Aspects of the transition to a digital bioeconomic society: Agriculture 4.0 and Organic 3.0

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Abstract

Bioeconomy is a concept developed in the past hundred years in humankind's search for a sustainable way of development. A special emphasis deserve the issues related to agriculture, as food is, along with energy, the metabolic basis of human beings and their societies. This paper contrasts the etymological meaning of the term bioeconomy to the meaning promoted by international institutions (OECD and EU) to explain why a digital bioeconomic society leads to the divergence of natural organisms with artificial organisms. The evolution phases of agriculture, respectively organic agriculture (1.0, 2.0, 3.0, respectively 4.0) are presented. The positive and negative aspects of digital technology use in agriculture are presented.

Keywords: Bioeconomy, Agriculture 4.0, Organic 3.0

JEL Classification: Q57

1. Bioeconomy: Etymology versus institutional promotion

The etymology of the word bioeconomy tells us that it comes from *bio-* (ancient Greek *bios* life) and *oikonomia* (ancient Greek *oikos* house + *-nomia* from *nemein* to manage) and has the meaning of household administration (stewardship). Thus, the bioeconomy is the "administration of the living household" and encompasses all the actions to ensure the use (production, consumption, exchange, distribution of goods and services) and stewardship of the Earth (the living household of the world). In this sense, when Nicholas Georgescu-Roegen, in the context of the analysis of the economic process subject to entropy law, advanced the concept of bioeconomy, he warned that "we must constantly keep in mind the biological origin of the economic process and thus highlight the problem of human existence of accessible, unequally distributed and owned resources" (Georgescu-Roegen 1977, 361).

In a completely different conceptual sense, the OECD promotes the bioeconomy as an economic sector in which biotechnology is widely applied, while for the European Union the bioeconomy is based on biorefinery (bio-based chemistry that must replace petrochemistry). These two institutional approaches push the digital (smart) development in both industry and agriculture. Concepts such as Industry 4.0 or Ind 4.0 and digital agriculture, Ag 3.0, Organic 3.0 or Ag 4.0 are discussed. For example,

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the Wageningen Journal of Life Sciences (NJAS) published a special volume in 2019 entitled *Social, economic and institutional dynamics of digital agriculture*[2].

2. The foundation for a bioeconomic society: Agriculture

Zambon et al. (2019) discusses in detail how technological development affects industry and agriculture. Similar to the phases of industrial development we can talk about the agricultural technology revolution that began with Agriculture 1.0 by using animal power; Agriculture 2.0 corresponds to the use of the combustion engine, and Agriculture 3.0 uses guidance systems and precision agriculture that became possible when military GPS signal technology was allowed for public use (Marucci et al., 2017). Agriculture 4.0 will be done by connecting with Cloud technology. In the authors' view, even Agriculture 5.0 could follow with a digitally integrated enterprise, which is based on robotic production processes and some forms of artificial intelligence. However, the economic sectors differ in terms of innovation:

“While industry 4.0 is, today, very advanced, both from the scientific and research standpoint and from the practical attitude, since many firms apply it, Agriculture 4.0 is still restricted and put off in theory. Furthermore, the future of industry is progressing towards a 5.0 industry, while the primary sector is still inadequate. The 4.0 revolution in agriculture is still limited to rare pioneering firms… Industry or Agriculture 4.0 can offer numerous advantages for large enterprises, while SMEs often face difficulties.”

Agriculture 4.0 cannot thrive without modern telecommunications infrastructure in rural areas. The Digital Transformation Monitor of July 2017 (Bonneau et al., 2017) clearly states that "Beyond the introduction of new tools and practices, the real promise of Agriculture 4.0 in terms of productivity increase resides in the ability to remotely collect, use, and exchange data" (Bonneau et al. 2017, p.3). Thus, “connectivity is the cornerstone of this transformation and IoT a key technology that is increasingly part of agricultural equipment” (Bonneau et al. 2017, p.1).

Smart farming or precision agriculture is described by Ajena (2018) as “a modern farming management concept using digital techniques to monitor and optimise agricultural production processes... The means of precision agriculture consist mainly of a combination of new sensor technologies, satellite navigation, positioning technology and the use of mass amounts of data to influence decision-making on farms.”

Junior et al. (2019) considers it necessary to take into account the concepts of Industry 4.0 for the development of Agriculture 4.0. They provide, as an example, an exploration of Brazilian farmers' perceptions of improvements post-technology implementation.

Similar to the development phases of agricultural technology (Agriculture 1.0, 2.0 to 5.0), for organic agriculture are also discussed Organic 1.0, 2.0, respectively 3.0.

Organic farming sprung, in the first half of the twentieth century, from a blend of traditional agricultural practices and social movements harboring a strong opposition to the chemical-technical intensification of agriculture. Organic 1.0 was the initial phase characterized by “numerous farmers’ groups working together with pioneer personalities for the benefit of soil fertility, environmental protection, nature

[2]*https://www.sciencedirect.com/journal/njas-wageningen-journal-of-life-sciences/special-issue/10TG0PSF9RJ*

conservation, diversity, animal welfare, healthy nutrition and family farming" to develop alternative solutions to the problems synthesized by Rachel Carson in her 1962 *Silent Spring*. In 1972, the International Federation of Organic Agriculture Movements (IFOAM Organics International) was established, marking the beginning of the Organic 2.0 phase; one of the main objectives was to set out minimum standards for organic labeling[3]. In 2010, a meeting of farmers in Schleswig Holstein, Germany, entitled *R-Evolution of Organic Agriculture - Organic 3.0 was the launch of Organic 3.0* (Strotdrees et al. 2011 quoted in Arbenz et al. 2017, p. 201).

Arbenz et al. (2017, p. 202) present some examples of how Organic 3.0 innovation could help:

- „Smart technologies such as robots and precision farming, information and communication technology, or intensified crop and livestock breeding techniques that avoid genetically engineered varieties.
- Use of modern Internet technology by social networks, by food, fashion, personal care and health movements, and by urban farming, community-supported agriculture, and collective land ownership initiatives, etc., to democratize the value chain.
- Foster relationship building, with innovative models and initiatives that reinforce interdependency, e.g., the economy of the common good."

Migliorini and Wezel (2017) argue that both agro-ecological agriculture and ecologic / organic agriculture could serve as a model for future agricultural policy. The common elements between agroecology and organic farming are the use of techniques and measures such as „crop rotations, mixed farming enterprises, organic fertilizers, systems-based robustness and resilience, preventive measures in plant and animal health, biological crop protection etc." (Niggli et al. 2015, p. 16). According to Niggli et al. (2015), agroecology is even more open to technology than organic farming to serve its objectives.

Beyond the digitization of agricultural production, Lezoche et al. (2020) discuss the agri-food supply chain by reviewing more than a hundred papers on new technologies in the field. The new methods available for supply chains are analyzed and contrasted to understand the future paths of the agri-food field using the concept of Agri-food 4.0 as an analogy with the term Industry 4.0 and coming from the concept of Agriculture 4.0.

The use of digital technology in agriculture can have both positive and negative aspects.

First the negative aspects:

- Changing the culture of a country / rural area.
- Artificial organisms, genetically modified organisms (GMOs), lead to bio-designed foods. What are the long-term effects and safety? What are the associated ethical and moral issues? Problems with antibacterial resistance and those related to patents, crossbreeding (genes from the mixture of GMOs with conventional cultures). A positive aspect promoted is that these crops are more resistant to disease and drought, allowing them to grow in areas where farming is difficult, if not impossible.

[3] *Based on Niggli et al. 2015, p. 7-8*

- Chemical fertilizers and pesticides have negative consequences for the environment and health.
- Problems related to monocultures due to the disappearance of variety in cultivated areas.
- Less work required, i.e. job losses in rural areas and migration to urban areas.
- Pesticides also kill useful insects (such as bees).
- Large amounts of energy are needed to produce and transport crops.
- Lack of knowledge needed by farmers.
- The high cost of maintaining technology and machines.

Now the potential positives:

- Precision farming can help increase yields by providing farmers with real-time data to adjust their processes. Farmers will be able to monitor the soil, its moisture, watering and plant growth. This could lead to a reduction in the consumption of external inputs and a reduction in CO_2 emissions.
- Precision farming can reduce the use of heavy equipment, further reducing CO_2 emissions (Balafoutis et al., 2017).
- Indoor / vertical digital farming can be done in old and / or tall buildings, by transforming old unused properties. It also allows food to be grown in urban areas much closer to the market, which reduces transport costs. Indoor digital farming allows control of environmental factors such as lighting, humidity and temperature (Benke and Tomkins, 2017). For this type of agriculture, there are usually fewer problems related to pests and diseases, thus improving food security and reducing vulnerability to extreme weather conditions. This allows year-round production, increased production and potentially reduced CO2 emissions. Most often, inland agriculture is done with hydroponic or aeroponic systems and is generally organic.
- Increased worker safety and reduced labor requirements.
- Increased food traceability.
- Leakage and pollution of groundwater and surface water are reduced.
- Reduce over-application or under-application errors.
- Food is becoming more accessible to the consumer.

Conclusion

The review of the new concepts related to the digitalization of agriculture (Ag 3.0 / Organic 3.0) in a bioeconomic society makes it imperative to recall that agriculture operates (still…) with natural organisms compared to the industry which operates with inanimate objects or artificial organisms. When agriculture becomes industrialized, the beings involved are treated as objects. We will not insist here on this discussion, but we emphasize Nicholas Georgescu-Roegen's warning about the *bioeconomy* which is based on *economic processes with biological origin*. We consider it necessary to extend bio-ethics as a field that covers the other beings necessary for human survival. In the case of agriculture that adopts digital technologies, we refer to crops and farm animals.

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