energies

Review

The Knowledge Based Agricultural Bioeconomy: A Bibliometric Network Analysis

Christina-Ioanna Papadopoulou [1], Efstratios Loizou [1], Katerina Melfou [2] and Fotios Chatzitheodoridis [1,*]

[1] Department of Regional and Cross Border Development, University of Western Macedonia, 50100 Kozani, Greece; aff00579@uowm.gr (C.-I.P.); eloizou@uowm.gr (E.L.)
[2] Department of Agriculture, University of Western Macedonia, 53100 Florina, Greece; kmelfou@uowm.gr
* Correspondence: fxtheodoridis@uowm.gr; Tel.: +30-24610-68113

Abstract: The last ten years have witnessed an increase in publications focusing on bioeconomy as a proposal to confront the global challenges of climate change, depletion of non-renewable resources and ecosystem degradation. This paper investigates the scientific literature on issues related agricultural bioeconomy by applying a bibliometric network analysis. Bibliometric analysis is applied to the publications of the Scopus database during the period 2010–2020 in order to provide an overview of the main aspects that characterize agricultural bioeconomy. The results showed that out of a total of 1100 scientific papers, only 2.45% were published in 2010, while the corresponding share in 2020 was 20.81%. In the five years of 2016–2020, cumulatively, 70.63% of the publications were made, showing the dynamic evolution of bioeconomy. In addition, out of 85 countries in total, Germany and Italy are the two countries with most publications, while the fragmentation of research is evident with the creation of two main nodes, the European and the American. Moreover, keyword analysis showed that biomass and sustainability are two main recurring concepts, confirming that, currently, bioeconomy operates at three different levels: energy demand, land demand, and governance. It is apparent that to boost the development of agricultural bioeconomy, the following aspects should be assessed: the effective use of resources, an understanding of the key drivers of agricultural bioeconomy, and a clear perception of their associations. There is still no consensus as to which are the key factors that will accelerate its sustainable development. Our pursuit is to use the tools of bibliometric analysis to reach more critical conclusions regarding the agricultural bioeconomy, rather than approach it in a static way.

Keywords: bioeconomy; agriculture; bibliometric analysis; VOS viewer

Citation: Papadopoulou, C.-I.; Loizou, E.; Melfou, K.; Chatzitheodoridis, F. The Knowledge Based Agricultural Bioeconomy: A Bibliometric Network Analysis. *Energies* **2021**, *14*, 6823. https://doi.org/10.3390/en14206823

Academic Editors: Paweł Chmieliński and Mariantonietta Fiore

Received: 25 September 2021
Accepted: 16 October 2021
Published: 19 October 2021

1. Introduction

Addressing global challenges such as climate change, scarcity of natural resources and environment pollution requires changes that can transform production and consumption systems in a sustainable manner. An economy based on bio-resources as an alternative to the use of fossil fuels is a major change in socio-economic, agricultural, and technical systems and energy use. The concept of bioeconomy can be attributed to the economy from which the basic structural elements for materials, chemicals and energy, such as plant and animal resources, originate [1]. This type of economy can meet many environmental, social, and economic sustainable requirements if it is intelligently designed and implemented.

At the same time, the growth of bioeconomy sectors represents an opportunity to promote innovation and create jobs in rural and industrial regions [2]. It is also an opportunity to revitalize both productivity and economic development, to rehabilitate marginalized areas, by improving the attractiveness of domestic industries through technological innovations [3] and by dependence on imported raw materials [4].

Potential benefits of adopting bioeconomy include reducing reduced greenhouse gas emissions, less dependence on mineral resources, prudent management of natural resources, and improved food security [5–8]. Job creation in both urban and rural environments is another significant positive impact of bioeconomy, as mentioned above. In addition, the creation of new markets for agriculture and crop production, such as bioenergy, along with existing food markets and in combination with alternative sources of income for farmers, can give significant momentum to rural areas [9]. The prospects for a positive impact from an ambitious bioeconomy appear to be enormous. Nevertheless, while the technical potential of bioeconomy is quite impressive—for example, over 90% of oil-based products could be replaced by bio-based alternatives—the key challenge is to achieve an increase in the scale of activities (e.g., in terms of biomass production) together with the attainment of key sustainability goals.

It can be said that bioeconomy includes different disciplines, e.g., life sciences, agriculture, ecology, engineering [10]; is depended on different primary resources from forestry, agriculture, fisheries, and aquaculture; and relies on a variety of sectors (food, chemicals, energy, industrial materials, tourism-recreation, and wellness). Bioeconomy is ultimately the viable utilization of biological resources to produce new biological products [11], providing at the same time conditions for increasing living standards [12].

According to the latest reformation of the EU strategy [13], bioeconomy is an essential component for the growth of the economy across Europe and the cornerstone of a carbon-neutral future, increasing business competitiveness, and strengthening the industrial base by creating new value chains. The updated strategy is based on the notion that the European organic companies diversify their products, business models, and service portfolios through the development of new products of a high value. The updated strategy is based on the idea that EU organic companies diversify their business models and product and service portfolios by developing new high value-added products. Furthermore, this strategy includes as a EU policy priority agriculture as one of the most important organic primary sector industries leading to biomass production [14,15]. Circularity and the use of renewable biological resources, for instance plant or animal biomass, are the fundamental elements of bioeconomy [16]. The bioeconomy, as an economic-productive model, provides innovative alternatives to meet the main socio-economic and environmental challenges of the 2030 Agenda, such as increasing agricultural production to meet the needs of a global population projected to reach 10 billion in 2050 [17]. In addition, it must be noted that the whole process should be performed using fewer resources, thereby protecting the environment and reducing CO_2 emissions [16,18]. Thus, greenhouse gas emissions could be reduced by 50% by 2050 if there is an increase in the use of biomass and waste for energy production. In general, the adoption and implementation of the bioeconomy has become more widespread since 2015, but its definition and approach vary in different countries pursuing different strategies [18].

The initiative to adopt bioeconomy involves an inherent, relatively high level of risk [19]. It stems primarily from the need to compete with mature and highly effective markets dominated by companies that still base their value creation on mineral resources. Consequently, factors such as limited data and restricted knowledge of market conditions, such as consumer acceptance of new organic products, put operators who adopt the bioeconomy at risk. The answer to this challenging condition lies in the specific approach of agricultural entrepreneurs to managing innovation, which clearly differs from the way established companies organize their innovative initiatives and which could be described as 'entrepreneurial experimentation' [20–22]. In this way, farmers who adopt the bioeconomy reduce risk and uncertainty about the usefulness of inventions by quickly testing new technologies, developing applications and new products based on these technologies, and learning quickly, as both products and farms are exposed to market dynamics. Such a business process engages consumers early on [23]. The concurrent use of practices such as rapid prototyping can also ensure that R&D produces results in a cheap and fast way, while decreasing risk [24]. Therefore, based on the above, key drivers for farmers' adoption of the bioeconomy are innovation, technological development, and market acceptance [25].

The transition to a bio-economy model can offer new business opportunities in rural areas; for example, in the vicinity of biorefinery facilities that process biomass to produce a diverse range of bio-based products such as food, feed, chemicals, bioenergy, biofuels, electricity, and heat. Due to the costly nature of transporting low-value feedstocks, rural areas could have a potential comparative advantage that would largely offset any higher value-added economies of scale [26].

However, as with renewable energy sources, which are also produced mainly in rural areas, there is no guarantee that the development of bioeconomy will enhance rural development as there are many obstacles to that effect. Some impediments include conflicting policies between countries or even within the same country, uncertainty about environmental impacts and lack of attention to rural development issues or objectives. In addition, in regions where fossil fuel economies are well developed, there are significant dependencies caused by investment and interest groups that bioeconomy proponents must address [27]. In summary, to develop the bioeconomy in rural areas and provide the benefits mentioned above, individual needs must be considered and appropriate actions must be implemented.

Within the above context, the main objective of the present study is to review the international scientific literature on the nexus between agriculture and bioeconomy, following its evolution through the application of bibliometric network analysis. Bibliographic network analysis provides statistics based on network data in the form of maps showing the relationships between organizations, countries, authors, and keywords in the scientific literature on agricultural bioeconomy. Next, the basic methodology employed is presented, the results of the analysis are in the following section, and the last section finally contains some concluding remarks.

2. Methodology Issues—Bibliometric Network Analysis

Bibliometric analysis is based on retrieving bibliography of relevant scientific publications from a recognized database, such as the Web of Science or Scopus. Sample delimitation can be defined by year of publication, geographical location of authors, selection of research fields, and thematic journal classification or selection of keywords [28].

Bibliometric analysis involves the processing and recording of data related to publications, i.e., the number of references to them from other publications, the number of publications, their distribution by country, scientific field, author, research center, etc. From the publication data it is possible to identify the trend in research output and its characteristics at the level of the organization, and country, as well as to determine the impact and appraisal of research work and to identify social networks between researchers and scientific areas [29]. The factors that influence bibliometric analysis are the following:

2.1. Scientific Areas

The comparison of indicators across scientific areas is challenging because there are many differences, not only within them but also between different research disciplines, in terms of publication reporting patterns and the time of obsolescence of research results. For example, in cancer research, there are hundreds of scientific publications per year, and it follows that the number of citations of these publications' peaks within a short period of time from the day of publication. In contrast, in the social sciences where publications occur at a slower rate, citations are observed over a long period of time from the day of publication. Finally, in computing, publications are mainly made at scientific conferences without necessarily being followed by the publication of results in a scientific journal. It therefore becomes clear that the bibliometric indicators of the respective scientific fields do not fully reflect the actual situation [29].

2.2. Time Period for Analysis of Reports

It is accepted that the number of citations to a scientific publication is related to the amount of time that has elapsed since its occurrence. In addition, older publications potentially have more citations, without this always implying the impact they have in the scientific community. To normalize differences arising solely from the natural increase in the number of citations to older publications, specific time intervals are set for measuring citations to a publication [30].

2.3. Type of Scientific Publications

Moed [31] attempted to present the reasons why authors cite each other in their publications. Most citations are positively oriented, i.e., they show that the author making the citation finds something useful in the material cited. Negative citations may affect the analysis of an article or author, but this negative effect is diminished in the clustered analysis of authors, as they occur in research centers, universities, and countries. Glanzel [32] pointed out that the number of citations in an article is influenced by the subject content; for example, research activity in physics is lower than that in medicine. Furthermore, publications in a research field with a high performance in the number of citations also receive, on average, more citations.

A bibliometric network is defined as the visual representation through complex nodes and links, and with multiple influences of bibliometric information, which allow the conversion of quantitative data into qualitative conclusions [33]. There are five basic methods of analysis used to determine the correlation of network terms [34]:

(a) Co-authorship analysis where the relevance of data is determined based on the number of co-authors.
(b) Co-occurrence analysis where the correlation of data is determined based on the number of publications that appear together.
(c) Citation analysis that determines the relevance of data based on the times that the authors refer to each other.
(d) Bibliographic coupling analysis where the correlation of data is determined based on the number of reports shared.
(e) Co-citation analysis which determines the relevance of data based on the times they are cited together

The VOSviewer software was selected to be used for the bibliometric network analysis in the current study [34]. The selection was based on four criteria: (1) It has been tested in similar studies [28,33,35]; (2) its operation is reliable and widely accepted [36,37]; (3) it is user friendly, does not require specialized knowledge; and (4) it is open-source software, and anyone has free access.

VOSviewer also fulfils certain requirements such as: (a) accessibility of the user to the survey data and tools, (b) repeatability of the results since they can be reproduced, and (c) validity of the results due to criteria a and b. VOSviewer is a bibliometric network visualization and reproduction software that combines mapping with a grouping method, thus overcoming the two-dimensional limitation [34]. VOSviewer has been used in recent studies such as Einecker and Kirby [38] on climate change and Tang et al. [39] on sustainability over the period 2009–2018.

For the collection of data an attempt was made to identify the maximum possible relevant scientific publications on agricultural bioeconomy. The research focused on the Elsevier Scopus bibliographic database. The Scopus database fulfils three additional criteria: (1) extensive coverage; (2) extensive availability of tools for searching, classifying and extracting bibliographic data and calculating performance indicators; and (3) open access to the database (not subscription-based).

3. Results

The research is based on the identification of the term bioeconomy in all publication titles, abstracts, and keywords. In addition, the search for the term was conducted in five different ways due to the differences observed in the way it is written the search results are presented in Table 1. The search was limited to the period 2010–2020 and in the type of document article. The results were then downloaded in csv format and the duplicates were deleted. The final search outcome in VOSviewer ended with 1100 paper publications.

Table 1. Alternative wording of the term bioeconomy.

Term	Time Limitation	Number of Articles	Number of Articles after Deleting Duplicates
Bioeconomy	Bioeconomy 2010–2020	1217	
Bio-economy	Bio-economy 2010–2020	296	
Bio economy	Bio economy 2010–2020	1865	
Bio-based economy	Bio-based economy 2010–2020	483	
Bio based economy	Bio based economy 2010–2020	1001	
Total		4379	1100

The term bioeconomy appears in 1217 articles in the period 2010–2020. Similarly, the terms bio-economy 296 times, bio economy 1865 times, bio-based economy 483 times, and bio based economy 1001 times. These data are posterior and incremental to the 1100 articles.

The definition of bioeconomy is closely linked to the general concept of bioeconomy in the relevant strategy [40]. Two main approaches can be identified:

According to the first one, bioeconomy is related to technology. Such a definition, employed in the strategies of various organizations, such as the Organization for Economic Co-operation and Development [6] and the US [7], limits bioeconomy to the development and application of current biotechnologies and scientific knowledge from life sciences. With this approach, new healthcare applications, such as personalized medicine and biomedicine, are considered part of bioeconomy. Biomass, as a raw material, does not feature prominently in these strategies. The economic importance of bioeconomy comes from its strong innovation capacity. Bioeconomy is considered to exist, but it needs to be supported, expanded, and have its economic potential optimally exploited.

According to the second approach, bioeconomy focuses on biomass resources and involves economic sectors that are employed in strategies emphasizing the transition from an oil-based to a bio-based economy [5,41,42]. Within this approach, bioeconomy includes the production, processing or use of biological resources [41]. In some of the strategies [41,42], related sectors are mentioned, ranging from agriculture and forestry to the food, timber, chemical, pharmaceutical, and energy industries, to their respective commercial sectors, with minor variations from one strategy to another. The present economic relevance of bioeconomy increases with the inclusion of traditional economic sectors such as agriculture and food industry. At the same time, it does not address the health sector. With the foreseen transformation of the economic resource base, bioeconomy represents a development objective that can be realized in the future. In this framework, the term bio-based economy is used as an equivalent to bioeconomy in some strategies [41]. Both terms are considered synonymous.

The term "knowledge-based bioeconomy" is used for the first time in the EU and can be traced back to the Lisbon Strategy. The label 'knowledge-based', not so widely used at EU level, is explicitly used in some national strategies, and echoed in others, as all strategies focus on new scientific knowledge and technologies and their transformation into economically profitable innovations.

3.1. Keyword Network Analysis

Keyword analysis produced 9722 results; however, only 723 keywords were displayed at least five times, which is the limit that has been set. The most common keyword was biomass, followed by the words sustainability, bioenergy, biofuels, circular economy, bioeconomy, agriculture, climate change, environmental impact, and raw materials (Table 2).

Table 2. The top ten keywords related to the agricultural bioeconomy, ranked by the co-occurrence.

Keyword	Co-Occurrence	Total Link Strength	Links
Biomass	143	1982	621
Sustainability	119	1345	453
Bioenergy	89	1338	419
Biofuel	71	1258	431
Circular economy	122	1194	428
Bioeconomy	141	1092	354
Agriculture	72	1054	402
Climate change	70	971	362
Environmental impact	60	946	356
Feedstocks	62	933	376

Moreover, most of these keywords (Figure 1) are either technological processes or products. This shows that interest in the bioeconomy concept, including innovative products and their production technologies, is rising in the scientific community. Therefore, the results indicate the main themes and ways in which scientists perceive the development of bioeconomy. These factors can have both positive and negative impacts causing acceleration or stagnation in the development of bioeconomy.

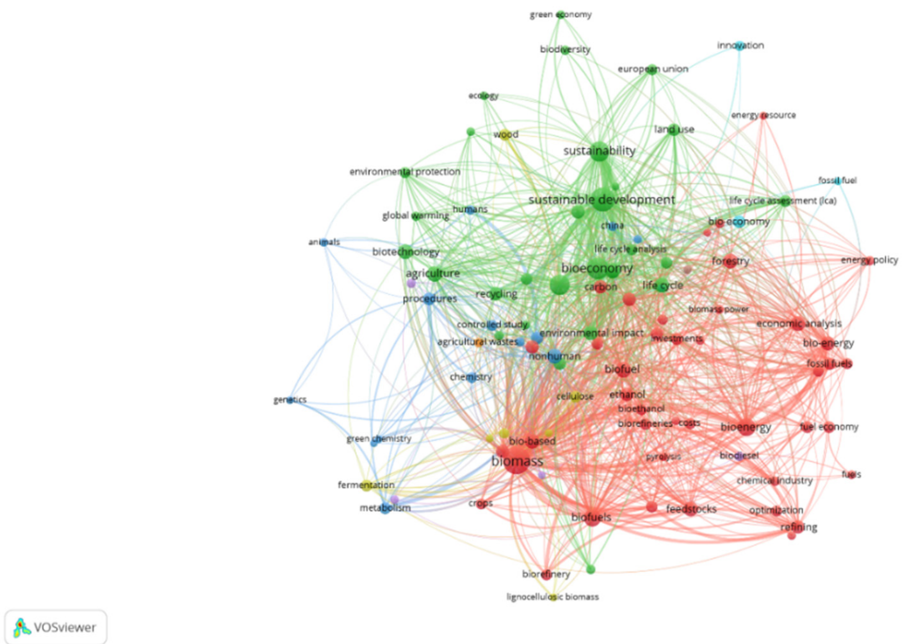

Figure 1. The top 100 keywords with the strongest links in Scopus related to bioeconomy.

These keywords are interdisciplinary, and their interdisciplinary character can be seen in the analysis of the areas in which we find relevant publications. As shown in Figure 2, the leading fields are environmental science, energy, engineering, agriculture, and biological sciences, while other fields are also represented indicating that bioeconomy is interconnected with all these fields and has an interdisciplinary character.

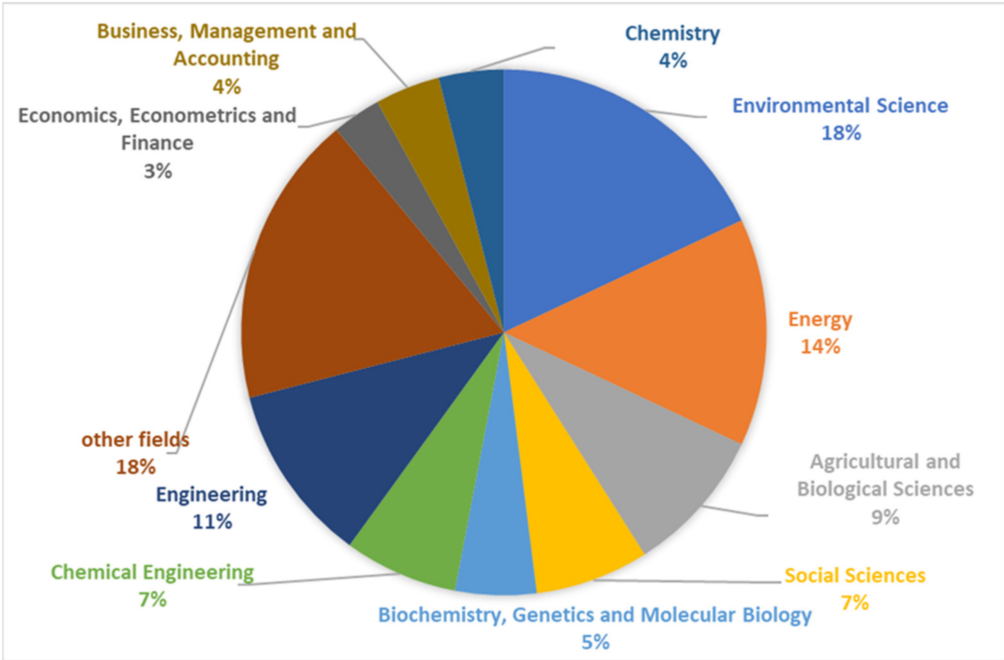

Figure 2. The main sectors with publications on bioeconomy.

The co-occurrence network map of keywords regarding agricultural bioeconomy (Figure 3) shows the most frequently used keywords, the size of the circle is proportional to the coexistence of the element and the distance between the elements shows the strength of their relationship.

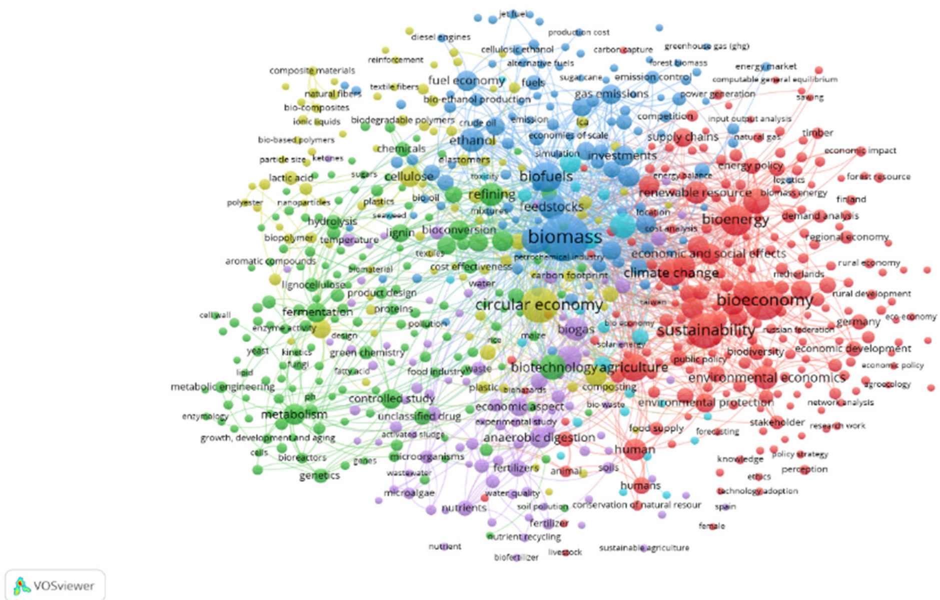

Figure 3. Co-occurrence network map of the most used keywords related to agricultural bioeconomy.

In the network map of agricultural bioeconomy there are five clusters of high co-occurrences. The red cluster looks at agricultural bioeconomy as a driving force for sustainability. The relevant literature reflects the lack of multidimensional studies on the socio-economic impact of bioeconomy [43], the contribution of bioeconomy to the current economic and ecological transition [2], the role of the primary sector [44], and the dynamics of unexplored resources to be used as bio-products and biofuels [45]. The blue cluster correlates biomass with bioenergy production to mitigate climate change. Bioeconomics aims to replace non-renewable resources with others of biological origin [46]. The green cluster focuses mainly on biotechnologies to produce chemicals and biofuels. According to the bioeconomy strategy adopted by China and based on seven sectors, the development of large-scale industry to produce biological materials and biological chemicals that will intensify the approach of green biotechnology in the chemical, food, pharmaceutical and textile industries is an innovative application of high efficiency and low consumption. The yellow cluster indicates the transition to the circular economy that is in progress. According to Székács [47], the term bioeconomy has failed to incorporate the claims of sustainability, so the transition to a new economic model, the circular economy is inevitable. However, little research has been undertaken to monitor, model, and evaluate the impact and course of specific sectors of the bioeconomy to formulate a policy framework [48]. Finally, the purple cluster examines biogas production through anaerobic digestion of biomass. The concept of the bio-refinery was in the forefront in 2017 but over the years its corresponding references have decreased.

From this point of view, the agricultural sector must play an important role in supporting bioeconomy through the provision of biomass but also with other services that contribute to the sustainable development and support of the ecosystem. Increasing biomass can reduce dependence on mineral resources for energy production as it is associated with high exploitation of crop residues (e.g., straw and twigs) in rural areas [49].

At present, there are at least two important gaps. First, the value chains of the bioeconomy need to be regulated. Experience with biofuels so far has revealed that, although there are concerted efforts to promote them internationally, regulations have never been established and production continues unabated in a very liberal governance environment, irrespective of its impact on global sustainability or food security [50].

Secondly, evolutions in the bioeconomy can both help address and accelerate the current imbalances in agricultural value chains. Securing the sustainability of agricultural and biofuel value chains is not guaranteed [51]. Greater flexibility in land use and diverse agricultural products can contribute to the dynamics of producers by creating further demand and reduce the influence of market volatility. However, if these changes in the bioeconomy are adopted only by existing agro-industrial complexes and expand selected monocultures, it is possible to increase the environmental footprint and reinforce the existing dominance of agri-tech companies and developed countries. However, let us not overlook the 1 billion people globally whose livelihoods depend on agriculture, and who could benefit substantially from the technological and economic growth through agro-bioeconomy which will provide them with a powerful solution for sustainable development. In this context, the control of value-added processes appears particularly crucial. Of course, which policies and policy instruments can most effectively achieve one outcome or the other is something that requires further research [52].

3.2. Country Network Analysis

The co-authorship analysis showed that 85 countries publish research on agricultural bioeconomy. Of these, eight countries that do not belong to a cluster are isolated. No restriction was applied to the final set of countries, i.e., all countries with at least one publication are included. The different approaches and relationships between national strategies are reflected in the network of scientific literature. Analysis of co-authors through VOSviewer software shows that different national orientations (strategies) translate into increased scientific collaboration-interaction between countries (Figure 4).

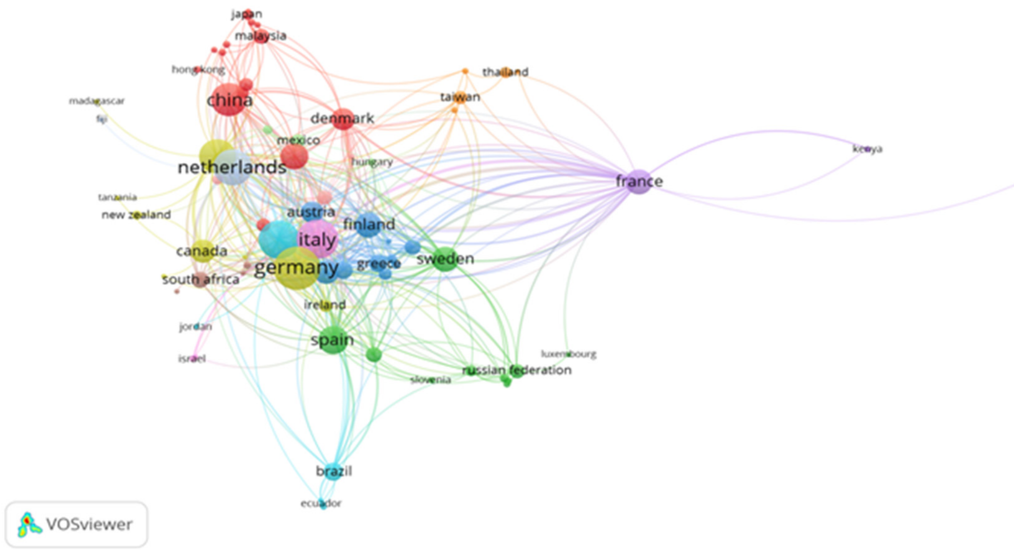

Figure 4. Co-authorship analysis/countries.

All countries linked to the current research can be seen above, in Figure 4. By analysing the software results in terms of the interaction that exists between the countries (based on the co-authors of the scientific articles), some significant findings were reached.

A total of 12 clusters are created, while there are six clusters with five or fewer countries. In addition, in the created network the directions of bioeconomy can be distinguished according to Bugge et al. [28]. The red cluster, for example, represents the vision of biotechnology, which focuses on the rapid use and commercialization of biotechnological research in various sectors of the economy; the blue cluster, the vision of biological resources, which emphasizes the sustainable use of biological raw materials; and the blue cluster, the vision of bio-ecology, which promotes the improvement of biodiversity and the ecosystem, as well as the avoidance of monocultures that cause soil degradation.

The red cluster (Figure 4) is made up of 15 countries and is the largest, which means it has a significant weight compared to the others. The size of China's node indicates that it outweighs other countries and is followed by Denmark and India. The primary purpose and objectives of the biotechnology vision are as expected economic growth and job creation [53,54]. Thus, despite considering the positive impacts on climate change and environmental aspects, economic growth is clearly prioritized over sustainability. Thus, feedback uses the results from the use of biotechnology, while often ignoring the risks and ethical considerations that are secondary priorities in economic development [55,56]. Value creation is linked to the application of biotechnology in various sectors, as well as to the commercialization of research and technology. It is expected that economic growth will follow from the exploitation of biotechnology and the important role played by the intermediaries between research companies and investors, in stimulating the economic activity around bioeconomy [57]. As a result, investment in innovation and research will lead to knowledge production. Research starts from locally operated processes and products and then moves on to production processes [58]. In terms of innovation drivers, the implicit understanding of innovation processes in the biotechnology vision is in many ways close to the so-called linear model of innovation, where processes of innovation are supposed to start with scientific research, which then turns into product development, production, and marketing. As a result, close interaction between academia and industry is required to ensure that relevant research works [59]. Towards this end, technological advances will resolve resource shortages and therefore such shortages are not a central parameter for analysis [1,53]. Similarly, it appears that waste will not be a key issue as biotechnology production processes result in little or no waste. Biotechnology applications can even help convert organic waste into new end products [60]. Since research is central to this vision, research centers and other sources of research funding become central to fulfilling the vision of the bioeconomy in actual development [61].

In the light blue cluster, which includes countries in America, there is an ambition that bio-innovations will offer both economic growth and environmental sustainability [62]. While economic development in the biotechnology vision will harness biotechnologies, in the bio-resource vision the harnessing of bio-resources itself is expected to lead to economic development. In the environmental impacts, sustainability will have a positive bias, with the focus on the technological development of new bio-based products, rather than on environmental protection [63]. Therefore, climate is rarely assessed in the impacts of the transition to a bio-economic model and sustainability receives rather less attention from policy makers [53,64].

Finally, the blue cluster countries, which are all part of the European Union, are in favor of the vision of bioeconomy, i.e., the conservation of biodiversity, ecosystem, and waste management, with a focus on the development of regional rural areas. The blue cluster mostly follows the European Bioeconomy Strategy, so as can be seen in Figure 4 it is particularly linked to all the nodes. What we see is that the countries in this cluster are oriented towards environmentally friendly, sustainable interventions that benefit regional development. They are examples of how the respective bioeconomy policy at national level can at the same time follow the European Strategy and vision.

The co-authorship analysis by country showed the fifteen strongest countries in link numbers in the period 2010–2020, as shown in Table 3.

Table 3. The 15 countries with the most publications.

Country	Co-Authorship	Links
Germany	148	135
Italy	123	121
USA	117	108
Netherlands	102	118
United Kingdom	93	108
China	86	43
Spain	64	61
India	56	14
Sweden	51	62
France	50	92
Finland	50	74
Belgium	45	72
Canada	43	41
Denmark	38	50
Austria	37	68

Germany tops the list with a significant difference from the next, also European country Italy. It is followed by the USA, the Netherlands, and the United Kingdom, which make up the top five. In summary, the bibliometric analysis shows that research on agricultural bioeconomy is becoming more visible after 2016 (Figure 5). Network research is still quite fragmented, with a core of European and American peripheral nodes. European countries are focusing on environmentally friendly, sustainable interventions that benefit regional development. In contrast, countries from other parts of the world, mainly Asia, are significantly less connected to the central bioeconomics research network, although it started relatively early, as early as 2017 (Figure 5).

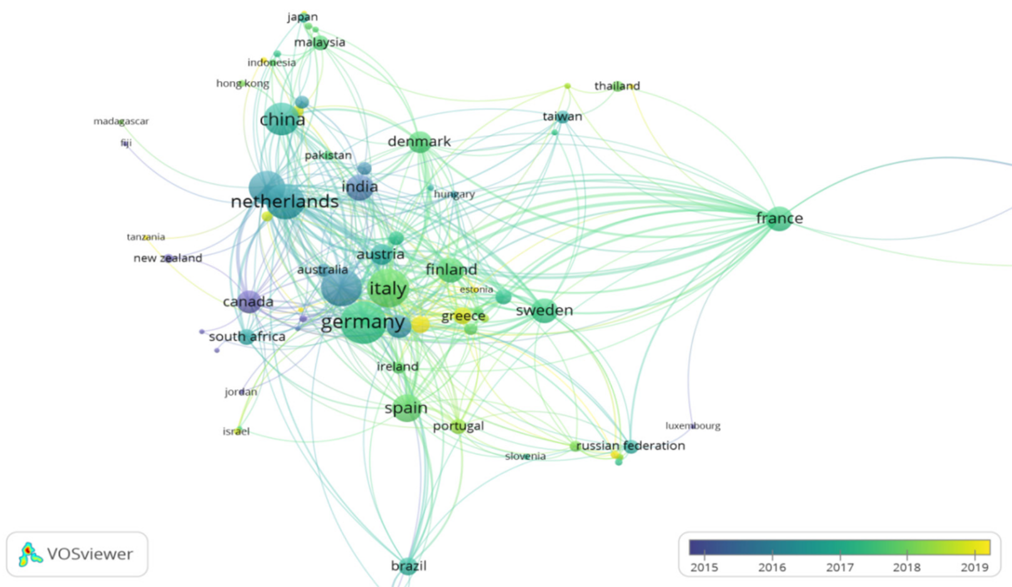

Figure 5. Co-authorship analysis/countries.

4. Discussion

In 2015–2016, research on bioeconomy focused on bioenergy and biofuels, since the primary objective was to find new sources of renewable fuels and to decouple from fossil fuels, the quantities of which are not inexhaustible. In 2017, research on biomass, biorefinery, and biofuels was at the forefront, followed in 2018 by intensified publications focusing on the bioeconomy within the context of sustainability. In 2019 to date, there is reference to the circular economy and recycling/reuse. It is not feasible to claim that any of the above disciplines have ceased to be studied or that the policy adopted has changed. However, we can confidently identify the dynamics of the bibliometric map and the rapid change in the dominant terms each year.

According to Konstantinis et al. [33] there are two possible hypotheses to explain the evolutionary state of bioeconomy. Initially it can be considered as a technocratic trend or as an attempt towards a radical transition away from the linear mineral-based model. As mentioned above, the terms biomass, biorefinery, and biofuels were under study before the growing interest in the bioeconomy seen after 2016. However, the central term that now dominates is that of the circular economy which is referred to from 2019 onwards. According to Székács [47] the term bioeconomy has failed to incorporate sustainability claims, so the transition to a new economic model is inevitable.

Research on bioeconomy is clearly separated into literature that focuses on defining terms and literature that focuses on monitoring [65]. The circular economy and the bioeconomy are two concepts that tend to overlap, and both focus on resources [66]. The circular economy aims to reduce resource use and consumption, promote recycling activities, and minimize waste and emissions [67]. Bioeconomy aims to substitute non-renewable resources with bio-based alternatives [46] with a focus on the introduction of bio-based energy and materials to decrease environmental risks [28]. A clear connection between these two concepts is represented by industrial symbiosis of production processes, where one industry's by-product is another industry's input [68]. Circularity and efficiency are not always incorporated into bioeconomy strategies [69], but some authors introduce the concept of circular bioeconomy to ensure that bioeconomy supports resource efficiency [70]. However, little research has been conducted to monitor, model, and evaluate the impacts and trajectories of specific sectors of bioeconomy to create a sector-specific and tailored policy framework [48,71,72]. Monitoring is of paramount importance to identify and assess alterations in economic, social, and environmental dimensions [73]. Monitoring allows for the evaluation and addressing of the effectiveness of proposed systems and environmental and management policies [74]. The selection of monitoring indicators [75] should involve a range of stakeholders and/or experts to ensure that heterogeneous views and knowledge contribute to the internal dynamics of specific sectors [76]. Stakeholders tend to differ in their interpretations of the preferences, strategies, and information that should be used to provide realistic input to the evaluation and design of public policies [77].

5. Conclusions

Attempting to give a definition of bioeconomy, it will be "an ever-evolving economic model based on sustainable economic growth and associated with different levels of technological maturity". Simultaneously, the role of agriculture in the bioeconomy has made its concept the subject of scientific studies. In recent years, publications on agricultural bioeconomy have grown, confirming the international strategies and policies that have been adopted and believe that bioeconomy can provide the solutions needed for climate change, sustainability, green jobs, food security, energy security, and rural development.

This study is based on articles published in the period 2010–2020 and showed that the strongest links to bioeconomy are links such as sustainability, circular economy, biomass, and biofuels. Looking at the wider system, according to scientists, the key role in the development of rural bioeconomy arises from the use of biological resources, higher value-added production, and technology. At the same time, the co-authorship analysis showed that the countries with the most publications are Germany, Italy, USA, the Netherlands, and the UK, which belong to closely related clusters. From a methodological point of view, bibliometric network analysis provides an overview of the main aspects of rural bioeconomy, expanding on the relationships between countries and the keywords used by researchers. Using data from Scopus and the analyses available through VOSviewer, the ways in which researchers produce knowledge in this area were visually presented. An advantage of the present method is the multidimensional approach to bioeconomy by analyzing a large bibliographic database (Scopus database). A disadvantage is the non-inclusion of gray literature (working papers) and non-Anglo publications that could contribute to the research.

In the future, the effects of an increasingly diversified agricultural bioeconomy could be analyzed using appropriate methods for calculating biomass indices at local and national level. In a state of uncertainty, the right indicators can contribute to the development of bioeconomy.

Author Contributions: Conceptualization, C.-I.P. and E.L.; methodology, C.-I.P., E.L., K.M. and F.C.; software, C.-I.P.; validation, E.L., K.M. and F.C.; data curation, C.-I.P.; writing—original draft preparation, C.-I.P.; writing—review and editing, C.-I.P., E.L., K.M. and F.C.; visualization, C.-I.P.; supervision, E.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We acknowledge support of this work by the project "80601" (MIS 5047196) which is implemented under the Action "Reinforcement of the Research and Innovation Infrastructure", funded by the Operational Program "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014–2020) and co-financed by Greece and the European Union (European Regional Development Fund).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. McCormick, K.; Kautto, N. The Bioeconomy in Europe: An Overview. *Sustainability* **2013**, *5*, 2589–2608. [CrossRef]
2. Vivien, F.-D.; Nieddu, M.; Befort, N.; Debref, R.; Giampietro, M. The Hijacking of the Bioeconomy. *Ecol. Econ.* **2019**, *159*, 189–197. [CrossRef]
3. Purkus, A.; Hagemann, N.; Bedtke, N.; Gawel, E. Towards a sustainable innovation system for the German wood-based bi-oeconomy: Implications for policy design. *J. Clean. Prod.* **2018**, *172*, 3955–3968. [CrossRef]
4. Hurmekoski, E.; Lovrić, M.; Lovrić, N.; Hetemäki, L.; Winkel, G. Frontiers of the forest-based bioeconomy—A European Delphi study. *For. Policy Econ.* **2019**, *102*, 86–99. [CrossRef]
5. European Commission. *Innovating for Sustainable Growth: A Bioeconomy for Europe*; The European Commission: Brussels, Belgium, 2012; p. 3.
6. Organisation for Economic Co-operation and Development (OECD). *The Bioeconomy to 2030. Designing a Policy Agenda*; Organisation for Economic Co-operation and Development (OECD): Paris, France, 2009; p. 12.
7. House, W. *National Bioeconomy Blueprint*; White House: Washington, DC, USA, 2012.
8. Sanders, J.; Langevald, H.; Kuikman, P.; Meeusen, M.; Meijer, G. (Eds.) *The Biobased Economy: Biofuels, Materials and Chemicals in the Post-Oil Era*; Routledge: Abingdon, UK, 2010.
9. European Association for Bioindustries (EuropaBio). *Building a Bio-Based Economy for Europe in 2020*; European Association for Bioindustries: Brussels, Belgium, 2011.
10. Golembiewski, B.; Sick, N.; Bröring, S. The emerging research landscape on bioeconomy: What has been done so far and what is essential from a technology and innovation management perspective? *Innov. Food Sci. Emerg. Technol.* **2015**, *29*, 308–317. [CrossRef]
11. Lainez, M.; González, J.M.; Aguilar, A.; Vela, C. Spanish strategy on bioeconomy: Towards a knowledge based sustainable innovation. *New Biotechnol.* **2018**, *40*, 87–95. [CrossRef] [PubMed]
12. Aguilar, A.; Bochereau, L.; Matthiessen, L. Biotechnology as the engine for the Knowledge-Based Bio-Economy. *Biotechnol. Genet. Eng. Rev.* **2009**, *26*, 371–388. [CrossRef] [PubMed]
13. European Commission. *A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment. Updated Bioeconomy Strategy*; The European Commission: Luxemburg, 2018; p. 7.
14. Bracco, S.; Calicioglu, O.; Gomez San Juan, M.; Flammini, A. Assessing the contribution of bioeconomy to the total economy: A review of national frameworks. *Sustainability* **2018**, *10*, 1698. [CrossRef]
15. Mohanty, A.K.; Misra, M.; Drzal, L.T. Sustainable Bio-Composites from Renewable Resources: Opportunities and Challenges in the Green Materials World. *J. Polym. Environ.* **2002**, *10*, 19–26. [CrossRef]
16. European Commission. *Review of the 2012 European Bioeconomy Strategy: Office of the European Union*; The European Commission: Brussels, Belgium, 2017.
17. Duque-Acevedo, M.; Belmonte-Ureña, L.J.; Plaza-Úbeda, J.A.; Camacho-Ferre, F. The Management of Agricultural Waste Biomass in the Framework of Circular Economy and Bioeconomy: An Opportunity for Greenhouse Agriculture in Southeast Spain. *Agronomy* **2020**, *10*, 489. [CrossRef]
18. Heimann, T. Bioeconomy and SDGs: Does the Bioeconomy Support the Achievement of the SDGs? *Earth's Future* **2019**, *7*, 43–57. [CrossRef]
19. de Assis, C.A.; Gonzalez, R.; Kelley, S.; Jameel, H.; Bilek, T.; Daystar, J.; Handfield, R.; Golden, J.; Prestemon, J.; Singh, D. Risk management consideration in the bioeconomy. *Biofuels Bioprod. Biorefining* **2017**, *11*, 549–566. [CrossRef]
20. Giurca, A.; Späth, P. A forest-based bioeconomy for Germany? Strengths, weaknesses and policy options for lignocellulosic biorefineries. *J. Clean. Prod.* **2017**, *153*, 51–62. [CrossRef]
21. Lazarevic, D.; Kautto, P.; Antikainen, R. Finland's wood-frame multi-storey construction innovation system: Analysing motors of creative destruction. *For. Policy Econ.* **2020**, *110*, 101861. [CrossRef]
22. Scordato, L.; Klitkou, A.; Tartiu, V.E.; Coenen, L. Policy mixes for the sustainability transition of the pulp and paper indus-try in Sweden. *J. Clean. Prod.* **2018**, *183*, 1216–1227. [CrossRef]
23. Lilja, K.; Moen, E. Orchestrating a new industrial field. The case of the Finnish wood-based bioeconomy. *Int. J. Bus. Environ.* **2017**, *9*, 266–278. [CrossRef]
24. Bueso, Y.F.; Tangney, M. Synthetic Biology in the Driving Seat of the Bioeconomy. *Trends Biotechnol.* **2017**, *35*, 373–378. [CrossRef] [PubMed]
25. Kuckertz, A.; Berger, E.S.; Brändle, L. Entrepreneurship and the sustainable bioeconomy transformation. *Environ. Innov. Soc. Transit.* **2020**, *37*, 332–344. [CrossRef]
26. Scarlat, N.; Dallemand, J.F.; Monforti-Ferrario, F.; Nita, V. The role of biomass and bioenergy in a future bioeconomy: Policies and facts. *Environ. Dev.* **2015**, *15*, 3–34. [CrossRef]
27. Diakosavvas, D.; Frezal, C. Bio-economy and the sustainability of the agriculture and food system: Opportunities and policy challenges. In *OECD Food Agriculture and Fisheries Papers*; OECD: Paris, France, 2019; Volume 136. [CrossRef]
28. Bugge, M.M.; Hansen, T.; Klitkou, A. What Is the Bioeconomy? A Review of the Literature. *Sustainability* **2016**, *8*, 691. [CrossRef]
29. Papavlasopoulos, S. *Scientific reporting and measurement tools in Bibliometrics*; Publisher Kallipos: Athens, Greece, 2015.
30. Simkin, M.V.; Roychowdhury, V.P. Theory of citing. In *Handbook of Optimization in Complex Networks*; Springer: Boston, MA, USA, 2012; pp. 463–505.

31. Moed, H.F. *Citation Analysis in Research Evaluation*; Springer Science & Business Media: Berlin/Heidelberg, Germany, 2006; Volume 9.
32. Glanzel, W. Bibliometrics as a Research Field a Course on Theory and Application of Bibliometric Indicators. 2003. Available online: https://www.cin.ufpe.br/~{}ajhol/futuro/references/01%23_Bibliometrics_Module_KUL_BIBLIOMETRICS%20AS%20A%20RESEARCH%20FIELD.pdf (accessed on 22 March 2021).
33. Konstantinis, A.; Rozakis, S.; Maria, E.A.; Shu, K. A definition of bioeconomy through the bibliometric networks of the scientific literature. *AgBioForum* **2018**, *21*, 64–85.
34. Van Eck, N.J.; Waltman, L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* **2010**, *84*, 523–538. [CrossRef]
35. Paletto, A.; Biancolillo, I.; Bersier, J.; Keller, M.; Romagnoli, M. A literature review on forest bioeconomy with a biblio-metric network analysis. *J. For. Sci.* **2020**, *66*, 265–279. [CrossRef]
36. Aristovnik, A.; Ravšelj, D.; Umek, L. A bibliometric analysis of COVID-19 across science and social science research land-scape. *Sustainability* **2020**, *12*, 9132. [CrossRef]
37. Saleem, F.; Khattak, A.; Rehman, S.U.; Ashiq, M. Bibliometric Analysis of Green Marketing Research from 1977 to 2020. *Publications* **2021**, *9*, 1. [CrossRef]
38. Einecker, R.; Kirby, A. Climate Change: A Bibliometric Study of Adaptation, Mitigation and Resilience. *Sustainability* **2020**, *12*, 6935. [CrossRef]
39. Tang, M.; Liao, H.; Wan, Z.; Herrera-Viedma, E.; Rosen, M.A. Ten years of sustainability (2009 to 2018): A biblio-metric overview. *Sustainability.* **2018**, *10*, 1655. [CrossRef]
40. Meyer, R. Bioeconomy Strategies: Contexts, Visions, Guiding Implementation Principles and Resulting Debates. *Sustainability* **2017**, *9*, 1031. [CrossRef]
41. BÖR. *Bio-Economy Innovation. Research and Technological Development to Ensure Food Security, the Sustainable Use of Resources and Competitiveness*; Bio ÖkonomieRat: Berlin, Germany, 2011; p. 14.
42. BMBF. *National Research Strategy BioEconomy 2030. Our Route towards a Biobased Economy*; Bundesministerium für Bildung und Forschung (BMBF): Berlin, Germany, 2011; p. 56.
43. Sanz-Hernández, A.; Esteban, E.; Garrido, P. Transition to a bioeconomy: Perspectives from social sciences. *J. Clean. Prod.* **2019**, *224*, 107–119. [CrossRef]
44. Asada, R.; Stern, T. Competitive Bioeconomy? Comparing Bio-based and Non-bio-based Primary Sectors of the World. *Ecol. Econ.* **2018**, *149*, 120–128. [CrossRef]
45. Gao, S.; Song, W.; Guo, M. The Integral Role of Bioproducts in the Growing Bioeconomy. *Ind. Biotechnol.* **2020**, *16*, 13–25. [CrossRef]
46. D'Amato, D.; Droste, N.; Allen, B.; Kettunen, M.; Lähtinen, K.; Korhonen, J.; Leskinen, P.; Matthies, B.; Toppinen, A. Green, circular, bio economy: A comparative analysis of sustainability avenues. *J. Clean. Prod.* **2017**, *168*, 716–734. [CrossRef]
47. Székács, A. Environmental and Ecological Aspects in the Overall Assessment of Bioeconomy. *J. Agric. Environ. Ethics* **2017**, *30*, 153–170. [CrossRef]
48. Schütte, G. What kind of innovation policy does the bioeconomy need? *New Biotechnol.* **2018**, *40*, 82–86. [CrossRef]
49. Nikodinoska, N.; Cesaro, L.; Romano, R.; Paletto, A. Sustainability metrics for renewable energy production: Analysis of biomass-based energy plants in Italy. *J. Renew. Sustain. Energy* **2018**, *10*, 043104. [CrossRef]
50. Lima, M.B.; Gupta, J. The Policy Context of Biofuels: A Case of Non-Governance at the Global Level? *Glob. Environ. Politics* **2013**, *13*, 46–64. [CrossRef]
51. de Man, R.; German, L. Certifying the sustainability of biofuels: Promise and reality. *Energy Policy* **2017**, *109*, 871–883. [CrossRef]
52. Lima, M.B. Toward Multipurpose Agriculture: Food, Fuels, Flex Crops, and Prospects for a Bioeconomy. *Glob. Environ. Politics* **2018**, *18*, 143–150. [CrossRef]
53. Staffas, L.; Gustavsson, M.; McCormick, K. Strategies and Policies for the Bioeconomy and Bio-Based Economy: An Analysis of Official National Approaches. *Sustainability* **2013**, *5*, 2751–2769. [CrossRef]
54. Pollack, A. White house promotes a bioeconomy. *New York Times*, 2012; p. 26.
55. Pülzl, H.; Kleinschmit, D.; Arts, B. Bioeconomy—An emerging meta-discourse affecting forest discourses? *Scand. J. For. Res.* **2014**, *29*, 386–393. [CrossRef]
56. Hilgartner, S. Making the Bioeconomy Measurable: Politics of an Emerging Anticipatory Machinery. *BioSocieties* **2007**, *2*, 382–386. [CrossRef]
57. Morrison, M.; Cornips, L. Exploring the role of dedicated online biotechnology news providers in the innovation econ-omy. *Sci. Technol. Hum. Values* **2012**, *37*, 262–285. [CrossRef]
58. Hansen, J. The Danish Biofuel Debate: Coupling Scientific and Politico-Economic Claims. *Sci. Cult.* **2014**, *23*, 73–97. [CrossRef]
59. Zilberman, D.; Kim, E.; Kirschner, S.; Kaplan, S.; Reeves, J. Technology and the future bioeconomy. *Agric. Econ.* **2013**, *44*, 95–102. [CrossRef]
60. Richardson, B. From a Fossil-Fuel to a Biobased Economy: The Politics of Industrial Biotechnology. *Environ. Plan. C Gov. Policy* **2012**, *30*, 282–296. [CrossRef]
61. Kearnes, M. Performing synthetic worlds: Situating the bioeconomy. *Sci. Public Policy* **2012**, *40*, 453–465. [CrossRef]

62. Levidow, L.; Birch, K.; Papaioannou, T. Divergent paradigms of European agro-food innovation: The knowledge-based bio-economy (KBBE) as an R&D agenda. *Sci. Technol. Hum. Values* **2013**, *38*, 94–125.
63. Duchesne, L.C.; Wetzel, S. The bioeconomy and the forestry sector: Changing markets and new opportunities. *For. Chron.* **2003**, *79*, 860–864. [CrossRef]
64. Ollikainen, M. Forestry in bioeconomy—Smart green growth for the humankind. *Scand. J. For. Res.* **2014**, *29*, 360–366. [CrossRef]
65. Morone, P. Sustainability Transition towards a Biobased Economy: Defining, Measuring and Assessing. *Sustainability* **2018**, *10*, 2631. [CrossRef]
66. Loiseau, E.; Saikku, L.; Antikainen, R.; Droste, N.; Hansjürgens, B.; Pitkänen, K.; Leskinen, P.; Kuikman, P.; Thomsen, M. Green economy and related concepts: An overview. *J. Clean. Prod.* **2016**, *139*, 361–371. [CrossRef]
67. Lazaridou, D.; Michailidis, A.; Trigkas, M. Exploring Environmental and Economic Costs and Benefits of a Forest-Based Circular Economy: A Literature Review. *Forests* **2021**, *12*, 436. [CrossRef]
68. D'Adamo, I.; Falcone, P.M.; Ferella, F. A socio-economic analysis of biomethane in the transport sector: The case of Italy. *Waste Manag.* **2019**, *95*, 102–115. [CrossRef]
69. Bezama, A. Let us discuss how cascading can help implement the circular economy and the bio-economy strategies. *Waste Manag. Res.* **2016**, *34*, 593–594. [CrossRef] [PubMed]
70. Karan, H.; Funk, C.; Grabert, M.; Oey, M.; Hankamer, B. Green Bioplastics as Part of a Circular Bioeconomy. *Trends Plant Sci.* **2019**, *24*, 237–249. [CrossRef] [PubMed]
71. Loizou, E.; Jurga, P.; Rozakis, S.; Faber, A. Assessing the potentials of bioeconomy sectors in Poland employing input-output modeling. *Sustainability* **2019**, *11*, 594. [CrossRef]
72. Jurga, P.; Loizou, E.; Rozakis, S. Comparing Bioeconomy Potential at National vs. Regional Level Employing Input-Output Modeling. *Energies* **2021**, *14*, 1714. [CrossRef]
73. Marchi, M.; Ferrara, C.; Bertini, G.; Fares, S.; Salvati, L. A sampling design strategy to reduce survey costs in forest monitoring. *Ecol. Indic.* **2017**, *81*, 182–191. [CrossRef]
74. Wells, G.; Fisher, J.A.; Porras, I.; Staddon, S.; Ryan, C. Rethinking monitoring in smallholder carbon payments for ecosystem service schemes: Devolve monitoring, understand accuracy and identify co-benefits. *Ecol. Econ.* **2017**, *139*, 115–127. [CrossRef]
75. Miola, A.; Schiltz, F. Measuring sustainable development goals performance: How to monitor policy action in the 2030 Agenda implementation? *Ecol. Econ.* **2019**, *164*, 106373. [CrossRef]
76. Monasterolo, I.; Roventini, A.; Foxon, T.J. Uncertainty of climate policies and implications for economics and finance: An evolutionary economics approach. *Ecol. Econ.* **2019**, *163*, 177–182. [CrossRef]
77. Doyen, L.; Armstrong, C.; Baumgärtner, S.; Béné, C.; Blanchard, F.; Cissé, A.; Cooper, R.; Dutra, L.; Eide, A.; Freitas, D.; et al. From no whinge scenarios to viability tree. *Ecol. Econ.* **2019**, *163*, 183–188. [CrossRef]