What are the challenges facing agriculture?

Benoît Dedieu, Emmanuel Prados

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Authors – *Benoît Dedieu, Emmanuel Prados.*

Acknowledgements (contribution, proofreading, editing) – *Véronique Bellon-Maurel, Ludovic Brossard, Frédérick Garcia, Nathalie Mitton, Alexandre Termier.*

Agriculture is already facing multiple challenges. These concern food security, the environmental impact of agriculture and the organisation of the sector. Can digital technology help build a desirable future to respond to these issues?

2.1 World food security under strain

The world's population is growing at an annual rate of 1.1% and is expected to reach around 9.5 billion people in 2050, according to the UN's median scenario. This population growth generates a considerable increase in global food demand, which is also accelerated by rapid development and the changing diet in China (*Bai et al.,* 2020). The world's agrifood system is increasingly subject to constraints, especially since it relies on a number of non-renewable resources that are becoming scarcer or more and more damaged (fresh water, phosphorus, oil, cultivable soil, etc.). This system will soon feel the full force of the impact of climate change, both directly (extreme weather events, drought, etc.) and indirectly (melting glaciers, proliferation and spread of harmful species of organisms and diseases, rising sea levels) (*IPCC,* 2014; *UNESCO,* 2019). It is also under threat from the current collapse of biodiversity in seeds, pollinators, crop auxiliaries, etc., which endangers many ecosystem services necessary for its proper functioning (*FAO,* 2019a). Conflicts over the use of products, land and water will also increase with, for example, the use of biomass for energy and the implementation of afforestation/reforestation programmes to capture CO_2 (also known as "negative emissions" techniques, which now underpin all IPCC scenarios limiting the temperature increase to 2°C). Moreover, for a number of cereals deemed critical[15] for food security, agricultural yields seem to have reached their limits in developed countries.[16] Lastly, the current agrifood system is not very resilient. It depends, for example, on globalised resources that are unevenly distributed around the world (phosphorus, oil, etc.) and a whole range of potentially fragile exogenous systems such as just-in-time transport and logistics systems, global markets and finance (speculation, price volatility, etc.) and flows of seasonal migrant workers. The Covid-19 health crisis has highlighted some of these vulnerabilities. [17]

The growing tension between supply and demand leads to a risk of worldwide food shortage in the medium term with multiple geopolitical consequences (*Brown,* 2012). The latest statistics from the FAO show that hunger is on the rise

15. i.e. which form the basis of diets.

16. For example, see analyses of the French Academy of Agriculture on the evolution of the average annual yield of wheat in France from 1815 to 2018 and on that of maize from 1960 to 2017.

17. See for example the Cirad press release of 29/04/2020 (https://www.cirad.fr/actualites/toutes-les-actualites/communiques-de-presse/2020/pandemie-coronavirus-menace-agriculture-alimentation) and the analysis by the association *les Greniers d'Abondance* of 16/04/2020 (https://resiliencealimentaire.org/covid-19-qui-veille-au-grain-pour-demain-lanalyse).

again (*FAO,* 2017). However, certain levers and opportunities could potentially have a positive impact such as changing eating habits in developed countries, drastic reduction of losses and waste (*FAO,* 2019b), capacities for recycling and use of by-products/co-products and the improvement of production techniques and organisations in the agrifood system to increase its resilience and adaptive capacities. While these levers are probably within our reach, it is crucial to move forward on these issues very quickly.

Alongside these food security issues, the WHO has observed that 13% of adults worldwide are obese. This aspect of malnutrition is another critical issue for the agrifood system alongside the development of related chronic diseases (cancer, diabetes, cardiovascular events) through the production of ultra-processed foods that often have a very high sugar content. The same is true of the use of antibiotics as growth promoters in certain livestock farming models. These food-related health issues are the focus of growing attention (see, in France, the *États généraux de l'alimentation* and the Égalim Law[18] in 2017-2018) and prompt a demand for healthy and sustainable food that is accessible to all and preferably local, agroecological and minimally processed.

2.2 There is an urgent need to reduce the negative environmental impacts of agriculture

The agricultural production system based on intensive farming has strongly contributed to the current collapse of biodiversity (*Sánchez-Bayo and Wyckhuys,* 2019)[19] and the reduction of soil fertility and water quality (*Caquet et al.,* 2020). There is an urgent need to drastically reduce the use of phytosanitary products and mineral fertilisers and reconcile agriculture and the environment generally. In addition, we must rethink our interactions with "natural" ecosystems (wildlife, forest and pastoral biodiversity reserves), bearing in mind that "natural" does not mean excluding all human intervention and activity. It is just as essential to improve livestock welfare: animals should be considered as subjects that are both sentient and conscious, working in cooperation with the farmer, and no longer as mere objects with biological functions. Farm systems that respect the animal and ensure a good life and an acceptable death must be designed (*Porcher,* 2011).

18. See issue 1566 (2017) of the Alim'agri magazine by the Ministry for Agriculture and Food, which summarises the various projects underway https://agriculture.gouv.fr/alimagri-les-etats-generaux-de-lalimentation.
The Égalim Law (agriculture and food), which follows on from this work, was enacted in 2018.

19. In thirty years, almost 80% of insects have disappeared in Europe.

The circulation of zoonoses (Covid-19 and other recent zoonoses such as H1N1) remind us of the porosity with regard to certain diseases between the animal – both wild and domestic – and human worlds. According to the OIE (International Organisation for Animal Health), more than 60% of human infectious diseases are zoonotic. This figure increases if we consider emerging infectious diseases (70%)[20] interactions between animal, human and ecosystem health are leading to the concept of "One Health" (*Gibbs,* 2014; *Zinsstag et al.,* 2015).

Lastly, agriculture is the third largest source of greenhouse gas (GHG) emissions in France (19% of the national total in 2018) (*CITEPA,* 2018). Agricultural and forestry machinery only account for 12% of these emissions, while livestock farming accounts for 48% (mainly *via* methane emissions) and crops for 40% (mainly *via* nitrous oxide emissions during soil fertilisation). Between 1990 and 2018, agricultural emissions decreased by 8% (national GHG emissions increased by 6% in the same period). Transformations and efforts must therefore increase if the country is to meet France's low-carbon strategy objectives[21] and its commitments in the framework of the Paris Agreements. In this context, crops, forests, grasslands and pastoral land and corridors could be of great help as they play an important role in carbon storage.[22] For example, the *"4 pour 1000"* (4 for 1000) project launched by INRAE aims to increase carbon storage in all the world's agricultural soils by 0.4% every year (i.e. the equivalent of the world's annual CO_2 emissions linked to human activities)[23] by developing alternative cropping practices such as intermediate crops, intra-plot agroforestry and temporary grasslands in crop rotation.

2.3 Agricultural dynamics have favoured intensification and specialisation

Farming is part of sector chains in which agricultural production and processing models are designed and locked, but also transformed and invented. At all levels of the chain, the agrifood model imposes costly requirements for competitiveness and sanitary standards linked with processes and product logistics. These chains

20. See https://www.oie.int/fr/pour-les-medias/une-seule-sante/

21. The 2018-2019 SNBC strategy aims to reduce emissions from the agricultural sector by 18% compared with 2015 by 2030 and by 46% by 2050. It aims for a global reduction of greenhouse gas emissions by 40% by 2030 (compared with 1990) and carbon neutrality, i.e. zero net emissions, by 2050.

22. For example, according to the ONF, forests store the equivalent of 15% of national GHG emissions.

23. The *"4% sur les sols pour la sécurité alimentaire et le climat"* initiative (4% on soils for food security and the climate) launched by France on the occasion of the Paris Climate Conference (COP-21), proposes to increase the carbon stock in the world's soils by 0.4% per year. This figure is the result of a simple initial calculation, considering that total annual CO_2 emissions from human activity currently account for the equivalent of 0.4% of the carbon stock (C) of the planet's soils (approximately 2,400 gigatonnes of C). An annual storage of 4 per 1000 (4% or 0.4%) in the full depth of the soil would therefore compensate for these emissions.

are part of sociotechnical regimes[24] focused on competitiveness through pricing (as low as possible). This has been made possible by greater productivity of labour through the substitution of the latter by capital (in the form of increasingly efficient machines and automated, climate-controlled buildings) and workforce competition, exacerbated by globalisation. This system is underpinned by the intensive use of increasingly sophisticated technology, which many users gradually rely on (agricultural machinery, biotechnology, pesticides, etc.). Among other things, this has led to a steady fall in agricultural employment in all OECD countries, including France[25], and to the specialisation of a growing number of farms in a single type of production. Through the CAP (Common Agricultural Policy), purchasing organisations and oligopolistic multinationals, the organisation of this system, from the individual farm to the consumer, is driven by tensions and unbalanced power relations between actors with different and sometimes divergent interests, contributing to lock-ins. Moreover, agricultural activity takes place in territories that have, in many cases, become specialised, leading for example to the spatial dissociation of livestock and crop production and the geographical concentration of sectors. All this forms a highly complex system characterised by the specialisation and interdependence of each element at the different levels, which demands very high levels of resources. This amplifies instabilities and multiplies the risk of failure. It is also an obstacle to change.

2.4 What are the agricultural models of the future?

The debate on which agricultural models would best respond to the present challenges is wide open, particularly since the rise in organic farming in France (which now accounts for 8% of the agricultural area) and the promotion of agroecology. These debates are not limited to the national framework but have taken on an international dimension. In 2016, the HLPE (High Level Panel of Experts) of the FAO proposed to address the future of agriculture (including livestock farming) according to two standard models: sustainable intensification and agroecology (*HLPE,* 2016). The first matches current trends to improve process efficiency and integration into long-chain systems. It is based on cutting-edge scientific knowledge and technological advances made possible by precision agriculture

24. According to *Geels* (2002) and the "multi-level perspective" model: a regime is a network formed of different economic and social actors around a product, service or, in our case, an agricultural model. The stakeholders are private and cooperative actors from the chains, but the system can be strengthened by teaching, research, the farm advisory system, national or European policies, etc., whether deliberately or not.

25. In some areas of the world, particularly Africa, demographic dynamics and the limited opportunities offered by the industrial and service sectors mean that the creation of jobs in rural and peri-urban areas must be considered as part of the challenges facing agriculture. This also applies to some hinterland areas in France.

and livestock production and genomics. The second standard model promotes agriculture based on natural processes and integration into local and sovereign food systems. It prioritises all forms of diversity (biodiversity, farming diversity and integration of cropping and livestock production), peer learning and the search for coherent systems that promote autonomy with regard to inputs and cost savings. Organic farming is one such approach (see insert on the Métabio metaprogram by INRAE). This model is increasingly supported by associations and local authorities who are developing territorial food projects and are strongly committed to promoting short supply chains. More detailed modelling has also been proposed. In particular, *Therond et al.* (2017) identify eight agricultural models positioned along two axes: dependence on inputs versus the implementation of ecosystem services; the territorial anchoring of food products versus long supply chains.

For example...

The "**INRAE METABIO**" metaprogram launched in 2019 proposing the "change in scale of organic farming" looks to explore the hypothesis in which the majority of the national supply of products comes from organic farming, in a context of strong demand and agroecological transition. It studies the challenges, levers and consequences of the change in scale of organic farming throughout the agrifood system. The aim is to explore scientifically supported proposals to anticipate consequences and inform the deployment of organic agrifood systems.

Another debate on models revolves around the structural characteristics of farms that could provide a response to the challenges outlined above. Here, there is a marked difference between family farming and more capitalistic models, such as the corporate agriculture described by *Gasselin et al.* (2015) and *Hervieu and Purseigle* (2013). In the first case, capital and labour are in the hands of the family whereas in the second, capital is held by non-agricultural actors and all workers are employees. The latter situation prefigures the megafarm,[26] which is underpinned by very high productivity made possible by extremely large-scale operations, mechanisation and, increasingly, adapted automation.

There is some contrast between these two types of models, because agroecology is more family-based while sustainable intensification is more capital-based. However, the diversity of systems cannot be reduced to these archetypes. There

26. The largest farm in the world is located in China with approximately 40,000 dairy cows; an even larger one (100,000 cows) is under construction... way beyond our controversial 1,000-cow farm!

are also many hybrid situations of what is known as “agriculture of the middle”. In addition, the opposition between these two types in the societal or professional debate does not exclude forms of coexistence in the territories – which may be spatial or work-based (exchanges) – and the urban food supply chain. Whatever the model, farmers want a decent income and working conditions (*Ghai,* 2003), that is, conditions that protect their health, offer social protection and preserve their ability to influence their future. They also want work that is meaningful, useful, attractive and maintains relationships with others.

2.5 The territorial nature of agriculture

Another element to be positioned in the debate on agricultural models is the territorial nature of agriculture. The question of the territorial inclusion of the models addresses certain needs: the economic and social development of these territories, their increased resilience, their environmental quality and the availability of opportunities to integrate activities that use by-products in local applications. How can agricultural models reduce material and energy flows? At what scales should production and activities be relocated and rediversified? How can city-countryside relations, short chains and agriculture near cities meet these needs? What strategies and tools should be mobilised (geographical quality indications such as PDO, AOC[27], etc.)? How can employment be promoted and sufficient economic value be ensured? These questions all position the territory (composed of its spaces, activities and actors) as an essential entity in addressing the challenges that agriculture must face, in particular through:

- the analysis of modes of coexistence and border sharing between agricultural models (*Gasselin et al.,* 2021) in food systems;
- the design of processes for the agroecological transition at the territorial level (*Bergez et al.,* 2019);
- the provision of information and decision-making tools for stakeholders, local authorities and government services concerned with the environmental and health dimensions that link agriculture to the other components of ecosystems, hydrosystems and pathosystems.

27. *Appellation d’Origine Contrôlée.*

Conclusion

Agriculture is currently facing critical challenges in terms of food security, pollution and resources that call into question the productive dimensions of the activity and profession of the farmer. They raise questions about which agricultural models could provide a response and about the territories themselves in which the concrete variations of these new models interact, contrast or coexist. It should be noted that they are subject to different dynamics, depending on the socio-technical regimes to which they are attached. Sustainable intensification is often associated with large farms with a small workforce and is linked to the evolution of the predominant regime inherited which relies on (large) private upstream and downstream companies, large cooperatives, advisory services from chambers of agriculture, the CAP and research leading to the prescription of technical solutions applicable in most environments. Agroecology is still a socio-technical niche, but a real change in priorities has been observed among multiple actors, including in research, public policy making and education. Agroecology is also associated with the idea of transition and radical transformation. It calls for the development of knowledge, methods and tools exploring levers to enhance the coherence and performance of agroecological systems. It also accompanies processes of change and facilitates the exploration of desirable situations, learning, adapted mechanisations. It supports the step-by-step reconfiguration of systems in a context of incomplete knowledge and uncertainty about the impact of actions.

In this context, digital technologies are considered above all from the perspective, for the precision of the information they provides and the new decision support regimes that they support. In this way, they can reverse the dynamics of simplified reasoning and actions brought about by the increase in farm's size. By providing tools for observing and managing increasingly large areas, digital technology acts as a lever for sustainable intensification and the expansion of structures, which becomes compatible with precision and individualisation. At the same time, digital technologies could also contribute to the development of the agroecological model on family farms. Indeed, part of this model is based on dialogue and learning among peers and on direct links with consumers: forums, online stores and social networks could become effective tools. More digital technology could help understand and manage the biotechnical, ecological and socioeconomic complexity of systems based on agroecological farming, although this remains to be confirmed. It could also "equip" the farmer to detect malfunctions sooner and help decision making (decision "support" information).

The territorial level is also of interest from the digital perspective, due to the ability of digital technology to deal with complex processes connecting spaces, activities and actors and to explore useful scenarios for multi-actor decision making, whether this concerns food systems, environmental issues or, increasingly, health issues (infectious animal or zoonotic diseases) (*Charrier et al.,* 2019).

Ultimately, to allow a quick transformation capable of meeting the challenges, it is necessary to question the capacity of digital technologies to respond to the demands of the different actors and stakeholders (public or private) and their urgent needs for:

- information, understanding of the complexity of the systems, risks and uncertainties;
- support for the development of strategies and policies and the multi-criteria assessment of agricultural production/food system scenarios at different levels (European, national, regional and territorial);
- support for decision making and managing compromises in single and multi-actor situations;
- and lastly, support for the components of concrete action that link humans, machines and tasks on the one hand and experiential dialogue between peers on the other.