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Obtaining the Factors Affecting Bioeconomy

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***Abstract* – At the scientific level it is being increasingly recognised that the concept of bioeconomy has transdisciplinary nature, but there is still no consensus on key factors that would accelerate the development of sustainable bioeconomy. Therefore, within the framework of this study, certain factors, their interactions and link strength with bioeconomy from a scientific perspective are identified. A bibliometric analysis method is used to achieve this aim in such a way that the keyword information on the published scientific literature in relation to the bioeconomy is translated into quantifiable data. This way the relevance of the bioeconomy factors and the strength of their direct and mutual interaction with the bioeconomy will be determined. From this study it can be concluded that the strongest links with bioeconomy are for biomass, bioenergy, biotechnology and innovations. No significant link was found for such factors as: behaviour, production, pollution and infrastructure. It becomes clear that, in the view of scientists, the decisive role in the development of the bioeconomy resulting from the use of bio resources in the higher value-added production is for technologies. These results are used to build a framework for a system dynamics model that can be used for modelling bioeconomy development scenarios in the future.**

Keywords* – Bibliometric analysis; bio-based economy; bio-economy; scientometric analysis; sustainable development; transdisciplinarity; *VOSviewer

1. INTRODUCTION

The concept of bioeconomy has become the main driver of economic development in recent years, despite the parallel development of other concepts that directly or indirectly affect the bioeconomy. The flourishing of the bioeconomy is linked to the launch of the European Union bioeconomy strategy in 2012 [1] and the updated strategy in 2018 [2].

At the scientific level, it is being increasingly recognised that the concept of bioeconomy has a transdisciplinary nature [3]–[8]. It is clear that in order to accelerate development of the bioeconomy, the following aspects should be recognised: development of bioeconomy, including meaningful use of resources, understanding bioeconomy key factors, their influence and link strength. So far, some studies have been carried out on the factors affecting bioeconomy [3], [9]. There is still no consensus on key factors that would accelerate development of sustainable bioeconomy. For example, in the previous study of authors [3], 22 factors affecting development of bioeconomy had been detected. In another study authors [9] had determined the main types of barriers for bioeconomy innovation: financial, policy, organizational, technology, resource, environmental and climate, behavioural and market. However, the results of these research studies had not quantified the significance of these factors, neither had they brought clarity to the question which of them are the most important.

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It is also clear that opinions on this issue differ between the parties involved [10], [11]. For example, the opinions of scientists, policy makers, entrepreneurs and society vary. The view of all of these parties should be considered in order to find the best possible solution for realistic theoretical assumptions.

This study has been carried out to generate methodology with the aim to identify the factors, their interactions and how strongly they are related to the bioeconomy from scientific perspective in the beginning and moving towards the holistic approach. A bibliometric analysis method is used to achieve this aim. Therefore, keywords on the published scientific literature in relation to the bioeconomy are translated into quantifiable data. This way the relevance of the bioeconomy factors and the strength of their direct and mutual interaction with the bioeconomy are determined. These results are used to build a framework for a system dynamics model. The model can be used to create bioeconomy development scenarios in the future.

An article on bioeconomy that have used bibliometric analysis has already been published [11]–[13], but it does not analyse the interrelation of keywords and is not considered in the context of the factors affecting bioeconomy. Additionally, the results from these bibliometric analysis studies have neither been used to develop a new methodology nor for further, in-depth and expanded studies. The methodology based on bibliometric analysis that has been used in this study can be considered innovative. The results of bibliometric analysis are not only used for primary analysis, but also as data for determining the strength of direct and indirect impact of bioeconomy factors. The results of the method could also be used for identifying the bioeconomy system and for indicators selection.

Previously, a number of studies to identify indicators have been carried out. The indicators that characterise the bioeconomy, which mainly distinguish such groups of indicators as environmental, social [14], and economic, [15]–[18], are the three main pillars of sustainability [19]. Other studies, for example, [20], have been supplemented by a group of technology indicators. But not all studies include indicators for innovation and research for the sustainable development of the bioeconomy [15], [20], although their essential role is recognised [15], [16] and confirmed by the EU Bioeconomy strategy [2]. For example, the project "BioEconomy Regional Strategy Toolkit" (2014) [16] integrates bioeconomy and innovation related indicators into economic and social criteria groups. Conversely, Natural Resources Institute Finland (LUKE), in the study [21] recognised that the indicator "Investment in research and innovations" is one of the most suitable key indicators under all bioeconomy objectives. In this aspect, the characterisation of bioeconomy indicators through the prism of the bioeconomy related factors and their interactions had not been conducted. That is why this study is considered to be a step in moving closer to the holistic exploration of the bioeconomy process.

2. METHODOLOGY

In order to determine which factors influence the development of the bioeconomy, and to evaluate their directly impact and interacting, a combined method is used (Fig. 1). Inputs from the previous studies have been used, and the results will be used for future research as well as modelling of different scenarios.

In the first phase of the methodology bibliometric (scientometric) analysis was performed, using *VOSviewer* version 1.6.11. First of all, (part A) author keywords related to the bioeconomy topic were selected from more than 7000 scientific publications indexed in *SCOPUS* database. The search for keywords in the abstract, title and keywords sections was

conducted. The 4 most popular keywords used to select bioeconomy are bioeconomy, bio-economy, bio economy, bio-based economy. Previously conducted bioeconomy studies, such as Sanz-Hernandez et al. [12], also use these keywords. Firstly, 100 author used keywords with the strongest links that directly match the bioeconomy theme were selected.

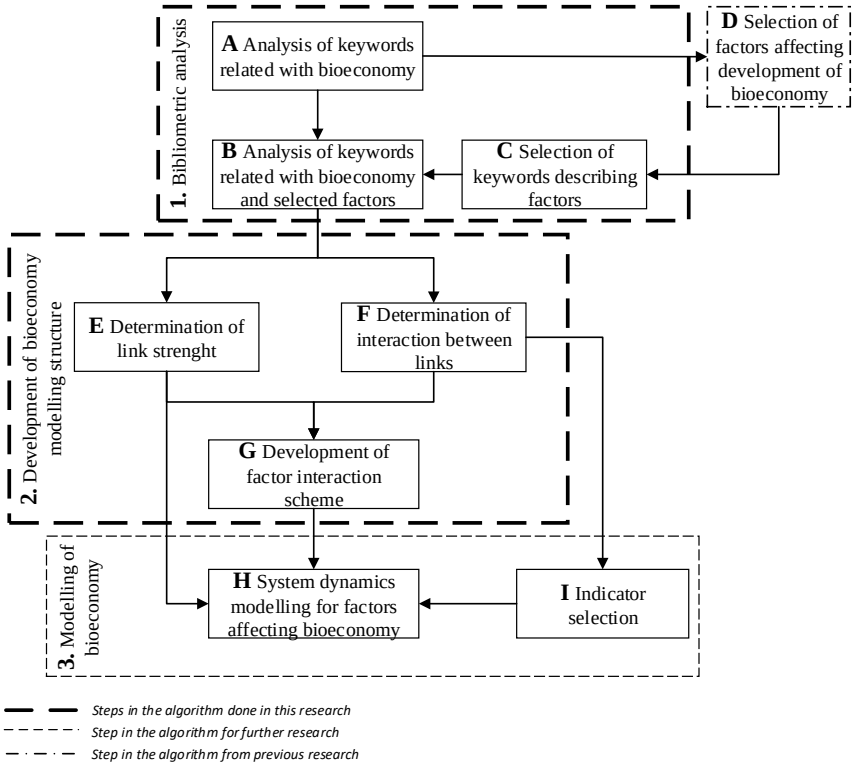

Fig. 1. Methodology algorithm.

Based on the authors' previous study (Phase D), the direct link of 24 factor keywords to the bioeconomy was examined (Phase B). These 24 factors have been selected on the basis of the previous research by the authors: land, waste, prosperity, climate change, bio-resources, non-renewable resources, human resources/population, research and innovation, energy consumption, education/knowledge, politics, health, behaviour, technology, water, natural environment, consumption, financial resources, economic growth, food/feed, production, pollution, infrastructure, primary renewable resources [3], assessing the factors that could influence the development of the bioeconomy, taking into account the natural and man-made environment and processes. One to four related keywords (Table 1) for each factor have been selected (Phase C), with which the relevant factor may be labelled. Using 4 bioeconomy designation keywords ("bioeconomy" OR "bio-economy" OR "bio economy" OR "bio-based economy") and the keyword group for each factor (for example, first factor, "land" OR "soil" OR "ground") documents selected in the abstract, title and keyword section of the searched keywords have been selected in the *SCOPUS* database. From these documents, author keywords have been selected, and then used to determine the strength of the interrelations

and links between the keywords that describe the factors affecting the bioeconomy with the help of *VOSviewer*.

TABLE 1. DOCUMENTS WITH BIOECONOMY RELATED FACTORS AND KEYWORDS SELECTED FROM *SCOPUS* DATABASE

No.	Factor	Related keywords selected	Documents found in SCOPUS database
1	Production	Production, manufacturing	884
2	Research and innovations	Research, innovations, science	858
3	Bio resources	Bio resources, biomass	661
4	Energy, energy consumption	Energy consumption, energy	651
5	Technology	Technologies	549
6	Policy	Policy, politics	477
7	Food and feed	Food, feed	454
8	Education and knowledge	Education, knowledge	309
9	Waste	Waste, rubbish, garbage	304
10	Land, land use	Land, soil, ground	251
11	Environment	Natural environment, environment	212
12	Climate changes	Climate changes, greenhouse gas emissions	178
13	Water	Water	174
14	Financial resources	Financial resources, finances, money, investments	167
15	Health	Health	160
16	Consumption	Consumption	142
17	Primary renewable resources	Primary renewable resources, renewable resources	133
18	Human resources, population	Human resources, population	111
19	Economic growth	Economic growth	75
20	Pollution	Pollution	69
21	Non-renewable fossil resources	Non-renewable resources, fossil resources, mineral resources	66
22	Infrastructure	Infrastructure	56
23	Behaviour	Behaviour, behavior	48
24	Wellbeing	Welfare, wellbeing	28

As it can be seen in Table 1, the most significant number of documents related to bioeconomy contain the terms production and research, and innovation. But this does not indicate that these factors are key factors that can accelerate sustainable development of bioeconomy. Therefore, a more detailed bibliometric analysis was performed, using the *VOSviewer* computer program.

In both cases, 100 keywords with the highest link strength have been selected to determine the structure and closeness of the system. The strength of the links is calculated by the

VOSviewer program, which indicates the number of publications overlapping the use of two keywords.

Using the results of the first part of the methodology, the structure of the bioeconomy model has been developed in the second part of the methodology. Using keywords, the relevance of the links (step E) and their interaction (Phase F) in the investigated system have been determined. This leads to the main directions on which the science focuses in the context of bioeconomy and the factors that should work in practice with legislation, science and financial help. Based on the results of the E and F stages of the methodology, a factor interaction scheme has been established. This scheme will be the basis for future research (3rd part of methodology) to perform bioeconomy development modelling, for example, system dynamic modelling (Phase H). To do this, it is necessary to identify the characteristic indicators (Phase I) of the most significant links of the bioeconomy system. Taking into account that Phase I is a section of future research, this study will select only one of the factors as an example. This example can be used in the future for other factors affecting bioeconomy.

As it was mentioned before, this research is conducted from the scientists' point of view, using bibliometric analysis methodology of scientific literature. Therefore, results show main topics and ways how scientists see development of bioeconomy. The factors can have positive and negative impact on the development of bioeconomy, causing acceleration or stagnation of the development of bioeconomy. Detection of the character of each factor is left for further studies.

3. RESULTS AND DISCUSSION

About 2000 scientific articles from the *SCOPUS* database have been used in the general bioeconomy analysis. This kind of analysis is complicated by the fact that the bioeconomy term in articles can be written in at least 4 different ways. Therefore, keywords' direct link strength with bioeconomy can be only indicative. It is shown in the Annex Fig. 1 that the majority of bioeconomy studies are related to sustainability, biomass, biorefinery and biofuels. Unfortunately, these leading factors (except for biomass, which is a resource, and biofuels, which is a product) are concepts and cannot be used as factors affecting bioeconomy. In addition, most of these keywords are technological processes or products. This shows that the interest of the bioeconomy concept, including innovative products and their manufacturing technologies, is becoming more common in the scientific community. Although such network cannot be used as a basis for building and analysing a bioeconomy system with a holistic approach. Another solution should be found that would answer the following research question: what factors and their interaction influence the development of bioeconomy and to what extent?

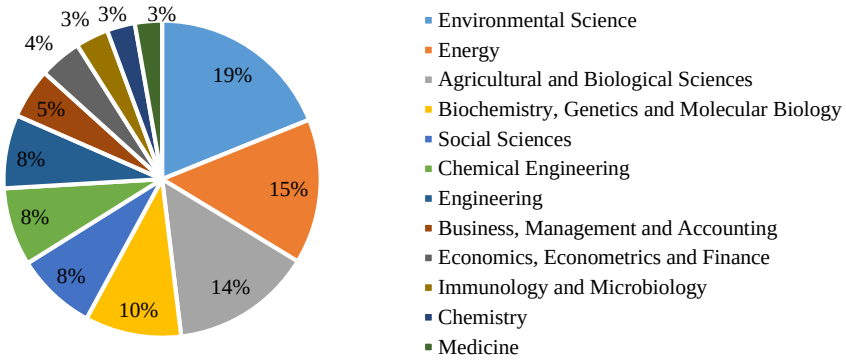

Fig. 2. Leading science sectors in which SCOPUS indexed articles on bioeconomy have been developed.

The pre-selected 24 factors and their relation to the bioeconomy have been used to determine the strength and interrelation of their direct relationship. Relevant scientific publications in *SCOPUS* database have been selected (more than 7000), and only 24 keywords and their interlinkages have been considered. Interdisciplinary nature can be found in the analysis of the sectors in which these publications have been published. As shown in Fig. 2, the leading sectors are environmental science, energy, agriculture and biology. Other sectors are also relatively represented, showing that the bioeconomy is interlinked and has interdisciplinary nature.

By selecting the set of 24 factor-related keywords (see Annex Fig. 2) the strongest link with bioeconomy was found to be “Biomass”, “Bioenergy”, “Biotechnology” and “Innovations”. No significant links were found for the factors “Behavior”, “Production”, “Pollution”, and “Infrastructure”. Among the links of factors in the context of bioeconomy, the strongest link is between Bioenergy and Biomass. Out of these results, the main factors influencing the development of the bioeconomy are clearly identified and can be used for modelling and for the development and analysis of bioeconomy scenarios.

Looking at the 24-factor system by selecting 100 keywords with the strongest links (see Annex Fig. 3), it is clear that the decisive role in the development of the bioeconomy resulting from the use of bio resources in the production of higher value-added products is in technology (industrial biotechnology, synthetic biology, metabolic engineering etc.).

For the 24-factors system that influence the development of bioeconomy, using the bibliometric analysis program *VOSviewer*, the strengths of the interlinks and the strengths of the links with bioeconomy have been determined for each factor as well as their relevance in the system (see Table 2). The relevance is expressed by the weight, the total of which in the system is 1.

TABLE 2. THE STRENGTH AND IMPORTANCE OF THE ANALYSED 24-FACTORS INFLUENCING BIOECONOMY

No.	Factor	Link strength with bioeconomy	Weight	Link strength with another factor	Weight	Weights difference, %
1	Health	11	0.008	38	0.024	–204.7
2	Environment	34	0.024	115	0.073	–199.9
3	Wellbeing	8	0.006	24	0.015	–162.0
4	Consumption	10	0.007	28	0.018	–151.0
5	Food and feed	27	0.019	74	0.047	–143.1
6	Land, land use	32	0.023	83	0.053	–131.0
7	Financial resources	11	0.008	23	0.015	–90.5
8	Research and innovations	165	0.118	223	0.141	–19.6
9	Non-renewable fossil resources	8	0.006	8	0.005	12.7
10	Primary renewable resources	58	0.042	55	0.035	15.7
11	Energy, energy consumption	306	0.219	285	0.181	17.4
12	Education and knowledge	44	0.032	39	0.025	20.6
13	Bio resources	315	0.226	241	0.153	32.2
14	Policy	88	0.063	60.5	0.038	39.7
15	Technology	198	0.142	133	0.084	40.7
16	Waste	24	0.017	16	0.010	41.8
17	Climate changes	58	0.042	24	0.015	63.9
18	Water	0	0	83	0.053	–
19	Economic growth	0	0	15	0.010	–
20	Human resources, population	0	0	10	0.006	–
21	Behaviour	0	0	0	0	–
22	Production	0	0	0	0	–
23	Pollution	0	0	0	0	–
24	Infrastructure	0	0	0	0	–
	Average:	58.2	∑ 1.00	65.7	∑ 1.00	

As shown in Table 2, the relevance of the links does not coincide with the importance of the direct relation to the bioeconomy in all cases. The biggest difference in weight is “Land, land use”, “Wellbeing”, “Health”, “Environment”, “Consumption”, “Financial resources” and “Food and feed”. For each of these 7 factors, greater importance is attached to interaction with other factors than to bioeconomy, although indirectly bioeconomy is most influenced by the following factors: “Energy, energy consumption”, “Bio resources”, “Technology” and

"Research and innovations". It is also in line with the factors that are most relevant to the bioeconomy in this system, only the numerical values of the weights differ (the difference ranges from 17.4 % to 40.7 %).

It has already been mentioned that 4 of the given factors (Behaviour, Production, Pollution, Infrastructure) did not find significant links with other factors in the common system. A significant direct link to the bioeconomy was not found in 3 other factors – "Human resources, population", "Water" and "Economic growth".

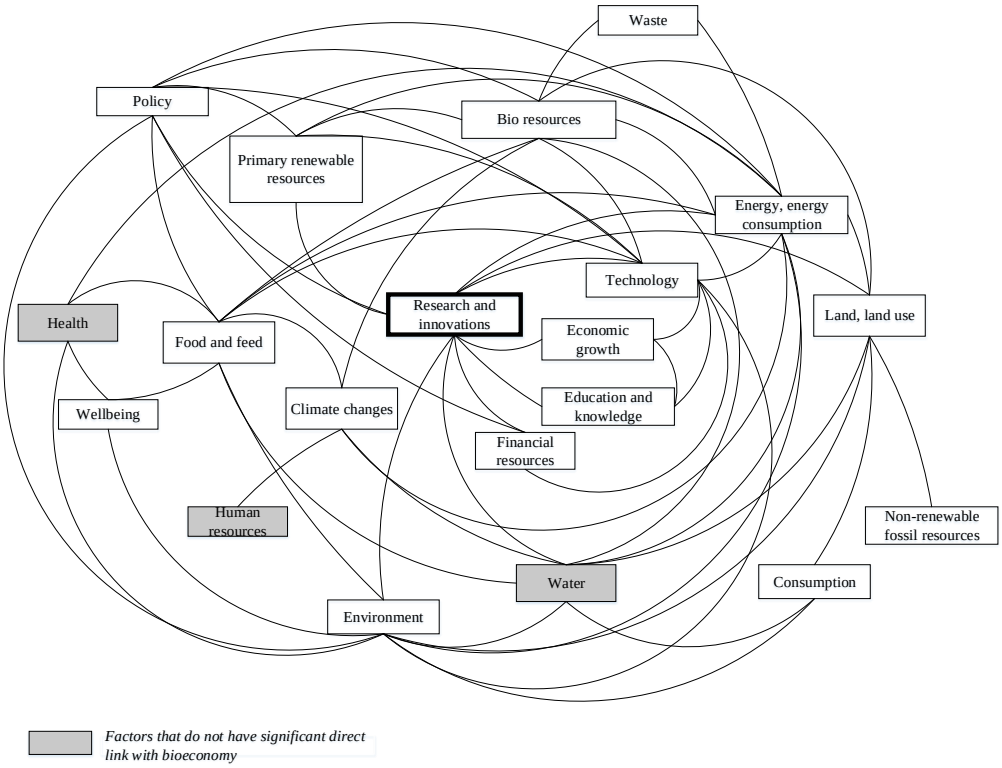

Fig. 3. Principal scheme of interaction between the factors influencing the development of bioeconomy.

The obtained results have been taken into account in order to create a scheme of interaction of the factors influencing the basic bioeconomy development (Fig. 3), which could be used to create a model for the analysis of bioeconomy development scenarios. It should be noted that this scheme is based on the current trends of scientific research on the bioeconomy. It is not excluded that there are other important links and factors that are not included here, which should be considered when the possibilities of bioeconomy development are estimated. To further develop the idea of this study, it is necessary to continue research in order to:

- Integrate the views of policy makers, entrepreneurs and the society to identify more objective links and factors influencing bioeconomy development;
- Direction of the links (the factors have mutual or only one-sided effect) and the strength of each direction link;
- To define what effect – positive or negative – this interaction creates;

- To create a causal loop diagram and a dynamic hypothesis for the holistic bioeconomy system;
- To identify equations and regularities that characterize the interaction of factors and direct interaction with the bioeconomy;
- To develop a dynamic model, validate it on a national scale, and evaluate different development scenarios to identify the most effective solution and the factors that should be worked on to accelerate bioeconomy development.

System dynamics modelling is recognised as the most appropriate modelling method to continue the ongoing research in the intended direction, as it is a method of studying the dynamic development of complex systems that can be used to solve complex issues. Despite the fact that a professor of system dynamics Sterman believes that system dynamics is fundamentally interdisciplinary [22], [23], it can also be used to address transdisciplinary issues by putting together and analysing the opportunities and interests of society and science. System dynamics have been used for searching for solutions for very different and complicated problems. For example, it has been used to find a relative effect of growth of demand for energy services due to changes in income, energy consumption per unit of demand due to technological development, changes in electricity price and household income on household electricity consumption [24]. So far, there have been some studies in which system dynamics modelling has also been used to model bioeconomy, for example [25]–[28]. As far as the authors know, no bioeconomy modelling has been performed till now with such a wide range of influencing factors as this article suggests.

TABLE 3. RESEARCH AND INNOVATION INDICATORS

	Input	Output	Indicators
Research	Expenditure on the development of innovation	Implemented scientific projects	Return on investment in innovation Research efficiency
	Science attracted fund-raising	Registered intellectual property rights	
	State support for science	Scientific publications	
	Science personnel involved		
Research and innovations	State funding for innovation development	Patent-Citations per Scholarly Output	
	Private funding for innovation development	Intellectual property rights have been sold	
	Attracted funds for financing the development of innovations		
	Workforce involved in the development of innovation		
Innovations	State funding for commercialization of innovations	Number of innovative companies	
	Private financing for the commercialization of innovations	Number of innovative companies	
	Attracted fund financing for commercialization of innovations	The added value of innovative companies	
	Workforce involved in the commercialization of innovations	Innovative products	

To build system dynamics model, each link should be expressed as mathematical equation and/or numerical values. Therefore, it is necessary to find the most appropriate indicators that characterise each link. Within this study, one factor is taken as an example, which is Research and Innovation (Table 3).

To obtain Research and innovations indicators "return on investment in innovation" and "research efficiency" directly in the context of the bioeconomy system, the indicators should be individually attributed to each related factor. That is a part of future studies of the work.

4. CONCLUSION

The study has analysed the most frequently used author keywords in more than 7000 scientific publications from *SCOPUS* database in relation with bioeconomy. The most relevant sectors related to bioeconomy from scientific view have been determined. In general, the study has shown that the strongest links with the bioeconomy are such factors as sustainability, biomass, biorefinery and biofuels.

Direct strength and their mutual closeness of 24-factor links, based on previous bioeconomy studies, found that the strongest links with bioeconomy are for biomass, bioenergy, biotechnology and innovations. No significant link was found in some factors, for instance, behaviour, production, pollution and infrastructure. Among the links between factors in the context of bioeconomy bioenergy and biomass are the strongest. Looking at this system more widely, it becomes clear that, in the view of scientists, the decisive role in the development of the bioeconomy resulting from the use of bio resources in the higher value-added production is technology (industrial biotechnology, synthetic biology, metabolic engineering etc.). The scheme of interaction of 20 factors influencing the basic bioeconomy development of this system has been developed, which can be used for further research and development of system dynamics model for analysis of bioeconomy development scenarios and determination of the most effective bioeconomy development.

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ANNEX

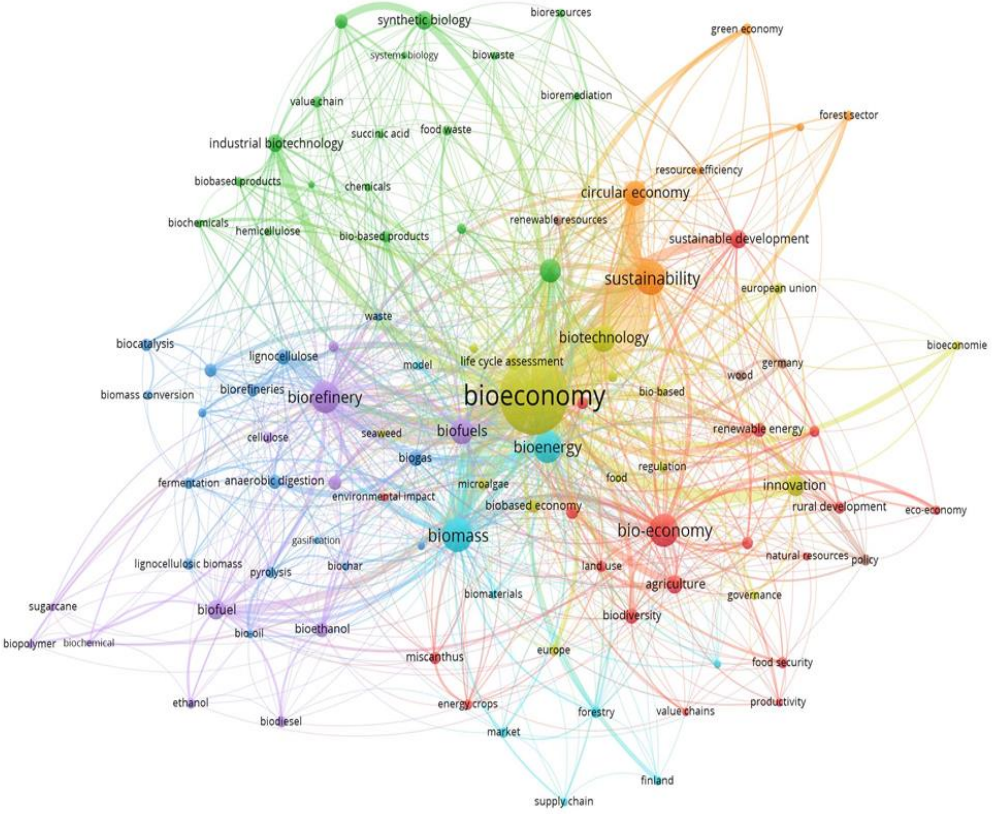

Fig. 1. Top 100 keywords from SCOPUS scientific publications related with bioeconomy.

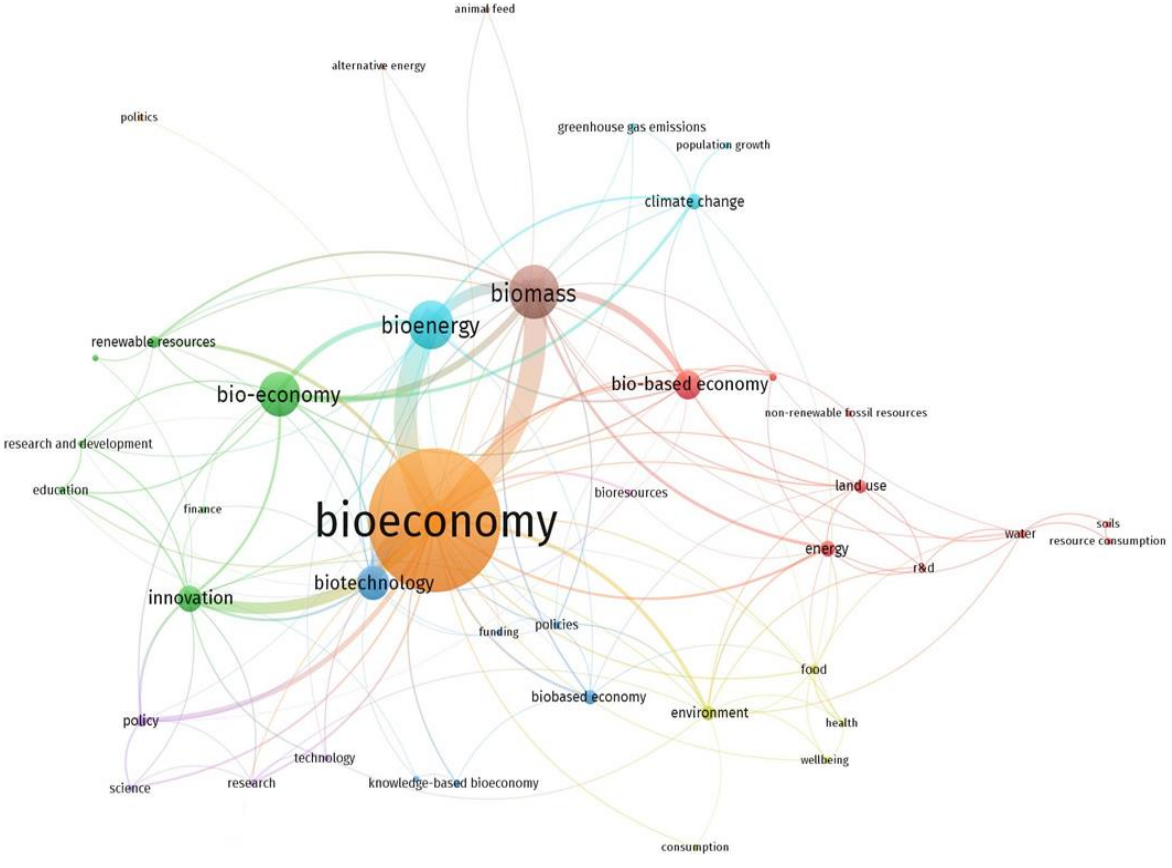

Fig. 2. Links from SCOPUS scientific publications with selected 24 bioeconomy affecting factors.

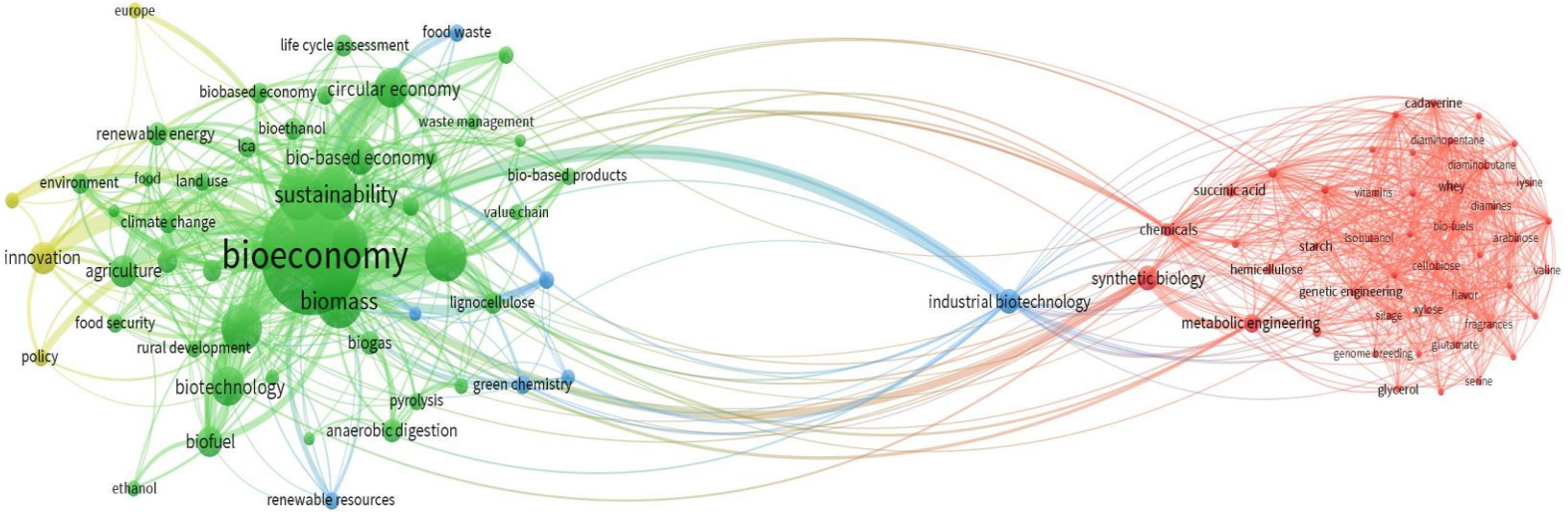

Fig. 3. Top 100 keywords with strongest links from SCOPUS scientific publications about bioeconomy related with selected 24 bioeconomy affecting factors.

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