

Review

# Bioeconomy—A Systematic Literature Review on Spatial Aspects and a Call for a New Research Agenda

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**Abstract:** Over the last 10 to 15 years, bioeconomy (BE) has evolved to a widely accepted alternative to the dominant use of finite raw materials around the globe. One of the essential prerequisites for the sustainable implementation of this future-oriented economic system is the consideration of spatial framework conditions. This review assesses whether spatial aspects are addressed in the scientific discourse on the bioeconomy. Between 2010 to 2021, 8812 articles were published dealing with the thematic field of bioeconomy. Using a keyword list covering themes related to spatial issues, 107 articles were identified. It was possible to demonstrate that spatial aspects are rarely discussed and large research gaps are evident. These gaps relate, for example, to the development of planning instruments for the protection of agricultural land or the assessment of the influence of intensification of agriculture on biodiversity or the multifunctionality of landscapes. In addition, the social aspects of transitioning to a bioeconomy, the role of regional planning with respect to decentralised versus centralised models, and the influence of policy and governance to foster a sustainable transition process and to avoid land use conflicts are all topics which need to be addressed in research. Based on these results, a research agenda was developed covering these and further issues to enable a sustainable spatial implementation of different forms of bioeconomy.

**Keywords:** bioeconomy; spatial planning; agriculture; regional development; ecosystem services; governance; land use change; social sustainability; priority zones; soil protection



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## 1. Introduction

In 2022, we can look back on a decade in which the bioeconomy (BE) has evolved from a theoretical economic concept to a widely accepted alternative to the dominant global system of using finite raw materials. This acceptance includes both political and scientific opinions. The former can be seen in the numerous national strategies developed in Europe and worldwide since 2010. Specific strategies were published by 10 of the 27 European Union members by April 2022. An additional seven strategies are being developed and a further six policy initiatives are dedicated to BE [1]. Currently, there are 49 bioeconomy or bioeconomy-related strategies available worldwide. [2]. At the same time, the scientific community has been dealing more often and more intensively with the topic of BE. This is demonstrated by a simple search in two extensive citation databases—Scopus and Web of Science (WOS)—with the keyword “bioeconomy”, showing an increase in published articles from around 20 in 2010 to around 1200 in 2021 (WOS), and from 27 in 2010 to 1000 in 2021 (Scopus). In addition to articles in scientific disciplines such as environmental sciences, economy, agriculture and forestry, biotechnology or energy, scientists have also dealt with cross-sectoral topics over the years, such as sustainable transformation processes [3], socio-economic aspects [4], the influence of politics [5] or the definition of the term bioeconomy per se. The latter, for example, by Bugge et al. [6], was based on a literature review. Other topics of bioeconomy have also already been addressed and examined in detail using this method. These include, for example, the necessary adaptation processes of

bioeconomy [7], the Life Cycle Analysis (LCA) of forest-based bioeconomy products [8] or trends in publications in the field of economics and business management [9].

As Grossauer and Stoeglehner noted [10], spatial aspects are often indirectly addressed in BE strategies and are, for example, referred to within topics such as land use, regional development, renewable resources or strategic objectives. The direct context of spatial planning is very rarely established. To examine this context, five spatial planning core themes were established by Grossauer and Stoeglehner (2020) to explicitly deal with the spatial aspects of the bioeconomy. These core themes comprise (1) the reduction of land consumption for a built-up environment, (2) the protection of agricultural as well as (3) ecological priority areas, (4) the optimisation of resource use and, (5) the inclusion of bioeconomy developments and their stakeholders in participatory planning processes. It became evident to the authors that there was a necessity to investigate these spatial aspects in the scientific literature. A decision was made to conduct a comprehensive review of the literature in order to clarify this issue.

In the authors' opinions, the preservation of bio-productive land is the prerequisite for a successful transition of our economic system to the use of renewable raw materials. Even if oceans will be available as sources in the future, only agriculture and forestry can presently provide raw materials in sufficient quantities for a wide range of products. At the same time, the required productive land is continually decreasing. This is caused, for example, by settlement expansion, infrastructure development or soil degradation and loss. Therefore, the review addresses all aspects of biological production (except soil quality) from the perspective of food and fibre. It narrows down the issue of energy transition to land use conflicts of agriculture and forestry. By implication, research fields that do not have a spatial focus due to their content and nature, such as biotechnology, were excluded from the review.

The following research questions are derived from these framework conditions: Is the context of spatial planning reflected in the scientific literature concerning the bioeconomy? Is the spatial relevance of the bioeconomy addressed? The final output of this article should be the development of a research agenda for spatial aspects of the bioeconomy.

## 2. Materials and Methods

The following paragraphs firstly explain the selection process applied to the final 107 documents which were reviewed and, secondly, assign them to the five core themes.

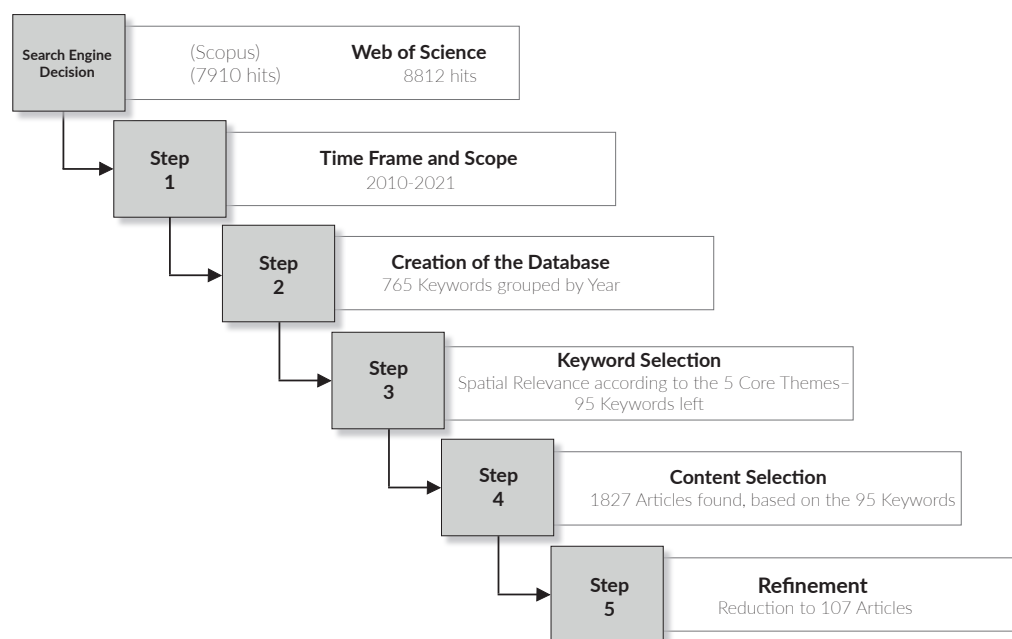
### 2.1. Selection of the Documents

Before starting the selection process of articles with spatial planning issues, the decision had to be made which of the two major search engines—Scopus and Web of Science (WOS)—should be used. To clarify this, a keyword search was carried out with the terms “bioeconomy”, “bio-economy” and “bio economy”, which are used in parallel and synonymously in the scientific literature. The query produced a total of 7910 hits with Scopus and 8812 hits with WOS (which is 11.5% more). Breaking down the results for each, WOS and Scopus, it shows the following numbers: “bioeconomy 3819/3002, “bio-economy” 695/610 and “bio economy” 5646/4298. It was therefore decided to use the WOS search engine as a more comprehensive result could be expected. The review was conducted in five steps (see also Figure 1):

**Step 1—Timeframe and Scope:** The review was carried out in January 2022 and included the time frame from 2010 to 2021 without further restrictions. 2010 was chosen as the beginning of the study because the first national bioeconomy strategy within Europe was published in Germany in that year [11]. The strategy was translated and published in English in 2011 [12]. The documents found were sorted by year.

**Step 2—Creation of a Database:** The content of the keyword list from each article was copied and compiled in an MS Excel file and subsequently sorted by years. Terms occurring several times were only listed once. Articles without a keyword list were marked and included in step 3.

Step 3—Keyword Selection: Keywords with a spatial relevance were selected (see Table A1, Appendix A). The five main core themes of spatial planning according to Grossauer & Stoeglehner (2020) served as the basis for selection: sustainable settlement development, establishment of agricultural priority areas, establishment of ecological priority areas, optimisation of resource use and planning processes. The zoning and establishment of priority areas is a direct way of protecting agricultural land from loss through settlement and infrastructure development. Various planning principles come into play in the case of sustainable settlement development. These include, for example, a mixture of spatial functions, adequate density, and the reuse of abandoned building land. During the selection process, it turned out that it was necessary to further subdivide three of the five core themes to provide a thematically clearly structured analysis, as the range of topics was very broad in parts. For example, the establishment of ecological priority areas, where, on the one hand, the preservation of biodiversity is an issue, and, on the other hand, the protection of small-structured landscapes. Both are threatened by the intensification of agriculture. The optimisation of resource use also specifically addresses the use of by-products from agricultural processing. However, it also relates to the decentralised organisation of the bioeconomy to shorten transport routes between agricultural production and processing sites, optimising logistic flows and necessary infrastructure. This leads to the strengthening of rural areas, where jobs can be secured or created and therefore social issues must also be considered in spatial planning processes.



**Figure 1.** Selection Process.

When talking about the fifth core theme, the (participatory) planning processes for implementing a bioeconomy on a regional and local level, it is important to take the influences of politics and governance into account. This also includes participatory processes for communicating the basic value on which the implementation is built and for avoiding and managing land use conflicts arising from competing use of the limited resource of arable land in order to produce food, feed, fibre or fuel.

If there was uncertainty about individual spatial planning content within articles, the authors conducted a further investigation to avoid eliminating documents with spatial relevance. After this selection, the keywords from each year were merged into one table. Terms that occurred multiple times were listed only once. Furthermore, words in plural were removed and only those in singular were left, having no influence on the search

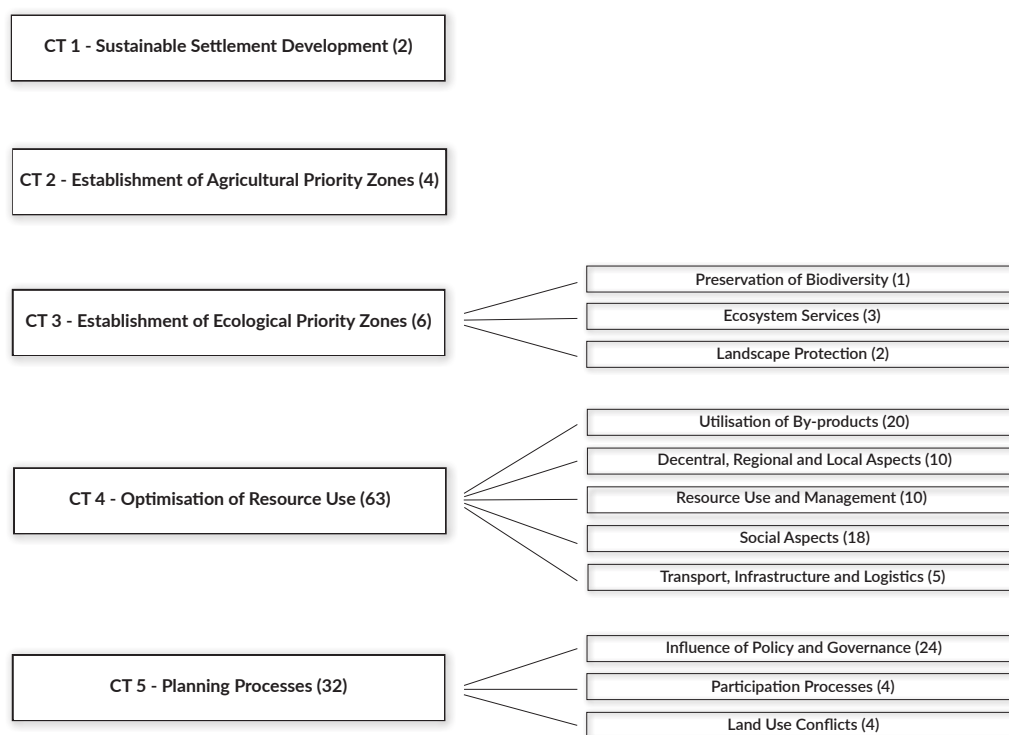
procedure. Different notations for the same term (e.g., bioeconomy, bio-economy, bio economy) were kept, in order not to exclude relevant articles.

Step 4—Content Selection: Based on the selected 95 keywords, all articles were checked for their spatial relevance using the software “Atlas.ti” (developed and serviced by: ATLAS.ti Scientific Software Development GmbH, Berlin, Germany). Throughout this process, the whole document was scanned, omitting only the references. A total of 1827 articles with probable spatial coherence was identified.

Step 5—Refinement: All articles were checked for a spatial reference based on the abstracts. Some years within the time frame contained a large number of articles. The year 2020 showed the highest figure and was prioritised to speed up the selection process, eliminating journals from the selection process with no spatial references. This included, for example, the subject areas of biotechnology, microbiology, pharmacy or chemistry. These journals were then applied as filters to the years 2015 to 2019 and 2021, reducing the number of articles by 353. If the spatial relevance could not be clarified based on the abstracts, the sections “Introduction” and “Discussion” were included in the review. This process was applied to 1474 articles, reducing the number to 107 articles to be examined in more detail (see Table A2).

## 2.2. Assignment to Core Themes

During step 5, the articles were assigned to the five core themes of spatial planning and subsequently into the thematic sub-areas. The respective number of selected articles was entered in a main table, sorted by years and topics (see Table A3—Appendix A). For the first two core themes, the content of the assigned articles was quite consistent. The articles related to the other three themes showed up different orientations, so that it was necessary to divide them into sub-topics or thematic areas to get a clearer structure (see Figure 2). The content structure of these thematic fields was based on the article by Grossauer & Stoeglehner and the professional experience of the two authors.



**Figure 2.** Assignment of the articles to the five core themes and respective number of articles.

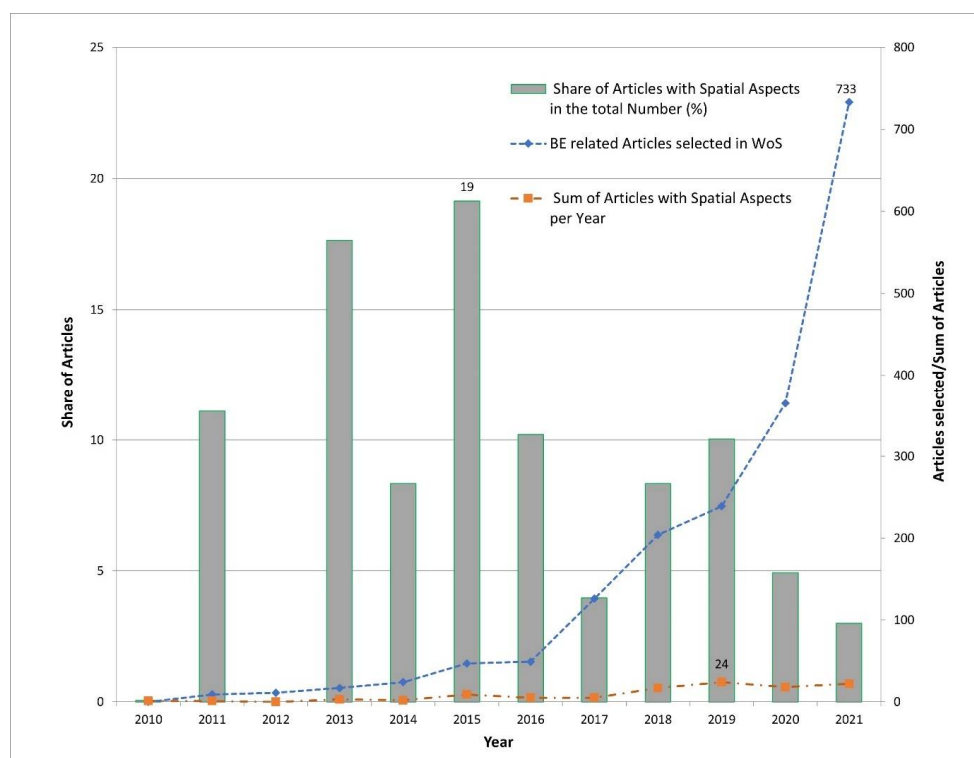
### 3. Results and Discussion

This section firstly analyses the body of literature, and secondly, it describes and discusses the spatial aspects of the articles (organised according to the five core themes). The authors decided to integrate results and discussion due to the structure chosen for this paper.

#### 3.1. Body of Literature

##### 3.1.1. Temporal Distribution

Looking at the distribution of the 107 examined articles over the selected study period using Table A2 (Appendix A), 24 were written in 2019, 22 in 2021, 18 in 2020 and 17 in 2018. The period from 2018 to 2021 thus comprises 75% of the total amount. Papadopoulou et al. come to a similar result in their bibliometric review on an agricultural bioeconomy [13], pointing out that 70.63% of the articles reviewed were written in the period from 2016 to 2020. The remaining 25% are distributed between the years 2010 to 2017 with an increasing momentum. A similar picture emerges when comparing the articles filtered with the keywords in WoS at the beginning of the process. Here, as many as 84% (1583) are part of the above-mentioned period, with papers from 2021 comprising 40% (733) of the total number of 1827 articles. This sharp increase is also very clearly visible in Figure 3 (blue graph). The chart also reveals that although the number of articles with spatially relevant topics is increasing in absolute numbers (orange graph), the proportion of relevant articles (grey columns) is decreasing with high volatility. This indicates that the number of scientific papers dealing with the bioeconomy in different subject areas has risen significantly in the last five years, but that spatial aspects only play a minor role.

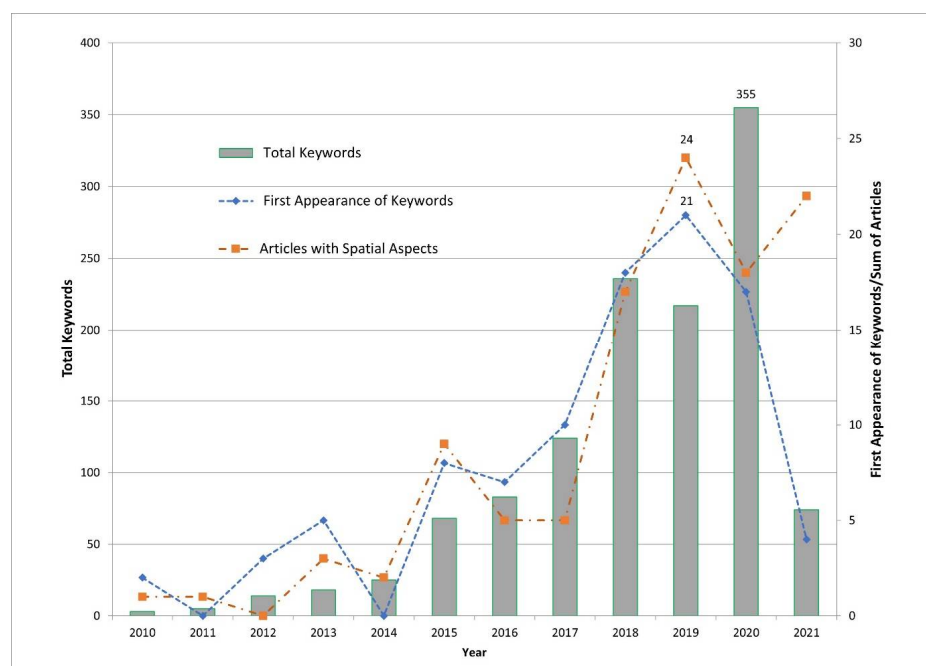


**Figure 3.** Distribution of articles over time and percentage of articles with spatial aspects.

##### 3.1.2. First Appearance of Keywords

The distribution of the keywords according to their first appearance was also examined. Figure 4 shows that their incidence closely follows the number of articles published in each year. Only in 2021 do the graphs diverge. In that year, only a few more new terms were found. However, the strong increase in the respective total number of keywords with

the peak in 2020 (355) is remarkable. It is therefore visible that these topics have gained relevance regardless of a spatial context.



**Figure 4.** Comparison of first appearance of a keyword with the total number of articles and keywords per year.

### 3.1.3. Assignment to the five Core Themes

Finally, Figure 5 illustrates the assignment of the 107 articles to the five core themes (CT). It demonstrates the quantitative dominance of core themes 4 and 5, as articles related to CT 4 could be found in the entire review period except for 2012, and those related to CT 5 from 2013 onwards. The annual amounts increase together with the sum of all papers per year. Articles that could be assigned to the other three core themes were only found from 2018 (CT 3) or 2019 onwards, with CT 1 only appearing once in that year and once in the following year 2020 (2% of the total). It may therefore be concluded that the topics of sustainable settlement development and establishment of agricultural or ecological priority areas did not find their way into the scientific literature in the context of the bioeconomy in the previous years and have not gained importance since.

## 3.2. Core Themes and the Related Articles

This section provides an outline of which specific spatial references were found in the selected articles. At this point, it must be mentioned that numerous articles address topics from different core themes. In these cases, the papers were assigned to the respective thematic focus. For the first three core themes, the individual articles could be described briefly, due to their small number. In contrast, the content of the numerous papers of CT 4 and 5 could only be discussed in a generalised way. For each CT, a table gives an overview of the key topics addressed and their main aspects and arguments as well as the corresponding references. For each core topic, the related articles are described at the beginning and the key topics and main arguments of the articles are summarised in a table. This is followed by a discussion of the results in relation to the research questions and reflections on the necessary research agenda.

### 3.2.1. Core Theme 1—Sustainable Settlement Development

Looking at the first of the five core themes, we see that the topic of “Sustainable Settlement Development” is only addressed in two articles (2%) from 2019 and 2020 (see

also Table 1). Specifically, both deal with the reuse of building land. Pallagst et al. [14] address the feasibility of using former brownfields for the sustainable development of shrinking cities. They talk about “Green Innovation Areas” and mention energy parks or urban farming as examples that could be used to establish a bioeconomy in an urban context. The second article deals with the possibilities of reusing contaminated, industrially used land. Francocci et al. [15] recommend a cross-cutting approach embedded in a strong bioeconomy framework to enable a systematic and consistent concept. They also address aspects from other core themes, such as regionality and socioeconomics (CT 4).

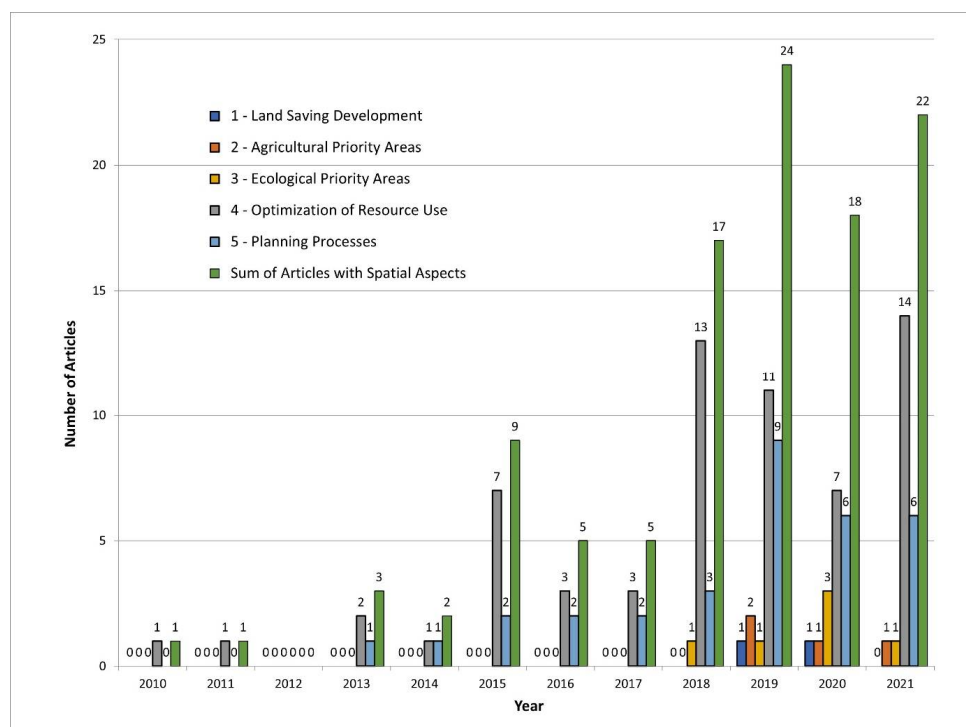


Figure 5. Number of Articles per Year related to the five Core Themes.

Table 1. Key topics and main aspects/arguments referring to Core Theme 1.

Core Theme 1—Sustainable Settlement Development		
Key Topic	Main Aspects/Arguments	Articles
Reuse of building land	Usage of brownfields for Green Innovation Areas	[14]
	Cross-cutting approach in a bioeconomy framework for the reuse of contaminated, industrially used land	[15]

The monothematic focus of the two articles from Core Theme 1 may be explained by the fact that a direct influence of the bioeconomy on sustainable settlement development (inward development) is only possible in connection with the reuse of building land. It cannot have an effect in other aspects such as a mix of uses, appropriate density etc. The reuse of brownfields represents a significant reserve of building land. However, this requires a cadastre showing the location, size, and existing infrastructure for interested investors. This should become a binding standard at national or at least regional level, and would support a comprehensive mobilisation of these sites.

The production of food through “urban farming” and “urban agriculture”, on the one hand, and “urban gardening”, on the other, is becoming increasingly important. With these production methods close to the consumer, transport distances will be kept short and lost agricultural land may be partly compensated. Looking for a reference to bioeconomy in reviews on the above-mentioned keywords (a total of 67 reviews), only one article could

be found [16]. The lack of discourse and the need for further research to connect urban farming, urban agriculture and urban gardening with the bioeconomy are evident.

### 3.2.2. Core Theme 2—Establishment of Agricultural Priority Zones

A similar conclusion to CT 1 is achieved regarding the establishment of “Agricultural Priority Zones”. There are four articles (see also Table 2) on this topic (4%), starting with Englund et al. [17] addressing the issue of land use change to create priority zones for the development of permanent grassland for biomass production. Gottero [18] discusses the pressure on farmland from competing land uses and develops an index for calculating the potential threat. He recommends its use for policy-making processes in soil protection and various planning instruments and so also refers to Core Theme 5. He explicitly addresses spatial planning in this context and is one of the few to point out the importance of this discipline for the protection of agricultural land. Choi and Entenmann [19] look at the potential of agricultural land for the cultivation of raw materials to produce fibre and fuel, excluding traditional farmland reserving it for the preparation of food and fodder. They indicate that this potential of additional agricultural land is much lower than previously assumed, and point to the influence of market liberation policies and therefore to CT 5. Helis et al. [20], on the other hand, assess the potential of marginal land for the cultivation of raw materials for energy production.

**Table 2.** Key topics and main aspects/arguments referring to Core Theme 2.

Core Theme 2—Establishment of Agricultural Priority Zones		
Key Topic	Main Aspects/Arguments	Articles
Land use change	Creation of priority zones for the development of permanent grassland for biomass production.	[17]
Pressure on farmland	Development of an index for calculating the potential threat Usage of spatial planning for soil protection	[18]
Cultivation of raw materials for fibre, fuel and energy	Check of the potential of marginal farmland to produce raw materials	[19,20]

Spatial planning is an instrument allowing intervention in a controlling as well as a protective way. This is explicitly pointed out in one of these articles. In this context, Haberl et al. [21] emphasise the significant loss of primary agricultural land through urbanisation. The trends towards suburbanisation and urban sprawl play a major role in that development. Conversely, resource-conserving development using spatial planning principles (dense and site-adapted building types, inward development, mobilisation of unused building land etc.) is a prerequisite for the preservation of arable land. The use of sectoral planning is another way to contribute to the protection of agricultural productive land. This includes, for example, the establishment of so-called “green zones” in Vorarlberg/Austria [22] or of “Crop Rotation Areas” in Switzerland [23]. They differ in their focus and restrictive impacts. The former is intended to preserve efficient agricultural production land in general, the latter are used to protect most productive farmland to safeguard food self-sufficiency in times of scarcity. However, they have the common goal of preserving fertile soil for agriculture by excluding other uses such as development of settlement or business and industrial sites. There is often a lack of basic data, however, for example on the distribution, quality and usage of fertile soils. Furthermore, the two examples demonstrate how different the approaches to the protection of arable land may be. Concerning the research agenda, a toolbox would be helpful in this regard, outlining possible approaches and their advantages and disadvantages in implementation and the adaptability to regional specifics.



### 3.2.3. Core Theme 3—Establishment of Ecological Priority Zones

Six articles or 6% are assigned to the thematic field of “Ecological priority areas” (see also Table 3). The one dealing with “Preservation of Biodiversity” analyses the influence of forestry production methods on biodiversity using northern European examples and concludes that regional conditions must be considered to protect biodiversity. Naumov et al. [24] recommend the application of integrative spatial planning processes to preserve valuable habitats on the one hand and to push for land-sparing forest management methods on the other.

**Table 3.** Key topics and main aspects/arguments referring to Core Theme 3.

Core Theme 3—Establishment of Ecological Priority Zones		
Key Topic	Main Aspects/Arguments	Articles
Preservation of Biodiversity	Applying integrative spatial planning processes to preserve valuable habitats	[24]
Ecosystem Services	Using spatial planning in combination with appropriate land management for the allocation of multifunctional areas	[25]
	Selecting specific measures to establish buffer zones around crops with a holistic approach	[26]
	Using marginal land to avoid land use conflicts	[27]
Landscape Protection	Loss of landscape mosaics and of biodiversity through intensification of crop production	[28]
	Sustainable forest management at local level through consideration of the specific landscape conditions	[29]

Three articles are assigned to “Ecosystem Services”. Englund et al. [25] deal with the possible multifunctionality of perennial production systems such as short-rotation coppices. They explored which services could be provided in addition to biomass production and conclude that spatial planning in combination with appropriate land management is able to contribute to this by allocating areas where multifunctionality may be best achieved. Blankenberg and Skarbøvik [26], on the other hand, studied the effect of buffer zones around crop fields and found that a holistic approach is needed when selecting specific measures. Von Cossel et al. [27] use the term “Environmental Services” synonymously with “Ecosystem Services” and try to monetise them, using the example of the use of *Miscanthus* as a raw material for biofuel production. They illustrate that *Miscanthus* may contribute to enhancing socio-economic welfare and landscape protection. This effect could be further improved if marginal land is used as the basis for production. They note that this would also avoid land use conflicts between feedstock production and biodiversity conservation, therefore connecting to CT 4 and 5.

Looking at the two articles that cover the “Landscape conservation” theme, different orientations can be seen here as well. Kyere et al. [28] use data from different sources to identify changes in agricultural landscapes caused by bioeconomy effects. They were able to demonstrate a reduction in field structures and thus an impairment of biodiversity resulting from an intensification of the production of maize and winter crops. Lazdinis et al. [29] focus on the integration of sustainable forest management (SFM) policy, using the example of the European Union. They show that this may only succeed at the regional and local level, considering the specific landscape conditions and land tenure and involving all relevant stakeholders. They call this “evidence-based landscape governance and stewardship towards sustainable forest landscape management” and thus also refer to CT 4 and 5.

Several articles around the topic of Core Theme 3 refer directly to spatial planning, and its importance as an integrative planning instrument is addressed. It can be used to maintain or enable the multifunctionality of landscapes and agricultural areas. This is not only about agricultural production, but also, for example, about the preservation of

biodiversity and the safeguarding of ecosystem services. A key aspect is also the avoidance of conflicts between different types of land use through forward planning. This instrument is most effectively applied at the regional or local level. The small number of articles found (6% of the total) demonstrates the low importance of the topic in this context and the need to intensify research. The agenda should focus on the multifunctionality of landscape and agriculture and their interactions as well as the impact on biodiversity and ecosystems through the transition to a bioeconomy.

#### 3.2.4. Core Theme 4—Optimisation of Resource Use

The thematic area “Optimisation of Resource Use” contains the largest number of articles (63 or 60%) with spatial relevance (see also Table 4). The 20 articles that could be assigned to the sub-theme “Utilisation of By-products” cover a wide range of topics. It starts with the fundamental importance of waste prevention and utilisation. It also includes the current methods of bioconversion of waste and by-product streams in order to develop biorefinery concepts. Three articles deal with the framework conditions and feasibilities for the valorisation of residual resources. Subsequently, it is of great importance to gain knowledge about the potentially available raw materials. Several articles discussed the use of biogenic by-products to produce energy or chemicals.

**Table 4.** Key topics and main aspects/arguments referring to Core Theme 4.

Core Theme 4—Optimisation of Resource Use		
Key Topic	Main Aspects/Arguments	Articles
Utilisation of By-products	Importance of waste prevention and utilisation	[31–33]
	Current methods on waste and by-product streams bioconversion	[34]
	Valorisation of residual resource	[35–37]
	The importance of knowledge about the existing raw material potentials.	[38–42]
	Usage of biogenic by-products to produce energy	[43–46]
	Usage of biogenic by-products to produce chemicals	[47–49]
	The interest of producers in recycling agricultural waste and by-products	[50]
Decentral, Regional and Local Aspects	Decentralised and local processing	[51–56]
	Availability of bio resources and optimisation of transport distances	[57–60]
Resource Use and Management	Efficient use of bioresources	[61,62]
	Intensification of bioresource use and its consequences	[63–66]
	Sustainable multipurpose biomass production	[67–70])
Social Aspects	Social aspects of the transition to bioeconomy	[71–75]
	Social sustainability	[76–80]
	Social acceptance	[30,81–83]
	Multiple aspects	[84–87]
Transport, Infrastructure and Logistics	Optimisation of transport routes	[88–90]
	Optimisation of site selection for biorefineries	[89–91]
	Advancement of district heating systems	[92]

This leads to the next sub-theme, encompassing 10 articles dealing with “Decentral, Regional and Local Aspects” of the bioeconomy. Five articles highlight different aspects of the decentralised treatment of biogenic waste, including the importance of local level

policies and the best locations for the processing of this waste. It is also stated that it is possible to restore growth and innovation through biorefineries by using local renewable resources, at the same time preserving and enhancing local ecosystems and biodiversity. The other articles of this sub-theme deal with different aspects of the availability of raw materials, focussing on spatial and temporal distribution and the optimisation of transport distances and costs.

Moving on to the sub-theme “Resource use and Management”, several articles discuss the efficiency and the intensification of bioresource use and its consequences. Two other articles deal with the optimisation of biomass use for biogas production. Competing demands are also addressed in the context of biomass production. To counter these, sustainable multipurpose biomass production is proposed. The authors argue for more research to aid the understanding of environmental and economic impacts due to increased industrial biomass use.

Looking at the “Social Aspects” related to spatial influences on the bioeconomy, it becomes apparent that the issues of transition or social sustainability are addressed most frequently. In the case of the former, the focus is on socio-economic effects, their impact and how to best control these effects. The articles dealing with social sustainability consistently criticise its absence or low priority compared to the economic aspects, or demand the inclusion of social and environmental concerns as well as local knowledge. Four articles address the social acceptance of bioeconomic measures covering a broad field, starting with the demand for an active involvement of consumers followed by the argument that a better understanding of science and technology leads to wider social acceptance, especially, when a value-driven approach is used. It results in the discovery that an expansion of bioenergy through cascading biomass use does not automatically lead to a higher social acceptance of such projects [30]. There are also four articles that address multiple issues, for example the capabilities of adapting industrial development to rural settings or the relevance of social ties in rural communities. These articles also discuss the relationship between town and country, or women in rural areas and their role in the production of functional food and setting up local businesses. At last, the importance of biogas plants is highlighted in regard to creating employment and the protection of natural anthropogenic resources and the environment.

Considering the five articles dealing with “Transport, Infrastructure and Logistics” of biogenic raw materials, a focus on the optimisation of transport routes or of site selection for biorefineries can be found. In this context, the support of governmental legislation through voluntary measures is addressed. Another issue discussed is the further development of district heating systems by the creation of added value such as the production of biogenic raw materials.

The results of CT 4 reveal that with improved use of biogenic resources and residues, it is possible to indirectly compensate the loss of agricultural productive land, in addition to increasing crop yields and other established measures. Subsequently, arable land can be used primarily for food and feed production. However, for a successful implementation of a bioeconomy, it is necessary to know the actual potential of existing raw materials and their spatial distribution. This also demonstrates the importance of planning on a regional level and the principle of decentral concentration. The latter has a positive effect on the required transport routes and optimises the spatial distribution of the necessary infrastructure. Spatial planning enables the provision of sites for establishing biorefineries and other processing plants that should be on the one hand close to agricultural production areas of biogenic raw material, and on the other hand should provide easy access to road and rail infrastructure for transporting the manufactured (half-) products to their destinations via the shortest possible route. Spatial planning decisions also may have a socioeconomic impact. Incorrect or poorly communicated decisions about sites for industrial plants, for example, may trigger conflicts between the authorities or operators on the one side and the public on the other, thus undermining the acceptance of the transition to the bioeconomy. On the other hand, site development in rural areas may lead to securing jobs and creating

employment and hence increased regional added value and prosperity. This may contribute to the stabilisation of the social fabric in economically weak regions. The necessity of steering these processes through politics and legislation is also emphasised several times. The dimension of the social impacts and the regional effects of the implementation of BE is still quite unknown and requires further research.

### 3.2.5. Core Theme 5—Planning Processes

Finally, the 32 articles (29%) assigned to the Core Theme “Planning Processes” are outlined (see also Table 5). The 23 papers discussing the topic “Influence of Policy and Governance” were subdivided, starting with the international level. Four teams of authors shed light on different aspects of EU policy in the context of the bioeconomy. The scope ranges from necessary systemic changes to successfully implement the transition, to the obstacles on the way to a BE policy field and the trade-offs that have to be made with agricultural food production. Two other articles address the integration of governance into policies to create a coherent framework, emphasising the importance of regional cooperation to meet the challenges ahead.

**Table 5.** Key topics and main aspects/arguments referring to Core Theme 5.

Core Theme 5—Planning Processes		
Key topic	Main Aspects/Arguments/Topics	Articles
Influence of Policy and Governance	International level	[93–97]
	National level	[10,98–102]
	Regional level	[97]
	Local level	[103,104]
	Sustainable policy	[105–110]
	Political Influences on BE implementation in general	[111–114]
Participatory Processes	Usage of participatory governance	[115]
	Consideration of the complexity and variety of participation	[116,117]
	A consensus on sustainable development through participatory processes	[118]
Land Use Conflicts	Monitoring of land use change to support sustainable development	[119]
	Application of effective policy and ethical guidelines to prevent competition for arable land	[120]
	Usage of marginal and contaminated land to avoid land use conflicts	[121,122]

Among the articles on the national level are contributions highlighting the numerous spatial planning issues that can be found in national BE strategies or comparing different paths of transition to a bioeconomy. Other articles criticise missing or one-sided policies and governance related to biobased materials, the agricultural biogas market, as well as the development of short-rotation plantations, or investigate what is needed for a comprehensive implementation of a circular bioeconomy. The regional level is addressed only by one article, which mainly also only discusses international issues. It emphasises the importance of regional cooperation to meet the challenges and opportunities that BE provides and therefore also refers to CT4.

Moving on to the local level, only two articles were relevant. The authors of the first article conclude that the subordinate role of local stakeholders compared to national or industrial interests could undermine the sustainability of biobased industries. The limitation to financial interests within the policy may lead to unpredictable local environmental

effects and to the increased appropriation of arable land as well as the exacerbation of conflicts. The authors of the second article report on a Finnish city affected by economic shrinkage. The local government was able to reverse this trend with the help of urban planning, material investments and a BE branding.

Another six articles have been grouped under the heading of “Sustainable Policy.” Several of those focus on the positive impact on achievable outcomes of using governance to engage affected stakeholders. It is pointed out that without regulatory policies, the achievements of some SDGs may be at risk, or that global impact of local action must be considered.

Four articles were found dealing in a general way with political influences on BE implementation, discussing BE as a policy project or presenting a model to enable policy development and testing. It is stated that future policies should encourage the production of biobased fossil product substitutes. One article sheds light on a special but also very fundamental aspect by focusing on soil governance. It points out the importance of soil as a production base for biobased raw materials and at the same time emphasises that this is an underdeveloped research area.

“Participation Processes” are closely linked to adapted policies and governance, integrating the public and relevant stakeholders in the transition to a bioeconomic approach. Various forms of public and civil participation and the complexity of this issue are discussed. It is noted that different aspects must be taken into consideration, among others the multiplicity and flexibility of stakeholders to reach a consensus on sustainable development.

The fifth core theme also addresses the issue of “Land Use Conflicts” that may arise from the shift towards a bioeconomy. It states that there must be a monitoring of land use change if the EU Bioeconomy strategy is to support sustainable development at the global level. A holistic approach is proposed to creating effective policies and ethical guidelines to prevent competition for arable land between food and non-food production. This approach is even more paramount when regarding the issue of energy crop production by recommending the use of contaminated soils and marginal lands. This refers to the efficient use of resources in CT4.

The maximum number of 23 articles referring to the sub-theme “Influence of Policy and Governance” highlights that many authors consider politics to be a major factor of influence on the implementation of BE. This relates to all decision-making levels, starting with the European Union as well as international agreements, to national and regional aspects and then down to the municipalities. It is remarkable that compared to the regional and local level (3 articles), a clear majority of 11 articles deal with the international and national level. It may be seen as evident that a comprehensive steering towards the sustainable implementation of a bioeconomy can only take place at these levels. In addition, there are 6 papers dealing specifically with the content of sustainable policies. Reference is always made to the importance of the regional or local decision-making levels. The topics related to participation and land use conflicts have only gained importance in recent years. With two exceptions (2013, 2014), the relevant articles were published in 2019 and 2020. In any case, further research is needed to determine how comprehensively and in which specific manner policies and governance may influence the sustainable implementation of BE. If politics and the economy are to achieve broad acceptance of this implementation, the public must be involved in these processes. This requires extensive information about the advantages and disadvantages of this economic system as a prerequisite for specific projects, such as the adaptation of crop rotation or the establishment of biorefineries. Conflicts over fertile land to produce food, feed, fibre and fuel may only be avoided or at least mitigated with a holistic policy approach. This must consider the availability of arable land as well as the safeguarding of viable agriculture, the protection of biodiversity and the preservation or expansion of ecosystem services. It requires new models integrating the different issues. Such models have already been applied in the field of integrated spatial energy planning (ISEP) [123]. Specific tools for ISEP show how this can be done successfully. A recent

study examines their advantages and disadvantages and indicates a path to the sustainable implementation of the bioeconomy [124].

#### 4. Conclusions

The analysis of the 107 finally selected articles shows that different aspects of spatial planning and their relevance are reflected in scientific literature. However, they also show that the integration of the bioeconomy does not have to be sustainable per se, as it must be spatially integrated and implemented in a regionally differentiated manner. Under these preconditions, a bioeconomy may lead to positive effects on socioeconomic and spatial development. There is, however, still a lack of scientific understanding. This also relates to the instruments of spatial planning to be able to guide a spatially sustainable bioeconomy implementation. This review has indicated that there are still substantial knowledge gaps. Furthermore, the fact that only nine articles refer to more than one core theme shows a lack of interdisciplinary discussion on the topic of the bioeconomy, even in spatial research.

A future research agenda must, therefore, at least shed light on the following aspects:

- Land acquisition for built environment as a restriction for the use of arable land for bioeconomy-related activities: land-saving urban development is ultimately linked to the land take of biologically productive land. Future research should highlight these land use conflicts and offer approaches to reduce land take.
- Creation of a toolbox offering different methods for the protection of fertile land: The protection of agricultural production areas must be adapted to the regional framework conditions. This requires different planning instruments and tools that have to be built on a comprehensive data basis, the existing regulatory frameworks and the societal discourses around sustainable spatial development.
- Influence of intensified agriculture on the multifunctionality of landscapes: research about bioeconomy strategies should include options for controlling this intensification by using spatial planning as well as landscape and nature conservation instruments to deal with land demand related to less intensive agricultural, horticultural and silvicultural production. It should also consider the protection of living spaces for wild plants and animals as well as the provision of sustainable land use combinations.
- Impacts of the transition to a bioeconomy on biodiversity and ecosystem services: further research should, inter alia, address the use of strategic environmental assessment and environmental impact assessment to integrate policies to reduce and adapt to environmental crises such as climate change, biodiversity losses or the degradation of biologically productive land.
- The role of the regional planning level with respect to the model of a decentralised bioeconomy: how centralised or decentralised should a bioeconomy be? These issues should be discussed on a basis of facts about necessary resource flows and their spatial organisation in the BE transition.
- Planning guidance to avoid land use conflicts and other negative impacts: Research has to be conducted on how to integrate regional effects and the socioeconomic impacts of BE implementation, in planning and governance processes. This also includes the:
- Development of new planning models and instruments that consider the above-listed aspects and combine them in terms of planning contents and processes.

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## Appendix A

Table A1. Keyword List.

Generalized Keyword	Quantity	First Appearance
Actors	1	2018
Adaptation	1	2020
Agricultural	1	2018
Agriculture	5	2013
Agro	1	2021
Agroecology	1	2020
Bio based	1	2019
Bio-based	3	2018
Biobased	1	2018
Biodiversity	6	2012
Bioenergy	10	2012
Biofloculants	1	2020
biofuel	14	2010
Biogas	7	2012
Biomass	11	2010
Biorefinery	16	2013
Bio-refinery	1	2015
Bioregion	1	2016
Bioresource	3	2019
Bio-resources	2	2017
Bio-sourced	1	2018
Cascade	1	2019
Cascading	5	2013
Circular	1	2018
Circularity	4	2018
Decentralized	1	2021
District heating	1	2018
Ecological	1	2017
Ecology	1	2021
Ecosystem	1	2020
Energy	4	2017
Environment	5	2013
Environmental	1	2020
Even-flow harvesting targets	1	2017
Farm	1	2021
Farmland	1	2020
Food	3	2018
Forest	2	2019

**Table A1.** *Cont.*

Generalized Keyword	Quantity	First Appearance
Forestry	3	2016
Fuels	1	2017
Geospatial analysis	1	2020
Governance	6	2015
Green belt	1	2019
Green building	1	2018
Green infrastructure	1	2019
Impact	2	2019
Indirect land use	1	2019
Land conflicts	1	2019
Land footprint	3	2015

**Table A2.** Results of the selection process.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Articles selected in WoS	3	9	11	17	24	47	49	126	204	239	365	733	1827
Excluded by Journal	X	X	X	X	X	4	9	21	33	44	228	14	353
Excluded by Title or Abstract	2	8	11	14	22	34	35	100	154	171	119	697	1367
Papers analysed	1	1	0	3	2	9	5	5	17	24	18	22	107



**Table A3.** Main Table with the results of the selection process.

Year		2010		2011		2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		Sum per Sub-theme	Sum per Theme																
Core Theme	Subtheme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme	Subt.	Core Theme																		
1 - Land Saving Development			0		0		0		0		0		0		0		0		0		1		1		0		2																
2 - Agricultural Priority Areas			0		0		0		0		0		0		0		0		0		2		1		1		4																
3 - Ecological Priority Areas	Preservation of Biodiversity	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3	0	1	0	6																
	Ecosystem Services	0		0		0		0		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Landscape Protection	0		0		0		0		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4 - Optimization of Resource Use	Utilization of Byproducts	1	1	0	1	0	0	0	2	0	1	1	7	2	3	1	3	4	13	5	11	2	7	4	14	20	63																
	Decentralization/Regionality	0		0		0		1		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Resource Use and Management	0		1		0		0		1		0		1		0		1		0		3		0		1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Social Aspects	0		0		0		0		0		0		0		0		0		0		2		0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Transportation/Infrastructure	0		0		0		0		0		0		0		0		0		0		1		0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 - Planning Processes	Influence of Policy/Governance	0	0	0	0	0	0	0	1	0	1	2	2	2	2	2	2	3	3	4	9	5	6	6	6	24	32																
	Participation processes	0		0		0		1		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Land Use Conflicts	0		0		0		0		0		0		0		0		0		0		0		0		0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum of Articles with Spatial Aspects		1		1		0		3		2		9		5		5		17		24		18		22		107	107																

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