Revitalizing agricultural sciences with design sciences

Lorène Prost

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Highlights:

- The agricultural sciences are facing issues that are design issues and they would benefit from drawing on the design sciences.
- I provide a brief summary of the work of design sciences and their various streams.
- Decision support systems (DSS) design and agricultural systems design may largely benefit from methodologies and concepts from design science.
- Design sciences can help us to change agricultural sciences so that they can support the transformation of agriculture towards sustainability.

Keywords

Participatory design; innovation; agroecology; sustainability; agricultural sciences; design sciences

Abstract:

In this perspective article, I explain why agricultural sciences are facing what I consider to be design issues, and why I strongly believe that agricultural sciences would benefit from more dialogue on these issues with design sciences. Using two examples concerning the design of Decision Support Systems (DSS) and of agricultural systems, I discuss the methodological and conceptual contribution that design sciences can make to agricultural sciences. I then elaborate on how design sciences are most needed to help us revitalise agricultural sciences so that they can more effectively support farmers and agricultural stakeholders on their road to sustainability – a process which requires a radical, creative and innovative design effort.

Text:

The term mission-oriented science, coined by Klerkx and Begemann (2020), reflects the part of the agricultural sciences that has always been dedicated to supporting and transforming the activities of agricultural actors, and not only to understanding the phenomena at work in agricultural production. This part of the agricultural sciences involves many activities in the design of new agricultural systems (at different scales) and of tools that enable farmers and other agricultural actors to transform their practices and sociotechnical systems. This perspective article aims to make agricultural scientists engaged in such activities aware that there is a whole research community working specifically on design, whose work they could use to be more effective. And this seems to me to be all the more necessary today as we are facing new challenges that require particularly consistent design efforts. It has become crucially important for us to contribute to the development of sustainable agriculture with farming systems that address global malnutrition, while stopping the depletion of natural resources and improving the working and living conditions of farmers and farm workers. We are in fact facing typical innovative design issues as they implicitly demand a transformation of agriculture in directions that are for now ill-defined, full of uncertainties, context-dependent and, in short, fundamentally unknown. The design sciences can help us meet these challenges.

Taking design activities seriously has already contributed to an interesting renewal of the agricultural sciences in the last 10-15 years (e.g. Coquil et al., 2009; Bos et al., 2009; Le Gal et al., 2011; Meynard et al., 2012; Martin et al., 2013; Dogliotti et al., 2014; Dumont et al., 2014; Altieri et al., 2015; Pelzer et al., 2017; Prost et al., 2018; Lacombe et al., 2018; Lesur-Dumoulin et al., 2018; Berthet et al., 2018; Pretty, 2020; Rossing et al., 2021). But we should go further by drawing inspiration from the scientific debates that exist on design, in the design sciences community. I will present these debates in order to then illustrate how they can help us, not only in our usual activities of designing tools or agricultural systems, but also, more fundamentally, in our reflection on how to evolve our research to meet the current challenges of developing sustainable agriculture.

What are design sciences?

Most of us associate the term design with an aesthetic dimension inherited from 19th century industrial design. Actually, the original meaning of design, which appeared in the Renaissance, is "project methodology" (Vial, 2015). The concept of *disegno* emerged to encompass the two stages that every project involves: ideation (objectives, intention, aim, ideas) and implementation (sketch, prototype, mock-up, final object), both oriented towards the goal of the project. We find this definition in Simon's *The Sciences of the Artificial*, often seen as the founding book of the design sciences: "*Design is concerned with how things ought to be, with devising artifacts to attain goals*" (Simon, 1969). It emphasizes the intentional and transformative nature of design, which seeks to bring out things that do not yet exist and that might never exist.

Several reviews trace the history of scientific work on design (e.g. Bayazit, 2004; Cross, 2007; Dorst, 2008, 2016; Papalambros, 2015). I provide a brief summary of these. While design activities have been documented for a long time (see Gero's contribution to Papalambros, 2015), the "scientification" of design began in the 20th century with the De Stijl and Bauhaus movements that set out to rationalize design in architecture. This concern spread after the Second World War, with the intention to (re)build quickly by being more systematic and more efficient. It led to the emergence of the "Design Methods" movement in the 1950s, based on the belief in a universal science of design for both architecture and engineering, that would define a logical and systematic approach to design processes. However, after a few years, some initiators of Design Methods themselves contested these studies that equated design to information processing, and they advocated for more context-relevant approaches to design, rooted more deeply in what design processes actually are. In the 1980-90s, two research streams maintained this opposition. On the one hand, there was work on design tools and methods, primarily among engineers, who further rationalized the design process and its sequencing. On the other hand, other researchers sought to develop a better understanding of design activity as it was actually practised. They worked on design as a social and context-dependent process. Since the 2000s, these two streams have remained active and two additional ones have emerged. The first of these consists of updated work on a generic theory of design, and was revived by an expansion of the fields of design (social design, service design, interaction design, ecodesign, organizational design, environmental design, etc.) (Cooper, 2017). The second stream is a reaction to the 1990s recession and globalization, which triggered a crisis in design that was accused by some of being an agent of consumerism. Following this crisis, some designers have pleaded for design to focus more on the meaning that designed objects have. This is the “semantic turn of design” (Krippendorff, 2005) that highlights the political impact of design since designed objects and techniques have effects on social functioning (Tromp and Hekkert, 2018).

The design sciences community is thus both multidisciplinary (from engineering to a wide range of social sciences) and multi-subject (designing industrial processes, objects, architecture and so on). It is the object of design that brings researchers together

How can design sciences help us to build agricultural sciences that support agriculture in its transformation?

How can design sciences inspire a new approach in agricultural sciences? I will take examples to illustrate this, with a gradient ranging from usual activities of agricultural scientists to a reflection on how agricultural sciences should evolve to support the development of sustainable agriculture.

First, let us consider the example of the design of decision support systems (DSS) in the agricultural field. The literature has long discussed the many failures of these tools and the reasons thereof, including the design methods of these DSS (e.g. Cox, 1996; McCown et al., 2002; Rose et al., 2016). To overcome these shortcomings, there is growing recognition that we need to involve future users in more participatory design processes (e.g. Jakku and Thorburn, 2010; Cerf et al., 2012). Yet agricultural scientists may feel powerless to implement such approaches that require know-how (in understanding of users’ expectations and constraints, and in animation and collaboration) and time (notably to establish efficient participatory work with other actors, often not academics). However, design sciences can provide them with the help they need. In fact, design sciences have produced and shared a large body of research on the ways of implementing participatory design methods (e.g. Schuler and Namioka, 1993; Kensing and Blomberg, 1998; Simonsen and Robertson, 2012), co-design (e.g. Sanders and Stappers, 2008; Steen, 2013) or open design (e.g. Boisseau et al., 2018). They apply different methods to identify the users' needs, desires, and constraints (like personas and user characterizations), and to explore and test solutions (e.g. use scenarios, hands-on experiences, and the use of several types of prototypes). These methods can help us to make a more systematic use of co-design methods (which is still far from being the case today; see for instance Rose et al., 2016; Ditzler et al., 2018) and give us keys to do so more efficiently. This is a matter not just of improving end-user experiences with intuitive interfaces, but of acquiring the means to better understand the actual activities of those whom we are trying to support, so that our tools may be more salient and legitimate (Cash et al., 2003). Cerf et al. (2012), for instance, detailed two methods inspired by design methods (and in particular by design ergonomics). The first is a method to diagnose uses. It consists of interviews and observations built to understand how the potential users of a future DSS actually perform the activity that the DSS will support. The aim is to identify the tools, methods and constraints (time required, data availability, available skills, etc.) of this activity, and to characterize its invariants, diversity, and difficulties, and then to adjust the design of the DSS accordingly. The second method involves early prototype testing by users, based on realistic use scenarios (with the users' data, respecting their real working conditions), to adjust the design of the DSS. We could and should push this cross-pollination with co-design methods and research further, to renew our work on decision support systems.

Another example is the design of cropping and farming systems, which has experienced major expansion in the 2000s, mobilizing modelling (e.g. Bergez et al., 2010), experimentation (e.g. Debaeke et al., 2009; Silva and Tchamitchian, 2018) and/or prototyping workshops (e.g. Vereijken, 1997; Lançon et al., 2007), increasingly in combination with one another. Design sciences are likely to develop our research on this subject in several directions. First, as with the design of DSS, design sciences invite us to further involve farmers in these design processes, for instance in design workshops with farmers. More radically, design sciences also invite us to consider farmers as the designers of their own systems. This obliges us to think about how we, as researchers, can support these design activities, which I think fundamentally changes the way we shape our contribution to agricultural systems design. We can do so in different ways:

- We can provide farmers with disruptive knowledge that might inspire them to identify radically different solutions.

- We can provide them with knowledge about what the design problem actually is (e.g., to help them imagine agricultural systems suited to a drinking water catchment, we can provide knowledge about how agricultural practices actually impact water quality).
- We can provide information to assess the impacts of changes on farmers' design goals (to carry on with the same example, if farmers want to try a new practice, how can we help them to assess the actual impact of this practice on water quality?).
- We can promote and facilitate these design activities to help farmers set aside time for design (e.g., by organizing farmers' workshops dedicated to design activities).

In each case, the scientific knowledge we must produce differs. The design sciences can help us to robustly work on each of these points. We should pay attention to the design sciences' research on the properties that knowledge should have if it is to be disruptive, on the ways of structuring and visualizing a problem, on eliciting the criteria that will be relevant for field actors to evaluate the performance of the imagined solutions, and on the methods to support design processes.

Actually, the question is perhaps even broader: what is our place among the range of AIS (Agricultural Innovation Systems) players who influence farmers' design activities through their requirements (e.g. Douthwaite and Hoffecker, 2017; Berthet et al., 2018; Davies et al., 2018)? Many research studies have shown that farmers are caught in, and constrained by, a matrix of requirements (from the processing industry, from those who market their products, from regulatory obligations, etc.) (e.g. Vanloqueren and Baret, 2009; Lamine, 2011; Meynard et al., 2018; Rossing et al., 2021), in addition to biophysical laws. This creates path dependency and lock-ins that limit the possibilities of innovation and change (unless these requirements change). The challenge is then to develop design processes that navigate these issues and involve all the actors to imagine truly innovative systems. The wealth of studies on open design and design for social innovation (e.g. Manzini, 2015) could help us, through their methods. These studies urge us to investigate how to analyse and enrol networks of heterogeneous actors around agricultural issues, how to frame (identify, define) a collective problem to be solved, how this problem challenges agronomic processes and farming systems, and how to stimulate collective creativity to go beyond the usual solution paths.

There are some examples of studies in agriculture that explicitly use these elements from design sciences and refer to them (e.g. Martin et al., 2013; Prost et al., 2018; Lacombe et al., 2018; Salembier et al., 2020). For example, Berthet et al. (2016)discussed several participatory design methods to foster agroecological innovations with multiple stakeholders, one of which derives directly from design research and has since been re-used in the agricultural field (e.g. Ravier et al., 2018; Leclere et al., 2018). Another example is the RIO (Reflexive Interactive Design) methodology (Bos et al., 2009), which aims at supporting the radical transformation of systems (like the design of sustainable dairy husbandry systems). It was likewise spawned by collaboration between agricultural scientists and design scientists, and has also been re-used in agricultural studies (Elzen and Bos, 2016; Romera et al., 2020). I would argue that these approaches are still not used nearly enough. Here again, the reason may be a lack of skills, a lack of knowledge, or a perceived difficulty in advocating for these approaches or publishing them in agricultural science journals. We, researchers interested in design issues in the agricultural field, have developed our own design methods, using previous studies and also our intuition and know-how. Yet drawing directly on design sciences would offer a real opportunity to identify and address extremely rich, important and salient research issues. For instance, design sciences draw our attention to the long duration of the design processes of agricultural systems. Design processes are known to be iterative in the sense that one advances along with the exploration and formulation of the problem (and the target to be reached) and of the solutions to solve this problem (and reach the target) by means of constant iteration of analysis, synthesis and evaluation (Dorst and Cross, 2001). Yet efforts in the agricultural sciences have mainly focused on designing target systems (*i.e.* the final systems that are aimed for). We have made far fewer propositions on ways to support the iterations that are typical of a farmer's efforts to implement design solutions (see for instance the notion of a step-by-step design approach (Meynard et al., 2012)). How to get there without giving up along the way is a question that is rarely considered. It would be of enormous value to develop more research on the temporalities of these processes, characterized by an entanglement of short-term and long-term dynamics (from the short time scale of action in the field or of crisis, to the long time scale of many ecological processes, of value chain evolution and of societal changes), and on indicators to inform these iterations (e.g. Toffolini et al., 2016; Perrin et al., 2020).

For my third and last example, I would like to come back to the idea that the transformation of agriculture raises questions requiring us to activate what the design sciences call "radical" (e.g. Verganti, 2011; Yannou, 2015), "non-routine" (e.g. Gero, 2000), "creative" (e.g. Cross, 1997) or "innovative" (Le Masson et al., 2006) design processes. Ika Darnhofer (Darnhofer, 2021) has recently given an excellent example of the kind of radical design we are facing when trying to contribute to "agricultural systems that are efficient in periods of stability *and* adaptive in times of change". It requires us to think differently, to imagine new research objects and new performance criteria. How does the literature about radical, creative, innovative design processes help us to implement them in the agricultural sciences?

Firstly, these innovative design processes try to reach a "desirable unknown" (Masson et al., 2019) that embodies a "political" intention (i.e. a project of transformation). This reminds us that designers have a responsibility for what they cause to happen through the objects they design. It encourages agricultural scientists to think about this political dimension in their research: what is their aim, how has it been defined and by whom, and has it been made explicit? This may be a very interesting way to make the agricultural science community discuss the agricultural model(s) they want to support or that should coexist (Gasselin et al., 2020). Methods from the design sciences, like Speculative Design (Auger, 2013), might be useful in this respect.

Secondly, many studies about innovative design processes have been devoted to creativity issues, to enhance creativity and inspiration, and to avoid fixation effects (Crilly and Cardoso, 2017; Crilly, 2019). The numerous methods that have thus been developed could inspire agricultural scientists designing new agricultural systems, for instance in the organization of design workshops with other actors, to foster individual and collective creativity (e.g. Reau et al., 2012; Berthet et al., 2016) and so reveal unexpected possibilities. Agricultural scientists could also apply creativity studies and methods from design sciences to their own scientific explorations, and thereby reveal the scope of the scientific questions they have investigated and those they have left aside. This would allow them to organize their research work in innovative directions. It has already proven to be extremely useful to identify research fronts and not to remain on known paths of research (see for instance Vourc'h et al., 2018; Brun et al., 2021).

More broadly, the design sciences draw our attention to new dimensions that we could explore to build a more sustainable agriculture. For example, design has an aesthetic aspect, an attention to form and sensible dimensions, which have hardly been considered in the agricultural sciences. Fields, farms or landscapes are largely shaped by the choice of species or breeds, and by the natural (e.g. hedges), hydraulic, or human-imposed land arrangements (i.e. cadastral boundaries). That is what makes them so complex. The sensible dimensions and the attention to form are part of this complexity and remain to be rediscovered, as recent discussions have shown, for example in permaculture (e.g. Ferguson and Lovell, 2014). Including them (and others) in our research would probably allow us to re-examine the boundaries of our research objects and of what the systems we are studying in the agricultural sciences actually are. In turn, it will give us new ideas of agronomic processes to study and transform.

To be continued….

The aim of this perspective article was to show that design sciences could be useful to agricultural scientists, owing to their methods, tools and concepts that can inform us in most of our activities aimed at transforming agricultural activities. They equip us to formulate complex problems (design sciences talk about "wicked problems"), to imagine creative solutions to these problems, and to do so in socio-technical systems that include a diversity of legitimate actors in the quest to resolve these issues. Actually, we, agricultural scientists, need to renew our design organizations, methods and concepts to support the transformation of agriculture. This requires that the agricultural sciences critically examine their concepts and methods, as several authors have called on them to do (e.g. Vanloqueren and Baret, 2009; Tittonell, 2014, 2020; Duru et al., 2015; Salembier et al., 2018; Darnhofer, 2021). As Le Masson et al. (Le Masson et al., 2013) pointed out: ''*each engineering revolution (e.g. chemical, electrical, electronic or software) was accompanied by the development of its own appropriate design tools and theories*''. If we hope to revolutionize agriculture, then we need to develop our own design tools and theories, with the support of design sciences. This endeavour, initiated at the end of the 20th century by pioneering research, has been growing over the last fifteen years or so but drawing inspiration and resources from the design sciences would most definitely strongly support it. A number of questions are of course still pending:

- How should research through design be organized?
- What implications does this have for the funding, monitoring and evaluation of this research, which claims not to pre-think all the directions of a research question but rather to explore it creatively as it progresses?
- And in what conceptual direction will "research through design" take us in the agricultural sciences?

I would tend to think that the particularities of our agricultural objects, at the interface between the natural and the artificial, systematically confront us, more and more, with unpredictability, uncertainty, and gaps in knowledge that cannot all be filled. This is likely to lead us to work on more adaptive, agile and resilient design processes that are creatively context-adapted. Yet other directions may emerge. After all, a characteristic of design processes is also that the outcome is never what it was originally expected to be. I look forward to finding out what that outcome might be.

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