Digital decision-support tools for designing agroecological farms? Reflections inspired by the multi-actor development of an online software for vegetable growers in France

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Abstract: Our objective was to explore the characteristics of a digital decision-support tool (DDST) that could match the specific expectations of agroecology networks. We relied on a case-study in France where we have been implementing a participatory approach to develop an online software (La Pépinière-Mesclun) since 2020 to support vegetable growers to (re)design and assess their cropping plan while integrating agroecological practices relying on diversification. The analysis of qualitative content gathered throughout the project showed that to be judged salient, relevant and legitimate by agroecology actors, the DDST had to match specific expectations characterized as 73 design choices, grouped into 14 design principles, underlied by 4 main design values: (i) respecting the diversity and complexity of farming systems; (ii) being accessible to a diversity of farming profiles; (iii) valuing peoples' expertise and fostering decisional autonomy; (iv) being designed and managed as a digital common. Fostering digital commons for agroecology raises many theoretical and practical challenges, among other related to relevant modalities collective of governance and contribution and to fair business models. This work corroborates and enriches the very few studies based on concrete field work investigating the conditions for digital tools to be compatible with expectations of radical agroecology networks.

Keywords: farming system design; participatory research; horticulture; innovation; sustainability

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1. Purpose

Although increasingly presented by mainstream actors as key pillars of a transition toward sustainable agriculture, digital decision-support tools (DDST) can face criticism or create controversies in agricultural networks defending a radical view of agroecology (Ajena et al., 2022; Bellon-Maurel et al., 2022; Leveau et al., 2019; Schnebelin, 2022). By radical agroecology, hereafter called simply “agroecology”, we mean a global approach to transition of farms and food systems toward more sustainability based on systemic redesign rather than seeking for optimization of existing systems (Duru et al., 2015). For example, DDST can be perceived as supporting dynamics of agricultural industrialization or threatening farmers' decisional autonomy. This perception is strengthened by the fact that farmers are rarely involved in the initial design of digital tools for agriculture (Di Bianco and Ghali, 2022). Nevertheless, DDST can also be considered as promising options to support the design and management of agroecological systems which are knowledge-intensive and complex. Our objective was to explore the characteristics of a DDST that could match the specific expectations of agroecology networks. Our main assumption was that involving farmers and farmers' networks in all steps of the DDST design and development would be necessary to reach our objective.

2. Design/Methodology/Approach

Our analysis relies on a case-study in France where we have been developing an online DDST (La Pépinière-Mesclun[1]) for vegetable growers since 2020. For vegetable growers, agroecological practices relying on diversification (longer rotations, cover crops, green manures) can increase drastically the complexity of spatial and temporal crop planning. Moreover, farmers need to assess the impacts of such practices on the farm sustainability and ensure the possibility to match marketing objectives, which is specifically challenging as it requires to combine throughout the year a large range of short cropping cycle vegetables to provide every week a diversified and sufficient offer for different marketing outlets.

The DDST we developed aimed at supporting vegetable growers in addressing such challenges in the (re)design of their farm. The 2 main use situations for which our DDST was developed relates to (i) vegetable farm creation where crop planning design is a key strategic element of the farm business plan, (ii) redesign of crop planning for existing vegetable farms which are involved in strategic change (e.g. diversifying production). The DDST was designed in the perspective of facilitating interactions between current or future (students) vegetable farmers, agricultural advisors and trainers. We assumed that to be really used by these end users, our DDST had to be perceived as credible (data and models judged adequate by end users), salient (relevant to their needs) and legitimate (respecting their diversity of values and situations) as suggested by Cash et al. (2003). To reach such objectives, we carried out a participatory design approach involving researchers from 4 units of our research institution (INRAE) and 8 organizations of the agricultural sector inspired by agroecology (RandD, Farmers' organizations and agricultural support, Education), 1 IT startup and 1 freelance designer. Inspired by Cerf et al. (2012), our methodology relied on two main stages: (i) a diagnosis of uses (based on initial interviews and collective workshops with end users) aiming at identifying the diversity of situations related to crop planning, exploring how stakeholders take their decisions, the role of existing tools and how the future DDST could make this decision process more effective and (ii) an iterative co-design methodology relying on frequent interactions based on a prototype (37 design and test workshops all across France) with 256 end users. Users' feedbacks were integrated to inform the design of mockups, software development and structuration of a database based on an agile development methodology (Anand and Dinakaran, 2016).

Based on a large database of vegetable temporal availability (from field and sheltered production), yields and prices of 75 vegetables, the user can design different marketing scenarios (number of outlets, quantity and diversity of vegetables sold every week, level of sales). The user can then explore different combinations of cropping cycles to match marketing objectives and allocate these cropping cycles (and cover crops) on different field and sheltered plots leading to a cropping plan (main output of the DDST). From this cropping plan and complementary inputs on farming practices and context, the DDST allows a multicriteria assessment of the sustainability of the cropping plan.

[1] Available at https://pepiniere.outils-mesclun.fr

We systematically tracked the content of the different workshops and the agile development meetings in a word document (372 pages at the end) extensively describing needs expressed by end users', discussions between participants, possible options considered, choices made and their justification. This content was processed through inductive qualitative analysis using thematic coding without any preexisting conceptual categories (Miles and Huberman, 1984). We characterized first "design choices", as basic analytical categories. Design choices were concrete design options considered in the DDST development based on end users' requirements and feedbacks, e.g. "not presenting mean vegetable yields but rather a range of yields to account for the fact that production is variable and uncertain". Design choices were then grouped into a second-level more generic category of "design principles", e.g "accouting for uncertainties and variability". Then we observed that design principles could be grouped in a last third-level more conceptual category of "design values" describing the ideological foundation underlying design principles, e.g. "respecting the diversity and complexity of farming systems".The concept of "digital commons" was used to characterize one of the design value. This concept was brought by researchers inspired by literature (Calvet-Mir et al., 2018; Dulong De Rosnay and Stalder, 2020) only at the end of the analysis because it deeply echoed what participants expressed.

3. Findings

During the workshops, end users expressed that they saw no contraction in using a DDST to promote agroecological approaches (trainers and advisers) or design agroecological systems (students and farmers) if and only if the DDST was designed in line with a set of principles and values echoing their specific experience and worldview (**Table 1**). Four distinct values were highlighted. The DDST had to (i) respect the diversity and complexity of farming systems, (ii) being accessible to a diversity of farming profiles, (iii) value peoples' expertise and foster decisional autonomy while not providing prescriptive solutions, (iv) be designed and managed as a digital common. Under these conditions, a DDST was perceived as having a great potential to support agroecological approaches while allowing users to explore and reflect on contrasting scenarios of crop planning. At the conference, design principles and choices will be illustrated with many concrete examples.

As illustration, we will focus here on the design principle of "Keeping it as simple as possible while valuing users' expertise rather than modelling to account for complex biophysical processes of agroecological systems". To this purpose, we can consider the necessity to account for the variability of tomato yields every week during the production season. This is a very complex problem as tomato production dynamic will rely on many interacting factors such as plant cultivar, farming practices, climate conditions. On a typical agroecological vegetable farm growing for example 50 vegetable species with 300 cultivars, including undocumented landraces and/or genetically evolving populations, this challenging problem becomes a nightmare of complexity. Based on participatory workshops, we decided to keep it simple. For each vegetable specie, the DDST provides a range of yield (low-medium-high) and this yield is considered to be the same every week of the harvest period (which is unrealistic). These data allow a first approximation of the potential production every week per unit area for a first broad approach of crop planning based on marketing requirements. However, the software is designed to enable farmers to distinguish varieties if they think it is relevant and to manually adapt yields every week based on expertise. If they do not have this expertise, they are encouraged to discuss with other farmers, their neighbors, agricultural advisors which leads to exchange of ideas, experience, learning. The results of this learning process, carried out in "real life" outside of the DDST, can then be set as input in the tool.

4. Practical Implications

Our work shows that there is space for the development of DDST adapted to the needs and values of end users promoting agroecological approaches. However, we think that involving end users throughout the whole iterative process was key to identify their specific needs and integrate their feedbacks to ensure that the DDST development was in line with their expectations. This makes the development process very time demanding. In this regard, this makes it challenging for private companies to develop digital tools for agroecology as they often need to ensure short term profitability. Although the project involved a private IT startup and a freelance designer, is was led by researchers from public institutions hand in hand with partners from organic agriculture RandD, agricultural education and farmers' organizations whose participation was funded by public money (French Ecophyto program).

Table 1. Design values, designs principles and related number of design choices for the participatory development of "La Pépinière-Mesclun"

Design values	Design principles	Design choices (nb)
Respecting the diversity and complexity of farming systems	Allowing a systemic multi-objective approach with functionalities, dimensions and indicators relevant to farmers	19
	Allowing flexibility regarding a diversity farming practices and socio-technical contexts	7
	Accounting for uncertainties and variability	3
	Providing dynamic interfaces which allow different approaches of crop planning	1
	Sub-total for this design value	**30**
Being accessible to a diversity of farming profiles	Limiting the amount of initial input data required	7
	Allowing different levels of precision according to users' needs, step and type of the design process (exploring phase or deepening phase, training purpose or real farm design)	4
	Presenting user-friendly interfaces	4
	Sub-total for this design value	**15**
Valuing peoples' expertise and fostering decisional autonomy	Keeping it as simple as possible while valuing users' expertise rather than modelling to account for complex biophysical processes of agroecological systems	6
	Developing functionalities to foster sharing of knowledge and training	5
	Enabling simulation and assessment of contrasting strategic options rather than providing an optimal prescriptive solution	3
	Sub-total for this design value	**14**
Being designed and managed as a digital common	Allowing open-access of non-personal data, models and codes	5
	Developing a governance model allowing the end users to discuss and orient strategic decisions related to the tool	4
	Creating a community of users who could contribute to improve the tool and supports its use in different networks	3
	Developing a business model considered as fair by end users and collectively discussed	2
	Sub-total for this design value	**14**
Total number of design choices		**73**

Without the participation of agricultural actors and institutions, the private IT company would never have had such an "easy access" to agricultural networks and the required legitimacy to work with them. This implies that a private-public partnership may be necessary for such projects. In our experience, this partnership was very fruitful but required time and attention to build a common language between researchers, private actors and farmers' organizations and to account for the specific constraints and objectives of everyone.

In our project, participants expressed that they were willing the DDST to be designed and managed in line with the 4 principles of "digital commons" defined by Dulong De Rosnay and Stalder (2020): (i) data, models and tools available online with an open access license allowing, (ii) a collective participation to the development and strategic orientation of the tool, (iii) based on alternative economic models beyond market and state, (iv) guided by a collective and horizontal governance. The first principle was followed while making the DDST, the related database, mockups and software codes available online with an open-access license. However, partners of the project highlighted many challenges to match the 3 other principles: how to make RandD and agricultural support organizations collaborate on the long term to contribute to the development of a common tool and share data as some of these organizations have competing interests and tend currently to develop their own tools and datasets only available to their members? How to develop a fair business model allowing end users to freely access the DDST while funding software future development and maintenance? (indeed while open software codes theoretically allow anyone to develop the software, this requires IT skills that interested actors may not have or not have the time or wish to employ for free) How to foster a long-term collective emulation and participation to the DDST development once the public funding (obtained only for the first development phase) has ran out? Which practical and legal forms could support a collective governance of the DDST? As very limited example of digital commons applied to agroecology are documented (Calvet-Mir et al., 2018), there is a strong research need to better investigate how to overcome those challenges.

5. Theoretical Implications

Some scientific papers or reports have made suggestions on the conditions for digital tools to support a radical transition, most of the time formulated a generic and prospective way as a research agenda conceptually articulating literature on digital innovation and literature on agroecology (Ajena et al., 2022; Bellon-Maurel et al., 2022; Leveau et al., 2019). Very few studies based on concrete field work investigate the conditions for digital tools to be compatible with expectations of radical agroecology networks. Our work is a contribution to fill this gap and highlight design values and principles which are globally in line with the more generic papers above-mentioned and with the few studies based on field work (Hilbeck et al., 2023; Wittman et al., 2020).

However, our field work brings interesting new insights. For example, conceptual papers highlight on one hand the need to empower farmers' decisional autonomy rather than providing optimal solutions and to value farmers' knowledge. On the other hand, they raise the dilemma of accounting for the high complexity of agroecological systems while promoting digital frugality. Our work shows that a way to overcome this dilemma is to articulate these two dimensions. It suggests that valuing farmers' expertise in complementarity of simple models not aiming to account for complex biophysical processes allows to keep the tool simple, to approach complexity and to empower farmers (see illustration provided in section 3).

Studies analyzing the use of digital tools by farmers often emphasize and discuss two types of tools: digital technology for production (tools designed to support farmers in operational decision making, e.g to optimize use of inputs) and technology for information and communication (to access and exchange knowledge, e.g. through social media) (Rose, 2016; Schnebelin, 2022). Schnebelin (2022) showed on organic farms that the use of digital technology for production tends to facilitates industrialization trajectory whereas technology for information and communication can support ecologization of farming practices. The DDST we developed belong to another category: digital decision-support tool for the design of agroecological systems (rather than for supporting operational decision). Our work shows that this type of DDST can be specifically relevant to agroecological farmers as radical agroecology relies on a systemic (re)design of farming systems (Duru et al., 2015; Martin et al., 2013) rather than optimizing existing practices (which is the goal of digital technology for production). We thus think that the role, potentialities, limits and characteristics of digital tools to support the (re)design of agroecological farming systems need more attention from research.

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