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NATURE BASED INNOVATIONS IN THE DEVELOPMENT OF BIOECONOMY[2]

Key words: bioeconomy, innovations, nature-based solutions, Gartner Hype Cycle

ABSTRACT. The main purpose of the article was to present the benefits and challenges related to the bioeconomy as a subsector of the economy, as well as the impact of the biological revolution on the bioeconomy. The market readiness of various nature-based innovations in agriculture was also assessed. The bioeconomy was found to be a right path to sustainable development, addressing social and environmental challenges while supporting economic growth. Thus, it determines a more resilient and resource-efficient development. Nature-based innovations harness the power of nature's resilience, efficiency and adaptability to meet societal challenges in a sustainable way. These innovations offer promising economic solutions while increasing the protection of biodiversity and the health of ecosystems. Based on feedback from key stakeholders, the Garther Hype Cycle model was developed. The productivity phase is reached by those technologies and products that have managed to break out of their niche and gain widespread acceptance. In the analysis, this level was achieved by biological control and the use of beneficial microorganisms. Biological control in particular has been identified as a nature-based technology that dominates today's agriculture and will increase in importance in the future.

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INTRODUCTION

Along with the growing challanges resulting from the critical need for implementation of the sustainable development paradigm, the pressure to search for innovative solutions is growing, in particular with regard to both elements and processes of the economic system. The implementation of the principles of the circular economy, emphasizing the reduction of entropy in the economy and the search for solutions based on natural processes, indicates the growing importance of the bioeconomy as the subsystem of economy. Therefore bioeconomy can be considered as an operationalization of the sustainable development paradigm [Bracco et al. 2018]. The bioeconomy aims to the sustainable use of renewable biological resources, such as crops, forests, and resources produced in the water as well as wastes for their conversion into value-added products, such as food, feed, bioenergy, and bio-based materials [Zilberman et al. 2018]. It encompasses various sectors, including agriculture, forestry, fisheries, and bio-industries [Bugge et al. 2016].

The concept of bioeconomy took the roots on the idea of development which should based on natural resources and the knowledge. As Mariusz Maciejczak [2022] stressed out the knowledge captured in the innovations becomes thus the driving factor of progres made in the bioeconomy. Therefore the concept encourages and requires research and development in various fields, including biotechnology, biochemistry, and materials science. This leads to technological advancements fostering new products and processes [Grossauer, Stoeglehner 2023]. Although advancements are taking place in various fields of knowledge the most impactful becomes developments in life sciences leading to the biological revolution.

The biological revolution refers to the transformative changes brought about by advancements in biological sciences, biotechnology, and the understanding of living systems. It encompasses various fields such as genomics, synthetic biology, bioengineering, and agricultural biotechnology [Richter et al. 2022]. The biological revolution has significant implications for the bioeconomy. It considerably changes the functioning of agriculture, processes aimed at production of consumer goods, energy and materials. These new capabilities improve current response to global challenges, from sustainability and climate change to recovery and resilience.

MATERIAL AND METHODS

The primary objective of this paper was twofold. Firstly, the benefits and challenges of the bioeconomy as a subsector of the economy were reviewed. Secondly, the impact of biological revolution in bioeconomy was presented and the readiness of different innovations was assessed. The literature review was performed in order to identify the benefits and challenges of the bioeconomy as well as impact of the nature based solutions on its development. Additionally, the primary data were collected using direct survey approach in order to assess the application readiness of nature based solutions in agriculture. The survey was conducted among Polish farmers, food processors, traders and retailers as well as advisors and policymakers using the CATI method based on randomized sampling in August-December 2022. As a result 74 full responses were obtained. The responses were used to develop the Gartner Hype Cycle model on nature based innovations in agriculture. Table 1 presents the respondents characteristics.

Table 1. Characteristics of respondents participating in the survey (N = 74)

Descriptor	Characteristics of respondents [%]		
	total	men	women
Sector			
Agriculture	20.3	10.8	29.8
Food processing	14.8	16.2	13.5
Trade	20.3	18.9	21.6
Retail	25.7	32.4	18.9
Advisor	13.5	13.5	13.5
Policymaker	5.4	8.2	2.7
Years in the sector			
To 3	24.3	28.6	18.8
From 3 to 10	45.8	50.0	40.6
More than 10	29.9	21.4	40.6
Education			
Secondary	16.2	8.1	24.3
Higher	83.8	91.9	75.7
Knowledge about bioeconomy (self assessment)			
Low	28.4	34.4	23.8
Medium	51.4	50.0	52.4
High	20.2	15.6	23.8

Sources: own research

RESULTS AND DISCUSSION

BENEFITS AND CHALLENGES OF BIOECONOMY

The literature review indicates several benefits associated with the development and growth of the bioeconomy. From the economic system perspective, primarly the bioeconomy promotes the use of renewable resources, reducing dependence on fossil fuels and non-renewable resources. The bioeconomy promotes the sustainable use of renewable biological resources, such as plants, animals, and microorganisms. By relying on renewable resources, it reduces dependence on finite fossil fuels and non-renewable resources. This also helps mitigate climate change by reducing greenhouse gas emissions and minimizing environmental degradation associated with traditional industries [Ronzon et al. 2017]. Secondly, the bioeconomy promotes the resource efficiency. Bio-based industries often utilize waste streams and by-products from agriculture, forestry, and other sectors. By transforming these waste materials into valuable products, the bioeconomy contributes to resource efficiency and reduces waste generation. Additionally, it allows farmers, foresters, and other stakeholders to diversify their income streams by engaging in bio-based production. This can help reduce vulnerability to fluctuations in commodity prices and provide additional revenue sources for rural communities [Casa et al. 2021]. Through, the bioeconomy offers opportunities for economic growth and job creation, particularly in rural areas where agricultural and forestry resources are abundant. Bio-based industries can provide employment opportunities across various sectors, including agriculture, manufacturing, research and development, and services. It fosters innovation and entrepreneurship by developing and commercializing bio-based products and technologies. This can lead to the establishment of new industries and business models, particularly in rural areas where agricultural and forestry resources are abundant [Viaggi, Zavalloni 2021]. It can be also indicated that through emphasizing on the sustainable management of ecosystems and biodiversity conservation, the bioeconomy is promoting sustainable practices, such as responsible forestry and fisheries management, and helps though to preserve natural habitats and protect endangered species. It also encourages the restoration of degraded ecosystems, contributing to biodiversity conservation efforts [Duque-Acevedo et al. 2021]. The bioeconomy is also important from the perspective of food security. It involves the development of innovative farming techniques, improved crop varieties, and sustainable food production systems. Additionally, it supports the development of bio-based fertilizers, pest control methods, and agricultural waste utilization, reducing reliance on chemical inputs and minimizing environmental impacts.

While bioeconomy offers several potential benefits there are also some challenges and problems associated with its development. Several authors emphesizes the fact that the

focus bioresources, mainly biomas impact the competition for them. The bioeconomy relies heavily on biomass resources, such as crops, forestry residues, and algae. The increased demand for these resources can potentially lead to resource competition with traditional agricultural and forestry activities, causing conflicts over land, water, and other resources [Wesseler, von Braun, 2017]. This competition may affect food security, biodiversity, and land-use practices [Ronzon, Piotrowski 2017]. With this regard the indirect land use become very challanging issue. While the bioenergy crop cultivation is expanding the agricultural activities are displaced to other areas. This may lead to indirect land use change which might cause deforestation or conversion of natural ecosystems [Vural Gursel et al. 2022]. And further environmental impact is also considered as the bioeconomy challange. While the bioeconomy aims to be sustainable, there can be environmental impacts associated with biomass production and conversion. For instance, intensive farming practices for bioenergy crops can lead to deforestation, habitat loss, soil erosion, and water pollution [Daneshmandi et al. 2022]. Additionally, the use of certain bio-based chemicals and materials may involve the use of pesticides or other potentially harmful substances [Masiero et al. 2020]. Finally, the bioeconomy relies on advanced technologies for the efficient conversion of biomass into value-added products. Developing and implementing these technologies can be complex, requiring substantial investments and infrastructure development. Scaling up bio-based industries and establishing efficient supply chains can pose significant challenges, particularly in regions where the necessary infrastructure is lacking [Klein et al. 2022]. Overally addressing bioeconomy challenges requires a holistic and integrated approach, combining scientific research, policy frameworks, stakeholder engagement, and ongoing monitoring and evaluation. It is crucial to balance the potential benefits of the bioeconomy with careful consideration of its potential negative impacts to achieve a sustainable and socially responsible transition.

NATURE BASED SOLUTIONS IN AGRICULTURE

The bioeconomy in agriculture offers opportunities to enhance the sustainability, productivity, and profitability of agricultural systems while reducing environmental impacts. By leveraging biotechnology, bio-based inputs, circular economy principles, and digital innovations, the bioeconomy contributes to a more sustainable and resilient agricultural sector. The biological revolution has unleashed the potential of life sciences to drive economic growth, sustainability, and innovation [Krauze, Wagner 2019]. Therefore by harnessing the power of biological systems and integrating them into various sectors, the bioeconomy is transforming industries, creating new markets, and addressing global challenges such as food security, energy sustainability, and environmental conservation.

Nature-based innovations refer to solutions and approaches that draw inspiration from nature to address various challenges and create sustainable and resilient systems [Sowińska-Świerkosz, García 2022]. These innovations take cues from the principles, patterns, and processes found in natural ecosystems, aiming to mimic or integrate them into human-made systems [Faivre et al. 2017].

The biological revolution in the bioeconomy has been advanced by understanding of genomics and genetic information. Genomic tools and technologies enable the identification of genes responsible for desirable traits, accelerating the breeding process for improved crops and livestock. Precision breeding techniques, such as marker-assisted selection and gene editing, allow for targeted genetic improvements, disease resistance, and enhanced productivity [Philp, 2023]. The genomic works enabled the development of biotechnology. Nowadays biotechnology and synthetic biology play a vital role in the bioeconomy by leveraging the power of living organisms and biological systems to develop innovative solutions. These fields enable the production of bio-based materials, biofuels, and biopharmaceuticals using engineered microorganisms or plant cells. Biotechnological approaches also contribute to sustainable agriculture through the development of biopesticides, biofertilizers, and biostimulants [Conteratto et al. 2021]. Additionally the biological revolution facilitates the transition to a circular economy by converting waste and by-products into valuable resources. Biological processes, such as anaerobic digestion and composting, enable the conversion of organic waste into biogas, bioenergy, and nutrient-rich compost. The valorization of agricultural residues and by-products contributes to resource efficiency, reduced waste generation, and the development of bio-based products [Navare et al. 2021]. Moreover the microorganisms play a crucial role in the bioeconomy across various sectors too. Beneficial microorganisms, such as plant growth-promoting bacteria and fungi, contribute to sustainable agriculture by enhancing nutrient availability, promoting plant health, and improving soil fertility. Microbes are also used in industrial processes, including fermentation for the production of biofuels, enzymes, and other bio-based products [Lindner, Suominen 2017]. Finally, the biological revolution has led to the accumulation of vast amounts of biological data. Bioinformatics and data analytics techniques are employed to analyze and derive insights from this data. These tools help in understanding biological systems, predicting traits, optimizing processes, and supporting decision-making in areas such as precision agriculture, personalized medicine, and bioprocessing [Christensen et al. 2022].

GARTNER HYPE CYCLE OF NATURE BASED SOLUTIONS IN AGRICULTURE

For the purpose of assessing the potential of nature-based solutions in agriculture as a key sector of the bioeconomy the hype cycle model of the analytical company Gartner was applied. As stressed by Dedehayir Ozgur and Martin Steinert [2016] this model is used to describe the process of introducing a technology to the market. The model shows the maturity level and adaptation of the reviewed technologies to the realities of demand. The model consists of five phases. The naming of the phases refers to the phraseology associated with mountain trips [Weinraub, Bridges 2014].

The Gartner Hype Cycle model has been used, however in limited number, in research aimed at assessing the readiness of particular technologies to be implemented in agriculture. The assessment has been executed with regard to the benefits of precission agriculture [Lamb at al. 2008, Lokhorst et al. 2019], expectations regarding applications of the unmanned aerial vehicle in agriculture [Freeman, Freeland 2015] as well as the early promise of molecular farming [Fischer, Buyel, 2020] or sustainable aquaponic for bioeconomy adaptation [Turnsek et al. 2020].

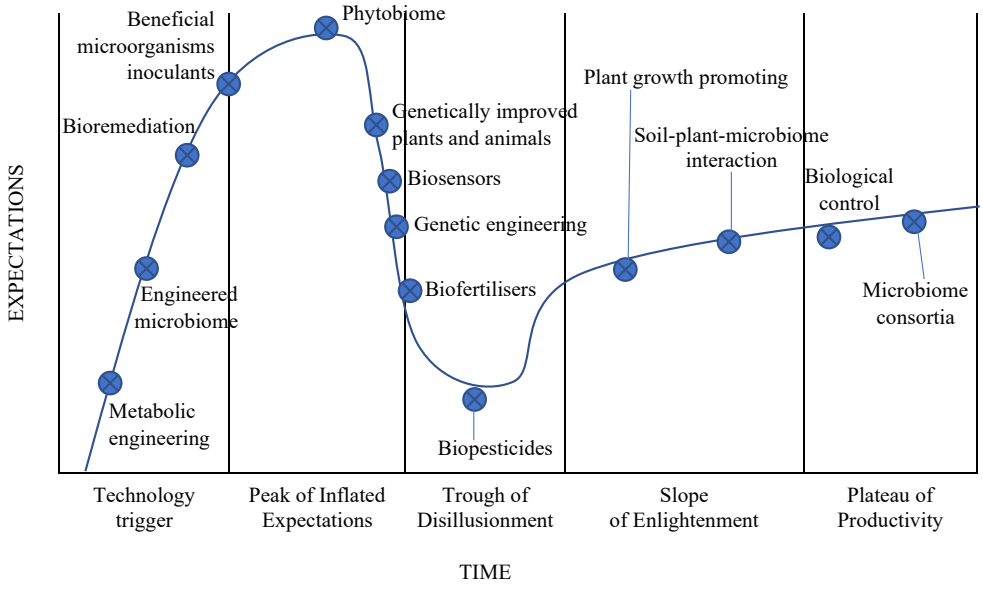

Figure 1. Gartner hype cycle of nature based solutions in bioeconomy
Source: own research

The Garther Gartner Hype Cycle model for nature-based solutions in agriculture is presented in the Figure 1. The first phase – the technology trigger – is the moment of the appearance of a new product and huge interest in it. In this phase the experts included engineered micorobiome solutions along with metabilic engineering and bioremediation as well as beneficial microorganisms inoculants. It indicates that the genomic-based solutions and biotechnology of microorganisms are the most promissiong innovations in the nature-based bioeconomy [Valdivia-Granda 2019]. The second phase – the peak of inflated expectations – takes place when users' expectations are met however more and more frequent signs of dissatisfaction with the product begin to appear. In this phase there were included genetically improved plants and animals, biosensors and phytobiome. Especially with application of phytobiome in agriculture it is still required to understand and direct the functions of phytobiomes taking into account their complexity [Leach et al. 2017]. In the next phase – the trough of disillusionment – the assessed innovations are considered as less useful than expected. In the anaysis in this phase there were included mostly biofertilisers and biopesticides. James Seiber et al. [2014] report that although the increase of these technologies is noted, there still some improvements are needed in case of the efficiency. In the fourth phase – the slope of enlightenment, which appears when the market realizes the practicality of implemented technologies, were included plant growth promotors as well as products based on soil-plant-microbiome interaction [Rai et al. 2014]. Finally, the pleateau of productivity phase is achieved by those technologies and products that have managed to break out of the niche and gain widespread acceptance. In the analyss this level achieved biological control and microbiome consortia. Especially biological control is the technology that todays agriculture is relaying on and which will be even more important in the future [Barratt et al. 2018]. Thus, it should be noted that technologies at this stage of maturity require special interest, above all from policymakers, because on their basis the conviction for nature-based solutions will be built not only among agricultural producers, after all, commercial companies will take care of it, but especially consumers.

CONCLUSIONS

The bioeconomy offers a pathway towards sustainable development, addressing societal and environmental challenges while fostering economic growth and creating a more resilient and resource-efficient future. Nature-based innovations leverage the power of nature's resilience, efficiency, and adaptability to address societal challenges in a sustainable and harmonious manner. They offer promising approaches for building a more sustainable future while enhancing biodiversity conservation and ecosystem health. However understanding the applicability and maturity of nature-based innovations

is crucial for policy and decision-makers to prioritize and allocate resources effectively. It enables the identification of economically viable projects, supports sustainable development goals, and facilitates the integration of nature into economic systems. It is important to conduct comprehensive economic assessments that consider both the short-term and long-term benefits and costs of these innovations.

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Słowa kluczowe: biogospodarka, innowacje, rozwiązania oparte na przyrodzie, Gartner Hype Cycle

ABSTRAKT. Głównym celem artykułu jest przedstawienie korzyści i wyzwań związanych z biogospodarką jako podsektorem gospodarki, a także wpływu rewolucji biologicznej na biogospodarkę. Dokonano również oceny gotowości rynkowej różnych innowacji bazujących na przyrodzie w rolnictwie. Stwierdzono, że biogospodarka stanowi drogę do zrównoważonego rozwoju, odpowiadając na wyzwania społeczne i środowiskowe i jednocześnie wspierając wzrost gospodarczy, a tym samym warunkuje bardziej odporny i zasobooszczędny rozwój. Innowacje oparte na przyrodzie wykorzystują siłę odporności, wydajności i zdolności adaptacyjnych natury, aby sprostać wyzwaniom społecznym w zrównoważony sposób. Innowacje te oferują obiecujące rozwiązania gospodarcze, przy jednoczesnym zwiększeniu ochrony różnorodności biologicznej i zdrowia ekosystemów. Na podstawie opinii kluczowych interesariuszy opracowano model Garther Hype Cycle. Fazę produktywności osiągają te technologie i produkty, którym udało się wyrwać z niszy i zyskać powszechną akceptację. W analizie ten poziom osiągnęły kontrola biologiczna i zastosowanie pożytecznych mikroorganizmów. Stwierdzono, że zwłaszcza kontrola biologiczna jest technologią bazującą na przyrodzie, która dominuje w obecnym rolnictwie i której znaczenie będzie wzrastało w przyszłości.

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