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Bridging or Excluding? Peasant Participation in the Digitalization of Agroecology in Brazil

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Table of Contents

1. Introduction..... 3
2. Literature Review 5
a. The Rise of Digital Agriculture and Its Implications for Small Peasants 5
b. Digital Agriculture and Agroecology: Tensions and Pathways for Participatory Integration 7
c. Peasant Participation and Social Inclusion in Designing and Engaging with Agroecological Digital Tools 12
3. Cases studied: 16
a. Co-Designing the Solis App: Peasant Participation and Digital Inclusion 17
b. Peasants Agency in the Digitalization of Agroecology: a Governance Perspective .. 20
4. Conclusion 25
Bibliography: 28

1. Introduction[1]

While Peasant literacy, participation and access to technology are not new dilemmas in the study of agroecology, the rise of the digital revolution brings new nuances, especially in considering how agroecological principles interact with emerging digital technologies (Ajena *et al*, 2020). As digital tools tend to incorporate a top-down and corporate driven approach, these technologies have been easily assimilated by large-scale farms and with the Green Revolution (Shelton et al., 2022). On another hand, small-peasants face unequal access, ability of accessing, finding, and benefiting from such technologies (McCampbell et al., 2025). The complexity and technocratic approach of technologies also risks minimizing peasant participation, agency and co-creation of knowledge by replicating (Hilbeck and Tiselli, 2020), and even replacing previous horizontal and inclusive social interactions between peasants, threatening a cornerstone element of agroecology (Shelton et al., 2022).

However, the effects of digitalization on the co-creation of knowledge and peasant agency within agroecology remain insufficiently understood - not only in the academic literature but also among peasant communities and agroecological activists themselves (Silva, 2022). Tensions frequently emerge between agri-tech and agroecological approaches, as the former often replicate the discourse and practices of the Green Revolution. Yet, some scholars argue that agroecology and digital technologies are not inherently incompatible (Rotz et al., 2019). On one hand, digital tools have been linked to the devaluation of traditional knowledge systems, the standardization of practices through datafication (Ajena et al., 2022; Shelton et al., 2022), and the emergence of predatory intellectual property dynamics, such as the digital sequencing of germplasm (Vogliano et al., 2021). Furthermore, unequal access to these tools can exacerbate inequalities among peasants, generating asymmetrical productivity gains that benefit adopters while excluding non-adopters (Brunori, 2024).

On the other hand, other scholars suggest that when appropriately designed and governed, digital technologies may enhance agroecological practices by fostering farmer-

[1] Use of artificial intelligence in this paper: This paper used ChatGPT Version 4.0. Its uses consisted only in language assistance (grammar checking, and ensuring translation between Portuguese, English and Spanish for analysing the interviews conducted), guidance on initial text structure, and in code debugging for the treatment of data and the Figures plotted in R-Studio for this paper.

to-farmer exchange and supporting more horizontal knowledge-sharing among peasants, researchers, and developers (Lacoste et al., 2025). Realizing this potential, however, depends on the ability to adapt technologies to local contexts while ensuring their economic viability - challenges that remain unresolved (Mason et al., 2023).

Thus, considering the complex dynamic between digitalization, agroecology, and peasant agency and participation, this research paper will explore such themes through the following questions: To what extent do digital tools enable or constrain meaningful participation in agroecological transitions at the territorial level? To answer this question, a set of three sub-questions were posed: (i) What tensions and opportunities emerge in the digitalization of agriculture to small-holders? (ii) How do digital tools align or conflict with agroecological principles such as co-creation of knowledge and resilient governance?; and (iii) Who are the actors involved in the design and governance of agroecological digital tools, and how do their participatory approaches affect peasants' agency and inclusion?

To answer these questions, the paper is structured in three parts. First, a literature review addresses the subquestions using academic articles, policy briefs, and program reports on the digitalization of agroecology. This includes a descriptive analysis of data from Dittmer et al. (2022a) on how digital tools incorporate agroecological and social inclusion elements. Second, two case-based sections will explore: (i) digital tools as a way for co-creation and knowledge sharing, focusing on the Solis app developed in Pará, Brazil under the Inclusive Digital Tools (ADTD) component of the Agroecological Transitions Program for Building Resilient and Inclusive Agricultural & Food Systems (TRANSITIONS). This case study is examined through program reports, baseline studies, and peer-reviewed analyses, as well as institutional evaluations (e.g., Funk et al., 2025; Oliveira et al., 2024). And, (ii) governance perspectives drawing on semi-structured interviews conducted by the author with agroecological activists from La Via Campesina in Brazil and Paraguay, alongside insights from TRANSITIONS interviews with policy and technical actors and peasants prior to Solis implementation (Freixêdas et al., 2022). Finally, the conclusion reflects on the limitations of existing literature and how the case studies respond to the research questions.

2. Literature Review

a. The Rise of Digital Agriculture and Its Implications for Small Peasants

Within the emergence of the Fourth Industrial Revolution, the incorporation of a wide range of technologies in the field has been characterizing digital agriculture as the most significant change in food systems since the Green Revolution (Rolz et al., 2019) It includes precision agriculture, which encompasses datafication on monitoring fields through drones, sensors and satellites and optimizing outputs, as well as the use of smart-devices, artificial intelligence, and the modernization of rural machinery with updated softwares (Niénelí Forum, 2019; Vercoreen, 2024). Embedded in these technologies is the promise of a higher productivity in scale, as well as an optimistic perspective that the management allowed through these tools will also make agriculture systems more efficient and environmentally sustainable (Mendes and Viola, 2023). Other authors, nevertheless, conceive that digitalization may in fact lead to a further exploration of the land in non-sustainable paths (Silva, 2022; Vogliano et al., 2021).

Also, Digital agriculture has been mainly a big player's game. That is, the development of different agricultural technologies (Ag-tech) has been done from big corporations already engaged in the market for rural equipment - John Deere, Bayer, Cargill - and for big scale production (Shelton et al, 2022; Vogliano et al., 2021). On this, despite reaffirming the transformational potential of different technologies to increase output, Klerkx and Rose (2020) mention that its over-emphasis on high-tech solutions may not lead to the actual improvement of food production in scale, as they remain concentrated in few big firms. This is associated with elevated prices of technology (Rotz et al., 2019), behavioural limitations in peasants to adopt innovations (Kok and Klerkx, 2023), as well as with the domain of investment and research and development (R&D) by capital (Klerkx and Rose, 2020).

These technological turns to digital agriculture also come with a prevalent narrative that, by posing technology as the main solution, replicates neo-malthusian ideas associated with the Green Revolution (Klerkx and Rose, 2020; Rosset et al., 2025). Furthermore, this risks diverting attention from alternative approaches - including traditional knowledge and agroecology -, and from low-tech products, by assuming a

standardizing, top-down and technocratic vision of agriculture (Klerkx and Rose, 2020). Therefore, digital technologies are primarily developed for economically viable large-scale farms that can afford them, rather than for smallholders - thereby reinforcing their marginalization and embedding technological change within existing power asymmetries (Shelton et al., 2022). By prioritizing the technology itself, digital agriculture risks exacerbating exclusion, as it may replace rather than support farmer-to-farmer exchange, traditional knowledge systems, and participatory forms of engagement (Klerkx and Rose, 2020).

In contrast to these broad structural critiques, the literature notes that small peasants' engagement with technology more often centers on "digital tools" (Burns et al., 2022; Petraki et al., 2025; Shelton et al., 2022; Vecoreen, 2024). These refers to applications, softwares, programs and instruments designed specifically for streamlining farmers tasks, being those of production (performance assessment), administrative, technical assistant, or even marketing purposes (Dittmer et al., 2022b; Vecoreen, 2024). These tools can range from mobile applications and software programs to hardware devices such as sensors and drones. For small-farmers, they are often used to manage resources, optimize irrigation, track weather through satellites, and generally improve decision making (Petraki et al., 2025).

Noticeably, the definition of digital tools is not consensual. These tools can range from mobile applications, to software programs to hardware, and some do not include digital platforms, or analog tools with a digital component (Vecoreen, 2024). Others incorporate online platforms, as they may foster the connection between peasants and other stakeholders, such as consumers, technical assistants, and other peasants (Gow et al., 2024; Petraki et al., 2025).

Thus, while a technological and digital gap are identified, small-holders are not completely dissociated from digital tools. However, their incorporation is challenged by redefined problems. While illiteracy levels persist as a problem in rural environments, digital illiteracy also acts as an additional barrier for peasants to access and understand the benefits of digital tools (Gow et al., 2024; Hackfort, 2021). Additionally, the fully capture of these tools provisions and effects goes beyond digital literacy, given their complexity, which also entails a growing gap as technologies advance (McCampbell et

al., 2025). Furthermore, Hackfort (2021) associates digital agriculture with inequality, as the adoption of digital tools by peasants is differentiated according to their skill and knowledge, as well as with their inclusion in co-creating the digital tools for their use. This also bumps into the complexity in understanding the implications of using digital tools, not only for their performance, but for their sovereignty over their own data. Individual farmers, collectives and social movements distance themselves from those, as their data could be appropriated for corporate gains and unknown implications (Brunori, 2024; Shelton, 2023; Silva, 2022).

Within the academic literature and in social movements reports, the internalization and use of such technologies have not been homogeneous within peasants (McCampbell et al., 2025; Kok and Klerkx, 2023; Vogliano et al., 2021). As this entails changes in engagement dynamics, and clashes of worldview and with agroecological elements, these challenges will be addressed in the next section.

b. Digital Agriculture and Agroecology: Tensions and Pathways for Participatory Integration

For the purposes of this research, agroecology is understood within different meanings, as it incorporates a scientific discipline, agricultural practices and elements, and social movements (Barrios et al., 2020; Wezel et al., 2009). This approach integrates social, economical and ecological principles, aiming for resilient agricultural systems that are rooted in indigenous and peasant agriculture (Petraki et al., 2025). Technocratic narratives that come with digital technologies could dislocate peasants and their their traditional knowledge from the center where agroecology placed them(Ajena and Clemént, 2020). As Agriculture 4.0 appears embedded in a narrative that continues the Green Revolution, an incompatibility between the two concepts has been rendered by part of the literature (Avaria et al., 2020). However, this is far from consensual, as some authors understand that the power relations, and not technology in itself, would be the reason behind a tension with small peasants and agroecological practices (Larbaigt et al., 2024; Rotz et al., 2019).

Thus, as inequality rises from the interaction of digitalization with the dominant food system dynamics (Rotz et al., 2019), a compatibility between digital tools and

agroecology remains possible (Ajena and Clemént, 2020). Again, it comes in discussion how these technologies are created and used, so as to understand how they may interact with agroecological elements. In a recent literature review, Petraki et al. (2025) mention that studies on the use of digital tools in agroecological contexts, their effectiveness and limitations, remain scarce. Yet, within current studies, lack of infrastructure, digital illiteracy, and concerns about effectiveness act as barriers for adoption (Petraki et al., 2025). This last reason is associated with what Shelton et al. (2022) mentions as a disconnection of digital tools from peasants' needs and input, as developers might not include peasants in the design of such tools. This challenges the element of co-creation and sharing of knowledge within agroecology (Altieri, 2002), as well as the centrality of human and social values as peasants are not central, and rather understood as clients for prepackaged tools (Ajena and Clemént, 2020).

This manifests as unequal power relations that rise between developers, scientists and farmers (Shelton et al., 2022). The disvaluing of peasant agency also overlooks local and traditional knowledge, another principle of agroecology (Shelton et al., 2022). As a consequence, beyond pre-existing challenges of affordability, awareness, access and ability, this entails a smaller availability of digital solutions in reach and of the appropriation of benefits (McCampbell et al., 2025). Digital tools could also inflict indirect societal costs. This could happen as it replaces farmer-to-farmer interaction, or peasants' social interactions with other stakeholders, such as technical extensionists (Shelton et al., 2022).

Moreover, this represents a challenge for policy formulation. Within the European Union, while both agroecology and digitalization appear as indispensable in their Farm to Fork strategy, maintaining coherence between both was considered a challenge (Ajena et al., 2020). On the Latin American side, while digital agriculture policies are emerging (Rodrigues and Mondali, 2024), and countries like Brazil lead investment and regulatory frameworks, those operate in parallel with agroecological policies and peasant movements (Rodrigues and Mondaini, 2024; Coq et al., 2024). While absent in the national governance, ground-level initiatives have been protagonists of socially inclusive digital tools within agroecological contexts (Dittmer et al., 2022b).

Such tools are capable of engaging with the voices of smallholders for its development and implementation (Shelton et al., 2022). While considering the several forms of exclusion aforementioned, peasants within agroecological productions can become co-creators of knowledge in the development of digital technologies with other actors (Ajena and Clemént, 2020; Dittmer et at., 2022a). This alignment with agroecological principles appears tied, within the literature, to key concepts of the such as transdisciplinarity and participatory action research (Bellon-Maurel et al., 2024; Méndez et al., 2013), which appear as central in understanding peasants relationship towards digital tools (Ajena et al., 2020; Dittmer et al., 2022b; McCampbell et al., 2025).

On this, Tiselli and Hilbeck (2020) drafted agroecology principles applied to Informational and Communication Technologies (ICTs). Within this framework, a crucial aspect resides in combining and harmonizing top-down (scientists and developers to peasants), bottom-up (peasants to developers and scientists), and farmer-to-farmer models of communication through the design and implementation of digital tools (McCampbell et al., 2025; Tiselli and Hilbeck, 2020). The adequacy of different ICTs products to agroecological principles in reality, may be diminished, as participation continuity and adaptation to contexts entails in further costs (Méndez et al., 2013), which developers might not be able to internalize (Burns et al., 2022). Moreover, different agroecological digital solutions may face challenges in scaling up to different territories, which would further their economic viability (Bellon-Maurel et al., 2022), or rather compromise their purpose (Shelton et al., 2022).

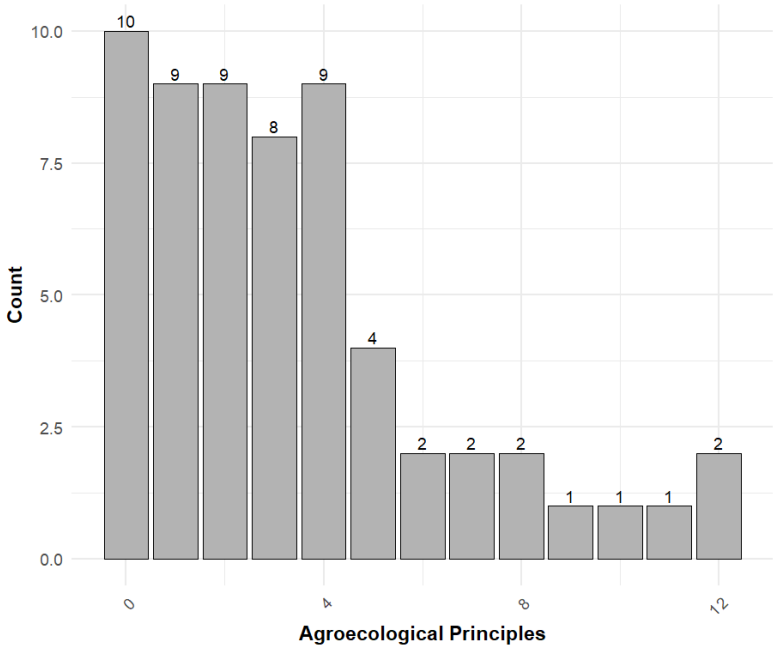
The possibility that digital technologies operate in harmony with agroecological principles does not mean that they currently are doing so. Within a review of 60 globally spread digital tools for technical assistance (TA) and performance assessment on agroecological transitions, Dittmer et al. (2022a, 2022b) identified a limitation on incorporating agroecological principles[2], as shown in Figure 1. As 75% of the tools address less than 4 principles, it is possible to observe that most of the digital tools implemented fail to internalize even a third of agroecological elements. A further analysis

[2] For this, the authors considered the 12 agroecological elements (i.e., principles) adopted and refined by the Food and Agriculture Organization, High Level Panel of Experts on Food Security and Nutrition, and the Tool for Agroecology Performance Evaluation (Dittmer et al., 2022a). Noticeably, the results are limited as only tools focusing on TA and performance assessment were included.

on the highest ranked tools shows how they differ in purpose. While some include holistic farm assessment technologies and real-time monitoring tools, others focus on e-commerce of agroecological products, or in local capacity strengthening - including through videos co-created by the community.

Figure 1. Agroecological Elements Addressed by Digital Tools (Dittmer et al., 2022a)

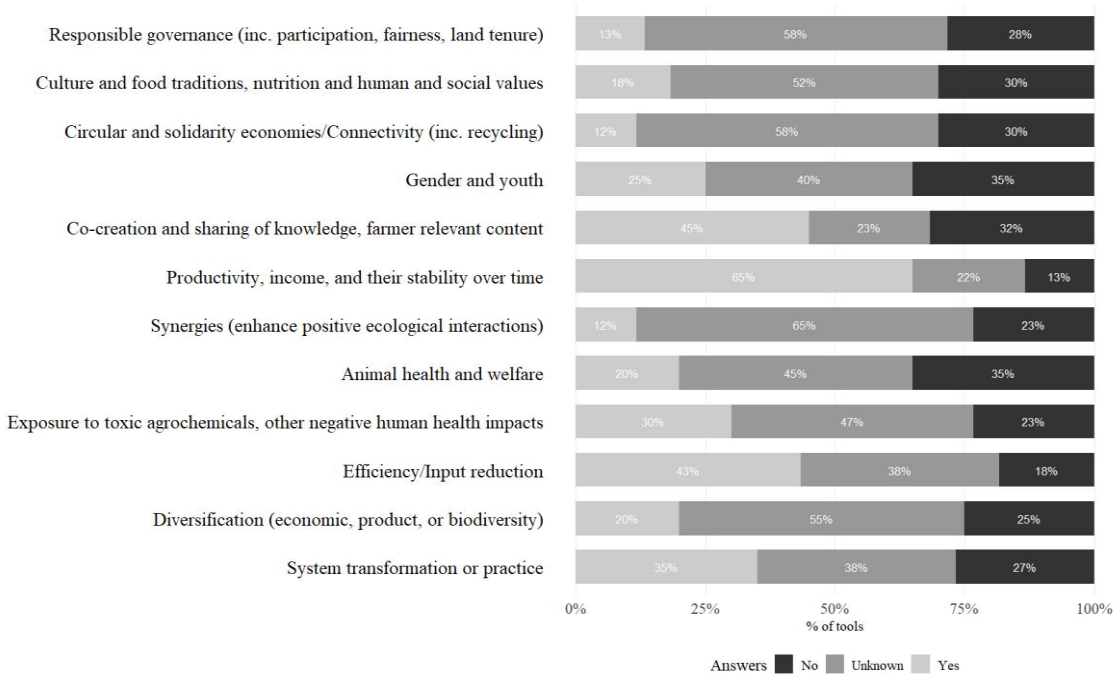
Note. The graph was elaborated by the author, through R (ggplot2), using the data made



available by Dittmer et al. (2022a).

Figure 2 breaks down the extent to which each principle or element is realized, revealing significant variation. Factors related to output increase, such as stability of income and productivity, and efficiency and input reduction, rank first and third as the most realized - 65 and 43%, respectively. At the same time, principles more connected to ecological sustainability rank lower - both Animal health and welfare and Diversification rank 20%, and Synergies ranks 12%. These results, while incipient, resonate with the literature on how digital technologies may favour productivism logics, and have challenges on addressing environmental sustainability (Silva, 2022; Vogliano et al., 2021).

Figure 2. Extent to Which Agroecological Elements Are Addressed by Digital Tools (Dittmer et al., 2022a)



Note. The graph was elaborated by the author, through R (ggplot2), using the data made available by Dittmer et al. (2022a).

Regarding social inclusion and participatory measures, Figure 2 exhibits contrasting and interesting realities. Co-creation and sharing of knowledge appears as the second highest principle realized (45%), while Responsive governance - which includes participation - appears as one of the least realized (13%). Thus, digital tools may engage peasants in generating and disseminating knowledge through them, but can demonstrate limits in empowering them at the governance level, being it fostering cooperation between stakeholders, community level governance, or deeper levels such as decision-making. This entails more investigation about not only what the tools provide, but how they are created, which actors are involved in this process, and how participatory governance is or is not present.

c. Peasant Participation and Social Inclusion in Designing and Engaging with Agroecological Digital Tools

In the literature, the congruence between agroecology and technology appears to be associated with knowledge generation and sharing through participatory methods, as well as equal accessibility and a transparent governance (Shilomboleni and Schnurr, 2025). Participatory processes here will be defined as collective learning and negotiation, which allows to address strategically power asymmetries amongst participants (Berthet et al., 2016). By adopting such a more critical perspective, it becomes possible to understand the underlying power dynamics that can arise within the design and implementation of digital tools for agroecology purposes, which relate to governance and decision-making (Berthet et al,. 2016; Wittman et al., 2020).

While not applied to digital tools, the intersection between agroecology literature with participatory action research (PAR) conceive several factors to reflect on effective participation. It includes the peasant setting the research agenda from the beginning, improving their engagement through intentional and explicit reflections (Méndez et al., 2017). Beyond those, the employment of the right partners, and cross-generational collaborations appear with great importance to establish long-term benefits (Wittman et al., 2020). As aforementioned in the previous section, the centrality of the peasants appears continuously as a need for the co-creation of both participatory processes and the digital tools. The recognition of local actors' capacity to identify problems and solutions have been associated with improved results of interventions for agroecological transitions (Shilomboleni and Schnurr, 2025; Stitzlein et al., 2020).

Meaningful peasant participation with digital tools is also associated with the different types of learning that may rise through participatory processes and dynamics. According to Berther et al. (2016), collective learning, in which actors develop a mutual understanding of the situation through knowledge sharing, appears essential to reach a common ground. Secondly, substantive learning, focusing on the interdependencies between actors and how it functions as a system, fosters a comprehension of how digital tools may affect and foster the existing coordination landscape. Thirdly, exploring the unknown, which focuses on identifying knowledge-gaps to guide interventions, allows for better guiding the interventions. This is associated with understanding how to address

lack of digital literacy, or concerns on data ownership, and how to address those through the innovations. Finally, by questioning underlying values, assumptions, problem framings, the double-loop learning can be fundamental in asserting peasant's centrality to digital tools, and even revise previous goals of scientists or digital developers (Berther et al., 2016).

These learning processes happen through different methods, such as workshops, in-field visits (McCampbell et al., 2025), interviews and focus groups (Abdulai et al., 2023), and role-playing games (Berther et al., 2016). Surveys might also complement those methods, helping to assert peasants' priorities that some would not share within a group setting (Imgram et al., 2022). Through the application of various methods, it is a common point in the literature that peasants resonate with the co-creation of digital tools (Berther et al., 2016; McCampbell et al., 2025), but it goes beyond. As the implication of digital tools on peasants' labour, data, and identity are unclear to them, concerns rise on how to democratize and improve transparency of such tools (Imgram et al., 2022). Hence, participation must also be understood at a governance level, involving the political mobilization of peasants and aligning with the social movement dimension of agroecology (Imgram et al., 2022; Vogliano et al., 2021; Wittman et al., 2020).

Considering the dynamics of participation, who is participating - that is, the actors involved in the design - is key. In their survey, Dittmer et al (2022a, 2023) mention a wide variety of actors: private companies, governments, non-governmental organizations (NGOs), international organizations such as Consultative Group on International Agricultural Research (CGIAR), academics and multistakeholder initiatives. On this, they all could possibly support participatory mechanisms in the design of such tools, but this adequacy faces particular challenges (Ajena et al., 2020; Wittman et al., 2020). Again, this comes as the costs of continuous participation, and problems in scaling the solutions (Shelton et al, 2022).

For example, private developers might favor the scalability of their tool, and not engage with real on-ground needs - diminishing their purpose -, while maybe raising concerns on the ownership and use of the data collected (Niéhely Forum, 2029, 2023). Also, locally adapting the tools created, independently from the actor, requires extra financial costs, which might limit the capabilities of NGOs in engaging with peasants,

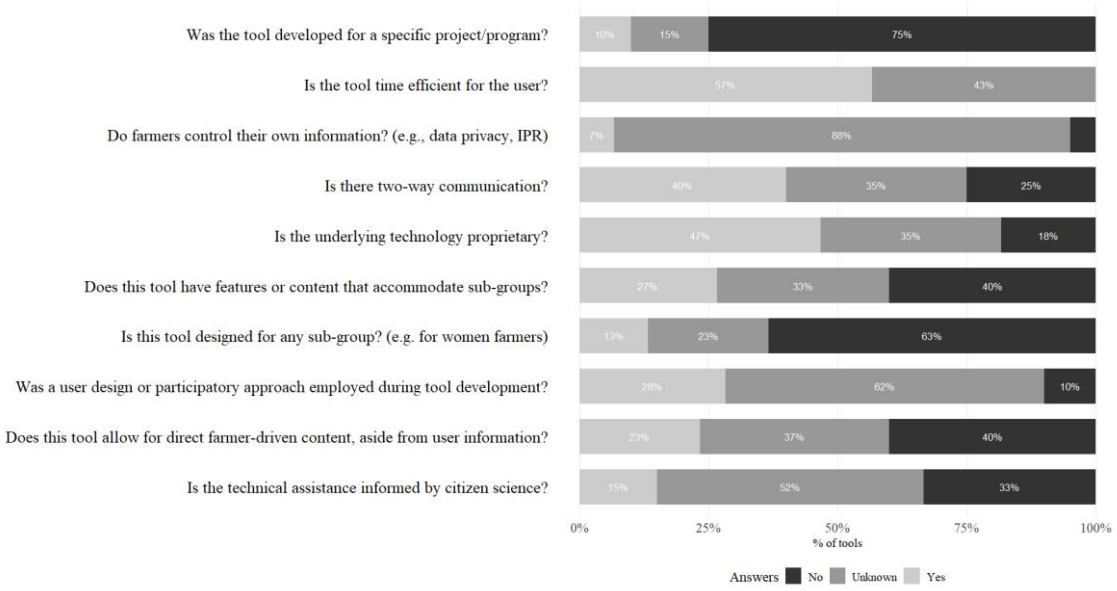
and divert private and public investment (McCampbell et al., 2025; Petraki et al., 2025). Notably, there is limited literature on the extent to which agroecological social movements are engaging - or choosing not to engage - in the design of digital tools.

In this realm of actors, the discussion on co-creation and governance also entails the understanding of how socially inclusive these tools are, and how they enable peasants' digital agency (Dittmer et al., 2022b; McCampbell et al., 2025). On this, social inclusion - understood as the ability, dignity, and opportunity for all groups to participate fully in society (World Bank, 2013) - also encompasses digital inclusion, which is essential in the context of emerging agricultural technologies (Shelton et al., 2022). Despite not being systematic, the co-creation and social inclusion indicators mapped by Dittmer et al. (2022a) in their global review, proportionate interesting understandings about how and at what level digital tools for agroecology include participatory approaches.

Figure 3 shows how the 60 tools mapped accommodate issues such as peasants integration as co-researchers - citizen science (McCampbell et al., 2025) -, if participatory approaches were taken during development, if dialogic exchange is possible between users and developers - two way communication (Dittmer et al., 2022b), and matters of propriety and data ownership. The graph shows how 47% of the technology is closed-source (proprietary), while little is informed about peasants owning their own data (88% unknown). This associates with the aforementioned preoccupation of peasants in engaging in such tools. Also, only 40% surely provide two-way communication, 28% were developed using participatory approaches, 23% allow for farmers co-creation and knowledge sharing through farmer-driven content, and 15% of the technical assistance engaged farmers as co-researchers. Combined, this poses a very limiting and problematic reality on the balance between digital tools and participation in agroecological contexts.

This daunting scenario becomes even more preoccupying as 75% of the tools are not specifically designed for a context. While this can suggest potential for scaling such tools, it does not appear that its distribution would happen within participatory approaches. Furthermore, only 12% of tools are designed for subgroups, such as women farmers and traditional communities, which suggest a trajectory of deepening inequality within farmers (Hackfort, 2021). Also, this may represent a challenge in making digital agroecological initiatives relevant to context and culturally appropriate (Tran et al., 2024).

Figure 3. Social Inclusion indicators present in digital tools (Dittmer et al., 2022a)



Note. The graph was elaborated by the author, through R (ggplot2), using the data made available by Dittmer et al. (2022a).

In conclusion, the previous three subsections underscored how the literature observes the emergence of digital agriculture as akin to the Green Revolution, with its benefits not uniformly distributed among smallholders. While digital tools - designed by a wide variety of actors - design and implementation can abide by agroecological elements and engage with peasants through participatory approaches, this has not been the case in multiple contexts. Digital tools still appear to replicate a top-down modus operandi, which also raises concerns related to the collection and use of peasants' data, and the usability and benefits of such tools. Besides co-creation of knowledge, participation of peasants within such tools connects to deeper governance issues both locally and at a state public policy level (Imgram et al., 2022; Vogliano et al., 2021; Wittman et al., 2020).

Considering the scarcity of the literature on digitalization of agroecology (Petraki et al.,2025), the effects of such participation, as well as the role of participation in the digitalization, is not clear. Nor is how digital tools that engage with participation may successfully gain profitability and scalability (Shelton et al., 2022). Moreover, while the literature mentions how local practices and the scientific aspects of agroecology interact with digitalization, little is mentioned about social movements' role as developers or

users. Further, in the next sections, the analysis will highlight and attempt to address some of these literature gaps, focusing on Brazilian and Latin American reality.

3. Cases studied:

In light of the literature review, digital tools in agroecology have varied implications for participation, particularly in two key areas: first, the extent to which peasants are involved in the co-creation of these tools and use them for knowledge exchange; and second, the governance dimension, which concerns how peasants and other stakeholders are included in decision-making processes related to the digitalization of agriculture. The analysis that follows is therefore structured around these two dimensions, with a primary focus on the Brazilian context, while also drawing broader reflections relevant to the Latin American region.

Firstly, a section on the co-design and implementation of a Solis, an app designed for increasing peasants' digital agency in small livestock farming initially in Novo Repartimento, Anapú and Pacajá cities (Pará State, North of Brazil). This section will highlight how small-holders were included, and the challenges during and after the process, through mainly documentation analysis of reports and presentations about the programme. A second session will address governance issues faced in including peasants and agroecological elements in the digitalization of agriculture in Brazil. For this, documental analysis of publications and interviews conducted by the Transitions Programme in Brazil with agents in ministries, governmental agencies, state governments, cooperatives, developers, private sector, and NGOs (Freixêdas et al., 2022) will be complemented by interviews conducted by the author with peasants and social activists within La Via Camponesa International in Brazil and Paraguay (while also a representative for the Latin American Coordination of Rural Organizations - CLOC). More details on the interviews can be found in Table 1.

Table 1. Interview details

Name	Organization	Related Expertise	Date and Format
Marciano Toledo da Silva	Movimento dos Pequenos Agricultures (Small Farmers Movement), Brazil, and La Via Campesina Internacional	Agronomist Engineer and activist for more than 20 years. Published texts about digitalization of agriculture and agroecology and the role of social movements on it. Acts as a representative of social movements in the FAO Intellectual Property Commission.	May 28th, 2025, 19:00 (CET) online (Teams) Interview conducted in Portuguese
Perla Alvarez Britez	Conamuri (Coordinadora Nacional de Organización de Mujeres Trabajadoras, Rurales e Indígenas), Paraguay, associated at La Via Campesina Internacional	Peasant and agroecology activist. She accompanies the team of digitalization within Latin American Coordination of Rural Organizations (CLOC) of La Via Campesina. Accompanies the Food Security Committee of the FAO.	May 28th, 2025, 10:30 am (CET) online (Teams) Interview conducted in Spanish

Note. Table elaborated by the author.

a. Co-Designing the Solis App: Peasant Participation and Digital Inclusion

The Agroecological Transitions Program for Building Resilient and Inclusive Agricultural & Food Systems (TRANSITIONS), is a project funded by the EU and managed by IFAD, that aims to enable climate resilient and informed agroecological transitions through farmers (TRANSITIONS, 2025). The project is being implemented from 2022 to 2025, and has an Inclusive Digital Tools front (ADTD), implemented in Brazil and Vietnam. Here, the focus will be on the Brazilian case, with the project localized in the Amazon frontier of Pará State, focused on small livestock production transition to agroecology.

Notably, while incipient, recent studies mention Brazil as a country that has institutionalized spaces, strategies and policies on digital agriculture and the expansion of digital access in rural communities, being at the forefront of Latin America (Alcântara and Bert, 2024; Massruhá, 2016). The same can be said by national agroecological strategies, which however do not address digitalization (Oliveira et al., 2024). This however occurs at the national level, while TA is mainly operated at the subnational State

level (Costa Jr et al., 2022). Heissler et al. (2023) mention the existence of diverse digital agricultural tools in Brazil, most of which lack environmental and agroecological considerations, and do not account for a participatory approach nor include other social inclusion elements, such as citizen science. In the baseline report for the ATDT intervention, it was identified that 95% of the small-holders in the region did not have access to TA, while the influence of the agribusiness model was prevalent (Costa Jr. et al, 2022; Laurens et al., 2023). At the same time, the use of smartphones and social media, especially Whatsapp, was also widespread, as was on-farm internet connection, which allowed for the development of further digital tools (Funk et at., 2025).

Solidaridad Latinoamerica, an international civil society organization, acted as implementator partner, developing the tool and acting as extensionist service provider. This organization was already present in the territory 10 years previous to the project, providing assistance to cocoa peasants and cattle ranchers, which helped to build trust with peasants (Oliveira et al., 2024). It already had previous experience developing digital tools to support AT. For understanding the peasants' needs, views, and digital maturity levels, iterative co-creation workshops took place, incorporating participatory methods and dynamics. They were also complemented by field days, in which the practicality of the knowledge constructed was contrasted with participants' reality, in a citizen science approach. Throughout the process, different types of learning and participatory mechanisms present in the literature review appeared (Belther et al., 2016). The engagement of Solidaridad also unfolded in the development of a training curriculum on agroecological practices for cattle farmers, in which their inputs were considered in adapting the previous framework.

The peasants participation in this case connects with the literature on the importance of co-creating digital tools and empowering digital agency (McCampbell et al., 2025). They are widely credited in the institutional reports for transforming the initial proposal (Funk et al., 2025), adequating it to their needs and to how real benefits could be accessed (Sheldon et al., 2024). The app Solis, was supposed to contain a tailored action plan for agroecological transition adapted from the training curriculum to each peasant. Through their input, the app also incorporated a digital learning community (Oliveira et al., 2024), a two-way communication format, in which they can access, publish and share videos about locally relevant agroecological practices (Laurens 2023).

By emulating a social media format, the app became familiar and useful once implemented, at the end of 2024. The usefulness arose from responding to immediate needs, sharing practices and action plans grounded within the locality, and allowing for farmer-to-farmer content (Laurens et al., 2023; McCampbell et al., 2025). Concurrent to the design of the tool, 5 engaged farmers and 2 extensionists were chosen as Ambassadors by Solidaridad, and received training previously to the launch of the app in 2024 in order to pilot the tool, encourage their adoption and train other farmers to do so (Funk et al., 2025). This connects with farmer empowerment present in the literature, shifting agricultural practices from the influence of the agribusiness and to agroecology through the co-creation of knowledge (Dittmer et al., 2022b; McCampbell et al., 2025; Wittman et al., 2020). Also, despite a general application, Solis curriculum changed accordingly to farmers' location, as different cities changed in priority, practices and even cultures cultivated. This also led to another gain of the platform: it expanded to different cultures, such as cocoa, which led to its adoption by more than 200 farmers right after launching (Oliveira et al., 2024).

This suggests the possibility of scaling the digital tool towards other regions and cultures, as the practices can be locally adapted (Oliveira et al., 2024), it also faces barriers. The application launch was stalled for a year, from December 2023 to November 2024, accounting for all inputs that rose from participation (Costa Jr et al., 2024). As it is recent, the entirety of the effects could not be evaluated (Costa Jr et al., 2024; Funk et al., 2025). While similar practices can be replicated, Solidaridad recognizes also a financial dilemma: at the current level of users, they can use sources of income from other developments to keep it running free of charge to peasants. However, its enlargement, if it were to lead to payment by farmers, could result in the tool's abandonment and failure, as they may not be willing or able to pay and thus be excluded from the platform (Laurens, 2025). This also relates to the data ownership, as information collected is not shared for financial reasons, but solely used for research and AT purposes, being regulated by the Brazilian Data Protection regulation, and subject to fast exclusion through user request in the app (Funk et al., 2025; Oliveira et al., 2024). The choice of not monetizing the data was associated with assuring peasant’s privacy so to ensure their engagement in the co-creation, and continuous use after launching (Laurens et al., 2023).

Thus, Solis appears as a demonstration of an inclusive and empowering digital tool, through which peasants participated as designers, scientists, and content creators, from design to implementation. Encompassing agroecological elements and social digital inclusion factors - such as two-way communication, participatory approaches in design, citizen science, farmer-to-farmer content -, it aligns well with what the literature suggests on the alignment of digital tools and agroecology (Dittmer et al., 2022b; Wittman et al., 2020). Also, it addresses power relations through peasant empowerment (Laurens, 2025; McCampbell et al., 2025), transitioning practices away from agribusiness influence in a deforestation hotspot area (Costa Jr. et al., 2024). Yet, the solution still faces financial and scaling issues, some of which connected to the time and resource costs of the participation - core to its design -, others to the product need to be financially accessible to users - core to its purpose -, dislocating the cost to developers (Laurens et al., 2023; Shelton et al., 2024).

Moreover, while the construction process also engaged with peasants' unions and the public sector, its purpose does not enlighten on the effects on the governance element of agroecology besides through the sharing of practices. In the next section, the participation within local, national and global governance will be discussed through the lenses of actors consulted within TRANSITIONS for the Brazilian project, and through the interviews conducted by the author with Brazilian and Paraguayan agroecologist activists.

b. Peasants Agency in the Digitalization of Agroecology: a Governance Perspective

The previous section highlighted how participation and inclusion may happen through digital technologies in agroecology, as well as limitations and challenges for it to happen locally. In the literature, most of the digital tools for agroecology mapped figures outside of institutionalized public policies and do not address the resilient governance element in agroecology (Dittmer et al., 2022; Heissler et al., 2023). In doing so, while they can be engaging peasants in co-creation and knowledge sharing, this empowerment not necessarily is translatable at the to community level governance, or their engagement in policy decision-making (Shilomboleni and Schnurr, 2025). This also comes with equity

and power implications, as the lack of governance is associated with patterns of inequality in digital agriculture (Hackfort, 2021).

The interviews conducted[3] during the TRANSITIONS implementation in Brazil - present in Freixêdas et al. (2022) - mentioned challenges in line with the literature for the implementation of inclusive digital tools for agroecology (Shelton et al., 2022). Lack of digital infrastructure, digital literacy, and the lack of tools adequate to small-holders and their local contexts figured across all interviews. Furthermore, representatives from the Ministry of Agriculture, Livestock and Food Supply (MAPA) and the Brazilian Agricultural Research Company (Embrapa) highlighted the existence of digital tools at the government level, in a "one size fits all" approach, mainly for production management, and not within an agroecological approach (Rocha, 2022; Skorupa, 2022). This general approach, however, was criticized by the Environment and Sustainability State Secretary of Pará, in which the size of the territory (1.2mi km², approximately the size of Angola) implies distinct dynamics that are not included in such tools (Lima, 2022).

The importance of peasants' inclusion in the digital tools appeared throughout all the interviews, mostly focusing on the need of their accessibility and adequacy to peasants' levels of digital literacy and smartphone use. Mentions to the incorporation of connections to Whatsapp, other social media platforms, and Radio was made by cooperative extensionists, policy-makers, and by developers themselves, as a form of tailoring the tool to the familiarity of peasants (Lopes, 2022; Knoch, 2022; Rocha, 2022). Nonetheless, the form in which peasants' participation was mentioned varied, and most only included the consultation of peasants' needs and the better communication about existing policies by the State (Freixêdas et al., 2022). Only one government representative, from MAPA, and one NGO Director, from The Nature Conservancy (TNC) mentioned the importance of peasants as co-developers of such tools, co-creators of knowledge within them (Rocha, 2022; Rossi, 2022). The NGO Director was also the only to mention the importance of bringing peasants to the administrative governance of such tools (Rossi, 2022).

[3] According to the report, the nine interviews aimed to: "(i) the use of digital tools, their barriers and opportunities; (ii) aspects that can make these digital tools more inclusive for rural producers; (iii) proposals and incentives for the adoption of best practices; and (iv) the role of digital tools in this process." (Freixêdas et al., 2022, p. 3, author translation).

These perspectives interact and contrast with the interviews conducted by the author with social and agroecological activists of movements associated with La Via Campesina International. Firstly, the digitalization of agriculture is understood with preoccupation, not only by the modernization it brings, but with the underlying individualism (P. Alvarez, personal communication, May 28, 2025). The top-down technocratic and generalistic approach of digital agriculture was understood in misalignment with their movements core beliefs and agroecological principles, while also digital tools came with dilemmas about data ownership (M. Silva, personal communication, May 28, 2025).

On this, peasants' preoccupation on how their seeds were privatized by companies through patents systems were transposed to the digital tools in general: their lack of understanding about the implications of giving their data, and possible commercialization was mentioned as a central factor for peasants and social movements to avoid digitalization (P. Alvarez, personal communication, May 28, 2025; M. Silva, personal communications, May 28, 2025). This is related to the literature mapped, and infrastructure, accessibility and digital literacy were also mentioned as barriers. Traditional and indigenous communities, despise users of different technologies - digital or not - were mentioned as marginalized in such discussions, specially in policy-making (Alvarez, personal communication, May 28, 2025).

Yet, the adoption of digital tools was not understood as a controversy on its own with agroecological purposes. Co-creation and participatory methods appeared in the interviews as a fundamental step in collectivizing digital tools for peasants' gains. Nevertheless, this has not been promoted through social movements in Brazil, Paraguay, and in other Latin American countries (P. Alvarez, personal communication, May 28, 2025; M. Silva, personal communication, May 28, 2025). Attempts to develop apps to further decision-making and consulting amongst peasant movements in Brazil was mentioned to have happened in the past, but was deemed to be impractical and costly when compared to the use of Whatsapp (M. Silva, personal communication, May 28, 2025). Meetings through calls and group discussions in this social media were also mentioned as a source of strengthening the social movements, while also a preoccupation on how this may replace face-to-face contacts (P. Alvarez, personal communication, May

28, 2025), a preoccupation also shared by Solis team about their tool (Laurens et al., 2023).

Further to the underlying power structure of digitalization, regional specificities and generational challenges were mentioned as barriers to social movements engagement with the theme. Regarding regional specificities, the digitalization of agroecology also was mentioned as a non immediate priority, in the face of challenges such as the right to land and to the use of traditional crops (P. Alvarez, personal communication, May 28, 2025; M. Silva, personal communication, May 28, 2025).As already recognized as a longstanding obstacle to agroecological transitions in the region (Giraldo et al., 2019; Rosset et al., 2022), the lack of secure land access also increases the perceived risk for peasants in adopting digital technologies—since any investment in such tools could be lost if they are expelled of their land (M. Silva, personal communication, May 28, 2025). According to Marciano Silva, these priorities also merge with the lack of knowledge on datafication and the benefits digital tools could entail to agroecology, further distancing social movements from their co-creation (M. Silva, personal communication, May 28, 2025).

The generational aspect was also highlighted, as the digitalization of big farms was mentioned as a source of fascination to the young generation, abandoning and weakening peasants and agroecological practices to work in modernized big farms. This trend was commented on by different movements within the CLOC-Via Campesina, and seen as a challenge of social movements in including youth and new perspectives on digitalization (P. Alvarez, personal communication, May 28, 2025). This dilemma, and the distancing of social movements from further discussions on digital tools was understood as problematic, as digitalization was understood as an unstoppable force (M. Silva, personal communication, May 28, 2025). Hence, the lack of engagement of agroecological and peasant movements with the theme was seen as further perpetuating the inequality posed by digital agriculture (Hackfort, 2021).

The interviews conducted for the TRANSITIONS project barely mentioned institutionalized spaces for participatory engagement with policies of digitalization of agriculture, nor the need for them. One of the Embrapa technicians interviewed mentioned the existence of a “Agriculture 4.0 Thematic Chamber” in the MAPA, but no

details were given on the level of peasants or social movements (Freixêdas et al., 2022). Social movements were only mentioned once, by a representative of the food industry, as a form of building trust with the peasants for the implementation of such tools (Amaral, 2022). A parallel can be traced by Perla and Marciano's criticism on the absence of inclusive digital tools policies for agroecology, and on the lack of meaningful participatory spaces for local and national level decision-making on the theme (P. Alvarez, personal communication, May 28, 2025; M. Silva, personal communication, May 28, 2025).

On this, Marciano mentioned that despite the existence of thematic chambers, they are immersed in a non-transparent governance, through which peasant movements inputs on public policy are limited. As agriculture and digitalization are spread in different ministries[4], activists can become cloudy in where to focus their limited resources for advocacy (M. Silva, personal communication, May 28, 2025). Moreover, the interviewees experience in such thematic chambers, in Brazil and in Paraguay, was that government officials and technicians would carry a biased view on agroecological movements and traditional knowledge (P. Alvarez, personal communication, May 28, 2025; M. Silva, personal communication, May 28, 2025). Marciano even mentioned technicians in these chambers called agroecological approaches and traditional knowledge "obscurantists" (M. Silva, personal communication, May 28, 2025).

Thus, while not antagonists to technology, social movements agency towards digital agroecological tools appears rather limited. This confirms also discussions on the literature about limitations on emerging digital agricultural policies in including stakeholders beyond big producers, and in operating in parallel with agroecological policies, distant from peasants realities (Alcântara and Bert, 2024; Rodrigues and Mondaini, 2024).

The findings above illustrate a dual problematic of the dilemmas digitalization of agroecology poses to participation: while local participatory initiatives like Solis

[4] In the interview, Marciano mentioned that different Ministries would be related to the theme of digitalization of agriculture, namely: Ministry of Agriculture, Livestock and Food Supply, Ministry of Environment and Climate Change, Ministry of Agrarian Development, Ministry of Social Development and Fight Against Hunger, and Ministry of Development, Industry, Trade and Services (M. Silva, personal communication, May 28, 2025).

demonstrate the transformative potential of inclusive digital tools in empowering peasants and enhancing agroecological transitions, they encounter limits in scaling due to the costs of participation and the financial business model they operate (Laurens et al., 2023; McCampbell et al., 2025). These tools also usually do not address the resilient governance element of agroecology (Dittmer et al., 2022b; Heissler et al., 2023). Moreover, peasants movements, while recognizing the importance of the field, face similar challenges to peasants (Shelton et al., 2022) to engage in discussions on the digitalization of agriculture and agroecology. The interviews also demonstrated limitations on the mechanisms of participation at local and national governance levels, that reduce participation to communicating policies to peasants and asking for their input, while not addressing small-holders and agroecological needs within public policies in Brazil.

4. Conclusion

This paper sought to understand the extent to which digital technologies enable or constrain meaningful participation in agroecological transitions at the territorial level. Through its literature review and case analysis, it aimed to comprehend the tensions and opportunities in the digitalization of agriculture entail to small-holders; how digital tools align or conflict with agroecological principles, especially co-creation of knowledge and resilient governance, and; who is involved in the design of such tools, and how do participatory approached affect peasant's agency.

The findings reaffirm many critical concerns raised in the literature. While it mentions the possibility of co-creation of digital tools for agroecological purposes, most of the current tools mapped are far away from incorporating agroecological principles and social inclusion in their design (Dittmer et al., 2022a). Thus, dominant top-down, corporate-driven approach may continue to frame most digital agricultural tools, embedding them within narratives of standardization and productivity associated with the Green Revolution (Klerkx & Rose, 2020; Shelton et al., 2022). These models tend to marginalize smallholders, exclude traditional knowledge, and risk deepening inequalities. While power relations are underlined in the literature, little is mentioned on the peasant's movement agency in digitalization of agriculture outside - valid - concerns with peasants data ownership and the corporate vision behind such tools. Their engagement on co-creating horizontal digital tools is not yet clear.

This echoes ongoing concerns in the literature and social movements, as the interviews conducted with peasant activists highlighted the urgent need for governance structures that prioritize inclusion, co-creation, and accountability. Interviews - conducted by the author and taken from the TRANSITIONS team - showed that despite some recognition of these issues, institutional mechanisms for participation in Brazil and Latin America remain opaque and fragmented. Additionally, the complexity of the technologies, other challenges faced by social movements regionally, and their limited resources could also explain their lack of engagement with digital agriculture.

The case of the Solis app in Brazil, however, demonstrates that inclusive alternatives are possible when participatory design, local knowledge, and peasant agency are prioritized. In this case, digital tools were not just assimilated by peasants but shaped through their direct input, enhancing both knowledge sharing and localized agroecological transitions. Yet, it also exemplifies how within digital agroecological tools, participatory processes may face tradeoffs with implementation speed and scaling, also related to challenges in their financing (Laurens et al., 2023; Laurens, 2025).

Still, several limitations may temper the findings of this study. Firstly, the literature on digitalization of agroecology is still scarce (Petraki et al., 2025), even more on the relationship between participation and digital tools for agroecological purposes. Secondly, Dittmer et al. (2022a) data was not exhaustive, lacked information about many tools, and does not reflect changes in the last 3 years. Furthermore, while the case study of Solis provided rich insights, it reflects a relatively successful initiative that may not be representative of the wider field, and a recent initiative, in which the total effects are yet unknown. Finally, the small number of interviews conducted by the author[5] affects the generalization about the engagement - or the lack thereof - of peasant movements with the themes. Thus, while the findings were important, the questions posed remain unanswered, and further research on different localities, tools and actors may conclude differently.

In light of these limitations, future research should expand both in depth and breadth, in themes such as financing for digital tools in agroecology, so as to understand

[5] Which may be expanded in the future.

their operational model, return on investment, and in identifying how different financial mechanisms that may be related to more agroecological elements and social inclusion realization, that is, more participation. Also, further research should focus on the role of peasant movements in co-creating, implementing, or even resisting digital technologies. Also, understanding how these actors influence the governance - locally or nationally, institutionalized or not - and values embedded in digital technologies is critical for a more democratic digital transition, and deserves deeper investigation.

Ultimately, if agroecology is to serve as an alternative to industrial and productivist agriculture, its engagement with digital tools shall not replicate the very structures it seeks to replace. Instead, it must be reimagined from the ground up - rooted in peasant agency, collective knowledge, and equitable governance (Laurens et al., 2023; McCampbell et al., 2025; Sheldon et al., 2022). This includes, but goes beyond inclusive design, towards also understanding governance and power dynamics (Rosset et al., 2025; Rotz et al., 2019). As digital technologies are rapidly embedded in food and agriculture systems, this paper highlighted how the challenge is not merely technological, but fundamentally about power, participation, and the future of agroecology, its practices, principles, and actors.

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