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How to reconcile innovation and precaution towards more sustainable agriculture – considerations for a new way forward

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Abstract: Our world is facing unprecedented energy, climate, biodiversity, and food crises. Food production (agriculture) is a main driver of these crises. Many national and international policies, such as the United Nations sustainable development goals, have acknowledged the need for our food systems to be more sustainable and resilient, while operating within planetary boundaries. Research and innovation can contribute to meeting sustainability goals. Here, we focus on biotechnological advances, such as genome editing techniques, as they provide new tools that complement the farmers' toolbox to improve the sustainability of agricultural systems. However, regulatory requirements to ensure the safety of emerging technologies can hamper innovation, so there is a need to reconcile innovation and precaution. While safety is a prerequisite for sustainability, regulatory requirements (and thus risk assessments) should remain proportionate to risk. There is an ongoing debate on whether sustainability requirements should be considered in the pre-market authorisation process of emerging technologies. Since sustainability is a highly complex systems approach, it is most challenging to assess the potential contribution of individual products or even potential future products to sustainability. Therefore, the way forward is to define a set of incentives for a more sustainable use of existing and new products, together with a transparent and inclusive process to improve public acceptance for innovative technologies. This will ensure that opportunities are not missed out and policy goals, such as food security and the safety for human, animal, plant and environmental health can be achieved.

Key words: agriculture, biotechnology, innovation, new genomic techniques, sustainability

Introduction

In 1972, the Club of Rome reported that the earth's limited resources cannot support unlimited growth (Meadows et al., 1972). In 2009, Rockström et al. (2009) introduced the concept of planetary boundaries and warned that the boundaries "rate of biodiversity loss", "climate change", and "human interference with the nitrogen cycle" have already been exceeded. Sustainability is a key term in many discussions about the future of economy, environment, climate, and in particular food systems. The foundation of guiding principles for sustainable development was published in the so-called "Brundtland report" (United Nations, 1987). Sustainable development has been defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainability is often described as having the three dimensions "Environment", "Society", and "Economy"

(Purvis et al., 2019). The United Nations Rio de Janeiro conference in 1992 highlighted how these three dimensions are interdependent and evolve together, and how success in one sector requires action in other sectors to be sustained over time. Starting from this perspective, a broad agenda for international action on environmental and developmental issues for international cooperation and development policy in the twenty-first century was drafted (United Nations, 1992a; b). Later on, all United Nations Member States adopted the 2030 Agenda for Sustainable Development with 17 Sustainable Development Goals (SDGs) for peace and prosperity for people and the planet, now and into the future (United Nations, 2015).

For agriculture, principles of sustainability are reflected in concepts like Integrated Pest Management, Integrated Production, or Agroecology. For example, the International Organisation for Biological and Integrated Control (IOBC) has been publishing guidelines since 1997 (Boller et al., 1997; https://iobc-wprs.org/ip-tools/). Sustainable agriculture is also high on the political agenda in the European Union (EU), reflected in the common agricultural policy (CAP) (https://commission.europa.eu/food-farming-fisheries/sustainable-agriculture_en) that feeds into the farm to fork strategy (https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en) and the European Green Deal (https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en).

Genetically modified (GM) plants are available for commercial agriculture since 1996 (ISAAA, 2019). While the majority of field-grown crops still consists of GM soybean, maize, cotton and canola with either herbicide tolerance, insect resistance, or both traits combined, an increasing number of different traits and/or different crops have been entering the market in the past few years (ISAAA, 2019). With the advancement of new genomic techniques, more precise and targeted changes in the genome are possible with the potential to speed up breeding at lower costs compared with conventional genetic transformation methods (Menz et al., 2020).

Potential risks of GM plants for the environment and human and animal health have been a major concern already before such plants have entered commercial production (Williamson, 1992; Bawa and Anilakumar, 2013). The Cartagena Protocol on Biosafety is an international agreement that ensures that transboundary movement of crops resulting from modern biotechnology intended to be released can only go ahead after risk assessment and approval by the importing party (SCBD, 2000). While many different GM crops have been commercialized in North and South America (ISAAA, 2023), the EU has been very restrictive. Only the Bt maize line MON810 is authorized for cultivation in the EU with several member states opting out (EC, 2015). In practice, MON810 is currently grown in Spain and Portugal (Álvarez-Alfageme et al., 2022; García et al., 2023). The supposed lack of sufficient data on long-term safety of GM crops and the precautionary principle that applies in the EU to innovations with potential for causing harm when extensive scientific knowledge is lacking, have been used by opponents of biotechnology to delay or ban approval of GM crops (Conko, 2002).

The high potential of certain genomic techniques, such as gene editing, the need for increasing amounts of high-quality food for an increasing global population, and the excess use of non-renewable resources leading to loss of biodiversity and climate change, have refueled the debate on the role of biotechnology in the transformation process towards sustainable agriculture. During a moderated discussion session at the 9th meeting of the IOBC working group "Modern Biotechnology in Integrated Plant Production", 28-30 Sept. 2022 in Berlin, Germany, the question how to balance innovation and precaution in this process was discussed. Thoughts that emerged during this discussion are summarized (and further elaborated) in the following.

Elements of sustainability of innovative products

For products to be sustainable in a broader and innovative sense, they have to match requirements in several dimensions (Figure 1).

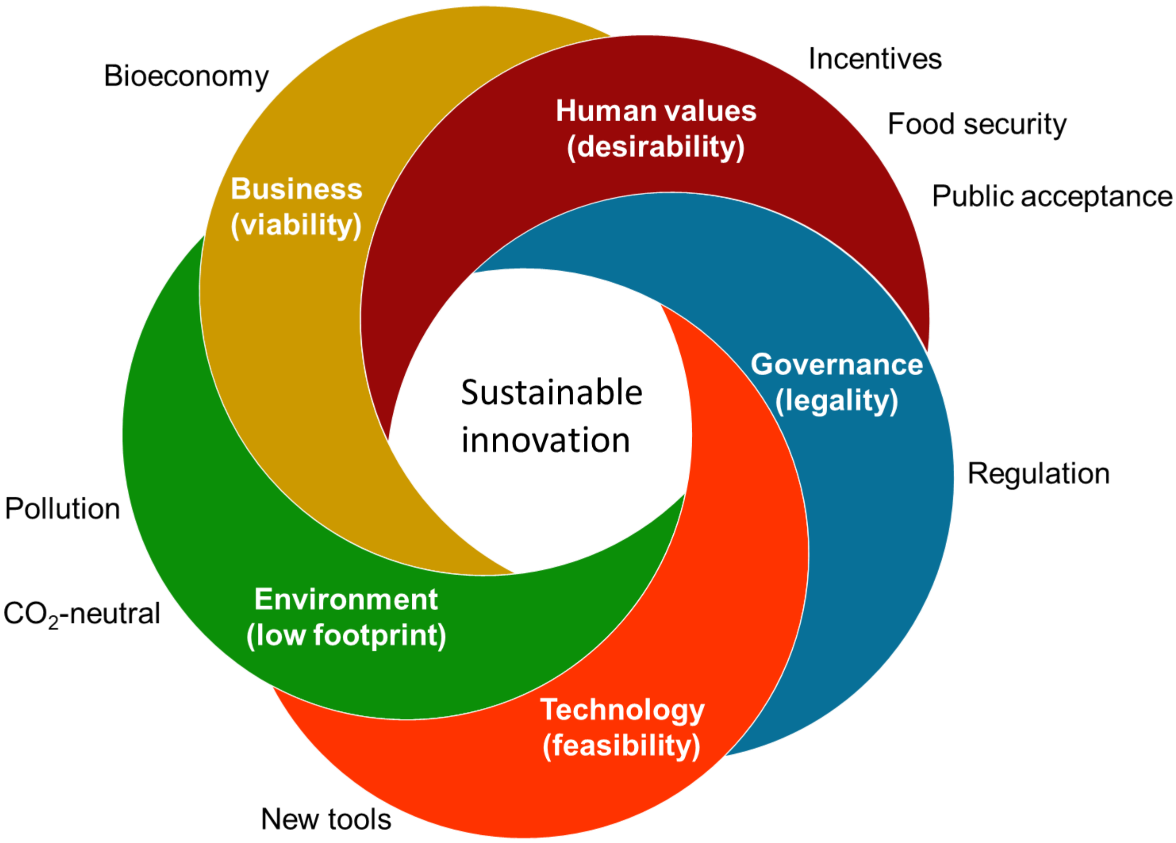

Figure 1. Key elements of sustainable innovation. Adapted from von Thienen et al. (in press).

First, to establish a new and innovative product, technology needs to be in place to produce such a product (feasibility). The product, e. g., a plant with a new trait generated by genome editing, needs to express the desired trait in sufficient quantity and in a reliable way. Second, for the product to be economically successful, business opportunities need to exist and companies in the value chain and finally consumers need to be willing or eager to buy the product (viability). On the human values side (desirability), societies aim at achieving food security and may impose particular incentives to promote certain products. On the other hand, lack of public acceptance of a technology may lead to hurdles for products created with this technology. Next, the environmental impact has to be low (low footprint) for innovative products to be sustainable. Ideally, the production and the use of the product should not pollute the environment and should be CO_2-neutral. For the discussion of the sustainability of new products, a common understanding of the different dimensions of sustainability beyond environmental aspects needs to be achieved. Finally, a product can only be successful if it is legal to produce and use it (legality). For GM organisms in the EU, Directive 2001/18/EC defines the regulatory process (EC, 2001). Because different societies have different values, the definition of what constitutes a GM organism and the translation of protection goals into specific regulation also differ among countries and regions.

Sustainability – about specific traits and beyond

Traits that offer context-specific solutions with a high potential to contribute to improved resilience and sustainability in agriculture include pest or pathogen resistance (less environmental impact of chemical pesticides) and increased water or nutrient-use efficiency (less impact on nitrogen cycle). Biotic and abiotic stress resistance should reduce yield losses, increase yield stability and improve food security and climate change resilience (Lotz et al., 2020). The way how a product is handled within the agri-food system is indicative for more or less sustainability and demand for products with traits that are intrinsically contradictory to sustainability goals is hard to imagine.

Societal aspects are important for the success of innovative products, which can be positively influenced by inclusivity, transparency and participation (Lotz et al., 2020). For example, data should be open to public scrutiny whenever possible. This allows to understand the values and the concerns of the public and helps in building trust and public acceptance.

In summary, single specific traits cannot be classified as being *per se* sustainable or not. Instead, the way of use, the environment, and the human values that define the agri-food system on a regional scale need to be considered. Because sustainability is a system approach, all dimensions of sustainability have to be respected adequately.

Sustainability – requirements and regulation

A main aim of regulation is to ensure the safety of specific products that are released into the environment on a case-by-case basis. This is very important because safety is a prerequisite for sustainability. To achieve this, environmental (and other) protection goals are defined according to the values of society that are reflected in the law. Protection goals mentioned in the law are by definition broad (e. g., protection of biodiversity or environment), but they can be made specific and meaningful for risk assessment and decision making in individual cases (e. g., protection of bees).

The wish to include specific regulatory provisions for sustainability in the legislation for plants produced by certain new genomic techniques has been raised by a majority of respondents (51 %) in a public consultation in the EU (EC, 2022). In any case, having requirements for sustainability implies that specific, measurable indicators need to be defined. Currently, such indicators are mostly applied post-release in the frame of monitoring to check whether policy meets the set goals. While a set of common, unifying criteria might be agreed on by stakeholders in an inclusive process, the development of an overall sustainability index is very difficult, because sustainability is highly complex and some inherent conflicts in defining such an index exist (Dendler, 2014). Numerical determination of the potential sustainability of a certain product before it is released on the market might not even be possible. The direction of development (e. g., yield, required plant protection measures, development of pest populations) might only become evident after the product has been used for a certain time period.

Because sustainability is a system-level goal that cannot be demonstrated for single technologies as such, integrating a requirement for sustainability into regulation for specific technologies, such as genomic techniques, might not be reasonable. For particular crops or products, however, the potential for sustainability relative to possible alternatives (including inaction) could be assessed before market release and monitored post-release to confirm the assumptions made. Ideally, such an assessment should be done independent of the technology that was used to generate the product.

Implications for policy and management

Policy goals can change over time, in particular if economic or environmental challenges arise (e.g., climate change). If the pressure for lower inputs (scarcity of resources) and higher productivity (growing populations) increases, a society may be willing to accept more innovation and less precaution to reach its strategic goals and to achieve progress.

Policy goals towards higher sustainability have been set by the Commission of the EU, i. e., 50 % pesticide reduction, 10 % less land used, and 20 % less fertilizer use. One needs to be aware, however, that sustainability is a global issue and the import of food, feed, natural resources, and industrial products should be considered in sustainability strategies. For Europe, which currently imports a large fraction of its used food and feed, it is important to achieve the goals set for more environmentally friendly production without the need for increased imports.

Improving sustainability in agricultural systems is certainly important and according to the EU Green Deal, every activity is scrutinized in terms of its potential for sustainability. In this respect, sustainability is a management goal and policy should set incentives to promote certain management options. However, it is once more difficult to decide on appropriate tools for monitoring progress towards the set goals.

Examples for management options might be rewards for farmers following best management practices, such as a reduced crop insurance premium when proper pest or herbicide resistance management is practiced (Beckie et al., 2019). Furthermore, investments in agricultural research programs might contribute to the development of more sustainable practices. Variety registration already today encompasses validating environmentally meaningful characteristics, such as high biotic or abiotic stress tolerance or improved nutrient or water efficiency during variety testing. Also, other aspects of sustainability (economic, socioeconomic, etc.) are included in the process. Any support for sustainability, however, should apply universally and independent of the breeding technology.

Importance of an enabling governance system

For innovation to take place, an enabling governance system is the best incentive. In the EU, companies may refrain from investing in products derived from new genomic techniques, because experience has shown that products derived by gene technology have low chances to enter the market. Current regulations with labelling, coexistence, and liability measures are discouraging. Furthermore, high regulatory burdens for new technologies generate the impression of high risk and may feed public unacceptance. In the EU, creating an enabling environment is not an easy task. Firstly, science-based criteria need to be established what constitutes a GM organism and what not. Secondly, scientific outcomes of risk assessments should be respected. Thirdly, the precautionary principle should not prevent the adoption of new technologies (Conko, 2002). Keeping in mind that products derived from new genomic techniques can, from a biological perspective, be highly similar to conventional products, e. g., when consisting of single nucleotide variants or when the introduced genetic material derives from a closely related donor (cisgenesis). Applying the precautionary principle for such products might not be justified and some of the data requirements applicable in the EU to classical GM organisms could be relaxed (Devos et al., 2022). Finally, differing value frames and private standards of different stakeholders should not prevent new products from entering the market once they have passed the risk assessment. On the other side, changes in policy and legislation are only possible if political majorities are in favour of such changes. To achieve this, benefits for the environment, the consumers, and the wider economy need to become evident to counteract an impression of green washing by the agribusiness. In addition, a number of current European politicians may have been elected because they promised to keep the market free of GM organisms for consumers or at least that such products are clearly labelled. It is difficult, however, to improve public acceptance if there are no products on the market that allow consumers to gain experience. Thus, a certain amount of openness in the public and in politics is needed to overcome the current blockage against GM organisms in the EU. Even if this openness might not be there yet, current discussions about new genomic tools pick up momentum. It is desirable to use this momentum to transform the system in a way that it is more responsive to scientific advances and that opportunities for consumers, farmers, agribusiness, and the environment are not missed.

Key messages

- Sustainable innovation comprises the five dimensions technology, economy, human values, governance, and environment.
- Sustainability is a systems approach on the agri-food level that cannot be linked to specific products or technologies.
- Integrating a requirement for sustainability into regulation for genomic techniques might not be reasonable.
- A transparent and inclusive process may improve public acceptance for innovative technologies, such as new genomic techniques, and may ultimately lead to an enabling environment.

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