

Agriculture 4.0: making it work for people, production, and the planet

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1 **Abstract**

2 Three tenets of sustainable intensification should guide the fourth agricultural revolution:
3 people, production, and the planet. Thus far, narratives of agriculture 4.0 have been
4 predominately framed in terms of benefits to productivity and the environment with little
5 attention placed on social sustainability. This is despite the fact that agriculture 4.0 has
6 significant social implications, both potentially positive and negative. Our viewpoint highlights
7 the need to incorporate social sustainability (or simply ‘people’) into technological trajectories
8 and we outline a framework of multi-actor co-innovation to guide responsible socio-technical
9 transitions. Through the greater inclusion of people in agricultural innovation systems guided
10 by responsible innovation principles, we can increase the likelihood of this technology
11 revolution achieving social sustainability alongside benefiting production and the environment.

12 **Keywords:** agri-tech; co-innovation; multi-actor; social sustainability; sustainable
13 intensification; technology

14

15 **Introduction**

16 Emergent technologies, such as Artificial Intelligence, robotics, big data, the Internet of Things,
17 gene editing, and drones, are being presented as solutions to challenges associated with food
18 production (Benke and Tomkins, 2017; de Clercq *et al.*, 2018; NFU, 2019; DW, 2019). The
19 associated digitalisation of all farming systems is often presented as being ‘inevitable’ (The
20 Telegraph, 2018) and is predominantly justified by the need to feed a growing human
21 population (Hickey *et al.*, 2019). Smart technologies may increase yields and reduce inputs
22 (*production*) (*ibid*), whilst in many cases, reducing labour requirements. Furthermore, they
23 may improve environmental health by enabling the production of more food on existing land,

24 thus sparing further land conversion (Phalan *et al.*, 2011; Balmford *et al.*, 2018), also increasing
25 eco-efficiency (*planet*) (Schieffer and Dillon, 2015).

26 A lack of attention has been given to the social impacts of new technologies in debates around
27 the fourth agricultural revolution. Social aspects are notably absent from major reports (e.g. de
28 Clercq *et al.*, 2018; NFU, 2019), something which has been acknowledged in a number of
29 recent papers (e.g. Bronson, 2018; Eastwood *et al.* 2017). This is problematic since the benefits
30 of a technology revolution will not be uniformly shared (Rose and Chilvers, 2018).

31 We argue here that the marginalisation of social sustainability (but see Wynne-Jones *et al.*
32 (2019) on the importance of social sustainability in the context of collaboration) is a significant
33 shortcoming and suggest that the fourth agricultural revolution (or ‘agriculture 4.0’) should be
34 guided by the concept of sustainable intensification (SI), holistically defined, in order that
35 benefits are provided to people, production, and the planet. Though the definition is contested
36 (Garnett and Godfray, 2012), the concept of SI identifies three hallmarks of sustainable food
37 production: people (social), production (of food), and the planet (environment) (Garnett *et al.*,
38 2013; Gunton *et al.*, 2016; Royal Society, 2009). SI and technology are closely linked, the latter
39 being seen as a key way of achieving the former (Dicks *et al.*, 2019). Existing debates about
40 agriculture 4.0 are rarely framed in the context of SI as many papers, policy documents, and
41 speeches fail to address all three components. Indeed, work on SI itself has widely failed to
42 give sufficient emphasis to social sustainability (Lobley *et al.*, 2018).

43 Of course, social sustainability includes people at all points in the food system, including
44 consumers, but here our focus is more on those involved in agricultural production. If we
45 neglect an investigation of the social context of agriculture, then three major challenges present
46 themselves, which we outline in more detail below. After highlighting the value of social
47 sustainability when considering the agri-tech revolution, we consider how new innovations

48 could be subjected to a ‘SI stress test’ to ensure that all aspects of sustainability (people,
49 production, and the planet) are considered during design and implementation.

50 **Challenge 1 Dominant narratives of food insecurity**

51 Justifications for agri-tech are predominantly built on the idea that we need to produce more
52 food to feed a rapidly growing population (Hickey *et al.*, 2019). Furthermore, innovation
53 pathways are increasingly being used by governments to address large-scale issues such as
54 climate change and poverty (Schot and Steinhilber, 2018). Whether a lack of food production
55 is the *main* problem can be questioned as food insecurity is caused by a lack of access to food
56 for certain people (Sen, 1999; Nally, 2016). Unequal distribution of food caused by gender and
57 economic inequality (amongst other forms) is the major cause of food insecurity in both
58 developing countries and within unequal developed societies. Promoting technology as the
59 solution can seem easier to powerful actors who wish to divert attention away from social
60 inequality (Nally, 2016). Hence, we can easily be seduced by a techno-centric solution to a
61 ‘simple’ problem. As a result, resources may be wasted if technologies are developed that do
62 not provide positive social outcomes and thus fail to achieve SI which must provide benefits to
63 all people.

64 **Challenge 2 Losers of the fourth agricultural revolution**

65 If the fourth agricultural revolution proceeds as predicted by some, then the nature of farming
66 systems will inevitably change beyond recognition¹ (Fielke *et al.*, 2019). Several areas of
67 potential controversy have been identified, including:

¹ Such changes are not necessarily negative (see Rose and Chilvers, 2018), but based on the relatively small amount of research addressing the social and ethical implications of the fourth agricultural revolution there are likely to be a significant number of losers who are receiving little to no consideration.

68 - *Changing nature of farm work* - the fourth agricultural revolution may improve some
69 aspects of farming life, for example through reducing manual labour, but for some it
70 will also change life on the farm in undesirable ways (Rose *et al.*, 2018). Research has
71 demonstrated the importance of physical work, traditional farm practices and embodied
72 experiences to farmers' engagement with, and understanding of, their land and
73 environment (Carolan, 2008). Increased technology use could result in the
74 marginalisation of experiential knowledge and a disconnect between the farmer and the
75 landscape. This may lead to loss of enjoyment and work-satisfaction and exacerbate
76 existing high levels of mental health problems prevalent in the sector (Lobley *et al.*,
77 2018). Changes to work practices may also challenge some of the core tenets of farming
78 cultures and identities, which we know to be central to farmers' sense of self and
79 wellbeing (Burton *et al.*, 2008). These consequences of changing farm workflows could
80 lead to many farmers (particularly small farmers) leaving the industry. However, few
81 decision-makers are envisioning what a world looks like with fewer farmers and bigger
82 farms both from farmers' and rural communities' perspectives and the views of the
83 general public surrounding aesthetics and cultural traditions.

84 - *Data ownership, lack of trust, and power imbalances* - A significant amount of data
85 will be collected by new technologies, but ownership of this data and how it will be
86 used and stored remains a concern (Regan, 2019; Wiseman *et al.*, 2019). Data produced
87 by commercial machinery could be used to target farmers with products and to
88 consolidate precious decision-making information in the hands of already powerful
89 companies (Bronson, 2019; Lioutas *et al.*, 2019; Regan, 2019). A lack of trust may
90 ensue (Jakku *et al.*, 2019). There is also the risk that developing countries involved in
91 agriculture 4.0 may not receive the benefits experienced by the foreign investors who

92 run farming enterprises or by the wealthier countries which import the food (D’Odorico
93 and Rulli, 2013).

94 - *Employment* - Nally (2016) questions the need for labour-saving technologies in parts
95 of the world suffering from high unemployment. An agri-tech revolution will
96 undoubtedly create jobs, but these will not suit many existing farm workers who are
97 already marginalised and under-appreciated by society (Rotz *et al.*, 2019). It is not only
98 workers such as seasonal pickers who might be fearful of their role in a digitalised work
99 environment; Eastwood *et al.* (2019) consider how farm advisors might continue to
100 provide value in an era of smart farming where machines increasingly make
101 autonomous evidence-based decisions without human involvement.

102 The public may become dissatisfied with the way in which food is produced as other potential
103 social implications, including concerns over perceived animal welfare impacts from the
104 introduction of robotic milking techniques (Bear and Holloway, 2019), may result in public
105 scrutiny. Both farmers and the public have also expressed scepticism towards UAVs due to
106 concerns about drones capturing images of their work and private lives (DW, 2019), a process
107 that Zuboff (2019) has termed ‘surveillance capitalism’ – the quest for powerful companies to
108 monitor, predict, and control people. There may also be public concern surrounding the safety
109 of autonomous farming vehicles.

110 **Challenge 3 Resistance to new technologies**

111 Cases of limited acceptance of agricultural technologies are not uncommon, resulting in a lack
112 of decision support system uptake (Rose *et al.*, 2016), resistance to genetic modification
113 technologies (Macnaghten, 2016), and societal resistance to insecticides (e.g. neonicotinoids)
114 and other chemicals (e.g. glyphosate) (Dicks *et al.*, 2013). If there is a lack of trust in new
115 technologies, widespread concern about private enterprises benefitting, worries about impacts

116 on employment and the nature of farming and rural communities, and public suspicion of the
117 way in which food is being produced, then resistance is more likely. It seems apparent that if
118 the fourth agricultural revolution works for people, it becomes more feasible that the whole of
119 society may embrace future agri-tech trajectories, which simultaneously allows us to maximise
120 the promised production and environmental benefits (Jakku *et al.*, 2019).

121 **Responsible sustainable intensification**

122 Here, we propose a framework to govern agri-innovation which uses responsible innovation
123 principles (Eastwood *et al.*, 2017; van der Burg *et al.*, 2019) and recognises that innovation
124 occurs within systems comprised of multiple actors (Klerkx and Leeuwis, 2009; Klerkx *et al.*,
125 2010). Involving these multiple actors is not a pre-requisite to success; as well as being time
126 consuming, this may create uncertainty if roles and objectives are not clear from the outset
127 (Botha *et al.*, 2017). If managed carefully, however, this can enhance the inclusiveness of the
128 innovation process (see Fielke *et al.*, 2018). Innovation is responsible if (1) diverse
129 stakeholders, including consumers, are included in projects to *anticipate* possible impacts of
130 new technology (both positive and negative), (2) the innovation system can *respond* to
131 problems created by technology, (3) it manages to *include* all actors in order to achieve
132 legitimacy, and (4) innovators listen to all stakeholders and respond by being *reflexive* and are
133 willing to change technology trajectories (Stilgoe *et al.*, 2013). Our inclusive five-step
134 framework of co-innovation (see Botha *et al.*, 2014; Rijswijk *et al.*, 2018) can guide the fourth
135 agricultural revolution so that it works for people, production, and the planet. It does so by
136 placing people and social sustainability at the forefront of agri-tech futures.

137 *1. Have open conversations about the future of agriculture (inclusion)*

138 A range of techniques are required to reach out across agricultural innovation systems to collect
139 the views of every stakeholder. We recognise the challenge of identifying the myriad of

140 different stakeholders affected by agricultural technologies from primary producers, farm
141 workers, and advisers through the supply chain to manufacturers, retailers, consumers, and
142 rural communities. Yet, it should be possible to conduct stakeholder-mapping starting with the
143 farmer's 'ring of confidence' (AIC, 2013) before expanding outwards to consider who will be
144 affected by this innovation (see Reed *et al.*, 2009 for a stakeholder mapping method). Whilst it
145 will rarely be possible to include everyone, a co-innovation process should always attempt to
146 include stakeholders beyond the usual suspects that tend to drive innovation processes. Doing
147 so will create a set of priorities which has not just been driven by policy-makers and the
148 research/innovation community. Initial questions should be broad, asking participants to share
149 their visions for the future and to identify challenges for food production. Typically, when
150 governments or innovators have consulted publics, they have used closed questions through
151 public forums, online consultations, or community meetings (Rose and Chilvers, 2018). For
152 example, online consultations and public forum exercises on agriculture in the UK regularly
153 engage the usual suspects – the same innovative farmers, middle-class members of the public,
154 well-resourced trade unions and NGOs – on predetermined leading questions (e.g. what are the
155 barriers to technology use?) rather than bigger questions about what the problem itself entails,
156 which may not lead to a technology-based answer. These techniques therefore rarely include
157 the crucial views of marginalised individuals, such as less technology-focused or
158 geographically isolated farmers who might possess differing opinions.

159 Engagement of publics in agri-food issues can be much bolder. Much can be learned from
160 scholarly attempts to 're-make' participation (Chilvers and Kearnes, 2016). Many of the more
161 deliberative engagement techniques identified by Chilvers and Kearnes (2016) work on the
162 premise that a range of stakeholders beyond the usual suspects need to be involved at an early
163 stage, sharing decision-making power. Deliberative workshops might be one method to engage

164 particular communities, for example through anonymous voting² to decide upon a mutually
165 agreed future. Attention must be placed on ensuring that engagement methods occur at a time
166 suited to the audience, which might be at a specific time in the farming calendar (or in the day)
167 and there must be some incentive for attendance. More innovative engagement techniques
168 include citizen juries (see e.g. Fish *et al.*, 2014), in which a representative range of individuals
169 are brought together to achieve consensus. Interactions seen within the online farming press
170 and social media can be extremely insightful as users often exhibit strong opinions when
171 conversing online due to the online disinhibition effect (Suler, 2004). We should note, however,
172 that many marginalised (older/rural) farmers may not have access to the internet or ICT skills
173 and so will be unable to contribute to online debate (Farrington *et al.*, 2015).

174 *2. Decide whether issues are techno-centric or not*

175 If engagement exercises are carried out effectively, a list of key questions, challenges, and ideas
176 for the future of agriculture will be gathered, though we note that these may be conflicting
177 (Fielke *et al.*, 2020; Klerkx and Rose, 2020; Klerkx *et al.*, 2019). The first task is to decide
178 which challenges demand a techno-centric solution (this could be scoped out in multi-
179 disciplinary workshops involving the natural and social sciences, and the arts and humanities).
180 Shortlisting of challenge types could be achieved relatively easily through collaborative
181 workshops attended by trans-disciplinary groups of policymakers, academics, and innovators
182 with expertise in food production, the environment, and society. For those challenges that need
183 a technology-based solution, incentives are then required to stimulate innovation and a suite of
184 key technologies could be developed.

² For example as used with farmers in: Fish *et al.* (2012) A license to produce? Farmer interpretations of the new food security agenda, *Journal of Rural Studies*, 29, 40-49.

185 3. *Anticipate production, environmental, and social implications of new innovations*
186 *(anticipation and inclusion)*

187 At this stage, a list of key technologies for solving particular challenges should be in
188 development. For example, if technology to further improve the precision application of
189 chemicals was identified as a priority the first step would be to convene the same network of
190 policy-makers, diverse academics, and innovators and ask those with technological expertise
191 to explain how the underpinning technology works without using jargon. The claims of
192 technologists can then be interrogated to assess how the product might contribute to all aspects
193 of SI – people, production, and the planet. The research community is often able to anticipate
194 environmental and production impacts as these can be tested rigorously and scientifically.
195 However, social impacts, which are often complex and difficult to generalise, must also receive
196 significant consideration. This will require the same participatory techniques as stage one:
197 citizen juries, public forums, and other consultation methods in which the purpose of
198 innovations are explained to diverse publics (including farmers, advisers, rural communities)
199 before allowing participants to articulate their views on how these innovations might change
200 the nature of farming, rural communities, and the nature of food production. These impacts
201 may be positive or negative, and trade-offs are likely to be required in every case, but, crucially,
202 technologies should only be prioritised if they are able to demonstrate probable benefits to the
203 SI agenda. Step three might take time but may, in fact, reduce adoption time in the long run if
204 more relevant technologies are developed.

205 4. *Listen and change (reflexivity)*

206 Stakeholder engagement exercises serve little purpose if policymakers and innovators fail to
207 change course after hearing societal views. A period of reflection is vital in which the potential
208 for technologies to achieve all aspects of SI are further interrogated (Fielke *et al.*, 2017;

209 Rijswijk *et al.*, 2015). Those innovations which fail to satisfy the stress test, perhaps because
210 they are likely to harm social sustainability, should receive less policy and private support (or
211 may be regulated against). This may require legislative change for privately supported
212 technology and/or alterations in guidelines for publicly funded innovation projects.

213 *5. Maintain a responsive system (responsiveness, reflexivity)*

214 Stages 1-4 have helped to identify a list of technologies which are relevant to real-world
215 problems faced by farmers and wider society and which are most likely to achieve SI, including
216 providing social benefits. The final stage is implementation to ensure benefits are realised. A
217 supportive institutional framework, led by government³, and ensuring that there are joined-up
218 advisory stems for farmers to draw on is a prerequisite to hold the network together, preventing
219 the fragmentation which currently plagues innovation approaches (Klerkx *et al.*, 2012). A long-
220 term commitment is needed from policymakers and other senior actors in driving innovation
221 systems. Ultimately, those who introduce innovations to (or ideally with) farmers need to
222 ensure that responsive systems are implemented to correct errors and to prevent repetition of
223 any potential controversies (e.g. safety issues/animal welfare). The government's role does not
224 stop once innovations are adopted; a continued period of reflection is required, which will
225 require updates to legislation, guidelines, and possible support for various technologies in the
226 form of skills training, improved infrastructure, or perhaps funding (although we recognise the
227 role of the market). Legislation and regulation can support or restrict the demand for certain
228 technologies, but usually lags behind development. This process may be repeated at regular
229 intervals as new food challenges and technologies appear.

230 **Conclusion**

³ We acknowledge that this might be idealistic, particularly if government pursue short-term win-wins and attempt to win the race towards ever-more sophisticated technological innovation. If we are to ensure that stages 1-5 are undertaken, there must be clear leadership from government.

231 The potential benefits for productivity and the environment of the fourth agricultural revolution
232 will be tempered if social benefits are not evenly shared. The concept of SI and its three
233 components is vital; it is essential that decision-makers support people to thrive in a different
234 agricultural system and that social issues relating to new technologies are resolved. Without
235 attention to such issues, new technology may create more social problems than it solves (Schot
236 and Steinmuller, 2018), raising the question of whether this transition to agriculture 4.0 is truly
237 justified. We hope that this viewpoint fosters more interest in the social and ethical implications
238 of the fourth agricultural revolution and consequently results in more research activity to
239 understand how society can be better included in technology trajectories. The framework
240 above, which encourages a multi-actor approach to agri-innovation, is one step towards
241 determining a responsible course for the fourth agricultural revolution to ensure that benefits
242 are provided for people, production, and the planet.

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