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Digitalisation and just transition - Research article

Agricultural digitalisation and just transition: a framework for the analysis

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Abstract. Digital agriculture is generally depicted as a new technological frontier allowing both the efficiency and sustainability of the agri-food sector to be increased through the introduction of innovative “green” and cost-effective solutions. However, there is still little empirical evidence on the wider environmental and socio-economic implications of ongoing agricultural digitalisation processes. The paper makes the point that the digitalisation of agriculture is a political and ecological process representing an important element of the uneven and combined patterns of the capitalist development of agriculture. At the same time, the practices that inform agricultural digitalisation are shaped by social, economic and environmental factors that change according to the context. Starting from these premises, the authors propose a critical framework for equipping empirical research on digital agriculture with a more comprehensive understanding of local contexts, while also retaining a wider political economy perspective inspired by the concept of “just transition”.

Keywords: agricultural digitalisation, food system, sustainability, agrarian labour, just transition.

JEL codes: O1, O3, Q1.

HIGHLIGHTS

- Agricultural digitalisation is a political and ecological process representing an important ingredient of the uneven and combined patterns of the capitalist development of agriculture.
- Empirical research on agricultural digitalisation is needed, as long as it is supported by appropriate frameworks enabling a more nuanced understanding of local contexts while also retaining a wider political economy perspective.
- The “just transition” perspective offers valuable insights into the socio-ecological impact of agricultural digitalisation.

1. INTRODUCTION

Agricultural digitalisation is generally portrayed as a necessary transformation for the agri-food system, allowing production targets to be reconciled with sustainability goals thanks to the diffusion of new cost-effective and eco-friendly farming solutions (OECD, 2022; Mondejar *et al.*, 2021; Lajoie-O'Mailey *et al.*, 2020). It is also presented as a process that can contribute to counteracting the rural exodus, establishing new connections between rural and urban areas, creating new opportunities for endogenous development, and improving food system outcomes (FAO, 2022; Trendov, 2019; Word Bank, 2017, 2019).

In line with these expectations, the European Green Deal attributes a central role to digital agriculture in the ecological transition and sustainable growth (European Commission, 2019). European Union (EU) Member States strongly envisaged “a smart and sustainable digital future for European agriculture and rural areas” (European Commission, 2020), and several EU policies, instruments and funds are currently serving the scope of digitalisation of agriculture (Reinhardt, 2022). Also the Farm to Fork (F2F) strategy, which is a pillar of the EU's Green Deal, places a strong emphasis on the role of research and (digital) innovation in addressing the challenges of sustainable food systems.

Notwithstanding the increasing enthusiasm towards digital agriculture, however, there is still little empirical evidence on its deepest environmental and socio-economic implications. The existing literature tends to focus on the potential outcomes of agricultural digitalisation in terms of productivity and market possibilities for farmers (Phillips *et al.*, 2019). Agronomic and engineering perspectives that focus on the pull and push factors of digital agriculture and its environmental impact understood as efficiency are not rare (Wolfert *et al.*, 2017; Bucci *et al.*, 2019). On the contrary, issues related to the broader effects that digitalisation may have on local ecosystems and agrarian structures are often neglected. For instance, there is still much to know about the potential role of digital technologies in reinforcing or contrasting existing power asymmetries and inequalities in agriculture and rural areas, as well as about their impact on the reconfiguration of the relationship between agricultural work and territorial sustainability (McMichael, 2023). Though several studies have explored the potential consequences deriving from asymmetries in digital technology adoption, as well as problems related to data access and control (Stone, 2022; Rolandi *et al.*, 2021; Dietz and Drechsel, 2021; Rotz *et al.*, 2019; Hackfort, 2011), there is still room to further prob-

lematise the role of digital agriculture (Brunori, 2022), especially with regard to labour issues and their intertwining with sustainability goals (Carolan, 2020).

Not surprisingly, institutional initiatives to promote digitalisation in rural contexts are usually based on a free-market rationale and rarely consider contextual specificities (Salemink *et al.*, 2017). In this respect, Alistair Fraser (2022) has warned against the risk of smart agriculture developing through the production of “misconfigured innovations”, mainly due to the limited parameters within which innovations are set to operate. According to him, “agricultural innovation processes will continue to introduce new misconfigurations when they pursue discrete solutions to specific problems, rather than integrated developments based on incremental adjustments in information-intensive iterative processes that target systemic or structural change” (*ibidem*: 203).

To avoid this risk, in-depth empirical studies are very much needed, as long as they are informed by critical perspectives able to shed light on the expected and unexpected outcomes that agricultural digitalisation may produce in each particular context, while also connecting it with the broader picture of the socio-ecological agrarian system.

Our assumption is that the digitalisation of agriculture is a political and ecological process representing a further ingredient of the uneven and combined patterns of the capitalist development of agriculture (Alarcón *et al.*, 2023; Smith, 2020). As such, broader perspectives on political economy and critical agricultural studies are needed to address this transformation and can provide relevant insights into the process of digitalisation and its consequences (Rotz *et al.*, 2019; Dietz and Drechsel, 2023). At the same time, it is also important to consider that the practices and discourses that inform agricultural digitalisation are strongly shaped by social, economic and environmental factors that may vary enormously across different settings.

To account for this complexity and facilitate a socio-ecological analysis of how digitalisation impacts agrarian change dynamics at a local level we suggest the relevance of a “just transition” perspective (Morena *et al.*, 2020; Benegiamo *et al.*, 2023). The concept of a just transition (JT) is hinged on the idea of ensuring that the shift towards more sustainable systems does not disproportionately harm certain groups, individuals or communities (ILO, 2015). This implies recognising that the ecological transition may have disruptive effects on the livelihoods of workers and farmers, and leave vulnerable groups behind.

Considering all the above, the main goal of this article is to elaborate a framework for equipping empiri-

cal research on digital agriculture with a more nuanced understanding of local contexts, while simultaneously exploring ongoing dynamics of agrarian change from a JT perspective.

The article is structured as follows: in the first section we set the context of agricultural digitalisation from a political economy perspective, providing a review of the existing literature on critical agrarian studies; in the second section we briefly introduce the concept of JT and the ongoing debate surrounding its application in the agri-food sector, stressing the potential of the JT perspective in addressing the social impact of digital agriculture; in the third section, we propose a framework to support empirical research on agricultural digitalisation in order to overcome the existing knowledge and analytical gaps.

2. AGRICULTURAL DIGITALISATION AND DYNAMICS OF AGRARIAN CHANGE: A BRIEF LITERATURE REVIEW

Concepts such as “digital agriculture”, “smart agriculture”, “agriculture 4.0” are often used interchangeably in reference to a broad set of digital technologies, tools, software and data-driven solutions allowing agricultural processes to be optimised, from agricultural inputs (seeds, insurance and finances) and on-farm operations, to food processing, transport, storage, retail and consumption (Clapp and Ruder, 2020; Rotz *et al.*, 2019).

Here, we refer to “agricultural digitalisation” as a phenomenon that is far from being simply a further step in the process through which technology is incorporated within farming systems. From a wider political economy perspective, indeed, the penetration of digitalisation into agriculture can be understood as a socio-economic process representing an important ingredient of the development of the capitalist agrifood system in the context of multiple and systemic socio-ecological crises (Akram-Lodhi, 2021; Akram-Lodhi, Kay, 2010a, 2010b; Smith, 2020; Friedmann, 1993; McMichael, 2013b).

Agrarian development has long been driven by the goal of increasing productivity through mechanical technologies and chemical inputs, resulting in a deep reconfiguration of local agrarian structures. Pursuing the declared goals of “feeding the world” while also improving incomes at farm level, the productivist approach adopted by governments and key global development actors from the 1950s onwards has produced highly controversial outcomes. Although with some significant regional differences, the agricultural sector has been characterised by a dramatic decline in employment levels

and an increasing concentration of arable land (Bagliolini, Gibbon, 2013), combined with the diffusion of agro-industrial intensification and growing environmental degradation (Rasmussen *et al.*, 2018). Especially with the rise of the so-called neoliberal “corporate-environmental food regime” (McMichael, 2005; Friedmann, 2013) – implying convergence of environmental politics and corporate power concentration – food crises have grown in frequency and intensity (Fama, Conti, 2022; FAO, 2021), exposing farmers to price-squeeze dynamics and making them increasingly dependent on the global value-chains controlled by transnational corporations (TNCs).

At the same time, as the limits of the efforts to modernise agriculture have become more evident, rising social claims and market tendencies have first pushed for a shift towards a post-productivist paradigm, finally setting the scene for an “ecological transition” within the context of market liberalisation. In the European context, the process for the Common Agricultural Policy (CAP) reform and its following implementation at the Member State level has displayed clear tensions between, on the one hand, the structural path-dependency and other mechanisms that lock entrepreneurial farmers into the dominant socio-technical regime, and, on the other hand, the ambition to support the transition towards more sustainable systems of food and farming, in line with the European Green Deal (Ploeg, 2020).

In this scenario, the role played by digital agriculture can be framed in highly different ways. Most enthusiastic narratives tend to depict it as a new technological frontier allowing the agricultural sector to be revitalised and sustainability improved through the introduction of innovative “green” and cost-effective solutions (Foresight. The Future of Food and Farming, 2011; Franks, 2014). To be sure, agricultural digitalisation as a support for precision farming can help farmers in optimising the use of chemical inputs and rationalising water consumption. Moreover, digital platforms can be used to reduce intermediaries, improve price transparency and ensure product traceability. However, the idea that digital innovation *per se* can provide effective responses to the ongoing “agro-environmental crisis” (Ploeg, 2018) and improve equity in the agri-food system has to be questioned.

According to critical agrarian studies, for instance, “green” technologies are a key component of neoliberal politics that is further exacerbating the socio-ecological contradictions of capitalism (Akram-Lodhi, 2021; Borras, Franco, 2018; Fairhead *et al.*, 2012; Weis, 2010). From this point of view, the digitalisation of agriculture does not challenge the agro-industrial model and its socio-ecological lock-in but rather risks accentuating its matrix, encouraging a progressive increase in

the agricultural scale and concentration of production means, with consequences in terms of rural dispossession and depopulation, a worsening of food security and the emergence of new problems of access to and control of production and reproduction factors for small farmers (Mooney, 2018; Rotz *et al.*, 2019; Benegiamo, 2023).

In this regard, Hackfort (2021) observed that the adoption and development of digital agriculture are embedded with power relations that end up feeding at least five patterns of inequalities: in digital technology development; in the distribution of benefits from the use of digital technologies; in sovereignty over data, hardware and digital infrastructure; in skills and knowledge; and in problem definition.

Along the same line, Rotz *et al.* (2019) identified three main challenges related to: data ownership and control; the production of technologies and data development; data security. The point made by the authors is that, since technological solutions are usually developed in ways that empower corporate actors rather than supporting independent farmers, the current paths of agricultural technology “may exacerbate inequities for marginalised food system actors, specifically between different sized farmers as well as farmers and agro-food corporations” (*ibidem*: 222). However, they do not consider agri-food digitalisation as something in sharp contrast with the possibility to engender greater equity in agriculture, for instance by supporting the diffusion of agro-ecological methods and approaches.

According to Glenn Davis Stone (2022), while digitalisation does not necessarily pose a threat to the autonomy of “industrialised farmers”, it is likely to jeopardise that of “peasants” in the Global South, who still produce a relevant portion of the food consumed globally (Ricciardi *et al.*, 2018; Samberg *et al.*, 2016). For this vast class of farmers, Stone (2022: 610) argues, the penetration of digital technologies calls directly into question a set of “*informational relations of production*, defined as relationships that control the creation, interpretation, dissemination and deployment of information needed for productive processes” and there is no doubt that some of these technologies “can – indeed aim to – disrupt and reformulate such relations”.

Against this background, it is important to distinguish the technologies that can support decision-making for small farmers from those that are used to appropriate their knowledge and increase their dependence on market dynamics (Lioutas *et al.*, 2019: 1). At the same time, a less technocentric and more holistic approach is needed, focused on digital agriculture as a multidimensional phenomenon in which different combinations of practices, actors and artefacts are established, transforming

the social and physical structures of the agri-food system (Aларcon *et al.*, 2023; Higgins, Bryant, 2020; Lioutas, Charatsari, 2021).

3. PROBLEMATISING AGRICULTURAL DIGITALISATION FROM A “JUST TRANSITION” PERSPECTIVE

As already mentioned, the idea of digital agriculture is strongly framed within the debates and policies for the ecological transition in agrifood, made particularly urgent by the impacts of and contributions to climate change by industrialised agriculture. Despite this, the possible social implications and changes to farmers’ and farmworkers’ conditions and livelihoods driven by digital transformation are still poorly discussed. This, as noted by Aubert *et al.* (2021), can be partly comprehended as a lack of ecological macroeconomics frameworks for the agro-industrial sector able to capture the socio-economic impacts of the transformation needed to bring it back within planetary boundaries. As a reaction to this gap, recently, a burgeoning discussion on just transition (henceforth JT) in agriculture has been established (Blattner, 2020; Moilanen, Alasoini, 2023; Kaljonen *et al.*, 2023), based on the idea that a fair transition process is one that does not leave behind farmers and farmworkers and the communities concerned.

The idea of JT implies that the transition to a climate-neutral economy must at the same time secure the future and livelihoods of workers and their communities. This means that social justice, with a special focus on decent work and quality jobs, must remain at the centre of any environmental analysis and policy regarding the ecological transition (ILO, 2015; OECD, 2017). According to ILO, the vision of a JT is embedded with the notion of socioeconomic sustainability, and the ILO’s guidelines state that: «a just transition for all towards an environmentally sustainable economy [...] needs to be well managed and contribute to the goals of decent work for all, social inclusion and the eradication of poverty» (ILO, 2015).

The concept of JT originated with the United States labour movement of the 1970s and broadened as labour organisations forged alliances with environmental justice groups starting in the 1990s. Initially, the idea of JT emerged in response to increased regulation of polluting industries in the wake of the National Environmental Policy Act and the establishment of a federal Superfund law in the U.S. Labour unions like the Oil, Chemical, and Atomic Workers (OCAW), long vocal about the environmental impacts of their work, faced widespread

job losses despite heavily funded cleanup efforts at contaminated work sites. Workers demanded a “superfund for workers” and a “superfund for communities” that included, in addition to retraining programmes and community support, broader efforts to plan and design a more environmentally-friendly approach to industrial production (Henry *et al.*, 2020; Mazzochi, 1993). Workers and their communities were called upon to play a leading role in this rethinking of work itself and of the relationship between the factory and the territory, based on the dual principle of the “right to know” and the “right to act” (Morena *et al.*, 2020).

Since 2015, with its inclusion in the Paris Agreement that resulted from COP21, the concept of JT has become increasingly widespread in the narrative used in the governmental arena. As concerns the agrifood sector, the 2015 Paris Climate Agreement already recognised the need for a “just transition of the workforce, and the creation of decent work and quality jobs, including in agriculture, forestry, and other land uses” (UNFCCC, 2015).

More recently, the principle of JT has also been adopted by the European Union as an important dimension of the European Green Deal¹. However, as a recent report by the Institute for European Environmental Policy (IEEP) states, compared to other industrial sectors the concept of transition and JT “take on a distinctive character when applied to the agricultural and food sectors”, making its realisation particularly challenging. Indeed, as stressed by the IEED, and with some exceptions in the meat value chain: “Unlike sectors facing redundant technologies and outright factory closure and cessation of production, agriculture and land use will continue in many cases but has to be transformed. Just transition for this sector will therefore go beyond the classical policy instruments for this purpose namely: financial redundancy payments, retraining and skilling, regional investment strategies and ensuring the mobility of the workforce” (Baldock, Buckwell, 2021: 2).

A further level of complexity arises from the diversity that characterises agricultural and food systems both globally and in Europe, where large commercial farms and highly industrialised monocultures contrast with the great fragmentation into small and micro family farms throughout rural landscapes. Moreover, in this context, as Van der Ploeg (2018) outlines, the industrial agricultural system is undergoing a process of disaggregation, with multiple trajectories of change coexisting, on which the processes of digitalisation are grafted,

making it difficult to predict the overall outcome of ongoing transformations.

Against this backdrop very different patterns of transition and digital transition need to be imagined and it would be more appropriate to talk of plural transitions to digital agriculture (see also Bock *et al.*, 2020). This is also related to the diversity of socio-economic contexts, rural ecosystems, soils and climate in which farms operate. For instance, farmers in marginal or peripheral lands, or residing in regions with relatively limited government support for the transition, as well as elderly farmers, are less likely to establish a competitive position in the use of new technologies (Murphy *et al.*, 2022) and are at greater risk of being put out of competition by early adopters more able to bear the economic cost of digital investment.

The fragmentation and disaggregation of the agrarian landscape are also reflected in the presence of very different labour positions that may be uniquely impacted by transition processes, including the one envisaged by digitalisation. Entrepreneurs, consultants, families and seasonal workers often co-exist in the same sectors. Moreover, manual and seasonal jobs are often performed by irregular and poorly protected migrant workers, mostly in conditions of severe exploitation (Corrado *et al.*, 2016; Rye, Scott, 2018). At the same time, while taking into account the different and non-comparable labour positions, it is important to stress the general need, upstream of transition processes, to improve working conditions in a sector where they are often too poor.

Regarding the impact of digitalisation on farmers and farmworkers, two main scenarios can be outlined. On the one hand, there is the idea that digitalisation will reduce the need for physical inputs, with a consequent decrease in the demand for labour (Wolfert *et al.*, 2017; Gorbart, 2012), but also a qualitative reconfiguration of agricultural employment that may lead to the gradual elimination of most precarious job positions (i.e. seasonal pickers, shepherds and livestock workers) or a further casualisation of the same tasks. On the other hand, new forms of precarious work could be associated with the specific needs of digital technologies and their use (i.e. logistics porters and food delivery couriers). At the same time, economic burdens from investing in the transition to digital agriculture could exacerbate the labour-capital conflict, inducing farmers to rely on less fair work schemes.

Another aspect to consider is the potential for digitalisation to exacerbate power asymmetries between, on one side, large farmers and, on the other side, peasants and agroecological farmers. The latter are often excluded from funding and incentive programmes, and digital technologies may not be suited to them, as

¹ The Just Transition Mechanism (JTM) is based on a set of tools, including financial ones, that have been incorporated within the European Green Deal “to ensure that the transition to a climate-neutral economy happens in a fair way, leaving no one behind” (EC, 2020b).

they tend to be tailored to the needs of larger and more influential players.

Against this backdrop, assuming a JT perspective allows the potential impact of digital agriculture to be assessed on all the different players within the agri-food system, but also to consider farmers and workers as social actors who can be drivers of emancipatory technical innovation, counteracting the tendency to analyse labour, sustainability and innovation as separate issues (Rathzel *et al.*, 2021).

At a policy level, indeed, digitalisation can offer the opportunity to promote a rescaling of agriculture towards place-based models and practices that have proven to be more resilient and capable of ensuring food safety and security (Marsden, 2013). To this end, policy interventions should be informed by a JT approach that perceives work as interconnected with the community, both the place-based community of the surrounding area and the wider community that connects consumers to producers (Murphy *et al.*, 2022). Such an approach is crucial to consider the food system as a whole, also in order to avoid placing the burden of the transition solely on the shoulders of farmers.

The framework developed by Aubert *et al.* (2021) for the ecological transition of the French dairy sector is in line with these considerations. Based on the requirements of the French National Low Carbon Strategy the authors devised two different scenarios. The first one, associated with greater job losses, envisages an adaptation and compensation strategy for the industrial sector which is limited to obtaining results in terms of reducing the emissions of individual companies. The second scenario, on the contrary, simultaneously considers the effects on biodiversity, health and employment by integrating a JT perspective. This allows more integral policy measures able to support the ecological transition while also preserving employment levels.

4. A JT FRAMEWORK FOR EXPLORING THE IMPACT OF DIGITAL AGRICULTURE

As highlighted in the above-mentioned debates, the penetration of digitalisation into agriculture entails risks and opportunities for the sustainability of the food system, depending on various technological, economic, environmental and social factors. Therefore, more nuanced empirical research is required to observe how these factors are combined within each specific context. In order to shed light on the socio-economic implications of digital agriculture, it is also fundamental to grasp the drivers of the diverse digitalisation patterns,

how these affect, and are affected by, the decisions made by the actors involved, and how these decisions are, in turn, influenced by the institutional framings of the ecological transition.

To better orient empirical research, a framework able to capture the interplay of all the dimensions of agricultural digitalisation can be helpful. The term “framework” refers to a heuristic model that can help guide empirical research and develop a comprehensive approach to understanding a complex phenomenon. It should by no means be considered as a rigid scheme to be followed strictly, but rather as a flexible tool to be adapted and refined according to the specific research question and context. It is also important to recognise that, while it can offer important descriptive information, a framework does not in itself provide a deep analytical understanding of the phenomenon being studied. Hence, it is essential to adopt it in conjunction with other analytical tools and approaches. A well-known example of a framework is the one developed by Ian Scoones (1998) for the analysis of sustainable rural livelihoods, where all factors affecting the subsistence of individuals are schematically illustrated in relation to five key indicators (context, conditions and trends; livelihood resources; institutional processes and organisational structures; livelihood strategies; sustainable livelihood outcomes).

In our framework, we propose to consider six dimensions, listed in Table 1. A set of questions is associated to each dimension. In addition, we have focussed on the idea of just transition, as an approach capable of combining work and territory within a transition perspective attentive to the intersectional impacts of transformations in industry sector models.

Building on Tribaldos, Kortetmäki (2022), for each dimension we have also identified criteria for just transition in food systems potentially applicable at a process- / policy-pathway evaluation level. These criteria are intended to provide guidelines and normative visions regarding desired directions of change, aiding clarification and discussion of what makes transitions just (see ILO, 2015; UNFCCC, 2020).

The criteria are derived from basic principles and fundamental rules of justice established in philosophy and social theories of social justice – corresponding to “A-level principles” in the model proposed by Tribaldos, Kortetmäki (2022)². For each A-level principle, more practical rules of justice serving as an analytical lens to just transition can be inferred – corresponding to

² According to the two authors, these are: distributive justice, cosmopolitan justice, ecology and non-human beings, procedural justice, recognition justice, capacities.

Table 1. Dimensions of agricultural digitalisation

Dimension	Description
<i>Context</i>	This dimension refers to all the context-specific factors that affect the adoption and outcomes of digital agriculture. Related questions should explore how the context shapes local agricultural practices, the strategies adopted by the actors and the different tools of agricultural digitalisation proposed and/or adopted.
<i>Actors and socio-cultural dynamics</i>	This dimension refers to the impact that digital agriculture has on social structures and rural communities as well as its relation with the symbolic and cultural spheres. Related questions should analyse the actors involved and the social networks in which their digital practices are embedded, the related processes of knowledge creation and transfer, and the factors (in terms of resources, values, beliefs) that affect digital agriculture tools adoption and impact.
<i>Technological infrastructure</i>	This dimension refers to the hardware, software and connectivity required for the digitalisation of agriculture. Related questions should explore the accessibility and quality of the technical options available in a given context, their potential socio-economic outcomes, as well as the factors that influence the extent of technology adoption, such as business structure, type of farm production, cost, perceived risks and benefits, cultural attitudes, literacy among farmers, etc..
<i>Economic model</i>	This dimension refers to the development model followed by the farms that innovate digitally, their scale and position within the value chains, and the broader economic implications of digital agriculture. Related questions should explore how digitalisation is connected with the different trajectories of agricultural development, its impact on value creation and distribution and the way it is affecting the labour market and the socio-economic structure of agri-food production. In a different vein, it is also relevant to grasp the economic context within which digital technologies are embedded, fabricated and promoted on the market. To assess the specificity of the technoscience market and its relations with, for example, financial tools or public incentives, on one side, and the specificity of the farm economy on the other.
<i>Environmental implications</i>	This dimension refers to how digital agriculture affects the “social production of nature” and the influence of nature over social production and reproduction. Related questions should investigate the immediate digital agriculture impact on the ecosystems, but also the unintended effects that the new practices induced by digitalisation can have in terms of biodiversity loss and ecosystem alteration, as well as the potential emergence of new consumption patterns and market dynamics that may have off-farms environmental implications. A focus on the entire value chain may also be relevant, including the impact of the agritech sector, as well as the underlying greenhouse gas and environmental footprint due to data mining and storage, which is becoming increasingly significant in terms of the overall footprint of IT.
<i>Institutions, governance and policies</i>	This dimension refers to the institutional processes, the regulatory framework and political dynamics governing agricultural digitalisation. Related questions should explore how the outcomes of digital agriculture are negotiated and affected by institutional factors, the influence exercised by policies and governance structures at local, national, and international levels, and the potential conflicts that may arise. This latter aspect is also related to the presence and type of participation mechanisms and the degree of inclusion of potential stakeholders, as well as their definition and relative power assimilations.

“B-level principles”. In our case, we have identified a list of B-level principles that include, but are not limited to: 1. right to food, labour justice (incl. farmers, herders and fishermen); 2. just food-chain structures and livelihood opportunities, (distributive justice); 3. global fairness (cosmopolitan justice), intergenerational justice and fairness; 4. ecological integrity and justice for animals (ecology and non-human beings); 5. just processes and access to relevant information (procedural justice); 6. respectful pluralism and esteem recognition and non-discrimination (recognition and intersectional justice); 7. capacity building (capacities).

For each of the dimensions identified, and with the aim of substantiating and operationalising them, Figure 1 lists a set of potential questions whose articulation with the criteria in Figure 2 makes it possible to narrow the focus of the analysis, according to the political economy perspective of the JT approach.

Answering the questions listed in Figure 1 allows a more comprehensive understanding to be gained of how

the digitalisation paradigm and specific digital technologies articulate into the research context, going beyond sectoral analysis about agricultural digitalisation. Taking into account the complexity of the analysed phenomena is indeed an increasingly recognised requirement of innovation and transition processes. This also includes the need to broaden the scientific capacity to include different perspectives and interests directly in the problem framing, as well as in the decision-making and implementation process, in order to recognise the systemic, normative and uncertain character of socio-technical transformation processes, such as those related to the challenges of climate change and sustainability (Funtowicz, Ravetz, 2003). In line with these arguments, once the above dimensions have been examined, we suggest integrating a political economy perspective based on the previously listed dimensions of justice as substantive elements for a JT approach. This makes it possible to develop a framework to assess whether and how, in a given context, the digital transformations of agriculture are

Figure 1. Exploring the impact of digital agriculture: potential questions.

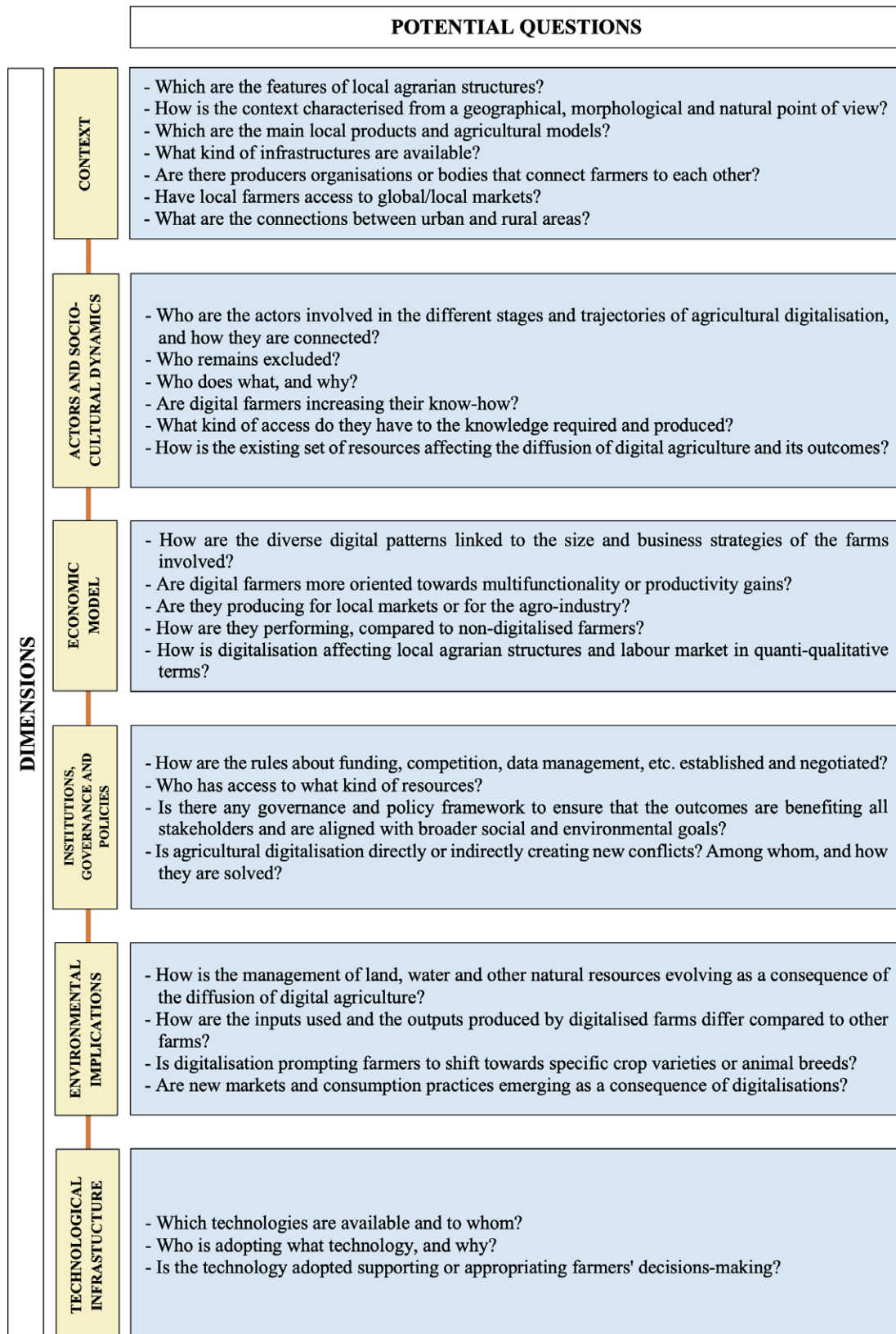
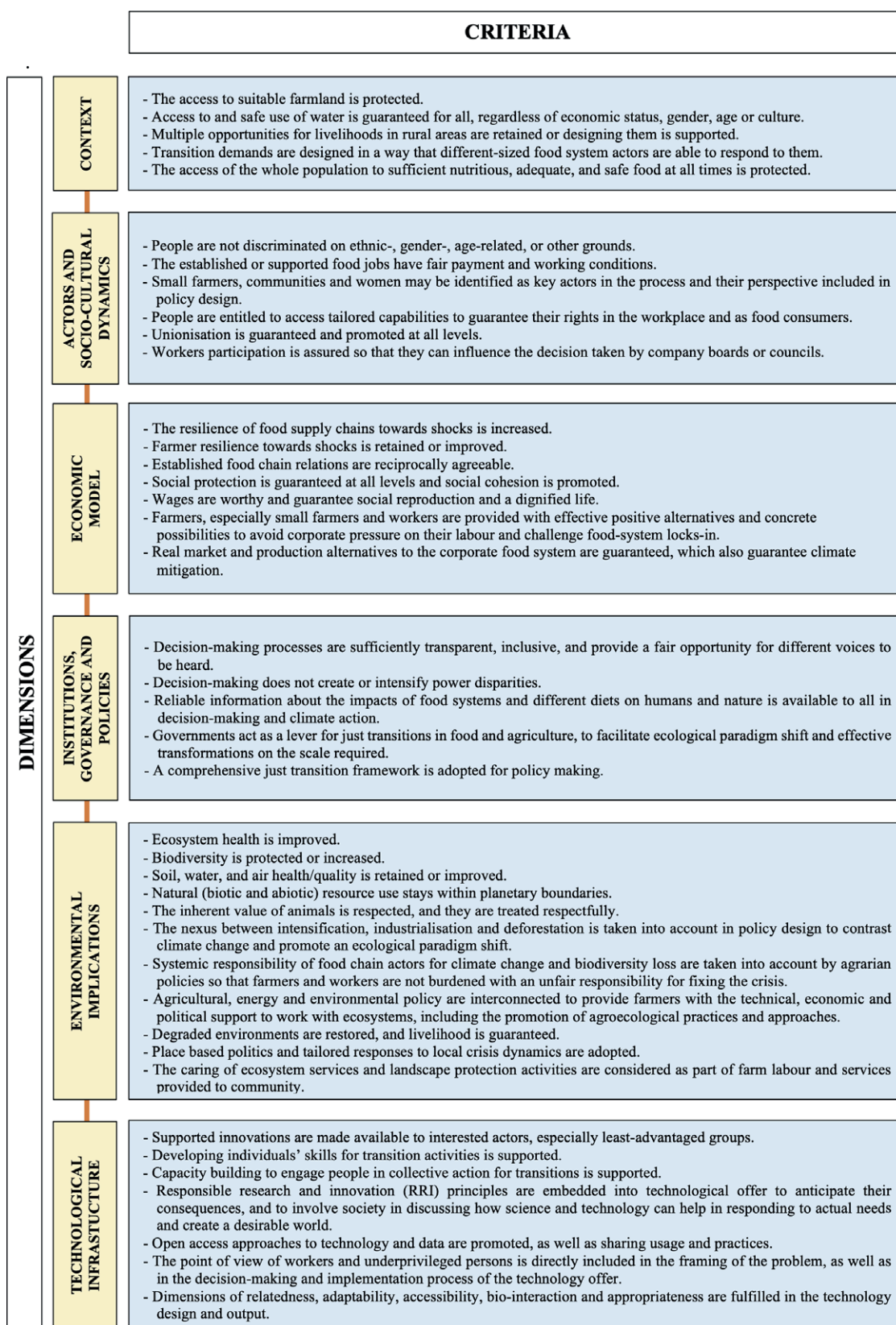


Figure 2. Exploring the impact of digital agriculture: JT criteria.



in line with the JT criteria in Figure 2 or whether they are exacerbating inequalities and leaving certain groups behind. The final step is to understand to what extent the different actors involved have the possibility to influence the ongoing digitalisation patterns, who bears the costs and who should benefit the most. The ecological dimensions of both labour and production process are also taken into account and articulated with the analysis of digital transformation.

5. CONCLUSION

The penetration of digitalisation into agriculture is a process entangled with the capitalist development of agriculture and the related politics of sustainability. Therefore, a wider political economy perspective is needed to shed light on the deepest implications of agricultural digitalisation, moving beyond most enthusiastic and techno-centric narratives portraying it as a win-win solution and a necessary transformation for the sustainability of the agri-food system.

From a theoretical standpoint, the existing literature has already outlined a number of potential risks surrounding agricultural digitalisation in the context of the “corporate-environmental food regime” (McMichael, 2005; Friedmann, 2013), especially for smaller farmers (Stone, 2022; Rolandi *et al.*, 2021; Dietz, Drechsel, 2021; Rotz *et al.*, 2019; Mooney, 2018; Hackfort, 2011). Nevertheless, it is important to take into account that the drivers and effects of agricultural digitalisation may differ enormously according to the specificity of the local contexts. While one must consider how the latter are structurally integrated into the existing food regime, it is also fundamental to keep in mind that the choice to innovate digitally is part of changing strategies adopted by farmers to cope with both endogenous and exogenous problems.

It follows the need for empirical research enabling a more nuanced understanding of local contexts while also retaining a broader political economy perspective. To this end, we proposed a framework aimed at exploring the different dimensions of agricultural digitalisation through a set of questions that, for the sake of conciseness, could be reframed as follows: a) what are the drivers of agricultural digitalisation and how is this process negotiated and affected by the context-specific strategies adopted by farmers? b) how are these trajectories of change connected to the long-term trajectories of the global agri-food system? c) how is digitalisation influencing the capacity of local ecosystems to sustain agriculture and vice-versa? d) who are the actors involved in the political definition of rural sustainability and who

are those that remain excluded? e) what are the effects of agricultural digitalisation on existing power relations and socio-economic structures?

Answering these questions implies the adoption of a JT perspective focused on whether ongoing agricultural digitalisation processes are exacerbating existing inequalities or leaving vulnerable groups behind. At a policy level, such an approach is essential to gain valuable insights into how to mitigate the potential negative effects of agricultural digitalisation and, at the same time, reframe sustainability goals and practices in a more equitable way. To be sure, the digitalisation of the agri-food system is an ongoing and evolving process. New elements and dimensions are likely to emerge, requiring continuous adjustments to the proposed framework.

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REFERENCES

- Akram-Lodhi A.H., Kay C. (2010a). Surveying the agrarian question (part 1): unearthing foundations, exploring diversity. *The Journal of Peasant Studies*, 37: 177-202. DOI: <https://doi.org/10.1080/03066150903498838>
- Akram-Lodhi A.H., Kay C. (2010b). Surveying the agrarian question (part 2): current debates and beyond. *The Journal of Peasant Studies*, 37: 255-284. DOI: <https://doi.org/10.1080/03066151003594906>
- Akram-Lodhi A.H. (2021). Food regimes and agrarian questions. In: Veltmeyer H., Bowles P. (eds.) *The essential guide to critical development studies* (pp. 275-283). Routledge, London.
- Alarcón-Ferrari C., Corrado A., Fama M. (2023). Digitalisation, politics of sustainability and new agrarian questions: The case of dairy farming in rural spaces of Italy and Sweden. *Sociologia Ruralis*, 1-26. DOI: <https://doi.org/10.1111/soru.12420>
- Aubert P.M., Gardin B., Huber É., Schiavo M., Alliot C. (2021). Designing Just Transition Pathways: A Methodological Framework to Estimate the Impact of Future Scenarios on Employment in the French Dairy Sector. *Agriculture*, 11(11), 1119. DOI: <https://doi.org/10.3390/agriculture11111119>

- Baldock D., Buckwell A. (2021). *Just transition in the EU agriculture and land use sector*. Institute for European Environmental Policy.
- Baglioni E., Gibbon P. (2013). Land Grabbing, Large- and Small-scale Farming: what can evidence and policy from 20th century Africa contribute to the debate? *Third World Quarterly*, 34(9): 1558-1581. DOI: <https://doi.org/10.1080/01436597.2013.843838>
- Benegiamo M., Guillibert P., Villa M. (2023). Work and welfare transformations in the climate crisis: A research pathway towards an ecological, just transition. *Sociologia Del Lavoro*, 165(1): 9-29. DOI: <https://doi.org/10.3280/SL2023-165001oa>
- Benegiamo M. (2023). *The ecology-labour nexus in the digitalisation of agrarian agriculture and the socio-ecological crisis of reproduction*. Paper presented for the Europe and the Extraction-Exploitation Nexus, international workshop, University of Barcelona - UAB, 28-29 July, Barcelona.
- Blattner C. (2020). Just Transition for Agriculture? A Critical Step in Tackling Climate Change. *Journal of Agriculture, Food Systems, and Community Development*, 9(3): 53-58. DOI: <https://doi.org/10.5304/jafscd.2020.093.006>
- Bock A.K., Krzysztofowicz M., Rudkin J., Winthagen V. (2020). *Farmers of the Future*. European Union, Luxembourg.
- Borras S.M., Franco J.C. (2018). The challenge of locating land-based climate change mitigation and adaptation politics within a social justice perspective: Towards an idea of agrarian climate justice. *Third World Quarterly*, 39(7): 1308-1325. DOI: <https://doi.org/10.1080/01436597.2018.1460592>
- Brunori G. (2022). Agriculture and rural areas facing the “twin transition”: principles for a sustainable rural digitalisation. *Italian Review of Agricultural Economics*, 77(3): 3-14. DOI: <https://doi.org/10.36253/rea-13983>
- Bucci G., Bentivoglio D., Finco A. (2018). Precision agriculture as a driver for sustainable farming systems: state of art in literature and research. *Calitatea*, 19: 114-121.
- Clapp J., Ruder S.L. (2020). Precision technologies for agriculture: Digital farming, gene-edited crops, and the politics of sustainability. *Global Environmental Politics*, 20(3): 49-70. DOI: https://doi.org/10.1162/glep_a_00566
- Carlisle L., Montenegro de Wit M., DeLonge M.S., Iles A., Calo A., Getz C., Ory J., Munden-Dixon K., Galt R., Melone B., Knox R., Press D. (2019). Transitioning to Sustainable Agriculture Requires Growing and Sustaining an Ecologically Skilled Workforce. *Frontiers in Sustainable Food Systems*, 3(96). DOI: <https://doi.org/10.3389/fsufs.2019.00096>
- Corrado A., De Castro C., Perrotta D. (2016). *Migration and agriculture: mobility and change in the Mediterranean*. Routledge, London.
- Dietz K., Drechsel F. (2021). Digital agriculture. In: Akram-Lodhi A.H., Dietz K., Engels B., McKay B. (eds). *Handbook of critical agrarian studies* (pp. 568-580). Edward Elgar Publishing, Cheltenham.
- European Commission (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: The European Green Deal. Brussels, 11.12.2019 COM (2019) 640 final.
- European Commission (2020a). EU member states join forces on digitalisation for European agriculture and rural areas.
- European Commission (2020b). The European Green Deal Investment Plan and Just Transition Mechanism explained.
- Fairhead J., Leach M., Scoones I. (2012). Green Grabbing: a new appropriation of nature? *The Journal of Peasant Studies*, 39(2): 237-261. DOI: <https://doi.org/10.1080/03066150.2012.671770>
- Fama M., Conti M. (2022). Food security and agricultural crises in a “financialized food regime”. *CAMBIO*, 12(23): 85-97. DOI: <https://doi.org/10.36253/cambio-13164>
- FAO (2020). *Realizing the potential of digitalization to improve the agri-food system: Proposing a new international digital council for food and agriculture: A concept note*.
- FAO (2021). *State of the Food Security and Nutrition in the World*.
- Foresight. The Future of Food and Farming (2011). *Final project report: Challenges and choices for global sustainability*. The Government Office for Science.
- Franks J.R. (2014). Sustainable intensification: A UK perspective. *Food Policy*, 47: 71-80. DOI: <https://doi.org/10.1016/j.foodpol.2014.04.007>
- Fraser A. (2023). Up in the air: the challenge of conceptualizing and crafting a post-carbon planetary politics to confront climate change. *The Journal of Peasant Studies*, 50(1): 96-111. DOI: <https://doi.org/10.1080/03066150.2022.2113779>
- Friedmann H. (1993). The political economy of food: a global crisis. *New Left Review*, 197(197): 29-57.
- Friedmann H. (2005). From colonialism to green capitalism: Social movements and the emergence of food regimes. In: Buttel F.H., McMichael P. (eds.). *New directions in the sociology of global development* (pp. 229-267). Elsevier, Oxford.
- Funtowicz S., Ravetz J. (2003). *Post-normal science*. In International Society for Ecological Economics (eds.), Internet Encyclopaedia of Ecological Economics.

- Hackfort S. (2021). Patterns of inequalities in digital agriculture: a systematic literature review. *Sustainability*, 13(22), 12345. DOI: <https://doi.org/10.3390/su132212345>
- Hebinck A., Klerkx L., Elzen B., Kok K.P.W., König B., Schiller K., Tschersich J., van Mierlo B., von Wirth T. (2021). Beyond food for thought – Directing sustainability transitions research to address fundamental change in agri-food systems. *Environmental Innovation and Societal Transitions*, 41: 81-85. DOI: <https://doi.org/10.1016/j.eist.2021.10.003>
- Higgins V., Bryant M. (2020). Framing agri-digital governance: industry stakeholders, technological frames and smart farming implementation. *Sociologia Ruralis*, 60(2): 438-457. DOI: <https://doi.org/10.1111/soru.12297>
- ILO (2015). *Guidelines for a Just Transition Towards Environmentally Sustainable Economies and Societies for All*.
- Kaljonen M., Kortetmäki T., Tribaldos T. (2023). Introduction to the special issue on just food system transition: Tackling inequalities for sustainability. *Environmental Innovation and Societal Transitions*, 46, 100688. DOI: <https://doi.org/10.1016/j.eist.2022.100688>
- Lajoie-O'Malley A., Bronson K., van der Burg S., Klerkx L. (2020). The future(s) of digital agriculture and sustainable food systems: An analysis of high-level policy documents. *Ecosystem Services*, 45(2020), 101183. DOI: <https://doi.org/10.1016/j.ecoser.2020.101183>
- Lioutas E.D., Charatsari C. (2021). Innovating digitally: the new texture of practices in Agriculture 4.0. *Sociologia Ruralis*, 62(2): 250-278. DOI: <https://doi.org/10.1111/soru.12356>
- Marsden T., Munton R., Ward N., Whatmore S. (1996). Agricultural geography and the political economy approach: a review. *Economic Geography*, 72: 361-375. DOI: <https://doi.org/10.2307/144519>
- Marsden T. (2013). Sustainable place-making for sustainability science: the contested case of agri-food and urban-rural relations. *Sustainability Science*, 8(2): 213-226. DOI: <https://doi.org/10.1007/s11625-012-0186-0>
- McMichael P. (2005). Global Development and the Corporate Food Regime. *Research in Rural Sociology and Development*, 11: 269-303. DOI: [https://doi.org/10.1016/S1057-1922\(05\)11010-5](https://doi.org/10.1016/S1057-1922(05)11010-5)
- McMichael P. (2013). *Food regimes and agrarian questions*. Fernwood Publishing, Halifax.
- Moilanen F., Alasoini T. (2023). Workers as actors at the micro-level of sustainability transitions: A systematic literature review. *Environmental Innovation and Societal Transitions*, 46, 100685. DOI: <https://doi.org/10.1016/j.eist.2022.100685>
- Mondejar M.E., Avtar R., Diaz H.L.B., Dubey R. K., Esteban J., Gomez-Morales A., Hallam B., Mbungu N.T., Okolo C.C., Prasad K.A., She Q., Garcia-Segura S. (2021). Digitalization to achieve sustainable development goals: steps towards a SmartGreen Planet. *Science of The Total Environment*, 794, 148539. DOI: <https://doi.org/10.1016/j.scitotenv.2021.148539>
- Mooney P. (2018). *Blocking the Chain*. ETC Group, Berlin.
- Murphy S.P., Cannon S.M., Walsh L. (2022). Just transition frames: Recognition, representation, and distribution in Irish beef farming. *Journal of Rural Studies*, 94: 150-160. DOI: <https://doi.org/10.1016/j.jrurstud.2022.06.009>
- OECD (2017). *Just Transition: A Report for the OECD*. Organization for Economic Cooperation and Development.
- OECD (2022). *The digitalisation of agriculture. A literature review and emerging policy issues*. Food, agriculture and fisheries paper, N° 176.
- Phillips W.B.P., Relf-Eckstein J.A., Jobe G., Wixted B. (2019). Configuring the new digital landscape in western Canadian agriculture. *NJAS: Wageningen Journal of Life Sciences*, 90-91(1): 1-11. DOI: <https://doi.org/10.1016/j.njas.2019.04.001>
- Rasmussen L.V., Coolsaet B., Martin A., Mertz O., Pascual U., Corbera E., Dawoson N., Fisher J.A., Franks P., Ryan C.M. (2018). Social-ecological outcomes of agricultural intensification. *Nature Sustainability*, 1: 275-282. DOI: <https://doi.org/10.1038/s41893-018-0070-8>
- Reinhardt T. (2022). The farm to fork strategy and the digital transformation of the agrifood sector – An assessment from the perspective of innovation systems. *Applied Economic Perspectives and Policy*, 1-20. DOI: <https://doi.org/10.1002/aep.13246>
- Ricciardi V., Ramankutty N., Mehrabi Z., Jarvis L., Chookolingo B. (2018). How much of the world's food do smallholders produce? *Global Food Security*, 17: 64-72. DOI: <https://doi.org/10.1016/j.gfs.2018.05.002>
- Rye J.F., Scott S. (2018). International labour migration and food production in rural Europe: a review of the evidence. *Sociologia Ruralis*, 58(4): 928-952. DOI: <https://doi.org/10.1111/soru.12208>
- Rolandi S., Brunori G., Bacco M., Scotti I. (2021). The Digitalization of Agriculture and Rural Areas: Towards a Taxonomy of the Impacts. *Sustainability*, 2021(13), 5172. DOI: <https://doi.org/10.3390/su13095172>
- Rotz S., Duncan E., Small M., Botschner J., Dara R., Mosby I., Reed M., Fraser E.D.G. (2019). The Politics of

- Digital Agricultural Technologies: A Preliminary Review. *Sociologia Ruralis*, 59: 203-229. DOI: <https://doi.org/10.1111/soru.12233>
- Rotz S., Gravely E., Mosby I., Duncan E., Finnis E., Horgan M., LeBlanc J., Martin R., Neufeld H.T., Nixon A., Pant L., Shalla V., Fraser E. (2019). Automated pastures and the digital divide: how agricultural technologies are shaping labour and rural communities. *Journal of Rural Studies*, 68: 112-122. DOI: <https://doi.org/10.1016/j.jrurstud.2019.01.023>
- Salemink K., Strijker D., Bosworth G. (2017). Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas. *Journal of Rural Studies*, 54: 360-371. DOI: <https://doi.org/10.1016/j.jrurstud.2015.09.001>
- Samberg L.H., Gerber J.S., Ramankutty N., Herrero M., West P.C. (2016). Subnational distribution of average farm size and smallholder contributions to global food production. *Environmental Research Letters*, 11(12), 124010. DOI: <https://doi.org/10.1088/1748-9326/11/12/124010>
- Scoones I. (1998). *Sustainable rural livelihoods: a framework for analysis*. IDS working paper, 72. IDS, Brighton.
- Smith G. (2020). Interrogating the Agrarian Question Then and Now in Terms of Uneven and Combined Development. In: Nonini D., Susser I. (eds.), *The Tumultuous Politics of Scale* (pp. 153-175). Routledge, London.
- Stone G.D. (2022). Surveillance agriculture and peasant autonomy. *Journal of Agrarian Change*, 22(3): 608-631. DOI: <https://doi.org/10.1111/joac.12470>
- Tribaldos T., Kortetmäki T. (2022). Just transition principles and criteria for food systems and beyond. *Environmental Innovations and Societal Transitions*, 43: 244-256. DOI: <https://doi.org/10.1016/j.eist.2022.04.005>
- Trendov N.M., Varas S., Zeng M. (2019). *Digital technologies in agriculture and rural areas: Status report*.
- United Nations Framework Convention on Climate Change (UNFCCC) (2015). *The Paris Agreement*.
- van der Ploeg, J.D. (2008). *The New Peasantries: Struggles for Autonomy and Sustainability in an Era of Empire and Globalization*. Earthscan, London.
- van der Ploeg J.D. (2018). Differentiation: old controversies, new insights. *The Journal of Peasant Studies*, 45(3): 489-524. DOI: <https://doi.org/10.1080/03066150.2017.1337748>
- van der Ploeg J.D. (2020). Farmers' upheaval, climate crisis and populism. *The Journal of Peasant Studies*, 47(3): 589-605. DOI: <https://doi.org/10.1080/03066150.2020.1725490>
- Weis T. (2010). The accelerating biophysical contradictions of industrial capitalist agriculture. *Journal of Agrarian Change*, 10(3): 315-341. DOI: <https://doi.org/10.1111/j.1471-0366.2010.00273.x>
- Wolfert S., Ge L., Verdouw C., Bogaardt M.J. (2017). Big data in smart farming—a review. *Agricultural Systems*, 153: 69-80. DOI: <https://doi.org/10.1016/j.agsy.2017.01.023>
- World Bank (2017). *ICT in agriculture: Connecting smallholders to knowledge, networks, and institutions*.
- World Bank (2019). *Future of food: Harnessing digital technologies to improve food system outcomes*.