Sustainable agriculture, forestry and fisheries: a challenge for Europe

Erik Mathijs, Gianluca Brunori[1]*, Michael Carus, Michel Griffon, Luisa Last*

1. Introduction

The fourth SCAR foresight exercise[2] aims to identify emerging research questions and anticipate future innovation challenges that can support the implementation of Europe's Bioeconomy Strategy. The concept of the bioeconomy brings together the agriculture, forestry, fisheries and aquaculture sectors (the primary sectors) and the sectors producing processed foods, chemicals, materials and energy. The fourth foresight exercise explores the interactions between the primary sectors and the broader bioeconomy. With an emphasis on the future, the exercise delves into what could happen by developing the paradigm of the bioeconomy within the fundamental constraint of sustainability.

2. Transitioning to a sustainable European bioeconomy: premises and conditions

In 2012, the European Commission launched its strategy for "Innovating for Sustainable Growth: A Bioeconomy for Europe". The bioeconomy concept is built on two premises. First, current biomass is being underexploited as many waste streams are not used in an optimal way. More materials and energy can be extracted from current biomass streams. Second, biomass potential can be enhanced by closing yield gaps to boost current yields, increasing productive land, introducing new or improved species that may or may not be generated by various biotechnological advances, and using new and improved extraction and processing technologies. Technology development in the field of use and transformation of living matter has opened the way to a variety of scenarios. Whether one scenario or another happens will depend on how the potential presented by the technologies will be integrated into rules, organisational patterns, policies, infrastructures and patterns of behaviour. Looking at future scenarios through the lens of bioeconomy implies broadening the scope of possible interdependencies related to biological resources and assessing any potential risks, costs and benefits.

Over the coming decades the world is expected to face enormous and unprecedented challenges influenced by wide scale environmental, social, political and economic changes currently underway. The global population is expected to reach more than nine billion people by 2050, which, together with projected rises in income, will result in increasing demand for consumables such as food, feed, fuel and materials to be provided by depleted and finite resources in an environment under growing pressure alongside the effects of climate change. Business-as-usual scenarios show that in the near future competition over the use of land, water and biological resources will increase as a result of the effects of climate, population growth, technology, economic and policy trends. Worst-case scenarios, based on the acceleration of some of the existing drivers, entail increased insecurity, inequality, conflicts and even collapse. In the best-case scenarios, solar, wind and other renewables will play a major role; waste will be fully recycled; policy decisions will be more coherent and submitted to sustainability and resilience checks; investments will be made responsibly and consumers will share responsibility for the outcomes of their action and change consumption patterns accordingly.

---

[1] Gianluca Brunori, University of Pisa, Deaprtment of Agriculture, Food and the Environment, Via del Borghetto 80, 56124 Pisa, Italy

[2] https://scar-europe.org/images/SCAR-Documents/4th_SCAR_Foresight_Exercise.pdf

For the bioeconomy to deliver on its goals of food security, sustainable resource management, reducing dependency on non-renewable resources, tackling climate change, creating jobs and maintaining competitiveness, a set of principles to strive for should be established:

- Food first: A global view of how availability, access and sue of nutritious and healthy food can be improved for all. Relevant policies, such as those related to agriculture, food, environment, health, energy, trade and foreign investments should be verified through a food security test and direct and indirect impact assessments should become common currency.
- Sustainable yields: Users should consider the renewable nature of biomass production and apply economic rules that govern their exploitation, such as the sustainable yield approach that prescribes that the amount harvested should not be greater than regrowth. This should be regarded from a holistic view, which takes all biomass into account, including that in the soil. An important indicator here is the amount of organic matter in the soil.
- Cascading approach: To avoid unsustainable biomass use, the concept of cascading use assumes that biomass is used sequentially as often as possible as materials before finally being used for energy. The cascading use of biomass improves resource efficiency, sustainable use and the generation of value added from biomass. It is also part of the circular economy. Creating stronger resource efficiency also increases the general availability of raw material supply because biomass can be used several times. While appealing in theory, there are two problems in the practical application of cascading rules: (1) how to implement a sequential use of biomass and (2) how to implement rules if they run contrary today's existing market environment.
- Circularity: The cascading approach does not address the issue of waste reduction. Waste is generated where the costs of reuse and recycling are higher than the value created. The concept of a circular economy is based on three principles: (1) waste does not exist, as products are designed for a cycle of disassembly and reuse; (2) consumables should be returned to the biosphere without harm after a cascading sequence of uses, contributing to biosphere restoration, while durables are designed to maximise their reuse or upgrade; and (3) renewable energy should be used to fuel the process.
- Diversity: Production systems should be diverse, using context-specific practices at different scales and producing a diversity of outputs. As diversity is key for resilience, innovations in the bioeconomy should be developed to foster diversity rather than limit it.

A transition to a sustainable bioeconomy is a process that cannot be governed only by markets and technology. It requires constant monitoring of these principles and a strong strategic orientation based on a clear identification of societal challenges, a holistic view, reflexive governance and a sound base of empirical evidence. Given the interplay of different issues, interests and actors involved, attention should be paid to processes of policy integration, which would imply giving attention to interaction patterns, tools and mechanisms. EU Member States should carefully and comprehensively evaluate the expected impact of support policies that change the intensity of material and trade flows and land use. Research should generate the knowledge base necessary to support coherent policies and to anticipate problems.

3. State of play in the bioeconomy

Food and feed together account for the majority of biomass demand. These products are generated by agriculture (including livestock), horticulture, fisheries and aquaculture. The main drivers of food and feed demand are human population growth and changes in diet. Strong population growth over the next few decades will mainly occur in Asia and Africa; Europe will potentially experience a slight decrease. Changes in European diets are expected to be small, while Asia will be the major driver of global dietary change due to projected economic and population growth in such countries as China and India. As a result, the demand impacts on Europe will mainly be a consequence of global trade, unless consumers respond to the efforts of governments to tackle diet and health issues. A number of recent foresight studies highlighted both current and future risks as well as opportunities arising from recent scientific advances. Meanwhile, food commodity markets are increasingly integrated with energy markets, which are more volatile and subject to geopolitical influences. The digital revolution may be an important game changer in supply chains and the retail industry, both of which are increasingly concentrated and globalised.

Currently, biomass for bio-based chemicals and materials is used in animal bedding, construction, furniture, pulp and paper, textiles and the chemical and plastics industry. The most interesting fields of innovation in the bio-based economy are the chemical-technical industry (pulp and paper) and the man-made fibre industry, which has the largest biomass fractionation facilities due to their history and long-standing expertise in biomass conversion. The oil-based chemical industry has matured into a central, sophisticated and advanced economic branch, achieving significant economies of scale and low transport costs of starting materials. If chemicals and products are to be made from sustainable resources, the whole chemical industry sector must undergo a transition with regard to starting materials, intermediates and processes. This requires a transitional period with oil refineries and biorefineries running in parallel. The economies of scale for biorefineries differ from those of oil refineries and the transport costs for the starting biomass are much higher. Economic efficiency must therefore be reached by different means than in traditional fossil fuel-based refineries. In order to cope with the mixed mode of operation of oil and biomass as starting materials, novel concepts that still require considerable support from basic research efforts at all levels will be necessary.

With regard to forestry, the future trend is to prepare the forestry sector for an improved and multifunctional use: energy, fuels, chemicals, plastics, construction, furniture, landscape, recreational activities and other ecosystem services. Platforms and specialty chemicals from biomass gain more importance in terms of the established uses in the pulp and paper and materials sectors. Forestry is directly affected by major changes in the chemical industries, where whole production lines are adjusted to manage an increased share of the (partly) new forestry starting materials. The pressure to operate high-value utilisation modes will rise. Additionally, new tree species will be tested for their ability to cope with climate change and to secure forest resilience. Forest management needs more efficient nutrition management while more diversified methods of generating raw materials and ecologically efficient approaches to wood harvesting are also necessary.

The current energy system is still highly dependent on fossil fuels and nuclear energy. Reducing our dependence on fossil fuels requires a significant shift from fossil fuel-based technologies towards the use of technologies based on renewable electricity, heat, and fuels for all end uses: industry, transport (electric vehicles, synthetic fuels, biofuels), buildings (heat pumps, solar and other renewables), etc. As a result, bioenergy and biofuels will play a double role: first, as a transition fuel until electrification is fully implemented, and second, for those applications for which electrification will be difficult to implement. The range of feedstocks that can be used for bioenergy and biofuel production is large. Currently, the largest share of biomass is wood and agro-biomass (i.e., energy crops and residues), but sewage sludge, animal waste, organic liquid effluents and the organic fraction of municipal solid waste are also used as feedstocks. However, these feedstocks must be pre-treated and biomass processing systems must be designed to avoid fouling and corrosion. Pre-treatment technologies aimed at upgrading the energy density of feedstocks include drying, pelletisation and briquetting, torrefaction, pyrolysis and hydrothermal upgrading. Biomass combustion for heat production is based on stoves, incineration or gas combustion and is available on a small scale for individual home heating as well as on a large scale. Biomass is converted into power, heat, and biofuels using steam turbines, thermal gasification, engines or biorefineries.

The current policy framework for the European bioeconomy consists of a multitude of regulations and strategies from several policy areas, including the Common Agricultural Policy, the EU Forest Strategy, the Common Fisheries Policy, the Blue Growth Agenda, the new EU aquaculture framework, quality schemes for agricultural products and foodstuffs, food and feed safety regulations, the Renewable Energy Directive (RED), the 2030 policy framework for climate and energy, standards, certification and labelling for bio-based products and the Circular Economy Package. The cascading use principle could be a valuable tool to ensure the most efficient use of renewable resources and should play a significant part in the package, but its implementation faces controversy. Furthermore, it has become clear that the RED has had adverse effects on bio-based chemicals and materials that could add value and be an innovative component in the bioeconomy. Finally, sustainability criteria is an area where policy decisions and scientific advancement are highly interdependent, as research aims are highly uncertain and there are different – and conflicting – interests at stake. Properly addressing sustainability criteria will require a specific research focus on how to develop appropriate inter- and transdisciplinary approaches and methods.

4. Scenarios

The difficulty in developing a research agenda to tackle future challenges and opportunities is that the future is unknown. What can be done, however, is to identify the biggest uncertainties influencing agriculture, forestry, fisheries and aquaculture (the primary sectors) and then explore what will, can and should happen in the alternative futures defined by these uncertainties. Two major uncertainties were identified to form a scenario framework. The first is the biomass demand growth for materials and energy. This variable depends on population and economic growth, traditional resource markets (e.g., fossil fuels), the evolution of bio-based and other competing technologies (influencing conversion efficiency and costs) and the evolution of non-biomass based technologies (e.g., other renewables). The second uncertainty is biomass supply growth. This variable is based on the development and implementation of new technologies and the rate of intensification in the primary sectors. We have selected three scenarios:

- Scenario A: BIO-MODESTY. This scenario assumes that the growth in biomass demand for materials and energy is relatively low; for instance, because solar, wind and other clean energy technologies take off more quickly than expected, making bio-based solutions less competitive. In this scenario, whether the supply growth is low or high is not as important, so only a medium level of supply growth is assumed.

- Scenario B: BIO-BOOM. This scenario assumes that growth in biomass demand for materials and energy is relatively high, while supply growth is also high. Here, high demand for biomass from the non-food biobased economy is met by supply.

- Scenario C: BIO-SCARCITY. This scenario assumes the same driving forces leading to high demand for biomass for non-food applications. Low supply growth is assumed; for instance, because of societal resistance towards new technologies. As a result, the amount of biomass available for bio-based materials/chemicals and bio-energy is lower than it is now (and even zero for biofuels). However, when the food-first rule cannot be enforced, high demand will considerably increase prices for biomass because biomass is a scarce commodity.

It can be concluded that similar research topics appear in all scenarios, but their relative importance differs across the scenarios. For example, governance must ensure that proper implementation of the bioeconomy strategy is included with respect to small-scale and diverse systems, while in the bio-scarcity scenario governance research is more highly focused on mitigating the negative side effects of biomass competition. Climate change research is much more pressing in the bio-scarcity scenario. Employment issues appear in all scenarios.

5. Recommendations

In order for the bioeconomy to achieve its multiple goals of food security, environmental conservation, energy independence, climate change mitigation and adaptation, and job creation, it must be implemented according to the previously outlined set of principles: food first, sustainable yields, cascading approach, circularity and diversity. Based on our analysis and three stakeholder workshops, the following research themes are proposed:

- New paradigms for primary production based on ecological intensification: Ecological intensification entails increasing primary production by making use of the regulating functions of nature. Its practices range from the substitution of industrial inputs by ecosystem services to the landscape-level design of agroecosystems. Research is needed to underpin ecological intensification to shift from the study of individual species in relation to their environment to the study of groups of organisms or polycultures in relation to each other and their environment. More insight is needed into the synergetic effects of combinations of ecosystem service processes, as current research mainly addresses how single service processes work in isolation.

- Emerging enabling technologies – the digital revolution: Sensor technology, remote sensing, etc. contributing to precision techniques in the primary sectors have great potential to improve resource efficiency. However, combined with other advances in technologies, the digital revolution fundamentally transforms the way science operates, as well as manufacturing, retail and even consumption. Research should further investigate how the digital revolution will affect primary production and their food and non-food supply chains, but also how these developments can help sectors address the diversity of production systems and their outputs with different qualities thus contributing to the realisation of a circular economy.

- Resilience for a sustainable bioeconomy: A resilient bioeconomy encompasses systems that are able to deal with different types of hazards. The bioeconomy and particularly the circular economy entail an increased coordination and integration of different sub-sectors. Combined with the increasing pressures from various driving forces, this may have significant effects on animal, plant and human health hazards as well as adaptation and risk reduction strategies tackling these hazards. Research should not only investigate the impact of the bioeconomy on resilience, but should also develop new solutions and systems that are more resilient from a biological and technological point of view as well as a social perspective.

- The new energy landscape: The transition to a new energy landscape involves abandoning fossil fuel-based technologies in favour of renewable energy technologies. This will have an enormous impact on primary production, which currently is still heavily dependent on fossil fuels, particularly the production of inputs such as fertilisers and pesticides. Research should investigate how this transition affects agriculture, forestry, aquaculture and marine resources, identify the needs of these sectors related to these changes and develop appropriate solutions.

- Business and policy models for the bioeconomy: A bioeconomy that is based on the concepts of circularity and cascading presents a particular challenge to making the economics work. Circularity implies new ways of designing and manufacturing products, new relationships between economic actors, new ways of recycling components and waste, etc. In other words, actors and activities will be reassembled in time and in space. In addition, different production models in terms of scope and size should not only be able to co-exist, but also capture the synergies between them. Public sector involvement is needed for these new business models to work, as public goods are generated in the circular economy but often not remunerated by the market. Research should support the development of these business models.

• Socio-cultural dimensions of the bioeconomy: A sustainable bioeconomy implies that knowledge about social impacts of technology and mechanisms of social change should progress as fast as technology itself. All stakeholders should be fully involved in the governance of the bioeconomy. Science may also radically change food production and consumption patterns, with the potential to reduce pressure on ecosystems, through changes in diet, the multifunctional use of land and aquatic resources, urban-rural nutrient cycles and the production of alternative proteins for animal feed and human consumption. However, this may break established routines and create resistance and anxieties, which need to be better understood.

• Governance and the political economy of the bioeconomy: The outcomes of the development of the bioeconomy through the implementation of a circular economy will depend on the rules put in place to regulate the system. The development of bio-based materials and bio-energy may create pressure on natural resources and on social inequalities in a scarcity-dominated world. Research should help develop a framework aimed at fostering the bioeconomy, including policies and sustainability and safety standards that are coherent, create a level playing field, avoid the overexploitation of natural resources and foster a diversity of practices. Research should also help in tackling the regional differences in national economic structures and the best use of national biomass resources.

• Foresight for the biosphere: Current foresight studies are mostly conducted using forecast-based modelling platforms, with comparative-static approaches and within a limited set of structural features. Research should also expand foresight capacity by integrating data and dynamic and flexible tools to avoid lock-ins and monitor the sustainability and resilience of the bioeconomy and the biosphere as a whole.

Research and innovation are built upon a knowledge and innovation system (KIS) that develops and diffuses knowledge, inspires and identifies opportunities, mobilises resources, helps manage risks and forms markets, legitimises activities and develops positive externalities. EC initiatives support the transition towards a system in which knowledge is co-produced by all actors that engage with each other in processes of learning and even co-evolution that has the following characteristics:

• Challenge-oriented: Rather than only being driven by scientific curiosity, the KIS should also be challenged-oriented. The KIS should strike the right balance between basic and applied research. Orientation is currently provided by the Europe 2020 strategy and more specifically the Grand Challenges for the bioeconomy.

• Transdisciplinary: The KIS should be transdisciplinary, that is, multiple theoretical perspectives and practical methodologies should be used to tackle challenges. Transdisciplinarity goes beyond interdisciplinarity as it transcends pre-existing disciplines.

• Socially distributed: Knowledge should be diverse and socially distributed in the KIS. Communication barriers have been largely lifted, such that knowledge is created in diverse forms, in diverse places and by diverse actors. However, several barriers still exist, such as intellectual property rights and unknown cost structures, hindering the inclusive and public-good character of knowledge. We recommend that open access and open innovation should guide knowledge production as much as possible. Particular attention should be devoted to social innovation and the inclusion of socially disadvantaged actors and regions.

- Reflexive: Rather than an ‘objective’ investigation of the natural and social world, research has become a process of dialogue among all actors. The KIS should devote sufficient attention to these reflexive processes, both within the boundaries of a research project and at the meta-level of organising and programming research. Current efforts of multi-actor participation and stakeholder engagement in projects and in programming are steps in the right direction.

- New rewarding and assessment systems: Quality control transcends the traditional peer review as transdisciplinarity makes old taxonomies irrelevant. Additionally, the integration of different actors also broadens the concept of quality into multiple definitions of qualities. As a result, assessment/rewarding systems relating to researchers, research projects and programmes, research institutes/bodies, other actors, education and even the organisation of regional/national/international KIS need to change. This makes the research and innovation process more uncertain from a traditional perspective on research.

Competencies and capacities: Researchers, other actors and stakeholders in the KIS need to acquire a new set of skills and competencies. Institutions of higher education in particular can play a key role by integrating these skills and competencies into their curricula. The capacity to engage in KIS not only depends on the aforementioned competencies, but also on resources that need to be invested by actors and stakeholders.