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Transition to a bioeconomy: Perspectives from social sciences

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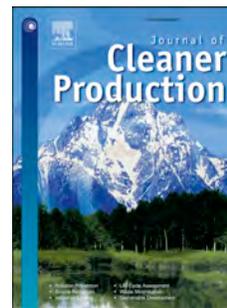
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**TRANSITION TO A BIOECONOMY: PERSPECTIVES FROM SOCIAL  
SCIENCES**

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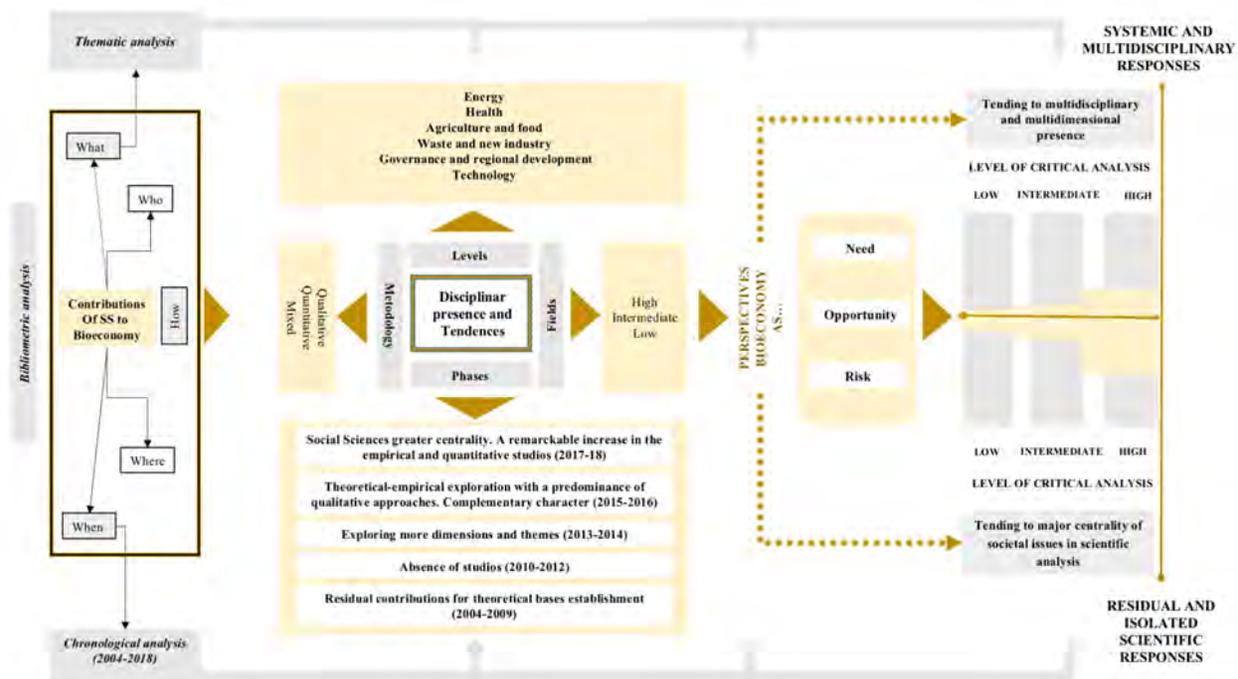
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## TRANSITION TO A BIOECONOMY: PERSPECTIVES FROM SOCIAL SCIENCES

### Abstract

More than 50 countries and international organisations worldwide are currently working on strategies and policies to promote a transition to a bioeconomy. This economic system centres on a sustainable use of bio- and renewable resources to guarantee sustainability. Although many contributions have been made to the field of bioeconomy, most focus on a science perspective (e.g. chemistry, engineering, technology, biomedicine or biology). Despite the significant importance of social and economic issues for a bioeconomy transition, studies from a social science perspective are largely lacking. This paper presents a systematic review of academic contributions to the field of bioeconomy from a social science standpoint. The results reveal the need for an in-depth analysis of the challenges and opportunities that the bioeconomy faces in social and economic terms.

**Keywords:** systematic review; bioeconomy; social sciences; bioresources; socioeconomic impacts.

## 1. Introduction

The concept of bioeconomics was introduced in the 1970s (Georgescu-Roegen, 1977) out of the necessity of connecting institutional, biological, biophysical and social issues with economic theory.<sup>1</sup> However, in the past two decades, the notion of bioeconomy has primarily been defined as an alternative to promote sustainable development. The definition of bioeconomy links two main ideas (Bugge et al., 2016; D'Amato et al., 2017): the use of renewable resources and the use of biotechnology in production processes. Following McCormick and Kautto (2013), the bioeconomy can be defined as *'an economy where the basic building blocks for materials, chemicals, and energy are derived from renewable biological resources'*.

Increasing environmental problems, especially resulting from human activities, require the control of production and consumer attitudes to protect natural resources and to achieve sustainable development. The use of renewable resources could allow societies to maintain their economic growth while limiting negative impacts on the environment and also preserving natural resources. Adapting to a bio-based economy requires an important change in production patterns, using alternative clean energies and renewable inputs in production processes. However, adapting consumer patterns and changing stakeholders' perceptions about the need for environmental protection are also prerequisites. While technical developments are a requirement for this objective, adapting policies and involving societies in the need for sustainable development also play a key role in the process.

The increasing interest in the bioeconomy as a solution for a sustainable global development is reflected in the elaboration and implementation of several national

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<sup>1</sup> A complete review of the main contributions and insights of Georgescu-Roegen's theories can be seen in Gowdy and Mesner (1998).

and international strategies and policies (Heimann, 2018). In 2004, the Organization for Economic Co-operation and Development (OECD) launched a document promoting the need to enhance a bio-based society (OECD, 2004). Later, in 2009, the OECD also published a policy agenda on the bioeconomy based on the analysis of diverse national bioeconomy strategies (OECD, 2009). In 2012, the European Union (EU) established a directive to foster the bioeconomy strategy (EC, 2012) and several countries developed their own; in fact, at least 50 have already adopted bioeconomy strategies or are in the process of doing so (OECD, 2018).

Despite the boost in bioeconomy-related literature, especially in recent years, the main body of research has focused on technological, chemical and biological issues, without paying much attention to specific social and economic aspects. The bioeconomy is projected as a new link between production processes and the environment concentrating on biotechnology and bioresources. However, it also involves a way to improve Quality of Life (QoL) and to promote rural economies (OECD, 2004). While technological aspects are mostly analysed from a bioeconomy perspective, studies covering economic, social and policy approaches are largely lacking. Recently, several authors have pointed out the need for better and more in-depth social and economic studies in this field (Wesseler and von Braun, 2017; Bugge et al., 2016).

This research aims to present a systematic review of contributions to the bioeconomy from a social science standpoint that have been published as research articles in the Institute for Scientific Information (ISI) Web of Science (WoS). Our systematic review differs from previous works (Staffas et al., 2013; Bugge et al., 2016) by solely focusing on contributions that have approached the bioeconomy from a social science perspective. Recently, Wesseler and von Braun (2017) reviewed existing empirical

studies quantifying and measuring the bioeconomy, especially from an economic perspective. We extend and contribute to this literature by focusing on studies covering broad aspects of social sciences. Additionally, as we aim to assess the interest of academic publications in the study of social science's contributions to the bioeconomy, we have based our analysis on articles collected in a research database (WoS).

Our principal goal is to highlight the current state-of-the-art of academic research articles whose main focus is a social science analysis of bioeconomy-related issues. It is important to acknowledge that several publications covering social science issues of the bioeconomy are collected in reports, policy papers and other documents not published as academic articles and not considered in this review. Our results are based on contributions made in the field of social sciences and collected in the WoS due to this database's legitimacy and its specific classification of articles into the social sciences category. Additionally, we selected articles that specifically include the term 'bioeconomy' and excluded publications related to biotechnology, bio-based societies, biofuels, etc.

The outcomes reveal the need for a broad analysis of social issues in the academic study of the bioeconomy. Social, economic and policy considerations in this field are still briefly considered and studies with a social or economic quantification of the bioeconomy impacts are scarce. We also observed significant gaps in bioeconomy subjects and methodologies covered by social science publications. Despite the significant increase in the number of contributions in recent years, several issues remain unaddressed. Current contributions cover a very varied range of topics; however, subjects related to the bioeconomy input in rural development, increases in QoL, consumer behaviour or political cooperation are still pending analysis from a

bioeconomy perspective. Implementing a bio-based economy requires proper and clear legislation and operational rules and, especially, stakeholder engagement. Without social involvement, efforts to promote sustainable economies might not provide the expected outcomes or could even result in the implemented processes failing. Consequently, a better understanding of bioeconomy-related impacts from a social perspective is necessary.

The remainder of the manuscript is as follows. The next section describes the systematic literature methodology and presents a bibliometric analysis of the publications. Section 3 analyses the selected contributions based on the implemented methodologies and the content of the articles. In section 4, we briefly summarise the main findings on the bioeconomy from a social science perspective. A discussion of the results is presented in section 5. Finally, section 6 contains our conclusions.

## 2. Systematic review

The analysis made consisted of a systematic literature review based on the proposals of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology by Moher et al. (2009). The PRISMA methodology provides guidelines and statements to perform a systematic review by following some scientific criteria.

### 2.1. Literature search

The systematic literature search is based on articles and reviews published in the ISI WoS. Data were collected from the WoS in April–May 2018 by using the strings: ‘bioeconomy’; ‘bio-economy’; ‘bioeconomy OR bio-economy’. For our purpose, we

selected all the articles and reviews that included any, or more, of the previous strings in the title, the abstract, and/or the keywords. Finally, we only chose English-language publications. Table 1 summarises the results of the systematic search in the WoS by strings and subjects.

At first sight, the results reveal how current research on the bioeconomy mostly focuses on ‘science’ subjects (e.g. engineering, chemistry, environment, technology, medicine, physics and biology); only 22% of all publications are based on social sciences. This result evidences the critical lack of studies and analyses approaching the bioeconomy from a social, political, economic or management perspective.

#### **INSERT TABLE 1**

**Table 1. Number of articles and reviews by string and subject area from WoS**

For the research purpose of this article, we performed a bibliometric analysis and an in-depth literature review with all the publications classified as ‘social sciences’ based on the WoS criteria. Figure 1 shows the complete study selection process. Additionally, the appendix collects the full list of the studies included in the analysis.

#### **INSERT FIGURE 1**

**Fig. 1. Flow diagram of the literature exploration and selection process**

## 2.2. Bibliometric analysis

Using all the selected studies (166 research articles), we performed a bibliometric analysis primarily focused on a chronological survey of the publications. Furthermore, we analysed the journals that published relevant social science issues related to the bioeconomy.

The chronological analysis presented in Figure 2 illustrates the temporal evolution of social science contributions to the field of bioeconomy. The results show how the first dates back to 2004. Although the first publication on bioeconomics dates back to the 1970s, the relevance of social science academic contributions to the bioeconomy is a more recent phenomenon.

### INSERT FIGURE 2

**Fig. 2. Number of contributions in the WoS based on bioeconomy and classified within the field of social sciences**

Based on the publication trend of Figure 2, we divided the articles into three groups. The first block comprises the origin of social science publications on the bioeconomy (2004–2014). The second group encompasses 2015 and 2016. During these years, a notable increase in social science publications on the bioeconomy can be observed. However, an upward trend is still missing. The final array of articles comprises 2017 and 2018, where we notice a clear and consolidated increase in the number of contributions.

The first stage of publications (2004–2014) comprises a total of 27 studies. The preliminary result from analysing this pattern is the low number of papers. Over this time period, the yearly publication average is around 2.5. On examining the main themes and contributions of these publications, we found significant heterogeneity in

the contents. Furthermore, most of the inputs are theoretical, with minor contributions covering empirical or quantitative issues and, in general, the inclusion of social science topics is very residual.

An important peak in the number of bioeconomy publications in social sciences can be observed in 2015, with 29 works in this year alone. However, in 2016 the number of contributions fell to 15 articles. We collated these two years as the second set of publications. In our opinion, these years represent the starting point for the analysis of the bioeconomy from a social science perspective. During this period, we observe a significant increase in the number of empirical applications and a boost in bioeconomy publications with a purely social science perspective.

Finally, from 2017 onwards there has been an upward trend in the bioeconomy-related literature in social sciences; by May 2018, the number of publications had risen to 90 articles. This last group of the literature covers the expansion of bioeconomy publications in social sciences. We found a prominent increase in the number of contributions and also in the methodologies, topics, and approaches covered. Furthermore, most of the experimental and numerical applications have taken place in these two years.

Together with the chronological evolution of bioeconomy publications in social sciences, another important outcome is the type of journals publishing this kind of research. In Figure 3 we collate all the journals with more than one contribution to bioeconomy research in social sciences. The results suggest that academic bioeconomy literature in social sciences is spread out across a large number of journals. The identified 166 articles were published in 99 different journals, with most of the journals releasing only one article (see appendix). We identified 24 journals that had published from two to five contributions, and only three journals had

published more than five articles on the bioeconomy from a social science perspective.

Based on the results reported in Figure 3, we can highlight two main points. First, bioeconomy research categorised in the field of social sciences has been published in a very heterogeneous range of journals. Second, a significant percentage of articles are published in journals not categorised in the field of social sciences by the WoS (e.g. Journal of Cleaner Production, Biomass & Bioenergy, Foresight, etc.). These results highlight how most of the research on the bioeconomy, even when the analysis is related to economic or social issues, is published in journals categorised in the field of science (e.g. environment, technology, medicine, bioresources and energy). The results also illustrate how social science journals, especially journals on economics, policy or sociology, do not publish many papers on this matter.

### **INSERT FIGURE 3**

#### **Fig. 3. Journals with more than one contribution to the bioeconomy research in social sciences**

The above bibliometric review highlights how the analysis of the bioeconomy from a social science perspective is a very recent addition to the body of the literature, even considering that the concept of bioeconomics dates from the 1970s. Additionally, publications in this field are spread out across a large number of journals, most of them classified in the field of sciences. It is important to recall, as we stated in the

introduction, that these results are based on the selected publications, which are academic research articles in the WoS.

### 3. Bioeconomy in social sciences: methodological and thematic analysis

Considering the identified 166 articles, in this section we exhaustively analyse the main focus and content of the contributions. A two-stage process was performed: the methodologies of the selected inputs were examined first, followed by an analysis of the main contributions.

In a first stage, we categorised the selected studies depending on the methodology used. To analyse the evolution of the methodologies, we organised the papers based on whether the analysis performed was theoretical, empirical or a survey.

#### **INSERT FIGURE 4**

**Fig. 4. Number of articles according to their principal methodologies**

The results show how around 52% of the articles are empirical, 38% are theoretical and 10% are reviews or literature surveys. A remarkable result is the fact that 40% of all the empirical articles were published between January and April 2018. Furthermore, before 2015, social science publications on the bioeconomy were mainly theoretical studies. It is in the last two years (2017–2018) that we observed a significant trend of filling the gap in experimental and numerical applications of the bioeconomy from a social science perspective. Additionally, by analysing the empirical methodologies covered (quantitative, qualitative or mixed analysis), we confirmed that most of the social science contributions to the field of bioeconomy

were qualitative studies. The evaluation of the impacts (positive and negative) of the bioeconomy and their implications for societies have barely been studied so far, at least judging by published research records in academic journals.

In a second stage, we focused on the specific content of the articles. We classified each of the selected 166 into two different groups. A first group of publications analyses specific bioresources and the strategies, management or biotechnology developments associated with them. A second group of articles focuses on a broad study of bioeconomy-related issues, for example policy and governance, society, economics, ethics, laws or education. Most of these contributions are theoretical and have no detailed analyses of specific sectors or bioresources.

The analysis of the first set of publications, which is related to a specific economic sector or to bioresources, reveals the existence of a small group of topics covered. The subject that has garnered substantial interest is the energy sector, with articles based on energy-related issues (biomass, biofuel or the sustainability of the energy sector). Furthermore, this body of publications, mainly published in 2018, shows increasing concern for the use of clean energies and their sustainability. Closely linked to the energy sector, the study of organic waste to either produce compost or energy has also been quite remarkable. Another relevant topic is the analysis of the forest and the agricultural sector. These contributions are basically related to policy and/or the repercussion, planning or management of these sectors and resources. Additionally, we found some publications based on the value chains of forest resources and the agricultural industry. Finally, another significant group of empirical articles covers biomedicine. A very recurrent topic is the field of human tissues and cell development and management. This research group spans across all the years. However, in 2018 we observed a decrease in the number of contributions to this specific subject.

The second set of publications consists mainly of theoretical contributions analysing general key issues in the bioeconomy. These articles, which are not explicitly related to any bioresource or economic sector, raise the debate on the political, social, economic or legal implications of the bioeconomy and bioeconomy-associated approaches. Some of these contributions address issues related to the implementation of regional and national bioeconomy strategies.

#### 4. Main contributions to the bioeconomy by social sciences

To receive broader feedback on current contributions, we organised the selected articles depending on their critical content of social sciences. We classified each paper based on an in-depth analysis identifying the specific social contribution. We catalogued the articles into three ranks: high-oriented, medium-oriented and low-oriented social science contribution. High-oriented articles comprehensively address social science issues. Medium-oriented publications cover social science issues, but the primary objective is not a social science topic. Finally, low-oriented articles treat social sciences as collateral issues, with no relevant implications in this field. Based on the above classification, we identified 91 high-oriented articles (55%), 43 medium-oriented (26%), and 32 low-oriented (19%).

The analysis of the high-oriented articles reveals that this literature emphasises the social dimension of the bioeconomy. Most of these articles include insights on the social, political or economic impacts on stakeholders or society as a whole. The analysis of the medium-oriented contributions shows that the main characteristic of this group is multidisciplinary. We have identified that, although a social science analysis is not the objective in these contributions, the papers contain an essential and/or complementary analysis of social, political or economic impacts. Finally, the

category including low-oriented social science articles comprises research focusing on science issues (e.g. chemistry, technology, health, biology, etc.). While all these articles include some insights into social sciences, these contributions are residual and not the main study aim.

A more in-depth analysis of the major contributions made by the 91 high-oriented articles allowed us to identify the principal topics and perspectives that are currently covered from a social science perspective. It also revealed pending issues and gaps in the study of the bioeconomy from a social science standpoint. In Figure 5, we summarise the resources and main issues already approached from a social science perspective.

### **INSERT FIGURE 5**

**Fig. 5. Main contributions of academic bioeconomy articles in social sciences**

#### 4.1. Bioenergy: clean energies and their sustainability

The bioeconomy is a political and economic proposal based on replacing fossil resources by biological resources. Therefore, it is logical that the central debates and frameworks around which social sciences revolve are: 1) sustainability; 2) implementation related to the positioning of the stakeholders (components): networks (interactions), institutions (rules) and infrastructures; and 3) consequences and impacts of implementing the bioeconomy.

Recently, the availability and cost of sustainable biomass seem to respond to the sustainability of the energy sector. Articles on increasing resource efficiency, sustainability and competition among energies are especially relevant. These topics appear within the framework of EU biofuel regime decisions, thus indicating the need

for greater integration between natural resources, climate, energy and nature conservation laws (Borgstrom, 2018).

The public debate on biofuels and their implementation as an object of interest in the academic field, especially in the European context, emerged in 2014 (Birch and Calvert, 2015; Puttkammer and Grethe, 2015). These works claim that the production of scientific knowledge in the biofuel field plays a key role in the literature on the bioeconomy (Hansen, 2014). In the context of the United States, implementation revolves around policy-based innovation and industry development (Kedron and Bagchi-Sen, 2017). In recent years, empirical studies have focused on examining the potential of plants as the new oil (Shortall et al., 2015).

Finally, concern for tools to measure the impacts within the bioeconomy has a central role in the articles. In this framework, studies aim to measure the sustainability of the transition in economic terms (Martin et al., 2018; Mattila et al., 2018). These contributions claim a need to integrate economic analysis and biophysical processes in policy design (Zilberman et al., 2018). Finally, another group of studies characterises the natural resource markets supporting biomass production (i.e. land supply and waste markets) or proposes ways to measure emissions to be considered in the design of governance systems (Philippidis et al., 2018, Eroy et al., 2018).

#### 4.2. Health: new industries and markets

An essential segment of scientific studies focuses on analysing the consequences of scientific and technological development in the field of biomedicine. These works deal with the appearance of new industries, markets and associated products (biobanks) related to research on cells, tissues or human organs. The commodification

of these new products linked to life and health generates interesting debates with ethical, political and social implications.

Some of the studies advise on the need for global regulations of these ‘new sub-sectors’, such as the umbilical cord stem cell market and placental banks (Fannin and Kent, 2015) or the human tissue market (Hauskeller and Beltrame, 2016). Other contributions focus on the assisted reproduction market, where biomedical practices and consumer choices are analysed (Schurr, 2017). Some papers analyse the geopolitical role and state strategies for regenerative medicine (Salter, 2009) and experimentation with stem cells to cure diseases such as cancer (Haase et al., 2015).

The social implications of the bioeconomy in the field of biomedicine, sometimes called the bioeconomy of the body (Tierney, 2016), are fundamentally related to drawing attention to the population’s unequal access to the benefits of new health industries on the rise (Hogarth, 2015; Ikemoto, 2015; Chen, 2015). The varying approaches within the articles show the coexistence of two economic models: gift or redistributive economies and market economies (Hauskeller and Beltrame, 2016; Tierney, 2016). The debate on these models concerns relevant ethical aspects related to participating in the economic benefits of biobank development (Timmons and Vezyridis, 2017). However, few studies have shown an interest in capturing the social perception, or social acceptance, of the innovations and developments in this sector (Fannin and Kent, 2015).

#### 4.3. Agriculture, land and food security

Zwier et al. (2015) state that ‘*the biobased economy is fully premised on thinking of scarcity and utility,*’ hence its tendency to highlight the existence of economic

problems regarding efficient production, especially in agriculture. Consequently, when studying European transitions, Levidow (2015) puts agriculture in a central place and analyses its role in the European agendas of the bioeconomy and the agroecology. Based on Levidow, these agendas embody current liberal neo-productivism and are the basis of EU strategies for assessing and addressing food and nutrition security challenges (Meijl, 2013).

The food security problem occupies a prominent place in the current bibliography since gaining in importance after the food scares in the 1990s (Ponte, 2009). The development of molecular biology has improved traditional farming and its application to agriculture has led to the introduction of genetically modified (GM) crops and the use of genetic engineering (GE). In 2015 it was estimated that these systems were applied to 180 million hectares in both developed (~ 50%) and developing (~ 50%) countries (Zilberman, 2015). The politics, legislation and conflicts of interest around this type of agriculture have occupied much of the debate on biotechnology. However, contributions also focus on analysing conflicts and social movements against GM herbicides and seeds in different regions (Beilin and Suryanarayanan, 2017; Schragger and Suryanata, 2018).

Another area of debate concerns the dilemma of food versus energy. Works on the effects of biofuel production on food security, supply and prices (with their consequences for poverty) are relevant. Some studies investigate scenarios that include an increase in raw materials, land use, energy generation, and projections for the labour market and income distribution or poverty (Ferreira and Bento, 2013). Finally, several articles focus on eco-efficiency (Kroger, 2016) and environmental adaptation (Varela-Candamio et al., 2018). Some of these studies propose designing

policies around renewable energies and implementing them in the agricultural sector (Tapio et al., 2017).

#### 4.4. Waste resources, chain value and industrial symbiosis

The bioeconomy and circular economy promote industrial convergence and symbiosis with major coordination among resource partnerships (Velenturf, 2017). The idea is to create new models involving a rupture of traditional networks of 'classical sectors' (e.g. forestry or agriculture) and the rise of new inter-industry segments. These inter-industry segments should coordinate a variety of perspectives and involve different agents (Golembiewski et al., 2015; Lilja and Moen, 2017; Nayha et al., 2015; Giurca and Metz, 2018; Kleinschmit et al., 2014).

Several contributions deal with waste reuse, recycling and repurposing. Some authors analyse the sustainable separation of natural products from waste: extraction, fractionation and purification (Zuin and Ramin, 2018). Other studies focus on technological or economic aspects of waste collection and processing (Thorenz et al., 2018; Husgafvel et al., 2018) or on its profitability (Cristobal et al., 2018).

Second-generation biomass resources, such as agricultural or forestry waste, are crucial for developing new bioeconomy industries. However, analyses of the value chains and markets for this waste remain uncommon (Mertens et al., 2018). The positioning of the stakeholders, their role in the value chains and the factors influencing their proper development is also a topic pending analysis (Mertens et al., 2018).

#### 4.5. Regulations, strategies and governance

Out of the 91 articles catalogued as high-oriented, 20 focus on governance matters. The bioeconomy is understood as a political project and an opportunity for development (Goven and Pavone, 2015; Devaney et al., 2017; Rosegrant et al., 2013). Several contributions in this group deal with implementing the political economy perspective on the dichotomy of national versus regional development. Relevant publications focus on how the bioeconomy could open new possibilities for rural environments (Valera-Candamio et al., 2018; Iagaru and Iagaru, 2017; Kuhmonen and Kuhmonen, 2015). Rural areas are considered fertile ground for the growth of grassroots-level innovations in the field of bioenergy (Kokkonen and Ojanen, 2018), wood-based products and the plant-based bioeconomy (Siebert et al., 2018; Ehrenfeld and Kropfhaeusser, 2017; Pannicke, 2015), or biotechnology applications (Grebenyuk and Ravin, 2017).

Several authors demand a more sophisticated analysis of regions' economic potential with the aim of designing policies and strategies with possibilities of success (Ronzon et al., 2017; Philippidis et al., 2018). It should be noted here that the economic quantification of the contributions of the bioeconomy is extremely complex because the boundaries between the bioeconomic and traditional sectors are not delimited and several value chains are not formally established (Hermans, 2018). However, qualitative methods (Scordato et al., 2018), social network analyses (Giurca and Metz, 2018), or computer models (Holtz et al., 2015) can provide complementary and necessary insights to complete the analysis.

We also need to refer to the considerable criticism made of the bioeconomic model. The main criticism rests upon the idea that the bioeconomy is built on possibilities that raise expectations and cause disappointments. The bioeconomy promises economic growth and environmental improvements by converting biological

resources into food, feed, fuel, chemicals or fibre (Devaney and Henchion, 2018); it is shaped as a promissory economy where ‘high-tech’ industries, sociotechnical futures and new forms of value come together (Martin, 2015). However, these changes are slow and complex because they affect existing institutional rules, regulations and culture (Van den Bergh et al., 2011; Hermans, 2018). The political process that must drive the transition should address innovation coalitions and the public debate on the benefits and dangers of the bioeconomy. It is a collective task to promote the transition from ‘regimes of hope’ to ‘regimes of truth’, where appearing to succeed is less important than succeeding (Ponte, 2009).

These papers are generally linked to bioeconomic implementation and methods as a way of achieving the sustainable development of economies. Although there are multiple approaches, most of these contributions deal with territorial issues, social perceptions, regional development and stakeholder engagement. A common feature is using social methodologies and the differentiated role of consumers and producers. This category also includes several contributions based on an economic perspective with a quantification of private and environmental impacts based on case studies and specific bioresources. Finally, another group of contributions is related to policies and regulations required for correct implementation of bioeconomic elements in societies.

##### 5. Discussion: the bioeconomy as a need, opportunity and risk

Current production and consumer patterns are causing several environmental problems worldwide. Human activities are the main driver of the intense depletion and contamination of natural resources, which is hampering global economic growth and society welfare. In this context, the concepts of bio-based societies and the

bioeconomy have emerged as possible solutions for sustainable development. The bioeconomy is a way to implement biotechnologies in the production process to respect natural resources while promoting economic development. Bioeconomy studies have proliferated in recent decades; however, most of the developments are still based on a science perspective, with social science contributions still representing a small part of the analysis.

The above assessment highlights how studying the bioeconomy from a social science perspective is quite recent. We have identified a general important gap in empirical studies aiming to estimate the impacts of implementing the bioeconomy. Furthermore, out of all the empirical studies examined, a large proportion is based on quantitative evaluations, without a proper quantification of social, economic, environmental or political impacts. In general, analysing the topics reveals how most of the publications are related to industrial applications and biotechnology development. Several studies incorporate a discussion based on social impacts or the promotion of sustainable development. However, pure social-oriented articles based on economics, politics or social issues have begun to be prominent in recent years. The first articles related to economic analysis, including finance and accounting publications, date back to 2009, although their number did not increase until 2017. We observe a similar behaviour with articles based on regional and rural development. The first article published on the bioeconomy within the category of social sciences is based on governance issues. Nevertheless, this topic did not start to be consolidated until 2015. The other contributions are surveys or theoretical contributions related to legal, normative and policy implications.

An in-depth analysis of the selected contributions indicates that the study of the bioeconomy in social sciences presents several shortcomings. Firstly, we can observe

that the topics covered in this field are very limited (Figure 5). The study of specific bioresources focuses on: 1) energy-related issues; 2) agricultural and food security sector; 3) health market and human tissues; 4) waste resources and recycling; and 5) strategies, policies and governance of bioresources. We agree with Hermans (2018) that there is a gap in studies on the spatial dimension and scale of transition to a bioeconomy. Additionally, empirical research based on case studies incorporating sociological and ecological perspectives is necessary (Raven et al., 2012; Thomas et al., 2018). Finally, the need to address how bioeconomic initiatives impact stakeholders (firms, bioclusters, policy, institutions) is a relevant question that has been ignored. The comparative analysis of the evolution of the dynamics in the bioeconomy, including regional contexts, agents and bioresources, will make it possible to highlight the factors facilitating and hindering the transition to bio-based societies.

Social sciences have been part of bioeconomy debates, mainly related to the above-mentioned topics, in three essential ways: a) arguing the need for a transition to the bioeconomy; b) highlighting the opportunities of territories within the framework of the bioeconomy; and c) making critical aspects of the model visible to risks, disagreements or conflicts. Based on the reviewed articles, we found a few issues among the subjects covered and the topics analysed.

Further contributions analysing the role played by stakeholders in ‘innovation niches’ that activate bioeconomic dynamics are necessary. Concerning interactions, more studies are also needed on the process of orchestrating multiple actors and the mechanisms for forming networks of collaboration or competition. Additionally, analyses on the regulation of the bioeconomy, the role of politicians and failures of innovation systems are fundamental (Weber and Rohrer, 2012). Finally, cultural

studies on values, social norms, entrepreneurial spirit and attitudes of the population are scarce, since this is an essential link for changes in production systems. We have also identified significant shortcomings in studies based on education, educational innovation, the evolution of values and attitudes, social entrepreneurship, responsible consumerism and interactive learning.

In Figure 6 we show the major bioeconomic topics already analysed from a social science perspective. We also highlight what we believe are the main shortcomings that this literature has not properly addressed yet.

INSERT FIGURE 6

**Fig. 6. State-of-the-art, trends and new challenges for the bioeconomy**

While social issues have been addressed in the bioeconomic literature, others remain pending. In our opinion, proper evaluations of the impacts, both positive and negative, of the transition to a bioeconomy are largely lacking, especially in empirical studies. While some regional analyses based on specific bioresources have been conducted, global perspectives are practically non-existent. Additionally, social sciences have focused on impacts on the production-side, while consumption-oriented and social-oriented contributions are residual. Another extremely important issue, the education and behaviour of societies to internalise the necessity of a sustainable development, is also scarce. In the political context, most of the academic contributions are theoretical. There are also several gaps in the analysis of how to implement bioeconomic strategies and regulations, especially in a global context. Implementing policies and regulations necessarily involves the participation of society as a whole

and the cooperation of all stakeholders. Again, not much work has been based on assessing agents' perceptions and on how to engage stakeholders to make bioeconomy strategies successful.

Finally, in our opinion two main issues remain pending: consumers and the environment. Little interest has been shown in studies of the environmental impacts of implementing the bioeconomy, and scant attention has been paid to the consumer side and market assimilation of the processes and innovations that the transition to a bioeconomy involves. There is an obvious risk in transitioning to a bioeconomy if the main social impacts and consequences are neither clear nor perfectly understood. Consequently, academic analyses under the perspective of social sciences are largely necessary to shed light on these challenges.

## 6. Concluding remarks

The bioeconomy is a political and economic project that gains ground as a regional development agenda in many countries. The concern for sustainability in both production and consumption has generated growing interest and regulations in transitioning to a sustainable economy based on the use of renewable biological resources. In 2014 it was estimated that around 13% of world trade had a biological origin (El-Chichakli et al., 2016). Considering the growing social and political interest, scientific production has increased considerably in recent decades. However, most analyses are based on a biotechnological perspective with hardly any proliferation of socioeconomic impacts or evaluation of bioeconomy effects and challenges.

The relevant elements for developing a bio-based economic policy are the use of water, energy and land resources (Rosegrant et al., 2013; Hertel et al., 2013). Competition for resources generates conflicts between interested parties and between territories, and it also anticipates risks with significant human and environmental consequences. This may result in critical social inequalities mainly related to access to energy, food or water resources that require adequate international regulatory frameworks (Kotsakis, 2014). The change towards sustainable economic models is unaffordable without engaging stakeholders and receiving the social acceptance of sociotechnical changes that accompany the transition towards a new global economy and society.

Our study analyses contributions to the bioeconomy published as articles and reviews classified in the field of social sciences in the Institute for Scientific Information (ISI) Web of Science (WoS) up until May 2018. The focus of this paper is the analysis of academic publications collected in the WoS. Therefore, we have not reviewed any other document types (e.g. working papers, political strategies, etc.) that could contain several insights and analyses of the social contributions to the bioeconomy. Every contribution has been evaluated on the basis of three criteria: chronological, methodological and thematic. These analyses have helped us to determine the current state-of-the-art in bioeconomy publications under the scope of social sciences.

The results suggest that most of the current analysis of the bioeconomy relates to genetics, chemistry, biotechnology, energy or biology issues. However, a proper interpretation of the significant implications of the bioeconomy from a social and economic perspective is still scarce. A more in-depth analysis of the articles, especially those with a higher content in social sciences, indicates the existence of several gaps in both the methodologies covered and in the bioresources studied. In

general, more empirical research and the development of mixed and refined methodologies are required. Studies have evolved from being theoretical (essays, general analyses and documentary studies) to empirical, with a significant presence of case studies, especially until 2018, when quantitative studies became more predominant. Since the complexity of the study of the bioeconomy tests the methods in social sciences and highlights limitations, new methodologies are required. We believe that the field of bioeconomy lacks mixed methodological designs and needs multidisciplinary research. In short, the studies lack a holistic and multidisciplinary vision that can account for such a multidimensional and complex reality, although a trend towards greater interdisciplinary cooperation in addressing the bioeconomy is visible.

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## Appendix. List of studies in the ISI Web of Science (WoS) related with bioeconomy under the category of Social Sciences

**Table A1.** Studies included in the analysis

Author	Journal	Year
Cristobal et al.	BIORESOURCETECHNOLOGY	2018
Shields-Menard et al.	BIORESOURCETECHNOLOGY	2018
Quinteiro et al.	SCIENCE OF THE TOTAL ENVIRONMENT	2018
Carraresi et al.	JOURNAL OF CLEANER PRODUCTION	2018
Varela-Candamio et al.	JOURNAL OF CLEANER PRODUCTION	2018
Scordato et al.	JOURNAL OF CLEANER PRODUCTION	2018
Bravo et al.	JOURNAL OF ENVIRONMENTAL MANAGEMENT	2018
Thomas et al.	AMBIO	2018
Kokkonen and Ojanen	JOURNAL OF CLEANER PRODUCTION	2018
Eory et al.	JOURNAL OF CLEANER PRODUCTION	2018
Philippidis et al.	ECOLOGICAL ECONOMICS	2018
Kwan et al.	BIORESOURCETECHNOLOGY	2018
Husgafvel et al.	JOURNAL OF CLEANER PRODUCTION	2018
Taddeo et al.	JOURNAL OF ENVIRONMENTAL MANAGEMENT	2018
Hemmerich et al.	BIOTECHNOLOGY JOURNAL	2018
Schrager and Suryanata	JOURNAL OF AGRARIAN CHANGE	2018
Spasic et al.	APPLIED MICROBIOLOGY AND BIOTECHNOLOGY	2018
Chatterjee and Mohan	BIORESOURCETECHNOLOGY	2018
Joyce et al.	FRONTIERS IN MICROBIOLOGY	2018
Panagiotou et al.	JOURNAL OF CLEANER PRODUCTION	2018
Zabaniotou	JOURNAL OF CLEANER PRODUCTION	2018
Krzyzaniak et al.	JOURNAL OF CLEANER PRODUCTION	2018
Ylimartimo	BIOFUELS BIOPRODUCTS & BIOREFINING-BIOFPR	2018
Hermans	BIOFUELS BIOPRODUCTS & BIOREFINING-BIOFPR	2018
Silva et al.	BIOFUELS BIOPRODUCTS & BIOREFINING-BIOFPR	2018
Evangelatos et al.	OMICS-A JOURNAL OF INTEGRATIVE BIOLOGY	2018
Ciriminna et al.	CHEMISTRYOPEN	2018
Giurca and Metz	ENVIRONMENTAL INNOVATION AND SOCIETAL TRANSITIONS	2018
Ciriminna et al.	ACS SUSTAINABLE CHEMISTRY & ENGINEERING	2018
Zilberman et al.	APPLIED ECONOMIC PERSPECTIVES AND POLICY	2018
Perez-Camacho et al.	WASTE MANAGEMENT	2018
Olsson et al.	WILEY INTERDISCIPLINARY REVIEWS-ENERGY AND ENVIRONMENT	2018
Ingle et al.	BIOENERGY RESEARCH	2018
Siebert et al.	INTERNATIONAL JOURNAL OF LIFE CYCLE ASSESSMENT	2018
Borgstrom	FOREST POLICY AND ECONOMICS	2018
Park et al.	TRENDS IN BIOTECHNOLOGY	2018
Thorenz et al.	JOURNAL OF CLEANER PRODUCTION	2018
Devaney and Henchion	JOURNAL OF CLEANER PRODUCTION	2018
Delisi et al.	JOURNAL OF CLEANER PRODUCTION	2018
Farinas et al.	JOURNAL OF RENEWABLE MATERIALS	2018
Zuin and Ramin	TOPICS IN CURRENT CHEMISTRY	2018
Martin et al.	SUSTAINABILITY	2018
Radulescu et al.	SUSTAINABILITY	2018
Mertens et al.	BIOMASS & BIOENERGY	2018
Mattila et al.	BIOMASS & BIOENERGY	2018
Matthies et al.	ECOSYSTEM SERVICES	2018
Korhonen et al.	CANADIAN JOURNAL OF FOREST RESEARCH	2018
Eriksson et al.	PHYSIOLOGIA PLANTARUM	2018
Peinemann and Pleissner	APPLIED BIOCHEMISTRY AND BIOTECHNOLOGY	2018
Satari and Keikhosro	RESOURCES CONSERVATION AND RECYCLING	2018
Birch	CULTURAL STUDIES OF SCIENCE EDUCATION	2017
Carter	CULTURAL STUDIES OF SCIENCE EDUCATION	2017
Aarden	SCIENCE AND PUBLIC POLICY	2017
Braun	DEVELOPING WORLD BIOETHICS	2017
Beilin and Suryanarayanan	ENVIRONMENTAL HUMANITIES	2017

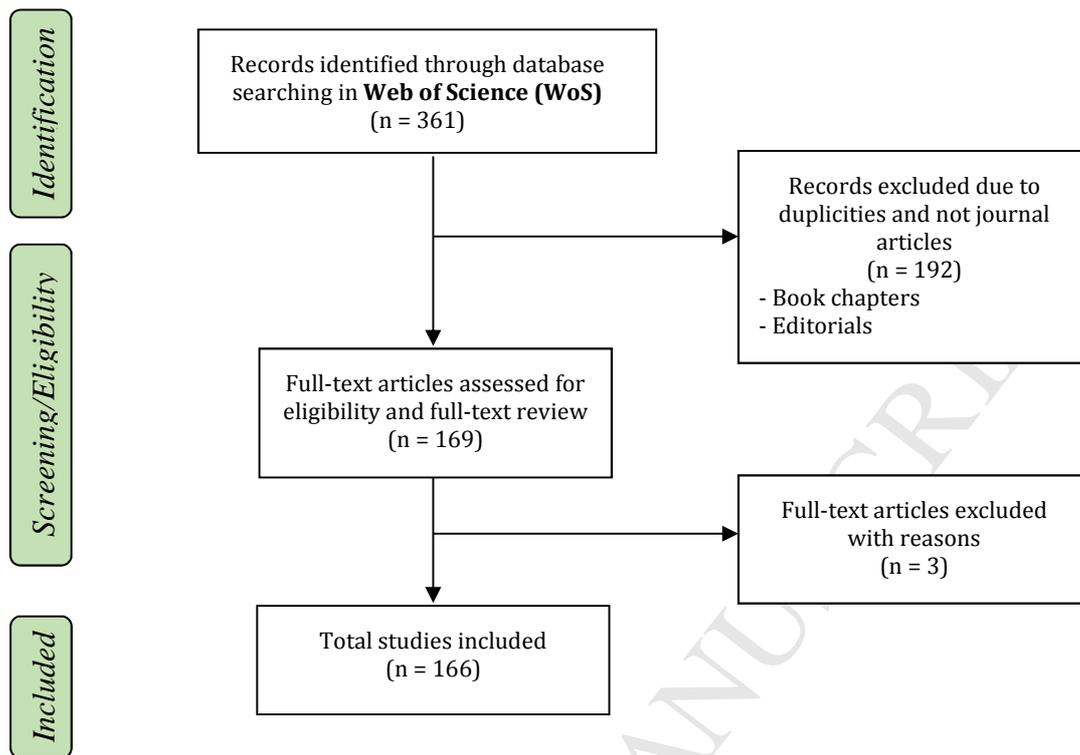
Dowdall	SCIENCE-FICTION STUDIES	2017
Timmons and Vezyridis	SOCIOLOGY OF HEALTH & ILLNESS	2017
Mukhtarov et al.	ENVIRONMENT AND PLANNING C-POLITICS AND SPACE	2017
Borge and Broering	CREATIVITY AND INNOVATION MANAGEMENT	2017
Devaney et al.	EUROCHOICES	2017
Straus	JOURNAL OF INTELLECTUAL PROPERTY LAW & PRACTICE	2017
Devaney and Henschion	ECONOMIC AND SOCIAL REVIEW	2017
Dumeignil et al.	JOURNAL OF CHEMICAL EDUCATION	2017
Birch	SCIENCE TECHNOLOGY & HUMAN VALUES	2017
Kedron and Bagchi-Sen	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	2017
Ehrenfeld and Kropfhaeusser	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	2017
Blair et al.	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	2017
Toppinen et al.	FUTURES	2017
Tapio et al.	FUTURES	2017
Schurr	ENVIRONMENT AND PLANNING D-SOCIETY & SPACE	2017
Bran	QUALITY-ACCESS TO SUCCESS	2017
Ciobanu et al.	QUALITY-ACCESS TO SUCCESS	2017
Tupasela	BIOSOCIETIES	2017
Ryman	INTERNATIONAL JOURNAL OF FEMINIST APPROACHES TO BIOETHICS	2017
Wield et al.	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	2017
Medina-Molotla et al.	TECHNOLOGY IN SOCIETY	2017
Szekacs	JOURNAL OF AGRICULTURAL & ENVIRONMENTAL ETHICS	2017
Alexandra	AUSTRALASIAN JOURNAL OF REGIONAL STUDIES	2017
Velenturf	REGIONAL STUDIES REGIONAL SCIENCE	2017
Lilja and Moen	INTERNATIONAL JOURNAL OF BUSINESS ENVIRONMENT	2017
Iagaru and Iagaru,	SCIENTIFIC PAPERS-SERIES MANAGEMENT ECONOMIC ENGINEERING IN AGRICULTURE AND RURAL DEVELOPMENT	2017
Gaitis and Ouzounidou,	JOURNAL OF INNOVATION ECONOMICS & MANAGEMENT	2017
Serban et al.	TRANSFORMATIONS IN BUSINESS & ECONOMICS	2017
Johnson	NEW GENETICS AND SOCIETY	2017
Grebenyuk and Ravin	FORESIGHT	2017
Saardchom	AGRICULTURAL ECONOMICS-ZEMEDELSKA EKONOMIKA	2017
Ronzon et al.	BIO-BASED AND APPLIED ECONOMICS	2017
Hogarth	NEW GENETICS AND SOCIETY	2017
Kragh-Furbo and Tutton	NEW GENETICS AND SOCIETY	2017
Crath and Rangel	CULTURE HEALTH & SEXUALITY	2017
Grundel and Dahlstrom	JOURNAL OF THE KNOWLEDGE ECONOMY	2016
Attebery	MEDICAL HUMANITIES	2016
Tierney	SOCIOLOGICAL THEORY	2016
Hauskeller and Beltrame	BIOSOCIETIES	2016
Colombino and Giaccaria	ENVIRONMENT AND PLANNING D-SOCIETY & SPACE	2016
Hoeltinger et al.	ENERGY POLICY	2016
Borgstrom and Mauerhofer	JOURNAL OF ENERGY & NATURAL RESOURCES LAW	2016
Salter et al.	SCIENCE TECHNOLOGY & HUMAN VALUES	2016
Sleehoff and Osseweijer	PUBLIC UNDERSTANDING OF SCIENCE	2016
Kroger	JOURNAL OF PEASANT STUDIES	2016
Lochhead et al.	ENERGY ECONOMICS	2016
Neimark	JOURNAL OF RURAL STUDIES	2016
Mouritsen and Kreiner	ACCOUNTING ORGANIZATIONS AND SOCIETY	2016
Sisto et al.	FUTURES	2016
Hauskeller and Beltrame	NEW GENETICS AND SOCIETY	2016
Jeong	NEW GENETICS AND SOCIETY	2016
Martin	BIOSOCIETIES	2015
Kuhmonen and Kuhmonen	TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	2015
Guthman	ENVIRONMENT AND PLANNING A	2015
Tironi and Farias	GEOFORUM	2015
Shortall et al.	ENERGY POLICY	2015
McDonagh	PROGRESS IN HUMAN GEOGRAPHY	2015
Levidow	JOURNAL OF RURAL STUDIES	2015
Sleehoff et al.	ECOLOGICAL ECONOMICS	2015
Festel	INTERNATIONAL JOURNAL OF INNOVATION MANAGEMENT	2015
Golembiewski and Broering	INTERNATIONAL JOURNAL OF INNOVATION AND TECHNOLOGY MANAGEMENT	2015

Asveld et al.	JOURNAL OF AGRICULTURAL & ENVIRONMENTAL ETHICS	2015
Chen	EAST ASIAN SCIENCE TECHNOLOGY AND SOCIETY-AN INTERNATIONAL JOURNAL	2015
Goven and Pavone,	SCIENCE TECHNOLOGY & HUMAN VALUES	2015
Hogarth	SOCIAL SCIENCE & MEDICINE	2015
Zwart et al.	JOURNAL OF AGRICULTURAL & ENVIRONMENTAL ETHICS	2015
Zwier et al.	JOURNAL OF AGRICULTURAL & ENVIRONMENTAL ETHICS	2015
Haase et al.	SOCIAL SCIENCE & MEDICINE	2015
Jaffe	INTELLIGENT SYSTEMS IN ACCOUNTING FINANCE & MANAGEMENT	2015
Johnson and Goldstein	ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS	2015
Petersen and Krisjansen	JOURNAL OF SOCIOLOGY	2015
Kent and Farrell	BODY & SOCIETY	2015
Ikemoto	JOURNAL OF LAW AND THE BIOSCIENCES	2015
Fannin and Kent	NEW GENETICS AND SOCIETY	2015
Birch and Calvert, Kirby	SCIENCE AND TECHNOLOGY STUDIES	2015
Viaggi	BIO-BASED AND APPLIED ECONOMICS	2015
Zilberman et al.	GERMAN JOURNAL OF AGRICULTURAL ECONOMICS	2015
Pannicke et al.	GERMAN JOURNAL OF AGRICULTURAL ECONOMICS	2015
Puttkammer and Grethe	GERMAN JOURNAL OF AGRICULTURAL ECONOMICS	2015
Goldstein and Johnson	THEORY CULTURE & SOCIETY	2015
Nayha et al.	FORESIGHT	2015
Miller	JOURNAL OF RESPONSIBLE INNOVATION	2015
Rosemann	SOCIAL SCIENCE & MEDICINE	2014
Kotsakis	TRANSNATIONAL ENVIRONMENTAL LAW	2014
Hansen	SCIENCE AS CULTURE	2014
Pradhan and Ruysenaar	ENVIRONMENT AND PLANNING A	2014
Horlings and Marsden	EUROPEAN URBAN AND REGIONAL STUDIES	2014
Petersen	SOCIAL SCIENCE & MEDICINE	2013
Fannin	BODY & SOCIETY	2013
Wield	TECHNOLOGY ANALYSIS & STRATEGIC MANAGEMENT	2013
Swinnen and Riera	AGRICULTURAL ECONOMICS	2013
Ferreira and Bento	AGRICULTURAL ECONOMICS	2013
Zilberman et al.	AGRICULTURAL ECONOMICS	2013
Deininger	AGRICULTURAL ECONOMICS	2013
Hertel et al.	AGRICULTURAL ECONOMICS	2013
Rosegrant et al.	AGRICULTURAL ECONOMICS	2013
Bureau and Sebastien	AGRICULTURAL ECONOMICS	2013
Abergel and Magnusson	TOPIA-CANADIAN JOURNAL OF CULTURAL STUDIES	2013
Mackenzie et al.	SCIENCE TECHNOLOGY & HUMAN VALUES	2013
Andreasen	BIOSOCIETIES	2009
Low and Isserman,	ECONOMIC DEVELOPMENT QUARTERLY	2009
Salter	GEOPOLITICS	2009
Porter et al.	JOURNAL OF MAPS	2009
Waldby	NEW GENETICS AND SOCIETY	2009
Ponte	SCIENCE AS CULTURE	2009
Kent	SOCIAL SCIENCE & MEDICINE	2008
Waldby	NEW GENETICS AND SOCIETY	2008
Martin et al.	NEW GENETICS AND SOCIETY	2008
Cooke	EUROPEAN PLANNING STUDIES	2006
Davies	TRANSACTIONS OF THE INSTITUTE OF BRITISH GEOGRAPHERS	2006
Lehtonen	ECOLOGICAL ECONOMICS	2004

<i>String</i>	Total	Science	Social Sciences*
'Bioeconomy'	614	476	138
'Bio-economy'	169	135	54
'Bioeconomy' OR 'Bio-economy'	738	573	169

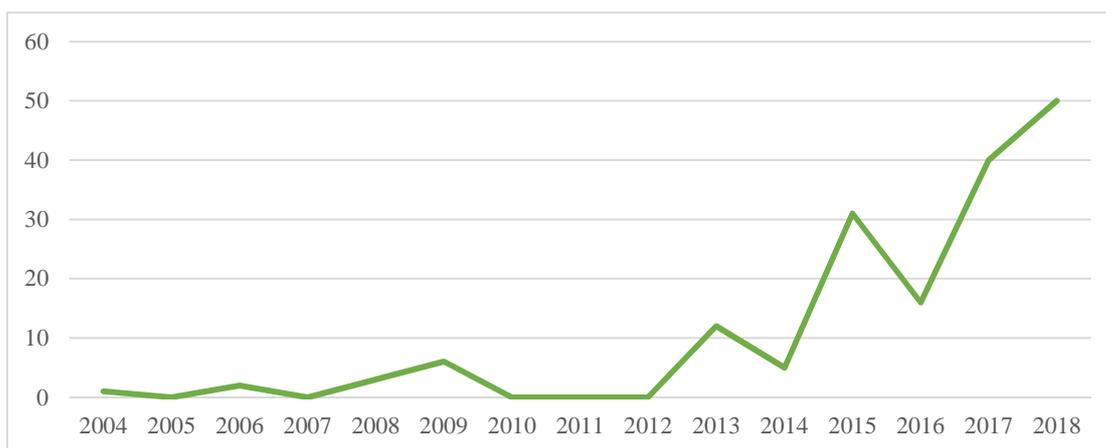
**Table 1. Number of articles and reviews by string and subject area from WoS**

\*Subject areas in WoS included in our definition of 'social sciences': economics, social sciences biomedical, planning development, management, history philosophy of science, social issues, geography, agricultural economics policy, sociology, business, business finance, ethics, cultural studies, public administration, law, educational research, anthropology, humanities multidisciplinary, behavioural sciences, political science, and urban studies.

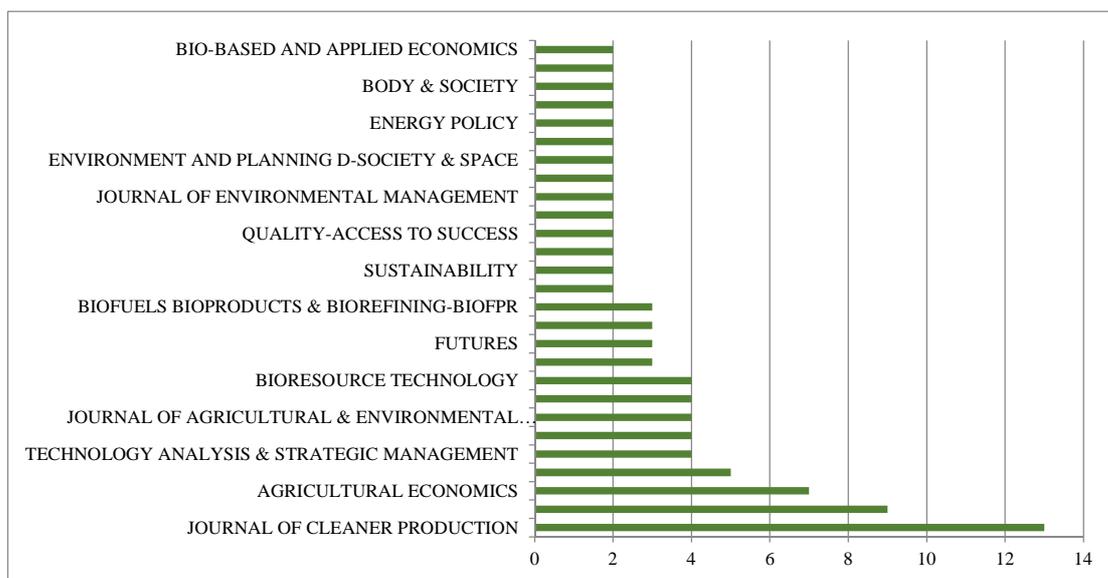


**Fig. 1. Flow diagram of the literature exploration and selection process**

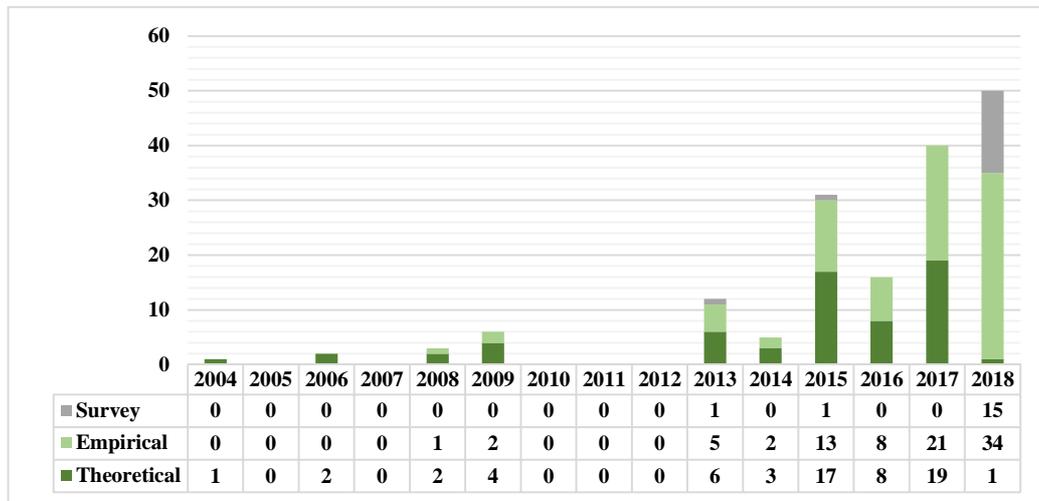
*Source:* Adapted from Moher et al. (2009)



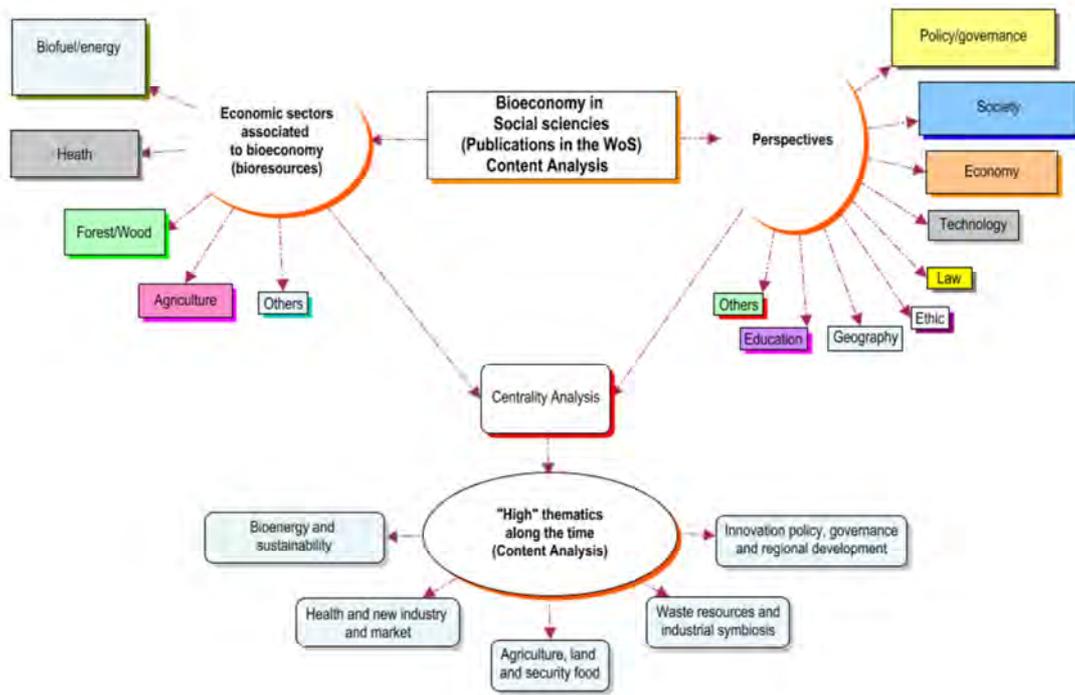
**Fig. 2. Number of contributions in WoS with the topic of bioeconomy and classified in the field of social sciences**



**Fig. 3. Journals with more than one contribution in bioeconomy research in social sciences**



**Fig. 4. Number of articles based on their principal methodologies**



**Fig. 5. Main contributions of bioeconomy articles in social sciences**

State-of-the-art	Trends	Challenges: to a bioeconomy agenda
<ul style="list-style-type: none"> <li>• Lack of social sciences' studies in the bioeconomy</li> <li>• Significant inequalities between disciplines contribution (e.g., absence of studies from anthropology, psychology, education, etc.)</li> <li>• High concentration of the empirical studies and case-studies in a few countries</li> <li>• Residual contributions of the social sciences' implications of biotechnology developments and applications</li> <li>• Low interest in social sciences' journals for publishing this topic</li> <li>• Significant weight of theoretical contributions</li> <li>• Lack of studies with centring the analysis in the individual role or actors' perspective</li> <li>• Large interest in analyses based on the optimization and efficiency of biotechnological developments and bio-based outputs</li> <li>• Focus on the supply chains: bio-resources, processes, bio-products, markets</li> <li>• Predominance of analyses on the political implications of the bioeconomy: governance and rural development</li> <li>• Most of the empirical studies cover regional and specific bio-resources. Global impacts of the bioeconomy are residual</li> </ul>	<ul style="list-style-type: none"> <li>• Social-awareness is starting of being relevant</li> <li>• Recent increases in academic contributions with a social science' objective in bioeconomy analyses</li> <li>• Gradually emergence of multidimensional analysis</li> <li>• Increase in the concern on social impacts by different countries and disciplines</li> <li>• Recent interest in empirical studies with valuation of the bioeconomy impacts</li> <li>• Increase in the relevance of the demand-side and the consumer behavior</li> <li>• Social integration in bioeconomy studies is pushed by the institutional framework (e.g. Sustainable Development Agenda 2030, UN)</li> </ul>	<p>Requirement for broad social analyses on the interactions and roles of the stakeholders and actors</p> <ul style="list-style-type: none"> <li>• <b>Scientific and Technical:</b> assessment of the negative and positive impacts on societies of the implementation of new bio-processes and outputs</li> <li>• <b>Economic:</b> <ul style="list-style-type: none"> <li>• Analysis on production and consumption patterns and the combination between them</li> <li>• Analysis of economic optimization and efficiency: valuation studies</li> <li>• Analysis of the dynamics and impacts of new economic, social, and political interactions</li> <li>• Studies on the demand chain perspective</li> </ul> </li> <li>• <b>Policy and Governance:</b> <ul style="list-style-type: none"> <li>• Interdependency between related agents</li> <li>• Analysis of social perception and stakeholders' engagement</li> <li>• Impact on the implementation of policies and rules for a bioeconomy transition</li> <li>• Regulation of natural resources and the impacts of bio-based processes</li> <li>• Implementation of sustainable policies in regional and global context</li> <li>• Analysis of inequality problems: 'just transition'</li> </ul> </li> <li>• <b>Ecological, Cultural and Educational:</b> <ul style="list-style-type: none"> <li>• Analysis of the regions to include bio-resources as principal elements into the production processes</li> <li>• Reducing dependence on carbon-based fuels and promotion of cleaner production</li> <li>• Common future, values and achievements of the SGDs</li> <li>• Promotion of social and ecological awareness</li> <li>• Promotion of environmental identities</li> </ul> </li> </ul>

Fig. 6. State-of-the-art, trends, and new challenges for the bioeconomy

## TRANSITION TO A BIOECONOMY: PERSPECTIVES FROM SOCIAL SCIENCES

### Highlights

- Significant gaps in bioeconomy contributions from a social science perspective
- Lack of multidimensional studies on socioeconomic impacts
- Mixed and refined methodologies are required, especially, empirical studies
- Academic studies on the bioeconomy require a major focus on opportunities and risks