the project, including what is being investigated and why: The overall aim of my PhD thesis is to understand agri-food system transformation. I aim to I explore how deep and structural changes can be enacted in food production and consumption patterns to achieve a long-term shift to systems governed by a balance in terms of ecological soundness, economic viability, and social justice (Gliessman, 2013b; Schiller et al., 2020). The Centre for Sustainable Agriculture and, later, the Sahaja Aharam Producer Company Ldt, can be considered as an example of ongoing transformation in Indian agri-food systems, as they have reframed not only the way farmers produce foods on farm (i.e. through organic practices), but also the way food is processed and marketed. Changes in consumers' consumption patterns are visible in the region, with increased awareness about the importance of consuming healthy, sustainably produced foods. The

institutional and policy landscape has also changed since the start of the initiative in 2004. The purpose of this project is therefore set i) investigate the history of the initiative to understand how it has changed production and consumption patterns in the region, what were the starting conditions, the barriers and the enablers and how these changed and evolved over time; ii) understand the extent at which the initiative has been able to break existing path dependencies and factors of resistance in agri-food systems (Conti et al., 2020), and enable a transformation, and at what level of scale (local, regional, national); iii) discuss the lessons derived from the case study for setting up and implementing transformation processes in other contexts.

Procedure. Please outline the project's research protocol (what procedures, research methods and analysis methods are being used) : Interviews with farmers and key stakeholders in the Centre for Sustainable Agriculture and the Sahaja Aharam Producer Company Ldt

Period over which the data collection is to be undertaken (note: data collection CANNOT commence until ethical approval has been granted as evidenced by this form signed and returned).

Proposed Start Date: 20/03/2022
Proposed End Date: 20/06/2022

3. THE RESEARCH:

a) Nature and number of participants who are expected to take part in your survey/focus group. Please estimate if uncertain. As ethical clearance involving minors is more complex because of safeguarding and consent issues, please consider carefully whether you need to involve minors under the age of 16 in your research.

Participants		**Number participating**
Minors under 16 years of age		0
Students	0	
Other members of the University	0	
Members of the general public		5
Businesses		6
Government officials		3
Other *If other please specify:*		Farmers (10), members of the Centre for Sustainable Agriculture (5)

b) Funding. Is the research supported by funding from a research council or other external sources for example a charity or business?

Yes ☐ If yes, please specify funder : Self-funded
No ☒

If yes, it is the responsibility of the applicant to check for any particular requirements of the funder regarding ethical review. Some funders may require that the application is reviewed by full University Committee and not the devolved School committee.

c) Recruitment. Please describe recruitment procedures. How have participants been selected? Are there any inclusion/exclusion criteria? Participants must be told on the Participant Information Sheet how and why they have been selected. You should attach ay recruitment materials to this application. The participants are selected based on their involvement in the Centre for Sustainable Agriculture and the Sahaja Aharam Producer Company Ldt. Dr Rasheed Sulaiman (a colleague) has put me in contact with Dr Ramanjaneyulu, the head of the Center, and he is willing to connect me with farmers and different key informants. Participants will be contacted by email prior to the interview.

d) Exceptions. Does the research involve minors, medical patients, individuals with learning difficulties, vulnerable adults, participants recruited through social service departments, or anyone in a special relationship with yourself/data collectors? E.g. Supervisor; lecturer to a group of students; or person in a position of responsibility for participants.

Yes ☐
No ☒

If yes, this may result in referral to the University Research Ethics Committee (please note their deadlines). Please provide extra detail here: Click here to enter text.

e) Where is the data collection to be undertaken? Specify country(ies) and specific location(s) The data collection will be undertaken in the city of Secunderabad, Telangana State, India. The face-to-face interviews, which will be conducted by me personally, will take place at the Sahaja Aharam Producer Company Ltd - Organic Food Store. This is the main office for the Sahaja Aharam Producer Company Ldt. The full address is: 12-13-485/5, Laxmi Starch Colony, Nagarjuna Nagar Colony, Tarnaka, Secunderabad, Telangana 500017. Some personal interviews might also be conducted online (specifically, on Skype).

f) What forms of data collection does the research involve?

Group discussion/ workshop	☐
Personal interviews	☒
Telephone interviews	☒
Questionnaire/paper survey	☐
Postal survey	☐
Email/ online survey	☒
Which software tool will be used, if any?	none
Other *(specify)*:	Click here to enter text.

g) Who will undertake the collection and/or analysis of data?

Myself	☒
Other MSc students	☐
Other Higher degree students	☐
Other contract research and/or academic staff	☐
Individuals outside University	☐
External organisations	☐

If individuals outside the University and/or external organisations are involved in the collection or analysis of data, give brief details below. Indicate how the ethical procedures and standards of the University will be satisfied: Click here to enter text.

h) Does the research require participants to consume any food products?

No ☒
Yes ☐

If yes, please provide full details and indicate measures in place to ensure excellent food hygiene standards and ensure participant safety. N/A

i) Do you consider there are any potential ethical issues in this project? Does the research require collection of information that might be considered sensitive in terms of confidentiality, potential to cause personal upset, etc.?

No ☒
Yes ☐

If yes, please provide full details and indicate how these issues will be addressed, how researchers will manage participant reaction. Support and de-brief sheets should be attached if relevant. N/A

j) Will the research involve any element of intentional deception at any stage? (i.e. providing false or misleading information about the study, or omitting information)?

No ☒
Yes ☐

If yes, this must be justified here. You should also consider including debriefing materials for participants which outline the nature and justification of the deception used. N/A

k) Are participants offered a guarantee of anonymity and/or that the information they supply will remain confidential?

Yes ☒
No ☐
If yes, give brief details of the procedures to be used to ensure this and particularly if the data has 'linked' or 'keyed' anonymity (eg. where published results are anonymous but participant details are recorded and held separately to the responses but keyed with reference number) : participants details are recorded and held separately to the responses but keyed with reference numbers. The information will not be shared with third parties and will only be used for the purposes of my research.

l) Will participants be required to complete a separate consent form? Many APD applications do not require participants to complete a separate consent form. Please see the templates provided.

☐ Yes. Names, addresses and copies of completed forms will be given to APD student office
☒ No. The data collection is anonymous and a combined information/consent sheet supplied
☐ Neither of the above, or the research involves participants under the age of 16
If 'neither of the above' selected, or the research involves participants under the age of 16, please outline the specific circumstances. N/A

m) Will participants be offered any form of incentive for undertaking the research?

No ☒
Yes ☐
If yes, give brief details, including what will happen to the incentive should the participant later withdraw their input or decide not to proceed : N/A

4. DATA PROTECTION

Data Storage, data protection and confidentiality. Please make sure you are familiar with the University of Reading's guidelines for data protection and information security. http://www.reading.ac.uk/internal/imps/

Please outline plans for the handling of data to ensure data protection and confidentiality. Covering the following issues: Will any personal information be stored? How and where will the data be stored? Who will have access to the data? When will it be deleted?

Personal information will be stored in terms of name and position/role (e.g. farmer, key informant etc) of the participant. Each participant will be given a serial number to maintain anonymity. The information will be stored in my own computer, protected by password, and will be deleted at the end of my PhD thesis (October 2023). I, together with my PhD supervisor, Giacomo Zanello, will be the only one to have access to the data. Data collected at interview will be stored with an id number only, i.e. keyed personal identifiers will be stored in a separate, password-protected file.

Applicants: Please now scroll to Section 7 to input your :

- Information Sheet(s) for Participants (mandatory)
- Data Collection Tools, for example: recruitment materials, interview/focus group protocols (how you are conducting the process), interview/focus group questions, questionnaires, online survey questions, debriefing and fact sheets
- Consent Forms (optional, may not be necessary if consent assumed in Information Sheet)

If the text boxes do not allow input in the desired format, please append documents separately to the email when sending this form.

Please then email your completed form (and any separate supporting documents) to your supervisor/project investigator. Project investigators or independent academics may return form directly to sapdethics@reading.ac.uk

A decision on whether ethical clearance has been granted will be emailed to you via the APD Student Office along with your authorised form.

You may NOT proceed with your data collection until ethical approval has been granted as evidenced by return of this approved form.

Note: The process of obtaining ethical approval does not include an assessment of the scientific merit of the questionnaire. That is the separate responsibility of your supervisor/project investigator in discussion with yourself.

5. Supervisor/project investigator review. Section to be completed by supervisor/PI where relevant.

Participant information sheet(s), data collection tools and any other supporting information may be pasted in section 7 below. Alternatively they may be attached to this email. Please review these documents and then complete the checklist below.

Checklist. Does this application and supporting documents adequately address the following ?

- ☒ The safety of the researcher(s) and those collecting data, the safety of the participant(s)
- ☒ Is the language /grammar/content appropriate (i.e. University standards and reputation upheld)
- ☒ There are no questions that might reasonably be considered impertinent or likely to cause distress to the participants
- ☒ The researcher has provided the participant information sheet (mandatory)
- ☒ The researcher has provided the questionnaire or survey/ workshop, focus group or interview questions (mandatory)
- ☒ The Participant Information Sheet gives sufficient information for the participants to give their INFORMED consent
- ☐ A separate consent form has been included (optional)
- ☒ Data will be handled, stored and deleted appropriately according to University guidelines, and the participants have been adequately informed about this in the Participant Information Sheet
- ☒ The Participant Information Sheet contains all relevant sections

- ☒ **I am satisfied that this application meets the minimum standards for APD Ethical Clearance to be granted**

Supervisor/Project Investigator, please forward this form as a WORD document and any separate supporting documents to sapdethics@reading.ac.uk. The form will be logged by the student office and allocated to an APD ethics committee reviewer. The APD ethics reviewer will review the application and complete section 6.

6. APD ethics committee review. Section to be completed by APD Ethics Committee member.

Decision

Clearance refused		☐	Resubmission required
Clearance granted as presented	☒		
Clearance granted subject to revisions suggested		☐	No need to resubmit once amended
Referred to APD Research Ethics Chair		☐	May require further information

Ethics Committee Member please enter comments, reasons for rejection, summary of revisions required before proceeding (if applicable):

For information only:

a. Note the additional final line added to the response at Q4.

Committee Member Name: Philip Jones **Date Reviewed :** 14/03/2022

APD Ethics Committee member electronic signature (For signature, save document as pdf, then open pdf and use 'sign' option. Alternatively check here if no electronic signature used ☒)

APD Ethics Committee Member : Now please email this completed form (as signed pdf) to sapdethics@reading.ac.uk together with any separate supporting documents . The student office will record the outcome and return the completed form to the applicant with the decision.

7. Supporting Documents.

Please cut and paste the following documents into the text boxes below.

- Participant Information Sheet(s),
- Protocols (the procedures, how you will conduct and administer the data collection, interviews, surveys)
- Data Collection Instruments (interview questions and survey questions)
- Consent Forms (if Participant Information Sheet does not assume consent)
- Recruitment Materials (if relevant)

It is preferable that all information connected to this application is contained in one document. However, if you find that the text boxes below are not adequate, you may attach and email these supporting documents separately.

Supporting Documents for this application are pasted below. The text boxes cannot accept some types of formatting when pasting in documents. If this is the case, append them separately to the email with this form.

1) Participant Infortmation Sheet

Date: (to be completed accordingly)

Recipient's Name: (to be completed accordingly)

Project name: Lessons for agri-food system transformation: A case study of the Centre for Sustainable Agriculture and the Sahaja Aharam Producer Company Ldt. In Andhra Pradesh and Talengana state, India

Dear Sir, Dear Madam,

I am an PhD Candidate at the University of Reading. As part of my thesis I am conducting research around the topic of agri-food system transformation.

This research project aims to find out how deep and structural changes can be enacted in food production and consumption patterns to achieve a long-term shift to systems governed by a balance in terms of ecological soundness, economic viability, and social justice. This is why I am interested in the work of the Centre for Sustainable Agriculture and the Sahaja Aharam Producer Company Ldt. To undertake this research, I am currently contacting farmers and key stakeholders in the Centre for Sustainable Agriculture and the Sahaja Aharam Producer Company Ldt to acquire more information on how these have changed food production and consumption patterns in Andhra Pradesh and Telangana State, India. We would like to invite you to participate in an in-depth interview that will take approximately 1 hour of your time. You have been selected as you have been appointed as a key informant by a relevant member of the organisation. You are encouraged to freely express your opinions durinh the interview, and please be assured that your views are valued and that there are no right or wrong answers to the questions asked.

We will not collect any names or personal details as part of the interview. Your identity will not be revealed to anyone other than the researchers conducting this survey. I will store your name and email address so that I can contact you in 6 months' time to ask follow up questions. Your name and email address will be linked to your original responses by means of a keyed spreadsheet held separately. As a participant, your details will be recorded and held separately to the responses but keyed with reference numbers. Please note that these reference numbers (or personal identifiers) will not be stored alongside any data that you share during the interview. They will only be stored with the unique number that is given to them.

This spreadsheet and contact details will be password protected and the password known only to me and my supervisor, and will not be shared with any third parties. The spreadsheet will be kept on my password protected PC and will be destroyed on December 1st, 2026. Your name and email address will not be published as part of my research. As all data is presented in aggregate format it will not be possible to identify any individuals from their responses.

Participation is entirely voluntary and you are free to withdraw from the interview at any time you feel uncomfortable or unwilling to participate, and you do not have to specify a reason. Any in-part or total contribution can be withdrawn up until the point at which are analysed, ideally before 20/06/2022. After 20/06/22 it will not be possible to withdraw your contribution from the results of the research. If you wish to withdraw, please contact Costanza Conti (c.conti@pgr.reading.ac.uk) , quoting the reference at the top of this page. The reference will only be used to identify your interview transcript and will not reveal any other information about you.

The discussion will be audio or video recorded if you agree, and the anonymised transcripts of the audio/video recordings will be used by the researcher working on the project. Once transcribed the original recording will be deleted. Your anonymity will not be compromised as only the reference number above will be used to identify the transcript.

If at any stage you wish to receive further information about this research project please to not hesitate to contact Costanza Conti (c.conti@pgr.reading.ac.uk)] before 1/04/2022. The findings will be written up into my thesis, and published in academic journals. This will not affect your anonymity.

All data I collect will be stored securely electronically on a password-protected computer or in hard copy version in a locked cupboard. The data will be destroyed on December 1st, 2026.

By participating in this interview,, you are acknowledging that you understand the terms and conditions of participation in this study and that you consent to these terms.

This research project has been reviewed according to the procedures specified by the University Research Ethics Committee, and has been given a favourable ethical opinion for conduct.

Thank you very much for your help and availability,

Best wishes,

Costanza Conti

Student Contact Details

Costanza Conti
School of Agriculture, Policy and Development
Agriculture Building
Earley Gate, Whiteknights Road
PO Box 237
Reading RG6 6AR
United Kingdom
Phone: (phone number specific for the project)

E-Mail: c.conti@pgr.reading.ac.uk

Supervisor Contact Details

Name Giacomo Zanello
Phone: +44 (0) 118 378 8971

E-Mail: g.zanello@reading.ac.uk

2) Protocols

This study will, as a whole, combine: i) a purposive search for relevant information, including published and unpublished documents from the Centre for Sustainable Agriculture, the Sahaja Aharam Producer Company Ldt, as well as journal articles, reports, government documents, academic and technical literature, and ii) interviews with members of the Centre for Sustainable Agriculture, the Sahaja Aharam Producer Company Ldt, who can provide information about the initiative, its history, its challenges and drivers. Initially, interviews will be conducted in person (Covid-19 situation permitting), and might be later complemented by Skype/phone calls/additional

in situ visits with informants in case additional information or details are required. This approach is similar to the one adopted in a recently published paper by (Glover et al., 2021).

3) Data Collection Instruments

Research questions (RQ) for the PhD thesis chapter:

1. Investigate the history of the initiative to understand how it has changed production and consumption patterns in the region, what were the starting conditions, the barriers and the enablers and how these changed and evolved over time;
2. Understand the extent at which the initiative has been able to break existing path dependencies and factors of resistance in agri-food systems (Conti et al., 2020), and enable a transformation, and at what level of scale (local, regional, national);
3. Discuss the lessons derived from the case study for setting up and implementing transformation processes in other contexts (this last point will not be addressed by specific interview questions but will rather emerge as a point in the discussion following the analysis of the data).

RQ1 and RQ2 will be assessed through the help of a framework provided by Conti et al. (2021).
Interview questions are presented in the page below. The questions presented here will provide a foundation for the questions asked in the interview, which will be adapted, expanded and deepened based on the evolution of the interview. The phrasing of the questions might also be modified to respond to contextual requirements (e.g. amount of time available) and the interlocutor (e.g. farmer/business person/government officials etc.).

RQ1	Questions for farmers	• What were the land/soil, social and economic conditions before the establishment of CSA? • What challenges were you facing prior to the CSA set-up? • Why did you decide to join CSA? • Who provided you with relevant information and training about sustainable agricultural practices? • Was it difficult to adopt the new agricultural practices promoted by CSA? • What challenges did you encounter? • How did the establishment of the SAPC change things for you?
	Questions for other stakeholders	• What were the starting environmental/social/economic conditions prior to the set-up of the initiatives (e.g. problems of land degradation, poverty, lack of government support for farmers etc.)? • Can you tell me, in your how words, the story of CSA and later, of Sahaja Aharam Producer Company Ldt (SAPC)? • What were the starting conditions in terms of technology, infrastructure, research priorities, policy support, private sector players, and farmers' as well as consumers' practices/habits?

		• How did the CSA idea emerge/what processes let to the creation of this Centre? • When, how and why was the SAPC formed? • What were the challenges and/or opportunities that CSA and SAPC encountered during the years? • What were the main policy/infrastructural/behavioral/ political economy challenges and issues? How did they affect CSA and SAPC?
RQ2	Questions for farmers	• How did the way you produce (and eventually consume) the food change after CSA and SAPC? • How did the way you market your products change (e.g. organic label)? • Did it also change the way you consume food? • Did you see a change in other factors such as policies (e.g. subsidies) or consumers' purchases or processing since the start of the initiatives? • How did the introduction of sustainable agriculture practice change the land/soil conditions, your income, and your sense of social/ economic security? • What do you think could have been done better? Any improvements or observations from your side about the functioning of CSA and SAPC?
	Questions for other stakeholders	• How has the level of reach of CSA and SAPC expanded over the years -specifically, in terms of farmers/consumers/producers/policymakers and other actors involvement? How was this possible? And how have relationships between different actors evolved during the years? • To what extent have production and consumption patterns changed? How did CSA and SAPC transform the agri-food system, and was it only at the local/niche scale, or did they bring bigger changes? • To what extent have these two initiatives changed technology choices, infrastructure, research priorities, policy support, private sector role, and farmers' as well as consumers' practices/habits at the local/regional/national scale? • Looking back, what do you think were the key enablers for the success of CSA and SAPC? And the challenges and pitfalls? What could have been done better? • What are the future challenges and opportunities? • What do you think are the key lessons for enabling change processes?

4) Consent Forms: not needed for this research.

5) Recruitment Material

The participants are selected based on their involvement in the Centre for Sustainable Agriculture and the Sahaja Aharam Producer Company Ldt.

Dr Rasheed Sulaiman, the Director of the Centre for Research on Innovation and Science Policy, India, and a close colleague from one of my consulting assignments, offered to put me in contact with Dr Ramanjaneyulu (https://csa-india.org/doctor/ramanjaneyulu/) the head of the Centre for Sustainable Agriculture.
Dr Ramanjaneyulu then confirmed his availability to connect me with farmers and provided me with names and contacts of key informants to conduct my case study.

Return to top of form
Return to Supervisor Ethical Review, Section 5

2) Interview summary

Summary from interviews 1-2

- Initially a lot of resistance from farmers, they used to laugh at organic practices
- Reasons for joining OA: 1) low budget (no pesticides) 2) good price to farmer 3) health
- Soil training: leaves extract, neem, tobacco, tea leaves, cow dunk/urine
- Initially, the farmer would come to CSA, and CSA would suggest practices which are specific to the agroecological conditions
- Training to farmers: not only about organic practices, but also about agricultural practices more in general: for instance, difference between non-veg pest and veg pests → non veg eat bugs that would otherwise eat the crop, pesticides would kill off everything,
- SA also takes care of storage, which would usually be risky business for farmers. Grains need to be stored for some time before they can be processed. If the farmer would process the food before selling, then he would be liable – SA takes this liability
- Small marginal farmers are becoming aggregated in FPOs
- FPO memberships gives a n of advantages: 1) advisory from CSA 2) produce margin increases 3) agricultural education 4) farm machines (weeders) 5) better price compared to private dealer
- Now farmers are more interested, they go and tell others, behavioral change

Summary from interviews 3-4-5-6

- CWS was operating in the area in the early 90s, but mostly focused on water related issues (e.g., irrigation) and forestry. It has no specific division for agriculture, thus there is a need to address this. Idea of CSA, NGO that is specific for agricultural issues, born out of need to stop/decrease farmers' suicides as well as reduce pesticide use, which was both increasing production costs (almost exceeding them) + creating health issues + creating environmental issue (soil depletion)
- 2004: only NPM techniques promoted by CSA funder
- 2007/8: CSA reach expands, farmers who first were skeptical now have seen evidence of success among farmers who practice NPM, thus they are increasingly interested in switching. BUT organic products have added value (specifically, in terms of acquiring the necessary knowledge+ skills) and initially there is no market
- Different farmers cooperatives to work on different bio inputs.

- SA funded because all cooperatives were spread out, it would be much more effective if they came together and sold as a retail
- 2009 it was a consumers' cooperatives, in 2014 it became an FPO
- They tried to open a franchising but there was not enough produce, there is a supply problem
- During covid disruption – they struggled as it was difficult to get the produce that needed to be processed to processing facilities, only fresh fruits and vegetables found nearby can be transported
- Consumers initially interested mostly in buying vegetables, but now they also buy other things
- CSA is a non-profit, it works with different organizations through farmers' producers' organizations and then market the produce through SA
- Initial conditions:
- Technology: initially fertilizers and pesticides → now natural product such as neem oil, cow dunk, cow urine to fertilize and ward off pests
- Farmers: initially used to pesticides, it took a long time to convince them, CSA had to conduct demonstrations, create demo plots to show how organic practices worked. Farmers' nutrition also got better because they produce what they consume, only sell the surplus, so from food that was full of pesticides now they consume organic…. Also, economic security increased, organic products get 5 to 15% more in terms of market price
- SA does not compete with the private sector, the market is very different
- Consumers: world of mouth and tv shows to raise awareness
- Infrastructure critically different now: CSA acquired mills to process grains, oils etc. and SA is now running them, so also revolutionized the infrastructure
- Lesson: working capital → farmers need money immediately, they cannot wait. In this context, SA has to buy immediately the products that need to be stored, taking a risk
- The transition has to be a "self-sustained venture" in which the actors benefit from the process.

Summary from interviews 7-8-9-10

- Marketing major challenge initially
- If farmers sell in market organic none will know
- Progressively, awareness, tv shows etc. from 2012 onwards

- 2017: participatory guarantee system, focused on quality insurance, set up by ministry of agriculture, developed for improving farmers' welfare (if organic, farmers get a higher %)
- Before, 327 certification bodies, now only 65. The government scrutinized. CSA is one of them (specifically, 2 kinds: service providers and regional councils, CSA belongs to reg counsel)
- CSA certification process (everyone can apply) → identify people who do organic farming, then collect data in terms of: i) farmers' details ii) farm data (land size, % under organic, GPS coordinates !!! certification is done for the land plot) iii) 1 year land history (which pesticides, before it was 3 years but then shortened)
- The conversion period is of 3 years, even though the certification is given immediately but with the label "under conversion"
- Before certification → training
- Also, seasonal inspections
- PGS:
- Individual farmer
    - Group certification (min 5 members)
    - Large area certification (e.g. entire village)
    - If one farmer doesn't follow, then the entire group is suspended (or cancelled), so peer appraisal every season to check what everyone is doing. After peer appraisal, the certification is uploaded on the PGS Indian portal
- 3 records are kept: i) meeting registered ii) training registered iii) farmer diary
- After regional council will inspect based on the data uploaded by the group/village, then CSA will approve appraisal on PGS portal. This generates the certificate which is valid for one year (even if seasonal inspection)
- 2016 PGS set up
- 2017 CSA became part of PGS system
- Before this, farmers didn't have knowledge, even if they were doing organic, they don't know, now they get a certificate and a premium price
- Both farmers come and ask for CSA to certify, and buyers want to see the certificate, as well as bulk suppliers want to see before procuring
- Now 25000 certified farmers
- Major challenge in 2000s: marketing + storage facility (especially in rainy season)

- Now: cost of cultivation reduced (no high inputs) and also price higher – even if no substantial increase in yields, profit increases, even in the conversion period, in which yields might be a bit less (farmer not yet familiar with the practices, there is still a higher profit margin)
- Last two years, with covid, health concerns increase, spend more on food less on medicines.
- Government initially laughed at organic farming, and would subsidize pesticides. Now ministry of agriculture is promoting organic farming, national government gives each state a target of acres under organic.
- PGS certificate → mandatory to sell organic, now PGS is a third-party certifier that is recognized nationwide.
- Sahaja is now planning to export to US and UK, LACON is the certified agency for export (different, based on different requirements of different countries).
- Bit expensive compared to PGS, 1000 farmers are now doing, but marketing is now a major issue.
- Other future plans: expand the retail, in each district there should be a farmer.
- Farmers will aggregate production in FPOs and then there SA collects and brings it to the packaging facility.

Interviews 11-12-13-14-15-16-17-18-19

- Chemicals inputs, suicides, degradation, farmers' suicides and health
- Establishing solutions is different than establishing solutions at scale → immediate recognition by CSA
- What enables scaling? A product can be easily scaled i.e., pesticides/packet of seeds you distribute in mass and give to many people whereas NPM is a knowledge-based practice, plus knowledge is very localized, each area is different and needs new ways of learning. That is why CSA started working with farmers' schools
- One of major challenges at the beginning: initially staff very scattered e.g., staff from department of agriculture is very tied to the bureaucracy, which makes things slower and more complicated → idea of community management for CSA, its own staff doing training, work with village community.

- Farmers' field school is a loose group, no institutional binding, so staff is hired by government or NGOs → does not respond to farmers !! so cooperatives so that staff can be paid by the cooperative based on their performance
- 2004: CSA began, CSA used to have staff in villages who used to do the training BUT then the staff became staff of the village. CSA got support from donor organisations: Hivos, later Oxfam
- 2005-2008: work with the government of AP. CSA was working on its own but also received government funding to scale the initiative. Partnership with the government to scale the initiative to bring 3 million acres under pesticide production (objective reached in 2010). The partnership was built as CSA was able to show evidence of success in few villages where they were operating. Based on that, the government gave the funding (evidence-based advocacy for NPM). The design of the program was based on farmer field schools and community management.
- 2008: realised institutionalisation is important; CSA starts building the cooperative. CSA realised that the government might change and so government funding, so it has to institutionalise and detach from external funding. The AP government partnership was only till 2008, then the government was not keen on cooperatives, which were seen as unavailable institutions. CSA detached from the government but was still supported by HIVOS
- Farmers' cooperatives started for two major reasons 1) community management 2) selling the production – in particular retail store
- 2009: Start of the retail store
- 2012: media starts getting to know about CSA and organic agriculture, promotion in the media (not sponsored by CSA), students also come for collecting data showing NPM as sustainable model of production. Popular tv film star – talk show on toxic food top Bollywood film actor, that became very popular and raised a lot of awareness.
- 2014: two national prizes: best rural innovation award for 1) community management model 2) non pesticide management so the technology as well as institutions were awarded!!
- 2014 federation of institution (cooperatives) to form SAPCO, more and more cooperatives start, first only a few sparse in AP and Telangana, nowadays more than 60
- 2016 Ted talk on importance of consuming organic food. It also started the certification. The government identified various agencies that can do the certification and today in India

7 lakh hectares certified, of which 1 lakh ($1/7^{th}$) is certified by CSA itself. CSA verifies and issues the certification. Farmers if certified get premium price varying from 5 to 15 %.

- Today CSA works in three states: AP, Maharastra, Telangana and in other 9 states (which "call" on CSA expertise and where CSA partners with local NGOs to share knowledge, experiences, set up training and demos around organic agriculture. More broadly CSA in these states works with other partners to provide extension services on the production side and also FPO management (how to set up etc)
- Value chain changes
    - Before: Farmer sells to → middleman in the village → middleman sells at the bloc level → that goes to processor → then goes to distributor → then goes to retailor/market
    - Now: At village level farmers aggregate (FPO/cooperative) → processing is done at the village level → product directly comes to the store where it is also packaged 2 mins from store (3 layers are cut off so that farmers' profit also increases → value addition total 15-20%)
- Policies
    - For cooperatives there is now support available (specifically in terms of learning how to manage) and extension services (also the ones done by CSA which sometimes gets grant based support), not for organic production, subsidies still go to pesticides.
    - Compared to 2004, government behaviour changed significantly specifically around cooperatives. Now there is a ministry of cooperatives, funded in 2022. In 2019 income tax exemption for cooperatives, plus 2021 GVT started large programs to produce FPOs to try to promote more cooperatives and FPOs
    - Ecosystem needs to be built: 3 years of support from government are not sufficient, cooperative cannot sustain on its own, necessary to build the ecosystem, also in talks with government to understand
- Cooperatives and FPOs: they both operate under cooperative principles, cooperative conventionally registered under coop act which is a STATE act, so coop is registered in the state, varies across states, and the state government can intervene in the functioning of the cooperative
- FPO: producer companies act is a national level act, government intervention is minimal, fpos can work outside the states
- FPOS are better to operate, have less boundaries and undergo less scrutiny

- Major challenges at the beginning. 2 sides: institutionalisations AND switching over to organic farming. Support from government is minimal to switch to natural/organic farmer is little whereas conventional agricultural is very subsidised. Proper knowledge and extension services for the farmers are not available on organic. Institutional side: credit is problem, FPOs have limited assets, financial issues.
- Plus, knowledge and skill building not addressed in rural youth. No entrepreneurial skills, whereas it would be necessary for youth to take active role in the cooperatives. CSA is doing a bit but this educational side should be taken in charge more by the government…How much can they do as an NGO?? Assets not sufficient
- What are the lessons for scaling? You need the scientific approach. Research institutions are not supporting, still aligned with high input agriculture. At the same time, ideologically is all well and good but agriculture is a livelihood, so it should be profitable: not only knowledge about the environment, but also knowledge of business models (skills necessary for that) that work.
- Green revolution in India could happen because there were corporations, research, policies etc. If you are not doing the same ecosystem for sustainability then it will not work!!! Even if you are talking about sustainability, you have to create the ecosystem for it! Transitions won't happen on its own. You have to engineer that. It needs new scientists, new business models, new extension. Not understood how it can be scaled up
- Other states reached out to CSA. From 2012 regularly written about, plus media, so seen as the core institution for organic agriculture and called upon.
- Getting recognition both in terms of knowledge(/research) by other steps was a very big achievement
- Farmers' challenges: they will gradually make a shift, but conventional agriculture is widely supported, economics won't work out when you are shifting.
- In 2004, 30/40% of the production costs went to chemicals, so people were very concerned, today 40% is on the labour, 10% is on the chemicals, today challenge is in terms of labour, farmers want something that is less labour intensive because labour has become intensive. We have to look at the challenges of today! Also, in 2004 farmers were making their own inputs, now CSA is looking at how inputs can be made by external enterprises that can do

- Food production: processing facility SAPCO owns the processing facility, only huge volumes are done by external facility, specifically rice needs to be done outside because it´s larger production so it is done by renting mills
- Capacity to address multiple sources of resistance
- Capacity to tackle multiple parts of the value chain
- 2 dimensions of change: the practices and the institutions (NPM would not have worked if not coupled with cooperative and FPO formation/institutionalisation)

Interviews 20-21

- Organic consumption has increased because increasing health issues (NCDs) and consumers have become aware that this it often because of high pesticide content and pollution of foods – so they want to avoid.
- Number of consumers has increased and staff has increased.
- Major challenge: not able to serve the demand, problem of inconsistency of the supply, sometimes certain produce is out of stock and consumers complain about that.
- Now high farmers' involvement as well as consumers' involvement. In the past there were almost no organic food now changes in health concerns have increased demand of organic food. SAPCO has grown a lot over the years

Interview 22

- She likes buying from SA because in market products are full of pollution as well as pesticides, which is not good for health.
- She is asthmatic and after cooking food with vegetables she had health issues consuming normal veggies and fruits, no issues with organic food.
- She has been told about CSA by her neighbors and she has since then told many people. In India and in the region the consumption is really changing because many tv programs come up and tell about the ill effects of pesticides insecticides affect the health, and stress the good effects of organic (also in social media among young people ad active population 15-35 everyone is very much aware.

3) Case study summary

The full case study summary is reported here. In the summary, the framework lens is not applied.

The roots of the CSA stories are to be found in the GR, which promoted "a development model that excludes the majority of rural people" (Chappell *et al.*, 2018) and instead benefitted powerful players on global markets, who constrained farmers' choices in terms on what to grow and how to grow it, while at the same time eroding their profits (IPES, 2015, 2016, 2017; Swinburn, 2019; Conti, Zanello and Hall, 2021). Together with an economic liberalisation that also negatively affected smallholder farmers, (Vaditya, 2017), the situation led to increasing farmers' suicides since the late 80s (Nair, 2009).

In response to these challenges, in 1986 Centre for World Solidarity (CWS), a Hyderabad-based NGO, helped farmers respond to pests and weeds problems and reduce their reliance on costly chemicals particularly applying principles of Non Pesticidal Management (NMP) – what is known today as "organic agriculture". Initial successes encouraged more villages to turn to NMP (Nair, 2009). The NGO also set up the Sustainable Agriculture Group (SAG), to specifically focus on agricultural issue. These first successes in NMP laid the foundation for its further expansion in the coming years. However, the CWS was not an agriculture-focus NGO, and had no solid research background in agriculture (Vicziany and Plahe, 2017). SAG thus winded down after the starting years. If in few villages NPM had already started to thrive, improving soil health while making farmers less reliant on costly inputs and less prone to health issues, there was no NGO that could help farmers tackle the multiplicity of issues that endangered their livelihoods, and NPM was only practiced at a very small level of scale.

AP&TG were in the news in the early 2000 for the large-scale migration of farmers following the agrarian crisis caused by drought in its central districts. Large numbers of farmer suicides were also recorded in the state (Nair, 2009). Many had become indebted to pesticide dealers, seed vendors and money lenders. An acute water shortage coupled with continuous and diverse pest attacks had caused huge losses for farmers: in 2004, when an estimated 1,200 farmer suicides were reported between June and August (Ramanjaneyulu and Rao, 2008a) (Nair, 2009). In this context, an agricultural scientist previously involved with SAG and the CWS, decided to continue SAG's work in terms of promoting NPM, coupling traditional agricultural practices based on indigenous know-hows in scientific knowledge and scientific research. In 2004, he funded CSA to implement NPM in a more organised manner through technical support, capacity building programmes, campaigns, and marketing. CSA organised farmers' field schools (FFS) to teach farmers about NPM, promoting community management, and organising weekly markets in Hyderabad where farmers could bring and sell their produce. A critical point at this phase was also CSA's ability to better

link farmers to markets. Organic products have an added value: not only because they are healthier, but also because they require solid knowledge on a variety of NPM methods. This added value had to reflect in the price of the product. At the time, there was not much awareness among consumers around the harms of pesticides, or the health benefits of crops produced under NPM. A major challenge was to create a market for NPM crops. This in turn required consumers' awareness – or consumers willing to shift purchasing and eating patterns towards pesticide-free, but relatively costlier, foods.

CSA's solution for this was the set-up of "special" markets for vegetables and fruits (initially, only these two were produced under NPM). Twice a week, farmers would come to the market and talk directly to consumers, to explain how food was produced without the use of pesticides. Progressively, consumers spread the word by talking to neighbours, friends, and acquaintances (there was no advertisement done by CSA).

However, funding for the NGO remained a problem. Financial resources were key for expanding the work of the NGO, that consequently tried to involve policymakers, inviting them on-site to verify the benefits of NPM. Following a visit by the AP minister for agriculture in 2004, the State government partnered with CSA with the objective of bringing 3 million acres under NPM, a target met five years later (in 2010). On the other, CSA was able to obtain international funding from Hivos, a Dutch-based organisation. Based on the successful uptake of NPM in numerous villages Hivos decided to fund CSA (Klaver *et al.*, 2015). These two collaborations not only helped CSA financially, but also increased its credibility and outreach.

Over the following 3 years, CSA involved more and more farmers in NPM, in a sense "re-skilling" them to move away from the high-input agricultural model promoted since the 80s. Many villages converted *in toto* to organic production. Partly, the agricultural produce would be consumed by the famer and its family, thus improving their nutritional security and health. The remaining part would be sold in farmers' markets set up by the CSA: this progressively increased knowledge around organic agriculture among consumers in AP. The first 'pioneer' consumers would spread the word to friends, neighbours and acquaintances: no formal advertisement was conducted by CSA.

Despite CSA's successes, however, a change in government in 2008 ended the collaboration and funding between the State and CSA. CSA kept providing training and/or technical support to farmers by using its own staff, but the expansion of NPM created a staff shortage. This brought about the recognition within CSA that changes in the government can always happen, and government funding is unreliable. CSA therefore needed to be self-sustained. For this, the

organisation had to become more institutionalised as well as financially independent. This could be achieved through the creation of farmers' cooperatives FPOs.

The first advantage of cooperatives and FPOs was that each cooperative would have its own staff (which would be previously trained by CSA), conducting NPM trainings and advising farmers. As the villages under NPM had become more numerous and were often located in remote areas, this would at once lower the load on CSA staff and promote accountability and efficiency among staff members. The co-operative itself would ensure that the staff fulfils its tasks in terms of training and supporting farmers in NPM. Cooperatives and FPOs were run by the farmers themselves. When operating alone, "small and marginal farmers by default command a smaller voice than industry" (Morin, 2016). The set-up of cooperatives and FPOs would unite and better organize farmers, not only equipping them with community management skills, but also, in the long run, empowering them by making them in charge of their own institutions (Morin, 2016).

The second advantage was in terms of financial independence. To run with its own funding, CSA needed to increase production volumes – and thus profit. Prior to CSA, farmers used to sell their produce to intermediaries (who would take a large margin of the profit) or, after CSA came along, they still had to bring it to the market themselves. This was not a viable marketing strategy – in the sense, it could not work at scale. Co-operatives could ensure that larger volumes of production would be achieved, and that produce would be uniform in terms of production modalities (i.e. organic) and in terms of quality. They would represent "hubs" to which farmers can bring his/her produce, thus no longer having to transport it to the market him/herself (Vicziany and Plahe, 2017). Another key point in the process was the acquisition by CSA of infrastructure to ensure that "50 per cent of the retail price of the food sold is returned to the farmers" (SAPCO, no date), compared to 20-30 % that the farmer gets on the mainstream market (Vicziany and Plahe, 2017).

Increasing knowledge and expansion of CSA had led to new crops produced under NPM, such as cereals, millets, pulses, oils and spice. For this, processing facilities (e.g., flour and oil mills) were acquired by CSA and managed by SAPCO. There, the food could be stored, processed and packaged. In 2008, the cooperatives united to create a farmer producer company – the SAPCO which is a federation of 23 FPOs and cooperatives, where each has an democratically elected chair person. Besides, in 2009, the first retail store selling organic products opened in Hyderabad. This further helped farmers to find a market to sell their products at a higher price while giving consumers an easier and more stable access point (compared to weekly markets).

From 2010 onwards, growing awareness countrywide on the dangers of pesticides, together with the deteriorating conditions among farming and rural livelihoods, and issues of environmental

degradation (mostly due to monocropping patterns and chemical use), made organic agriculture look more and more appealing to a "panicking" Indian Government, which decided to orchestrate efforts towards expansion of area under organic production.

It set up a number of schemes, such as the Capital Investment Subsidy Scheme, the National Project on Organic Farming, and the National Paramparagat Krishi Vikas Yojana Scheme (Government of India, 2010c, 2010a, 2010b).

CSA and SAPCO started becoming increasingly popular and known at the state as well as national scale when a nationally streamed popular TV show, Satyamev Jayate, featured them in 2012. The show was viewed by 1.2 billion people, and was considered as one of the mostly talked about TV shows of all times (Harris, 2012). Aamir Khan, a beloved Bollywood celebrity, brought to the attention of the public the dangers of pesticides, and presented CSA as a lead example of healthy production, while explaining what organic agriculture was and its benefits. It has been reported that "after the Toxic Food episode was aired, the NGO was flooded with hundreds of visitors and received many phone calls enquiring about its NPM" (Satyamev Jayate, 2013b). Several studies started being conducted on CSA: scholars from both Indian and international institutions came to look at their practices and business model, increasing its visibility. CSA's popularity was based on two major factors.

One was, indeed, its expertise in implementing NPM. When in 2013, a study from the Food Safety and Standards Authority of India under the Union Agriculture Ministry analysed common food items and found that they contained pesticides in quantities 1,000 times higher than permissible limits (Prasher, 2013; Satyamev Jayate, 2013a), several Indian States started calling on CSA to help them in the implementation of NPM. Usually in collaboration with local NGOs, CSA staff would conduct demonstrations and trainings on NPM techniques, while developing further expertise to adapt NPM to the specific agroecological conditions of each state.

The other was in terms of farmers 'empowerment – or the ability of CSA and later SAPCO to organise farmers in their own institutions. The success of these organisations in educating and uniting farmers for the fulfilment of democratically agreed objectives (e.g. expansion of NPM production, sales etc) made the government aware of FPOs/cooperatives potential to further farmers 'rights and making rural livelihoods less vulnerable. In 2013, the government recognized the success of co-operatives (and FPOs) for advancing farmers 'rights and empowerment. If prior to 2013, the legislation for setting up cooperatives was muddled, a new legislation was promulgated in that year to make the requirements for registering cooperatives and FPOs clearer and easier to fulfil. More farmers could thus register as FPOs and cooperatives.

The success of CSA was confirmed when the NGO won two national prizes: one for the "Best Rural Innovation" and one for the "Best Community Management Model". In in a sense, this meant that both the technology and the institutions received a prize.

In 2016, CSA's funder also gave a famous TED talk on the importance of consuming organic foods. The talk went viral and was viewed by more than 3.5 million people. Concerns over the danger of consuming foods produced using pesticides, which had grown over the years, reached a peak. Consumers demanded food that were organically produced and could prove to be so. Thus, the government was pressured to better implement a certification bestowed to agricultural product, which went under the name of "Participatory Guarantee System" – commonly referred to as "PGS". PGS had been set up as early as 2006 to certify crops produced under organic principles. However, the PGS system was highly dysfunctional: the implementation of the legislation had been scattered, and even if 327 PGS centres were allowed to certify, the process was slow, the quality controls were lax and suffered from corruption, and overall the certification was unreliable. In 2016, the government decided to better implement PGS by scrutinizing the different centres. Only 65 were deemed reliable to release the certification. CSA applied to become a certifying body – formally known as "PGS regional council". CSA could now not only promote NPM, but also encourage farmers to apply for the certification and guide them in the process. This gave them right to a premium price and satisfied consumers' concerns in terms of veracity of organic claims. Now both individual consumers and bulk suppliers purchase the product only if certified.
Besides, as it became apparent to CSA that FPOs are a key tool to" help in transition towards economically viable and ecologically sustainable agriculture" (https://fpohub.com/about/), the centre also established a collaboration with the Grameen Academy to create, in 2016, "FPOhub" – an initiative which aims to support farmers in setting up their own FPO. This includes mentoring support to develop viable business strategies, promoting market linkages, setting up infrastructure facilities for FPOs, input and digital services and legal compliances support (https://fpohub.com/).
Over the last few years, SAPCO kept supporting and furthering consumers' awareness by setting up consumer-targeted initiatives, such as nutritional Counselling sessions, urban gardening, household waste management and composting, water harvesting and recycling activities are regularly conducted, along with periodic cooking festivals and exhibitions. It also runs activities in schools to create awareness in children about healthy consumption. (Ramanjaneyulu, 2019). To date, this ensures that consumers have the right means to improve their consumption and purchasing behaviour.

Even if in 2019 the pandemic threatened the functioning of the retail stores (in particular, lockdowns made it hard for the produce to move from remote locations to the stores, while the processing hubs had to initially halt production), after the first harder months, consumers' flocked to the SAPCO retail store, wishing to "spend money on healthy food rather than for buying medicines"[32]. Besides, the government continued to increase its support for farmers'cooperatives by i) establishing an income tax exemption on cooperatives (2019); ii) subsiding them for the first three years (in particular, covering administration costs) (2020) and iii) setting up a National Ministery solely dedicated to Cooperatives (the Ministery of Cooperatives) in 2022.

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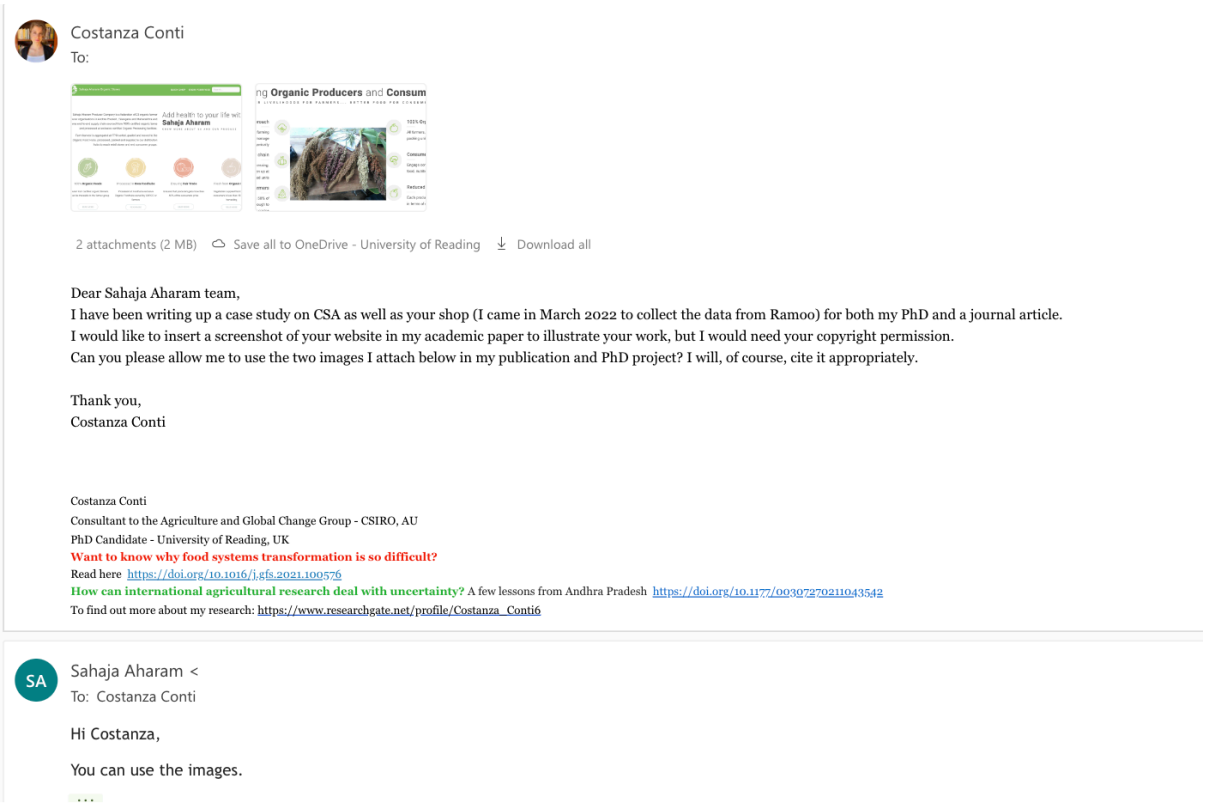

Costanza Conti
To:

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Dear Sahaja Aharam team,
I have been writing up a case study on CSA as well as your shop (I came in March 2022 to collect the data from Ramoo) for both my PhD and a journal article.
I would like to insert a screenshot of your website in my academic paper to illustrate your work, but I would need your copyright permission.
Can you please allow me to use the two images I attach below in my publication and PhD project? I will, of course, cite it appropriately.

Thank you,
Costanza Conti

Costanza Conti
Consultant to the Agriculture and Global Change Group - CSIRO, AU
PhD Candidate - University of Reading, UK
Want to know why food systems transformation is so difficult?
Read here https://doi.org/10.1016/j.gfs.2021.100576
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SA Sahaja Aharam <
To: Costanza Conti

Hi Costanza,

You can use the images.

...

[32] This line came up multiple times in different interviews.