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

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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.

Keywords

Inertia, lock-in, path-dependency, agri-food systems, innovation, systemic change

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[1] in a way that is better aligned with aspirations for sustainable and socially inclusive patterns of food production and consumption (Caron et al., 2018; Fanzo et al., 2020; FAO, 2018; Herrero et al., 2021). The need for new directions is evidenced by the persistence of environmentally damaging agriculture and food practices (CCAFS, 2020; Kopittke et al., 2019) 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. Countries in the Global South 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 et al., 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

[1] Agri-food systems are defined as 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) . They also include the web of institutional and regulatory frameworks that influence those systems. Agri-food systems are inherently complex, operate at multiple levels of scale (international/national/regional/local) and time (especially in terms of timing of the outcomes) (Hall and Dijkman, 2019).

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 (Chhetri et al., 2010; Kemp, 1994; Radulovic, 2005); (ii) the way mutually supporting systems components create "lock-ins" that perpetuate existing directions of innovation (Kuokkanen et al., 2017; M.-B. Magrini et al., 2018b) (iii) and the way inertia in existing systems halts changes towards new directions (Dury et al., 2019a; Leach et al., 2020). These ideas have manifest themselves in the socio-technical transition literature (Geels, 2002 and 2004; Geels and Kemp, 2007), and more recently, in the sustainability transition literature (V. De Herde et al., 2019; M.-B. Magrini et al., 2018a; 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, 2019a). 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 (De Schutter, 2017; Stirling, 2014). 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, 2014). 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., 2010, 2007; Mooney et al., 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 weakness and gaps that would benefit from further attention.

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 shows 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 1) (Arthur, 1988; David, 1985; Nelson and Winter, 1982). 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; Jacquet et al., 2011; Liebowitz and Margolis, 1995; McGuire, 2008). 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 (Della Rossa et al., 2020; Feyereisen et al., 2017; Rudolf Messner et al., 2021). Path- dependency is used to express that “history matters”, describing how initial choices in the past influences 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 individual level, it is used interchangeably with "lock-in" to describe individuals' disinclination towards change (Tonkin et al., 2018; Yen, 2018); at 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). Box 1 uses the example of the dominance of pesticide-related technologies to illustrate how these phenomena work together in causing resistance to changing to new directions in the agri-food systems.

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 1 about here]

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 1) outlines the key choices (keywords, databases, type of publications, language and start year) and steps for our systematic review. Additional information can be found in the Supplementary Material.

[Figure 1 about here]

4 Results

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 et al., 2011; Le Velly et al., 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 High-Income countries.

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) (Henke et al., 2018; S. Ng et al., 2021; Thow et al., 2016). More ambiguous was however the use of 'path-dependencies' and 'lock-ins'. The two terms were used almost interchangeably (Berkhout and Carrillo-Hermosilla, 2002; Chhetri et al., 2010; Kay, 2003). 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[2]. This

[2] 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.

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.

4.2 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 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 1, together with key references identified for each research domain. The explainations of resistance as mentioned in the different domains are detailed in Table 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 et al., 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 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 (Grin et al., 2010) (Frank W Geels, 2002). 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[3]" 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

[3] 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).

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.

[Table 1 about here]

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. Six thematic explanations of resistance emerge from this analysis: (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 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 2 about here]

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 (M Farstad et al., 2020; M.-B. Magrini et al., 2018b; Ruttan, 1996; Sutherland et al., 2012; Wilson and Tisdell, 2001). 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 (Newton et al., 2020) (Desquilbet et al., 2019; Jacquet et al., 2011; Luna, 2020; Pradhan and Mukherjee, 2018) (Bonke and Musshoff, 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 (Bonke and Musshoff, 2020; Bruce and Spinardi, 2018; 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 (M. Farstad et al., 2020; Huyghe and Brummer, 2014; M. B. Magrini et al., 2018; Morel et al., 2020). For example, chemical control of pests, weeds and diseases has become a well-established and persitant 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 (Bakker et al., 2020; Bardsley et al., 2018; Barnes et al., 2016; Flor et al., 2019, 2020; M. B. Magrini et al., 2018; Wagner et al., 2016; Wilson and Tisdell, 2001).

4.2.2 Institutions and policies create incentives misaligned to new change directions

65 shortlisted publications explore the role of institutions[4] 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 (Alpha and Fouilleux, 2018; Leta et al., 2020; R. Messner et al., 2021; E Zukauskaite and Moodysson, 2016a). Specific institutions, such Intellectual Property rights or food labelling regulations, are examples of institutions as lock-ins, incentivising certain forms of behaviour (Feyereisen et al., 2017; IPES, 2017, 2016; S. Ng et al., 2021; C. Russell et al., 2020) 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 (R. Messner et al., 2021; Turner et al.,

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[4] The term institutions is used here to intend costums 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 (Leta et al., 2020; Williamson, 2009, 2000).

2016; van Bers et al., 2019; E Zukauskaite and Moodysson, 2016a). 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 (M. B. 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 (Kimmich, 2016; Klimek and Hansen, 2017; Leta et al., 2020; Oliver et al., 2018; Thow et al., 2016; Van Assche et al., 2014; E Zukauskaite and Moodysson, 2016b). For example, a case study in the 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 (Baret, 2017; Benoit and Patsias, 2017; de Krom and Muilwijk, 2019; Engström et al., 2008; Kickert and van der Meer, 2011; S Ng et al., 2021; Rutz et al., 2014; Thow et al., 2016). 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 (Benoit and Patsias, 2017; Henke et al., 2018; Kay, 2003; Kuhmonen, 2018; Lăşan, 2012; Rac et al., 2020; Rutz et al., 2014). 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.

4.2.3 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 explainations 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 (Barnes et al., 2016; Beilin et al., 2012; Bonke and Musshoff, 2020; V De Herde et al., 2019; Gonçalves et al., 2015; IPES, 2016; Reenberg et al., 2012; Renwick et al., 2019; Stassart and Jamar, 2008; Wilson, 2008). 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 et al., 2020).

Findings also show how attitudinal and cultural drivers create inertia among consumers (Chen et al., 2021; Jacobsen and Dulsrud, 2007; Obih and Baiyegunhi, 2017; Webb and Byrd-Bredbenner, 2015; Yen, 2018), keeping them "stuck" along certain patterns of consumption. For example, the decision to purchase and consume food is influenced by "cultural understandings" (Rudolf Messner et al., 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).

4.2.4 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 et al., 2021) 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 et al., 2012; IPES, 2017, 2016, 2015; 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 (O De Schutter, 2017; IPES, 2017, 2016; Murphy et al., 2012; 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 that (IPES, 2016). On the other hand, large corporations can undermine political priorities and regulatory interventions (Bui et al., 2019; Foster et al., 2012; C 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 (IPES, 2015; Murphy et al., 2012). Furthermore, 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).

4.2.5 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 (Clar and Pinilla, 2011; Hale et al., 2020; Pradhan and Mukherjee, 2018; Thompson and Scoones, 2009), 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 (Beilin et al., 2012; Kimmich, 2016; Radulovic, 2005). However, this issue remains mostly overlooked in the selected publications.

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 explaiantions. 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 (Glover et al., 2021; A. J. Hall and Dijkman, 2019; Turner et al., 2016). This manifests in: short-cycle projects developing incremental solutions (A. J. Hall and Dijkman, 2019; IPES, 2016); 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 (Anderson and Maughan, 2021; Flor et al., 2020). 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 (Anderson and Maughan, 2021; Baret, 2017; IPES, 2016).

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 emerging from 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.

5.1.1 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 (Gonçalves et al., 2015; Wilson and Tisdell, 2001). 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 (El Bilali, 2019a; Hinrichs, 2014; Markard et al., 2012).

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 (Hinrichs, 2014; Markard et al., 2012).

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, 2019a; 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. Furthermore, even though agri-food systems clearly have interlinkages with the transport and energy sector, which impact their overall sustainability. Despite extensive evidence that path-dependencies and lock-ins are well present in these two sectors energy and (Barter, 2004; Klitkou et al., 2015; Seto et al., 2016; Trencher et al., 2020; Unruh, 2000), how these dependencies intertwine with agriculture and food and contribute to deepening resistance to change is a neglected topic.

5.1.2 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.

(Leta et al., 2020; E Zukauskaite and Moodysson, 2016a). 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 (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 (M. B. 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 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 explainations 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 2).

[Figure 2 about here]

This whole system reconceptualization of resistance to change shares much in common with the STS concept of a socio-technical regime (V. De Herde et al., 2019; Geels, 2004; Lamine et al., 2012; 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., 2020).

5.1.3 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, 2016, 2014).

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 et al., 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 (IPES, 2016; Thompson et al., 2007b; Thompson and Scoones, 2009).

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.

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Supplementary materials – Systematic Review process

1. 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.

2. 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[5]. 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).

[5] 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/woscc/searchtips

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.

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, <u>11 records</u> 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 and Burch, 2012; IPES, 2016, 2017; Dury *et al.*, 2019; 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).

<u>**A total of 122 documents were thus selected for the analysis.**</u>

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.

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