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1 **Title:** Revitalizing agricultural sciences with design sciences

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4

5 **Highlights:**

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

13 **Keywords**

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

15 **Abstract:**

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

24 **Text:**

25 The term mission-oriented science, coined by Klerkx and Begemann (2020), reflects the part of the
26 agricultural sciences that has always been dedicated to supporting and transforming the activities of
27 agricultural actors, and not only to understanding the phenomena at work in agricultural production.
28 This part of the agricultural sciences involves many activities in the design of new agricultural
29 systems (at different scales) and of tools that enable farmers and other agricultural actors to
30 transform their practices and sociotechnical systems. This perspective article aims to make
31 agricultural scientists engaged in such activities aware that there is a whole research community

32 working specifically on design, whose work they could use to be more effective. And this seems to
33 me to be all the more necessary today as we are facing new challenges that require particularly
34 consistent design efforts. It has become crucially important for us to contribute to the development
35 of sustainable agriculture with farming systems that address global malnutrition, while stopping the
36 depletion of natural resources and improving the working and living conditions of farmers and farm
37 workers. We are in fact facing typical innovative design issues as they implicitly demand a
38 transformation of agriculture in directions that are for now ill-defined, full of uncertainties, context-
39 dependent and, in short, fundamentally unknown. The design sciences can help us meet these
40 challenges.

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

50 **What are design sciences?**

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

60 Several reviews trace the history of scientific work on design (e.g. Bayazit, 2004; Cross, 2007; Dorst,
61 2008, 2016; Papalambros, 2015). I provide a brief summary of these. While design activities have
62 been documented for a long time (see Gero’s contribution to Papalambros, 2015), the
63 “scientification” of design began in the 20th century with the De Stijl and Bauhaus movements that
64 set out to rationalize design in architecture. This concern spread after the Second World War, with

65 the intention to (re)build quickly by being more systematic and more efficient. It led to the
66 emergence of the "Design Methods" movement in the 1950s, based on the belief in a universal
67 science of design for both architecture and engineering, that would define a logical and systematic
68 approach to design processes. However, after a few years, some initiators of Design Methods
69 themselves contested these studies that equated design to information processing, and they advocated
70 for more context-relevant approaches to design, rooted more deeply in what design processes actually
71 are. In the 1980-90s, two research streams maintained this opposition. On the one hand, there was work
72 on design tools and methods, primarily among engineers, who further rationalized the design process and
73 its sequencing. On the other hand, other researchers sought to develop a better understanding of design
74 activity as it was actually practised. They worked on design as a social and context-dependent process.
75 Since the 2000s, these two streams have remained active and two additional ones have emerged. The
76 first of these consists of updated work on a generic theory of design, and was revived by an expansion of
77 the fields of design (social design, service design, interaction design, ecodesign, organizational design,
78 environmental design, etc.) (Cooper, 2017). The second stream is a reaction to the 1990s recession and
79 globalization, which triggered a crisis in design that was accused by some of being an agent of
80 consumerism. Following this crisis, some designers have pleaded for design to focus more on the meaning
81 that designed objects have. This is the "semantic turn of design" (Krippendorff, 2005) that highlights the
82 political impact of design since designed objects and techniques have effects on social functioning (Tromp
83 and Hekkert, 2018).

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

87 **How can design sciences help us to build agricultural sciences that support agriculture in its** 88 **transformation?**

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

92 First, let us consider the example of the design of decision support systems (DSS) in the agricultural
93 field. The literature has long discussed the many failures of these tools and the reasons thereof,
94 including the design methods of these DSS (e.g. Cox, 1996; McCown et al., 2002; Rose et al., 2016).
95 To overcome these shortcomings, there is growing recognition that we need to involve future users
96 in more participatory design processes (e.g. Jakku and Thorburn, 2010; Cerf et al., 2012). Yet
97 agricultural scientists may feel powerless to implement such approaches that require know-how (in
98 understanding of users' expectations and constraints, and in animation and collaboration) and time

99 (notably to establish efficient participatory work with other actors, often not academics). However,
100 design sciences can provide them with the help they need. In fact, design sciences have produced
101 and shared a large body of research on the ways of implementing participatory design methods (e.g.
102 Schuler and Namioka, 1993; Kensing and Blomberg, 1998; Simonsen and Robertson, 2012), co-design
103 (e.g. Sanders and Stappers, 2008; Steen, 2013) or open design (e.g. Boisseau et al., 2018). They apply
104 different methods to identify the users' needs, desires, and constraints (like personas and user
105 characterizations), and to explore and test solutions (e.g. use scenarios, hands-on experiences, and
106 the use of several types of prototypes). These methods can help us to make a more systematic use of
107 co-design methods (which is still far from being the case today; see for instance Rose et al., 2016;
108 Ditzler et al., 2018) and give us keys to do so more efficiently. This is a matter not just of improving
109 end-user experiences with intuitive interfaces, but of acquiring the means to better understand the
110 actual activities of those whom we are trying to support, so that our tools may be more salient and
111 legitimate (Cash et al., 2003). Cerf et al. (2012), for instance, detailed two methods inspired by design
112 methods (and in particular by design ergonomics). The first is a method to diagnose uses. It consists
113 of interviews and observations built to understand how the potential users of a future DSS actually
114 perform the activity that the DSS will support. The aim is to identify the tools, methods and
115 constraints (time required, data availability, available skills, etc.) of this activity, and to characterize
116 its invariants, diversity, and difficulties, and then to adjust the design of the DSS accordingly. The
117 second method involves early prototype testing by users, based on realistic use scenarios (with the
118 users' data, respecting their real working conditions), to adjust the design of the DSS. We could and
119 should push this cross-pollination with co-design methods and research further, to renew our work
120 on decision support systems.

121 Another example is the design of cropping and farming systems, which has experienced major
122 expansion in the 2000s, mobilizing modelling (e.g. Bergez et al., 2010), experimentation (e.g.
123 Debaeke et al., 2009; Silva and Tchamitchian, 2018) and/or prototyping workshops (e.g. Vereijken,
124 1997; Lançon et al., 2007), increasingly in combination with one another. Design sciences are likely to
125 develop our research on this subject in several directions. First, as with the design of DSS, design
126 sciences invite us to further involve farmers in these design processes, for instance in design
127 workshops with farmers. More radically, design sciences also invite us to consider farmers as the
128 designers of their own systems. This obliges us to think about how we, as researchers, can support
129 these design activities, which I think fundamentally changes the way we shape our contribution to
130 agricultural systems design. We can do so in different ways:

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

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

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

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

161 There are some examples of studies in agriculture that explicitly use these elements from design
162 sciences and refer to them (e.g. Martin et al., 2013; Prost et al., 2018; Lacombe et al., 2018;
163 Salembier et al., 2020). For example, Berthet et al. (2016) discussed several participatory design
164 methods to foster agroecological innovations with multiple stakeholders, one of which derives
165 directly from design research and has since been re-used in the agricultural field (e.g. Ravier et al.,
166 2018; Leclere et al., 2018). Another example is the RIO (Reflexive Interactive Design) methodology
167 (Bos et al., 2009), which aims at supporting the radical transformation of systems (like the design of

168 sustainable dairy husbandry systems). It was likewise spawned by collaboration between agricultural
169 scientists and design scientists, and has also been re-used in agricultural studies (Elzen and Bos,
170 2016; Romera et al., 2020). I would argue that these approaches are still not used nearly enough.
171 Here again, the reason may be a lack of skills, a lack of knowledge, or a perceived difficulty in
172 advocating for these approaches or publishing them in agricultural science journals. We, researchers
173 interested in design issues in the agricultural field, have developed our own design methods, using
174 previous studies and also our intuition and know-how. Yet drawing directly on design sciences would
175 offer a real opportunity to identify and address extremely rich, important and salient research issues.
176 For instance, design sciences draw our attention to the long duration of the design processes of
177 agricultural systems. Design processes are known to be iterative in the sense that one advances
178 along with the exploration and formulation of the problem (and the target to be reached) and of the
179 solutions to solve this problem (and reach the target) by means of constant iteration of analysis,
180 synthesis and evaluation (Dorst and Cross, 2001). Yet efforts in the agricultural sciences have mainly
181 focused on designing target systems (*i.e.* the final systems that are aimed for). We have made far
182 fewer propositions on ways to support the iterations that are typical of a farmer's efforts to
183 implement design solutions (see for instance the notion of a step-by-step design approach (Meynard
184 et al., 2012)). How to get there without giving up along the way is a question that is rarely
185 considered. It would be of enormous value to develop more research on the temporalities of these
186 processes, characterized by an entanglement of short-term and long-term dynamics (from the short
187 time scale of action in the field or of crisis, to the long time scale of many ecological processes, of
188 value chain evolution and of societal changes), and on indicators to inform these iterations (e.g.
189 Toffolini et al., 2016; Perrin et al., 2020).

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

199 Firstly, these innovative design processes try to reach a "desirable unknown" (Masson et al., 2019)
200 that embodies a "political" intention (*i.e.* a project of transformation). This reminds us that designers
201 have a responsibility for what they cause to happen through the objects they design. It encourages

202 agricultural scientists to think about this political dimension in their research: what is their aim, how
203 has it been defined and by whom, and has it been made explicit? This may be a very interesting way
204 to make the agricultural science community discuss the agricultural model(s) they want to support or
205 that should coexist (Gasselin et al., 2020). Methods from the design sciences, like Speculative Design
206 (Auger, 2013), might be useful in this respect.

207 Secondly, many studies about innovative design processes have been devoted to creativity issues, to
208 enhance creativity and inspiration, and to avoid fixation effects (Crilly and Cardoso, 2017; Crilly,
209 2019). The numerous methods that have thus been developed could inspire agricultural scientists
210 designing new agricultural systems, for instance in the organization of design workshops with other
211 actors, to foster individual and collective creativity (e.g. Reau et al., 2012; Berthet et al., 2016) and so
212 reveal unexpected possibilities. Agricultural scientists could also apply creativity studies and methods
213 from design sciences to their own scientific explorations, and thereby reveal the scope of the
214 scientific questions they have investigated and those they have left aside. This would allow them to
215 organize their research work in innovative directions. It has already proven to be extremely useful to
216 identify research fronts and not to remain on known paths of research (see for instance Vourc'h et
217 al., 2018; Brun et al., 2021).

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

229

230 **To be continued....**

231 The aim of this perspective article was to show that design sciences could be useful to agricultural
232 scientists, owing to their methods, tools and concepts that can inform us in most of our activities
233 aimed at transforming agricultural activities. They equip us to formulate complex problems (design
234 sciences talk about “wicked problems”), to imagine creative solutions to these problems, and to do
235 so in socio-technical systems that include a diversity of legitimate actors in the quest to resolve these

236 issues. Actually, we, agricultural scientists, need to renew our design organizations, methods and
237 concepts to support the transformation of agriculture. This requires that the agricultural sciences
238 critically examine their concepts and methods, as several authors have called on them to do (e.g.
239 Vanloqueren and Baret, 2009; Tiftonell, 2014, 2020; Duru et al., 2015; Salembier et al., 2018;
240 Darnhofer, 2021). As Le Masson et al. (Le Masson et al., 2013) pointed out: “*each engineering*
241 *revolution (e.g. chemical, electrical, electronic or software) was accompanied by the development of*
242 *its own appropriate design tools and theories*”. If we hope to revolutionize agriculture, then we need
243 to develop our own design tools and theories, with the support of design sciences. This endeavour,
244 initiated at the end of the 20th century by pioneering research, has been growing over the last
245 fifteen years or so but drawing inspiration and resources from the design sciences would most
246 definitely strongly support it. A number of questions are of course still pending:

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

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

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