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Review

Forest Biomass and Bioenergy Supply Chain Resilience: A Systematic Literature Review on the Barriers and Enablers

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Abstract: This research aimed to systematically review the development studies pertaining to forest biomass and bioenergy supply chain resilience (SCR). In this regard, a mixed procedure was implemented in order to explore and analyze the relevant publications, and to answer the research questions. First, the databases and journals working on forest biomass and bioenergy supply chains (SCs) were identified based on the indices of the review process and the indices of the barriers and enablers. Next, data refinement was employed to filter the publications into four levels and determine the semifinal cases. Moreover, the references of the semifinal publications were tracked in order to achieve the final cases. Consequently, 88 papers were determined as the final cases through which the barriers and enablers were explored and analyzed. Furthermore, in order to meet the research gap in this area and prove the connections of those barriers and enablers with the resilience capability, their relationships with the main resilience factors were investigated. According to the assessment, the findings of this research on the definition, barriers and enablers of forest biomass and bioenergy SCR can be applied as a basis for the comprehension and optimization of the structure of SCs in the forest biomass and bioenergy industries.

Keywords: forest biomass supply chain resilience; forest bioenergy supply chain resilience; resilience barriers; resilience enablers; resilience main factors; systematic literature review

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1. Introduction

Biomass is one of the sources of energy available in many countries. It is defined as the series of organic raw material that originates from plants and animals [1]. In the case of plants, it is derived from green plants transforming sunlight into organic material through the photosynthesis process and contains all kinds of vegetation and organic wastages [1]. Given the fact that it takes millions of years to transform biomass into fossil fuels, and that burning them will disrupt the balance of carbon dioxide in the atmosphere, these are not considered renewable in the desired time period based on the human life cycle [2]. When biomass can be used in the short term, it can be considered as a renewable source of energy. As such, while biomass and fossil fuels are fundamentally interconnected, they have fundamental differences in outcome and their impact on the environment, which are directly related to the duration of their formation and use. Furthermore, bioenergy is defined as a type of primary renewable energy, in that its constant use does not broadcast greenhouse gases into the atmosphere [3]. As one of the more promising outcomes, the enhanced use of bioenergy can lead us to meet the goals of the framework convention on climate change (FCCC) regarding the stabilization of the atmospheric densities of greenhouse gases under perilous levels [3]. Indeed, bioenergy is a form of clean energy generated from raw materials under the title 'biomass', for operation in line with producing transportation fuels, heat, electricity and products by considering the modern standards [4].

1.1. Forest Biomass

This type of energy source can be converted into solid, liquid or gaseous states. Forest biomass comprises preliminary residues produced during forest proceedings, secondary residues produced during industrial wood conversion proceedings, tertiary residues emanated from destruction, manufacturing, and packaging operations, and finally customary firewood [5,6]. Preliminary residues are presently the major feasible source of novel feedstock for bioenergy in temperate locations and forests [6]. In this regard, logging residues—including the tree tops and branches produced within harvesting proceedings—can be considered as an available and beneficial source of forest biomass [5]. Within harvesting proceedings, logging residues are often amassed at a location that is suitable for easy transportation or rotting; otherwise, they are abandoned on the forest locality and only require retrieval [5]. The managerial and technical progresses driven by biomass and bioenergy industries certainly augment the number of localities from which residues are removed, which will lead to the optimized amount of biomass being removed from a locality in the future [5,7,8]. Hence, the sustainability of the forest locality regarding the growth removal of logging residues, mainly within clarification, is a considerable concern [5]. In the meantime, understanding forest biomass potentials is vital in order to examine their effects on the environment and other industries, especially in the bioenergy sector [8].

1.2. Forest Bioenergy

The bioenergy generated from forest biomass is called forest bioenergy. In line with the optimal application of the renewable energy, it is necessary to consider the forest biomass for bioenergy and biofuel generation leading to acceptable local advancement [9,10]. Forest bioenergy generated from local sources can meet the industrial or non-industrial needs of beneficiaries from various perspectives [11]. Based on the literature, the optimal and structured use of forest bioenergy in potential locations can reduce the use of fossil fuels, leading to reduced greenhouse gas emissions and boosting confidence in the clean energy industry [12]. For instance, the utilization of accessible biomass for the generation of the bioenergy in British Columbia could lead to 15.7% greenhouse gas emissions mitigation [12]. Forest bioenergy is often obtained from wood residues gathering during timber harvesting and within the wood processing industry, such as wood pellets, black liquor and recovered wood waste [13]. The future of this industry in all its forms will be affected by a wide range of characteristics, such as demand, policies, environmental potentials, and technical and managerial advancements. As such, continuous targeting, planning and activities are important issues for systematizing this industry and ensuring a bright future ahead.

1.3. Forest Biomass and Bioenergy Supply Chains (SCs)

Forest biomass and bioenergy SCs can be defined as the network among the forests, biomass producers, biomass distributors, bioenergy producers, bioenergy distributors, and final consumers associated with each of them. It covers various individuals, organizations, resources, software and hardware technologies, and all of the physical and non-physical routes, procedures, and outcomes to obtain the relevant products or services [14]. Understanding the SCs is a vital issue in implementing a reliable framework based on a strategic planning process and efficient activities to reach the strategic targets. Hence, the continuous improvement of organizations working on the forest biomass and bioenergy sectors remarkably lies at the back bone of the situation of their SCs' structures. In fact, the forest biomass and bioenergy SCs provide the opportunities for producers, distributors and consumers to better understand the targets, plans and activities that are incorporated in the whole network, leading to more efficiency and competitiveness of the relevant industries in the present and future. Diversity and changeability within these kinds of SCs, mostly due to the features of the raw material, the economic situation and demand fluctuation, has impact on the energy generation and consumption levels [14]. As such, the extensive forest biomass and bioenergy SCs that include the various components influenced by uncertainty increase the instability in the costs and revenues more than other types of energy [14]. Somehow, it plays a significant role in generating extra revenue streams for the renewable energy industry by regulating the supply demand rates and organizing the operations [15]. It is necessary to investigate the environmental, economic, social, technical and strategic potentials of the forest industry in order to achieve an efficient and prospective structure [15]. However, the question is "How can such an efficient structure be developed for the forest biomass and bioenergy SCs?" Indeed, answering this question is the key prerequisite to continuous improvement in this scope.

2. Research Process

In this research, a Systematic Literature Review (SLR) was conducted in order to investigate the current literature on forest biomass and bioenergy supply chain resilience (SCR). The attempts were focused on realizing the main challenges and issues, and covering the theoretical and practical dimensions of this sector. Figure 1 shows the framework of the research process. The framework applied to collect the relevant data included many phases, which are as follows.

Phase 1: Defining the Research Questions

The research questions, in fact, show the existing gap, and the reason of and contribution to the research. Therefore, designing these questions not only regulates the research process but also increases the understanding of the research findings. Accordingly, the main contribution of this research is the identification of the barriers and enablers in the field of forest biomass and bioenergy SCR based on the relevant literature.

Phase 2: Data Collection and Indices

In the data collection phase, at first, the particular keywords for the exploration of the databases and journals were determined. Some of the main research keywords included "forest biomass supply chain", "forest bioenergy supply chain", "forest biomass supply chain resilience", "forest bioenergy supply chain resilience", "resilient forest biomass supply chain", and "resilient forest bioenergy supply chain". Secondly, the publications after year 2009 were explored. The consideration of the year 2009 as the start point was because the concept of supply chain management in forest biomass and bioenergy industries has undergone a major transformation since 2009. Thirdly, in order to conduct a high quality literature review, the Engineering Research Database, Google Scholar, Science Direct, Wiley Online Library, Springer, Taylor and Francis Online, MDPI, and Canadian Science Publishing were investigated, in addition to top journals in the subject of renewable and sustainable energy. In order to achieve comprehensive insight about the findings, all of the sections of each piece of research were evaluated. Furthermore, the theoretical and practical aspects were considered in order to reach reliable findings. Table 1 shows the journal classifications based on Academic Journal Guide (AJG) 2018 qualification.

Phase 3: Data refinement

During the data refinement process, four essential steps were conducted, which were identification, screening, eligibility and inclusion. In the identification step, all of the articles were identified based on the relevant keywords. In the screening step, the duplicated studies containing irrelevant texts were removed from the identified collection. In the eligibility step, the articles that did not include an adequate connection between the resilience concept and forest biomass and bioenergy SCs were excluded. At the end, the articles that necessarily and adequately answer the questions of this research were included for the final analysis. Furthermore, an important part of this phase was devoted to reviewing the relevant references used in the included research. Hence, the procedure led to a systematic, accurate and valid overview of the theoretical and practical background of the application of resilience-related concepts in this field.

Phase 4: Data analysis

In this phase, the data obtained in the previous phase were analyzed. The analysis of the data showed the quantity and quality of the research on the application of resilience in the sector of the forest biomass and bioenergy supply chain network (SCN). The outcomes of this phase included: (1) the range of the theoretical and practical background, (2) definitions of forest biomass and bioenergy SCR, (3) a set of barriers of forest biomass and bioenergy SCR, and (4) a set of enablers of forest biomass and bioenergy SCR. Therefore, the findings of this SLR can be used as a comprehensive reference in this area.

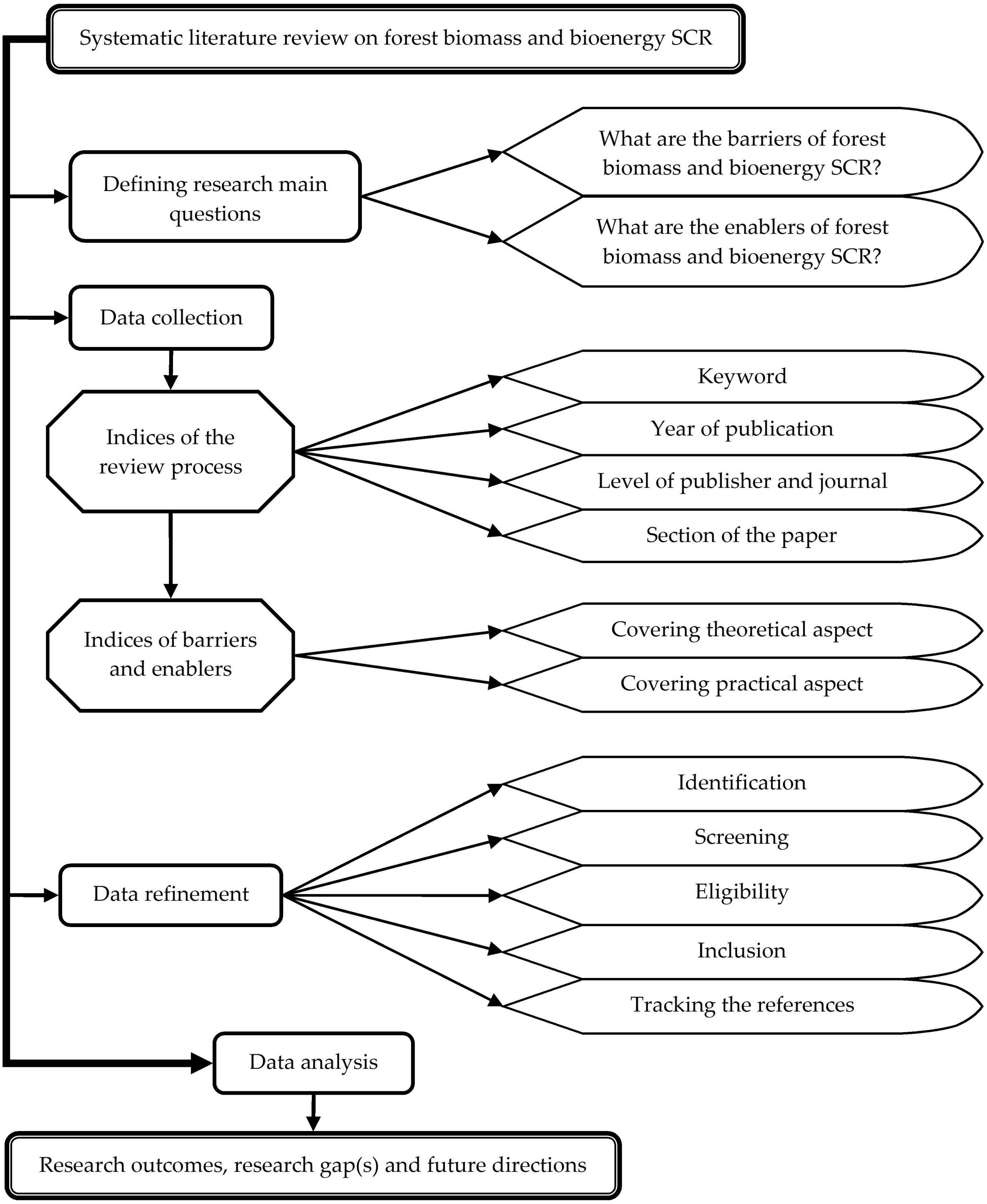

Figure 1. Research process.

Table 1. Journal classifications based on AJG 2018 qualification.

List of Publishers	List of Journals	IF *	SJR **	SNIP ***
Elsevier	Renewable and Sustainable Energy Reviews	12.110	3.632	4.351
	Applied Energy	8.848	3.607	2.865
	Resources, Conservation and Recycling	8.086	2.215	2.584
	Bioresource Technology	7.539	2.430	2.012
	Journal of Cleaner Production	7.246	1.886	2.394
	Renewable Energy	6.274	2.052	2.366
	Energy	6.082	2.166	2.012
	Journal of Environmental Management	5.647	1.321	1.839
	International Journal of Production Economics	5.134	2.379	2.714
	Energy Policy	5.042	2.168	1.931
	Biomass and Bioenergy	3.551	1.110	1.415
	Biosystems Engineering	3.215	0.857	1.970
	Forest Policy and Economics	3.139	1.127	1.482
Wiley Online Library	Gcb Bioenergy	5.316	1.810	1.180
Springer	Current Forestry Reports	4.972	1.320	2.070
	Biomass Conversion and Biorefinery	2.602	0.550	0.770
	Bioenergy Research	2.195	0.620	0.970
Taylor & Francis	Scandinavian Journal of Forest Research	1.755	0.590	0.840
	International Journal of Green Energy	1.388	0.42	0.630
	International Journal of Forest Engineering	1.386	-	-
	Australian Forestry	1.370	0.370	0.540
	Journal of Sustainable Forestry	1.272	0.390	0.740
MDPI	Forests	2.221	0.650	0.940
Canadian Science Publishing	Canadian Journal of Forest Research	1.812	0.630	0.880

* Impact Factor 2019, ** SCImago Journal Rank 2019, *** Source-Normalized Impact per Paper 2019.

3. Results

3.1. Characteristics of the Publications

Based on the research process, an overview of the literature structure on SCR in the forest biomass and bioenergy industries is presented in this section. Table 2 indicates the results of the data refinement. In the identification step, 883 publications were identified relating to the mentioned keywords. The most prolific journals with the largest share of publications were the Journal of Cleaner Production, with 17%; Biomass and Bioenergy, with 16%; Applied Energy, with 12%; Renewable and Sustainable Energy Reviews, with 12%; and Energy, with 10%. In the following stages, 281 publications were selected during the screening step, followed by 149 during the eligibility step, and 51 during the inclusion step. In addition to the 51 publications, others mentioned within the text were reviewed in the supplementary process. In this way, the 37 publications used as references of the included cases were investigated because of relationship of them with the barriers and enablers in this field. In total, 88 publications were determined and analyzed. Figure 2 shows the year-wise distribution of the final selected publications. Accordingly, most related studies were conducted in the years 2017 to 2019. In order to achieve comprehensive insight into the application of resilience capability in the forest biomass and bioenergy SCN, the keyword-wise distribution of the final selected publications is presented in Figure 3. Based on the results, all of the publications applied just two keywords, which were "forest biomass supply chain" and "forest bioenergy supply chain", and words dependent on them. Actually, there is no significant research paper that specifically applied the keywords including "resilience" or "resilient" in the selected journals. All of them are indirectly related to the resilience concept. This indicates that there was a significant research gap in the application of this capability in forest biomass and bioenergy SCs up to the end of 2020. However, SCR has been one of the main topics in the scientific community in recent years. Therefore, it is necessary to conduct extensive and multifaceted research on this topic. In this way, both the direct and indirect relationships among resilience capability and the barriers and enablers of forest biomass and bioenergy SCs were considered in this SLR during the data refinement process. However, the viewpoints of authors and experts were also considered in order to link the barriers and enablers to the main resilience factors identified in previous studies. This supplementary process helped the researchers to better comprehend the findings.

Table 2. Results of the data refinement.

List of Journals	Identification	Screening	Eligibility	Inclusion	References
Renewable and Sustainable Energy Reviews	103	34	17	12	3
Applied Energy	109	36	19	9	-
Resources, Conservation and Recycling	10	3	2	2	-
Bioresource Technology	27	6	2	0	1
Journal of Cleaner Production	151	41	22	7	4
Renewable Energy	43	17	9	2	2
Energy	85	22	15	5	1
Journal of Environmental Management	5	1	1	0	-
International Journal of Production Economics	11	6	1	0	-
Energy Policy	40	10	6	0	2
Biomass and Bioenergy	142	48	24	5	2
Biosystems Engineering	15	2	2	1	-
Forest Policy and Economics	10	9	4	2	2
Gcb Bioenergy	17	6	4	0	-
Current Forestry Reports	4	4	4	0	-
Biomass Conversion and Biorefinery	2	2	1	0	-
Bioenergy Research	23	6	2	1	-
Scandinavian Journal of Forest Research	8	7	4	1	1
International Journal of Green Energy	2	1	1	1	-
International Journal of Forest Engineering	8	5	2	1	-
Australian Forestry	2	1	1	1	-
Journal of Sustainable Forestry	3	3	2	1	-
Forests	6	5	2	0	-
Canadian Journal of Forest Research	6	5	2	0	-
Others	→	→	→	→	19
Total	**883**	**281**	**149**	**51**	**37**

Up to November 2020.

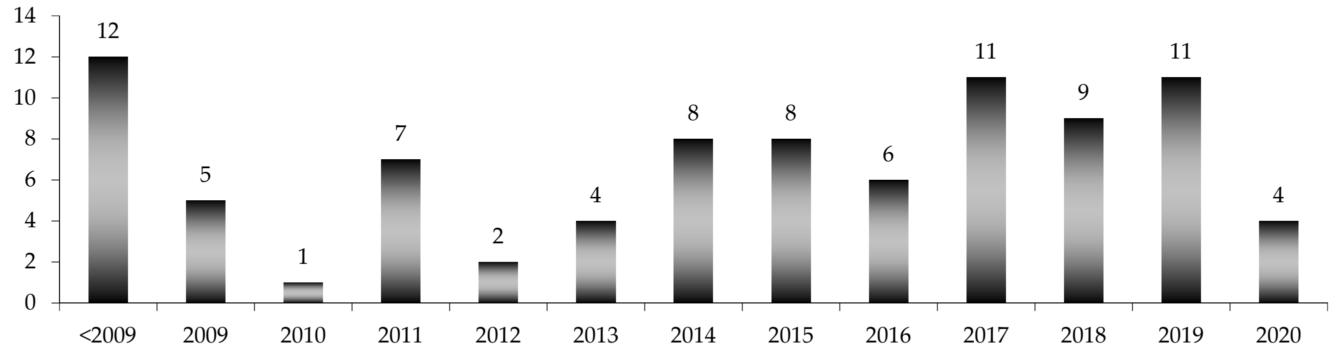

Figure 2. Year-wise distribution of the publications.

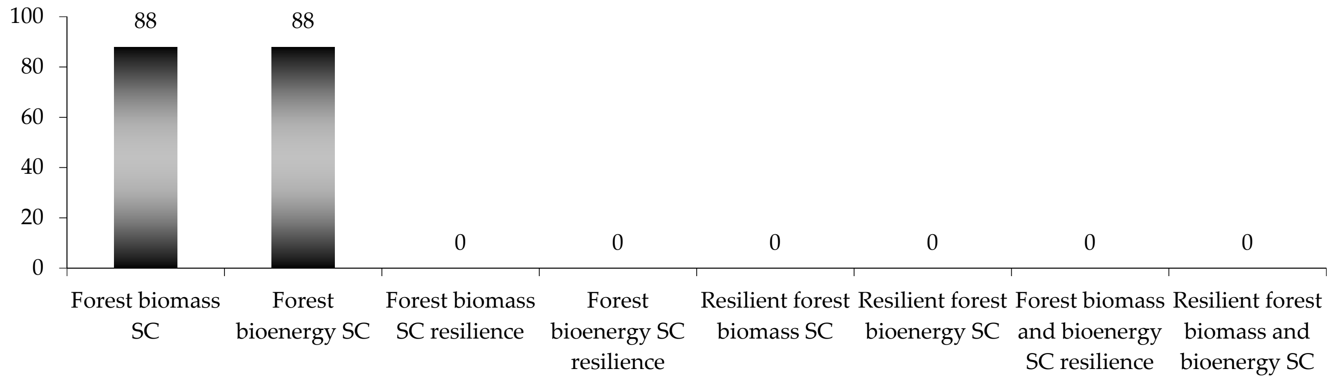

Figure 3. Keyword-wise distribution of the publications.

3.2. Forest Biomass and Bioenergy SCR

Resilience is defined as the capability to enhance the potentials of systems or individuals to perform their functions optimally and continuously, in line with predetermined goals and plans, during various situations [16–18]. For this reason, the development of resilient structures has attracted much interest in recent years. The definition provided in this SLR for the forest biomass and bioenergy SCR is:

> . . . the capability of forest biomass and bioenergy SCN to return from sustained difficulties, for sustainable development during and after a foreseeable or unforeseeable event in a short period of time, by an efficient preventive-progressive procedure and with high performance quality, in keeping with environmental, economic, social, technical, and strategic standards.

This type of SCN can play a significant role in the consumption of more clean energy within the industrial and non-industrial environment, through the timely and adequate supply of biomass and bioenergy [19]. Therefore, in order to achieve environmental, economic, social, technical and strategic advantages, improving the resilience level in this sector should be considered as a forward-looking issue. Numerous components affect the resilience capability in forest biomass and bioenergy SCs, some of which have a negative impact and some of which have a positive impact. According to empirical evidence, the identification and evaluation of the impact of the components are associated with optimization of the resilience capability at the micro and macro levels. By reviewing the literature on the application of resilience in the forest biomass and bioenergy SCs, a critical research gap can be recognized, which includes the determination of the resilience components of this type of supply chain at different levels. This is the main purpose of the current research and the attempts made in this way to bridge this research gap.

3.3. Barriers of Forest Biomass and Bioenergy SCR

The identification of the barriers of progress in any field is one of the important issues that will lead to the achievement of the goals. There is an undeniable research gap in the investigation of the resilience capability within the forest biomass and bioenergy SCN. Hence, the barriers were extracted in this review that directly and indirectly affect the resilience level. Table 3 shows the resilience barriers in this way. In general, the identified barriers are incorporated in five dimensions, which are the environmental, economic, social, technical and strategic dimensions. Therefore, by eliminating them, the needs of systems can be met and the performance level can be improved. Based on the results, 38 resilience barriers were finally determined. For instance, the "reduction of forest fertility, indigenous diversity and productivity levels" [15,20], as an environmental barrier, is affected by the excessive use of the materials on the ground and underground, and affects the forest land fertility and future harvest rates. The "financial return on investment" [21,22], as an economic barrier, is affected by the targets, plans, and functions of stakeholders, managers, and employees, etc., and affects the business structure of biomass and bioenergy industries. Furthermore, the "limitations of the quantity and quality of jobs creation and incomes in forest biomass and bioenergy industries" [15], as a social barrier, are affected by micro and macro decisions in the design of forest industry, and affect the attitudes of land owners, investors and employees. The "technical and technological limitations in forest biomass and bioenergy industries, qualitatively and quantitatively" [23,24], as a technical barrier, are affected by the amount of investment and research and development activities, and affect the quality and quantity of the processes and flows throughout forest biomass and bioenergy SCN. Moreover, the "legislative limitations and changes" [21,22], as a strategic barrier, are affected by local and global policies, and affects the efficiency of the biomass and bioenergy SCs' structures. Therefore, the identified barriers can give managers and researchers comprehensive viewpoints regarding the challenges within forest biomass and bioenergy SCR.

3.4. Enablers of Forest Biomass and Bioenergy Supply Chain Resilience

The enablers of a capability play vital role in being able to optimize it or not. Indeed, by investigating the enablers of a capability and improving them, the whole capability can be optimized. This SLR aimed to identify the resilience enablers in the forest biomass and bioenergy SCN. As mentioned earlier, due to the research gap, the components were explored that directly or indirectly enable resilience capability. Table 4 indicates the 61 resilience enablers. Generally, they affect the environmental, economic, social, technical and strategic dimensions of this type of SCR. For example, the "preservation of the soil productivity" [25,26], as an environmental enabler, is affected by environmental potentials, needs and changes, and affects the forest management efficiency and the quantity and quality of utilization. The "optimal investments in importing and exporting capabilities" [27], as economic enabler, are affected by the decisions on a micro and macro scale, and affect the extension and productivity of forest biomass and bioenergy SCN. Furthermore, the "improvement of public awareness and perceptions levels" [28,29], as a social enabler, is affected by training and the revelation of advantages and disadvantages to the public, and affects the acceptance and development rates of these industries. The "technology innovations with technical improvements in forest industry" [30], as a technical enabler, are affected by efficient research and development procedures, and cause the infrastructure in forest biomass and bioenergy SCN to be innovative. Furthermore, the "optimal logistics strategies" [31,32], as a strategic enabler, are affected by managerial knowledge and time-related and location-related potentials, and affect the ability of forest biomass and bioenergy SCN to operate in coordination according to the norms. Consequently, the identified enablers of forest biomass and bioenergy SCR provide a reliable platform for researchers and managers to be able to optimize the resilience and performance levels in the whole network.

3.5. Relationships among the Barriers or Enablers of Forest Biomass and Bioenergy SCR with Resilience Main Factors

In line with the identified barriers and enablers, their relationships with the main resilience factors were investigated in order to prove the findings and answer the research questions. This is due to the existing research gap in the application of resilience capability for the optimization of the forest biomass and bioenergy SCN. The 14 main factors [17,18] used in the analysis play an important role in developing a resilient structure in uncertain situations. Hence, recognizing the relationships among these components provides a platform to enhance the insights about the findings. In this step, a committee including the authors of this research and industrial experts were tasked with recognizing the relationships. In order to better understand the composition and function of the committee, the following information is important. There were seven members in the committee, including two authors of this research to investigate and prove the theoretical aspects of the relationships, as well as five industrial experts to investigate and prove the practical aspect of the relationships, who were members of the board in their company or organization. The composition of the committee members helped to simultaneously consider the theoretical and practical aspects during the decision-making process. It should be noted that all of the industrial experts had more than 5 years of experience at the highest management level in related fields. All of the steps of polling the members of the committee were performed in the form of online interviews, and separately, so that the opinions of the members were not influenced by each other. Finally, theoretical and practical opinions with the same coefficient were used to find an unbiased result. In order to achieve the final viewpoint, the mode procedure (the response or opinion that appears most often in a set of responses or opinions) was applied. Given that this article is a review, the most appropriate procedure to find a simple but efficient result was the mode procedure. Of course, in order to obtain more detailed and comprehensive findings, modern quantitative and qualitative methodologies should and will be applied in future research studies. Tables 5 and 6 show the results, respectively. The results indicate the extent to which the barriers and enablers identified by reviewing the literature are associated with resilience capability, and level thereof in forest biomass and bioenergy SCs. In this context, the direct and indirect relationships were determined. A direct relation refers to an association between a barrier or enabler and a main factor in which they progress or regress in value together. An indirect relation refers to an association between a barrier or enabler and a main factor in which they do not affect each other directly, but rather through another component(s). It should be noted that Tables 5 and 6 prove that the barriers and enablers affect the resilience capability, such that in order to find out about the details of the relationships, conducting independent research on each of them is necessary. It is beyond the scope of this SLR to state all of the reasons for the determining relationships; therefore, one item from each table will be addressed as an example.

Based on Table 5, the barrier of "variability in quantity and quality of forest biomass and bioenergy feedstock" directly affects the flexibility by undermining the ability of the SCN to change or react in the shortest possible time, at the lowest cost and with optimal performance, when faced with foreseeable and unforeseeable circumstances. It indirectly affects the information technology by undermining the level of trust of members, stakeholders and consumers in the available information and verification process in the relevant industries, which in itself leads to a regression in researching, designing, developing, deploying, optimizing and supporting information systems. On the other hand, based on Table 6, the enabler of the "integration of the technical, economic, social and environmental objectives" directly affects the adaptability by reinforcing the ability to optimally alter the goals, plans, and activities to deal with the new challenges, to meet the new needs, and to apply the new opportunities. It indirectly affects the responsiveness by increasing the coordination of potentials, demand and supply rates in relevant industries, which in itself leads to an increase in the quantity and quality of the response to the needs of members, stakeholders and consumers in the shortest possible time, at the lowest cost and with optimal performance in a variety of situations. Consequently, all of the relationships can be interpreted in such a way that they will be discussed in detail in future studies.

Table 3. Barriers of forest biomass and bioenergy SCR.

Dimensions	Barriers	References
Environmental	1. Reduction of forest fertility, indigenous diversity and productivity levels.	[15,20]
	2. Forest land availability to grow energy crops.	[21,22]
	3. Environmental vulnerability.	[28,29]
	4. Ongoing pest epidemic in forests.	[9]
	5. Increasing forest disturbance rate.	[33,34]
	6. Negative effects of climate change on forest industry.	[35]
	7. Health and environmental hazards and costs of greenhouse gas emissions.	[36,37]
	8. Potential risks for disruption because of natural disasters and man-made events.	[29]
Economic	9. Costly and complex logistics of forest biomass and bioenergy.	[1,15]
	10. High capital costs of technologies in the SCN structure.	[15,38]
	11. High capital and operational costs of pretreatment processes and high uncertainty in the time and prices.	[39,40]
	12. Variable capital and operational costs of storage facilities in different situations.	[39,41]
	13. High costs of the forest biomass and bioenergy supply management.	[42,43]
	14. Competition from other investments.	[21,22]
	15. Financial return on investment.	[21,22]
	16. Economic vulnerability.	[28,29]
	17. Variable delivery time and costs of forest biomass and bioenergy.	[44]
	18. High feedstock production costs.	[45,46]
	19. High costs of machinery and equipment in the SCN structure.	[45]
	20. Cost/profit allocation problems.	[47,48]
Social	21. Limitations of the quantity and quality of jobs creation and incomes.	[15]
	22. Lack of specialists in the biomass and bioenergy industries.	[21]
	23. Social vulnerability.	[28,29]
	24. Collaboration complexity in the SCN structure.	[49]
Technical	25. Variability in quantity and quality of feedstock.	[15,50]
	26. Technical and technological limitations, qualitatively and quantitatively.	[23,24]
	27. Limited types of storage and capacity in the SCN.	[51,52]
	28. Collection of feedstock in only one form.	[51,53,54]
	29. Capacity of machinery to recover biomass and bioenergy.	[55,56]
	30. Technical vulnerability.	[28,29]
Strategic	31. Complexity of procedures in the SCN structure.	[14,57]
	32. Uncertainty in the SCN structure.	[14,58,59]
	33. Fluctuation in demand of the feedstock and products.	[60]
	34. Strategic vulnerability of the SCN.	[28,29]
	35. Legislative limitations and changes.	[61,62]
	36. Changes in global market pertaining to the forest industry.	[9]
	37. Lack of sourcing and development in the SCN.	[63,64]
	38. Various targets, plans, and interests of stakeholders across the SCN.	[63,65]

Table 4. Enablers of forest biomass and bioenergy SCR.

Dimensions	Enablers	References
Environmental	1. Collection of forest biomass and production of forest bioenergy in various forms.	[51,53,54]
	2. Desirability of climate change.	[21]
	3. Security of the SCN.	[21]
	4. Preservation of the soil productivity.	[25,26]
	5. Conservation of the ecosystem's ecological balance.	[25,26]
	6. Optimal carrying capacity, compatible with the forest ecosystem.	[66,67]
	7. Optimal location-allocation of the facilities.	[68,69]
	8. Forest management by afforestation and reforestation targets, plans, and activities under the clean development mechanism.	[70]
	9. Mobilization of potentially robust resources of the forest biomass and bioenergy.	[49]
Economic	10. Alternative investments.	[71]
	11. Incorporating a multi-objective terminal within the SCN.	[72]
	12. Optimal investments in importing and exporting capabilities.	[27]
	13. Optimal inventory management of forest biomass and bioenergy.	[73,74]
Social	14. Information-based procedures.	[75]
	15. Improvement of public awareness and perceptions levels.	[28,29]
	16. Job creation based on the forest biomass and bioenergy types and candidate locations.	[28]
	17. Respect of values, acceptable commitment, and reliable relationships with vitalization.	[63]
	18. Enhanced collaboration within the SCN as well as among the forest owner associations, academy, industry, and government.	[35,63]
	19. Efficient human resource for the SCN.	[76]
	20. Founding the forest biomass and bioenergy sale and purchasing associations.	[35,77]
	21. Create programs for constant training and learning in the SCN and relevant industries.	[36,78]
	22. Occupational health and safety.	[36]
Technical	23. High efficiency and optimal scale of pretreatment conversion technology.	[39,40]
	24. Application of the various types of storage systems in different conditions.	[39,73]
	25. Road network optimization.	[39,79]
	26. Utilizing advanced and modern technologies.	[14]
	27. Optimal design and management processes.	[14]
	28. Modern information technology and system.	[80,81]
	29. Optimal forest biomass and bioenergy recovery and recycling processes.	[82]
	30. Optimal decision support system for design and management.	[83,84]
	31. Optimal timing of operations in the SCN.	[75]
	32. Precision supply scenarios.	[75]
	33. Efficient forest biomass and bioenergy facilities.	[9]
	34. Optimal innovation in the SCN structure.	[63,85]
	35. Self-sufficiency with flexible production of forest biomass and bioenergy in multiple-scale.	[76,86]
	36. Optimal design, planning and management of plants and sites.	[87,88]
	37. Reliability of the supply-demand structure of the SCN.	[89]
	38. Technological innovations with technical improvements in forest industry.	[30]

Table 4. *Cont.*

Dimensions	Enablers	References
Strategic	39. Feasibility of targets, plans, and activities for the SCN infrastructure.	[15]
	40. Integration of the economic, environmental, social, and technical objectives.	[15]
	41. Integration of the strategic, tactical and operational decisions.	[44]
	42. Optimal logistics strategies.	[31,32]
	43. Optimal strategic, tactical and operational decision making levels.	[43,90]
	44. Optimal storage strategies and decision-making tools.	[82,91]
	45. Flexible structure of the SCN.	[80,81]
	46. Integration of long-term, medium-term and short-term goals, plans and activities.	[51]
	47. Global and local policies and government incentives.	[23,92]
	48. Risk confrontation and management of the SCs and operations.	[25,93]
	49. Optimal and timely anticipating ability.	[28]
	50. Optimal configuration of SCN based on the potentials, changes and needs.	[71,94]
	51. Optimal long-term, medium-term and short-term planning.	[95,96]
	52. Optimal coordination in the SCN.	[63,97]
	53. Optimal control in the SCN.	[63,97]
	54. Optimal policy-making framework and system leading to the perspective policies.	[63,92,98]
	55. Robustness of the SCN.	[99]
	56. Application of centralized or decentralized systems in the SCN based on the potentials and needs.	[35,77]
	57. Optimal allocation mechanisms and strategies.	[47,48]
	58. Integration of the new infrastructure with existing facilities.	[94]
	59. Forest waste management mechanisms and strategies.	[49,100]
	60. Implementation of necessary equipment upgrades within SCN and relevant industries.	[101]
	61. A various range of best management practices within SCN and relevant industries.	[102,103]

Table 5. Relationships among the barriers of forest biomass and bioenergy SCR and the main resilience factors.

Barriers	Adaptability	Anticipation	Collaboration	Commitment	Flexibility	Information Technology	Innovation	Integration	Leadership	Redundancy	Responsiveness	Risk Management	Robustness	Vulnerability
1	D	I	I	I	D	I	I	D	I	I	D	D	I	D
2	D	D	D	D	D	I	I	I	I	I	I	D	I	D
3	D	I	D	D	I	I	I	D	D	D	I	D	D	D
4	I	D	I	I	I	I	I	I	I	D	D	D	D	D
5	I	I	I	D	I	I	I	D	I	D	I	D	D	D
6	D	D	I	I	D	I	I	I	I	I	I	D	I	D
7	I	D	I	D	I	I	I	D	I	I	I	D	D	D

Table 5. *Cont.*

Barriers	Adaptability	Anticipation	Collaboration	Commitment	Flexibility	Information Technology	Innovation	Integration	Leadership	Redundancy	Responsiveness	Risk Management	Robustness	Vulnerability
8	I	D	I	D	I	D	I	I	I	D	I	D	D	D
9	D	I	D	I	I	D	I	D	I	I	D	I	I	I
10	D	I	I	I	D	D	D	I	I	D	I	I	I	I
11	D	D	I	I	D	D	I	D	I	I	I	D	D	I
12	D	I	I	I	D	I	I	I	I	D	D	D	I	I
13	I	I	I	I	I	D	I	D	D	I	I	D	I	I
14	I	D	D	I	I	I	I	I	D	I	I	I	I	I
15	I	I	I	D	I	I	I	D	I	I	I	I	I	I
16	D	I	D	D	I	I	I	D	D	D	I	D	D	D
17	D	D	I	D	D	I	I	I	I	I	D	I	I	D
18	D	I	I	I	D	I	D	I	I	D	D	I	I	I
19	D	I	I	I	D	I	D	I	I	D	D	I	D	D
20	D	I	D	D	I	I	I	D	D	I	I	I	I	I
21	D	I	D	D	I	D	I	I	D	I	I	I	D	D
22	I	I	D	D	I	D	D	I	D	I	I	I	D	D
23	D	I	D	D	I	I	I	D	D	D	I	D	D	D
24	D	I	D	D	D	D	I	D	D	I	I	D	D	I
25	D	D	I	I	D	I	D	D	I	D	D	D	D	D
26	D	D	I	I	D	D	D	D	I	D	D	D	D	D
27	D	D	D	I	D	I	D	D	D	D	D	D	D	D
28	D	I	I	I	D	I	D	D	I	D	D	D	D	D
29	D	I	I	I	D	I	D	I	I	D	D	I	D	D
30	D	I	D	D	I	I	I	D	D	D	I	D	D	D
31	I	I	D	D	I	D	I	D	D	I	I	D	I	I
32	D	D	I	D	I	D	I	I	D	D	I	D	D	D
33	D	D	I	I	D	D	I	D	I	D	D	D	I	D
34	I	D	I	I	I	D	I	D	D	D	I	D	D	D
35	D	I	I	I	D	D	I	I	I	I	D	D	I	D
36	D	D	D	I	D	I	I	D	D	I	D	I	D	D
37	I	I	I	I	D	D	D	D	D	I	D	D	D	D
38	D	I	D	D	I	I	I	D	D	I	I	I	I	I

Direct: D; Indirect: I.

Table 6. Relationships among the enablers of forest biomass and bioenergy SCR and the main resilience factors.

Enablers	Adaptability	Anticipation	Collaboration	Commitment	Flexibility	Information Technology	Innovation	Integration	Leadership	Redundancy	Responsiveness	Risk Management	Robustness	Vulnerability
1	D	D	D	I	D	I	D	D	I	D	D	D	D	D
2	D	D	I	I	I	I	I	I	I	I	I	D	I	D
3	D	D	D	D	I	D	I	I	I	I	I	D	D	D
4	D	I	I	I	D	I	D	D	I	I	D	D	D	D
5	D	D	I	I	I	I	D	I	I	I	I	D	D	D
6	D	I	I	I	D	I	D	D	I	I	D	D	D	I
7	D	D	I	I	D	D	I	D	I	D	D	I	I	I
8	D	D	D	D	D	D	D	D	D	D	D	D	D	D
9	I	I	D	I	I	I	I	D	D	D	D	D	D	D
10	D	I	I	I	D	I	D	I	D	D	D	D	D	D
11	I	D	D	D	I	D	I	D	I	D	D	I	I	D
12	D	I	I	I	D	I	I	D	D	I	D	I	I	I
13	D	D	I	I	D	D	I	D	I	I	D	D	I	D
14	D	D	D	I	I	D	D	I	D	I	D	I	I	I
15	D	I	D	D	I	D	D	D	D	I	I	D	D	D
16	D	I	D	D	D	I	I	D	I	I	D	I	I	I
17	D	I	D	D	I	D	I	D	D	I	D	D	D	I
18	D	D	D	D	I	D	I	D	I	I	D	I	I	D
19	I	I	D	D	I	D	I	I	I	D	I	D	I	D
20	D	I	D	D	D	D	I	D	I	D	D	I	I	D
21	I	I	D	D	I	D	D	I	D	I	I	I	I	D
22	I	I	I	D	I	I	I	I	I	I	I	D	D	D
23	D	I	I	I	D	D	D	I	I	D	D	D	D	D
24	D	D	I	I	D	I	D	D	I	D	D	D	D	D
25	D	D	D	I	D	I	I	D	I	D	D	D	D	D
26	D	D	I	I	D	D	D	I	D	D	D	I	I	D
27	D	I	I	D	D	I	D	I	D	D	I	D	D	D
28	D	D	D	I	I	D	D	I	D	I	D	D	I	D
29	I	I	I	I	D	I	D	I	I	D	D	I	I	I
30	D	D	D	D	I	D	D	D	D	D	I	D	I	I
31	D	D	D	D	D	D	D	D	I	I	D	I	I	I
32	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Table 6. *Cont.*

Enablers	Adaptability	Anticipation	Collaboration	Commitment	Flexibility	Information Technology	Innovation	Integration	Leadership	Redundancy	Responsiveness	Risk Management	Robustness	Vulnerability
33	D	I	I	I	D	I	D	I	I	D	D	D	D	D
34	D	D	I	I	D	D	D	I	I	D	D	I	I	D
35	D	D	I	I	D	I	I	D	D	D	D	D	D	D
36	D	D	D	I	D	D	D	D	I	D	D	D	D	D
37	D	D	I	D	D	D	I	I	I	I	D	D	D	D
38	I	D	I	I	I	D	D	I	I	D	D	I	D	D
39	D	D	D	D	D	D	D	D	D	D	D	D	D	I
40	D	D	D	I	D	I	I	D	D	I	I	I	D	D
41	D	I	D	I	I	D	I	D	D	I	I	D	I	D
42	I	D	D	I	I	D	I	D	I	I	D	D	I	D
43	I	I	I	D	D	I	I	D	D	D	I	D	D	D
44	I	D	D	D	I	D	I	D	D	I	I	D	I	D
45	D	I	D	I	D	I	I	D	I	D	D	I	I	D
46	D	D	D	D	D	D	D	D	D	D	D	D	D	D
47	D	D	D	D	I	D	I	D	D	I	I	I	I	D
48	I	D	I	I	I	D	D	D	D	D	I	D	D	D
49	I	D	I	I	D	D	I	I	D	D	D	D	I	D
50	D	D	D	D	D	D	D	D	D	D	D	D	D	D
51	D	D	I	I	D	D	I	D	D	I	I	D	I	D
52	D	D	D	D	I	D	I	D	D	I	D	D	D	I
53	I	D	I	D	I	I	I	I	D	I	I	D	I	D
54	D	D	D	D	D	D	D	D	D	D	D	D	D	D
55	D	D	D	D	D	D	D	D	D	D	D	D	D	D
56	D	D	D	I	D	I	I	D	I	D	I	D	D	D
57	D	D	D	I	D	D	I	D	D	I	D	I	I	D
58	D	I	D	I	I	I	D	D	I	D	D	I	D	D
59	I	I	I	I	I	D	I	I	D	D	I	D	I	I
60	D	I	I	I	D	I	D	I	I	D	D	D	D	D
61	D	D	D	D	D	D	D	D	D	D	D	D	D	D

Direct: D; Indirect: I.

4. Discussion: Findings and Future Directions

In this SLR, three general questions (including the first, second and fifth questions) and two main questions (including the third and fourth questions) in the context of forest biomass and bioenergy SCR were asked:

1. What is the current circumstance of the research and work in forest biomass and bioenergy SCR?
2. What is the Definition of forest biomass and bioenergy SCR?
3. What is the set of barriers in forest biomass and bioenergy SCR?
4. What is the set of enablers in forest biomass and bioenergy SCR?
5. What are the existing gap(s) and necessities of forest biomass and bioenergy SCR for the academy and industry?

This study was the first literature review on the forest biomass and bioenergy SCN which aimed to investigate the resilience capability and relevant components. In this regard, an integrated framework was implemented to collect the data. First, two basic research questions were determined, the answers to which are the main basis of the findings. Next, the suitable indices were determined for a more accurate and comprehensive review process. In this way, the keywords, databases and publishers were specified in order to find the relevant publications in high-quality journals in which both theoretical and practical aspects were considered. The indicators of IF, SJR and SNIP, as three reliable rating tools, were used to distinguish among the high and low quality journals. Furthermore, the references of the included publications were tracked in order to identify the other linked studies. Through this phase, the identification of 883, screening of 281, eligibility of 149, and inclusion of 51 publications indicates the relevant publications in four levels. Furthermore, 37 publications were recognized from the tracked references. Reviewing publications at four main levels and a supplementary level helped us to finally select those which really answered the research questions. In the following, the findings and the directions for future works on forest biomass and bioenergy SCR will be summarized.

4.1. Characteristics of the Publications

In Table 2, the results of the data refinement that indicate the accuracy rate of the reviewing process regarding the identification of the barriers and enablers within the forest biomass and bioenergy SCN which directly and indirectly affect the resilience capability are incorporated. The data show the journals that have significantly dealt with this issue. Furthermore, 6% of all of the identified publications pointed to barriers and enablers in this field. By tracking the references of the included publications, relevant studies were identified, including 42% of the final publications. In this regard, 49% were published in the selected journals, as well as 51% in other journals. It should be noted that 32% of the publications that were selected by tracking the references were published before 2009.

Figure 2 indicates the year-wise distribution of the publications. The data indicated a mutation of the research and development from 2014 for works on forest biomass and bioenergy SC capabilities, and that the majority of the research was conducted by researchers after 2017. It revealed that the field was attracting the attention of both researchers and practitioners to address the effective components in recent years. On the other hand, Figure 3 indicates the keyword-wise distribution of the publications. The keywords of "forest biomass supply chain" and "forest bioenergy supply chain" were used in almost all of the final publications working on the barriers and enablers. However, there is no significant study using other selected keywords that specifically addresses resilience capability in this field. However, many studies have been conducted on overall SCR and even its sub-sections. Therefore, this is a significant research gap.

This review of the literature revealed a critical need to investigate the resilience capability in forest biomass and bioenergy SCN. As the development of a resilient structure is an important issue in various scopes, the identification and evaluation of the barriers and enablers play a vital role in the optimization of forest biomass and bioenergy SCN. It is obvious that mathematical modeling and simulation are the common approaches that have been applied for the optimization of the SC structure. Hence, there is an unmet need to use other approaches such as conceptual modeling for the evaluation of the importance of the barriers and enablers, the relationships among them, and the capabilities in the overall network. The barriers and enablers identified in this SLR are related to the overall aspects of the forest biomass and bioenergy SCN. However, the investigation of their relationships with the main resilience factors provides a situation to reveal their effects on the resilience level, and to consider them as resilience barriers and enablers in this field. Therefore, future studies could analyze the ways in which these components can be operationalized and appropriately measured. Finally, the comprehension of the barriers and enablers would provide noteworthy intuition on the development of resilience capability in the forest biomass and bioenergy industries at different levels that could be a thought-provoking and comparatively untapped topic.

4.2. Forest Biomass and Bioenergy SCR

In order to obtain a definition for forest biomass and bioenergy SCR, the relevant literature was reviewed. As a significant research gap that affected the identification of barriers and enablers, there is no reliable study working on forest biomass and bioenergy SCR. Hence, in order to obviate the hesitancy about the meaning of resilience in this field, a reliable definition was proposed according to the extant body of literature in this SLR. In order to do this, the definitions of forest biomass and bioenergy SCN and the overall SCR were investigated and used to create a precise definition. It can be stated that the topic is active and hypaethral for future works, and that it needs both theoretical and practical research.

4.3. Barriers and Enablers of Forest Biomass and Bioenergy SCR

In this SLR, an integrated framework was proposed to investigate the states of the definition, barriers and enablers of the resilience in forest biomass and bioenergy SCN. According to the existing research gap, the barriers and enablers were identified based on the literature on the overall forest biomass and bioenergy SCN. Then, in order to prove their impacts on resilience capability, their relationships with the main resilience factors were investigated. Finally, the results were abridged and the comprehensive sets of resilience barriers and enablers were presented.

This study provides various directions for future works on forest biomass and bioenergy SCR. In the context of resilience capability, a fundamental query still unanswered is the relative importance of barriers and enablers in the structure of forest biomass and bioenergy SCN that could affect environmental, economic, social, technical and strategic dimensions, theoretically and practically. Therefore, future research works ought to address resilience capability through the evaluation of the interactions between the components and their importance, the advantages and disadvantages, and the effects of components on forest biomass and bioenergy SCR and performance quality.

5. Conclusions

In this study, by reviewing the literature, 88 publications were identified in which the barriers and enablers to which they referred directly and indirectly affect the resilience capability. The publications contained a wide range of scopes, such as large-, medium- and small-sized forest biomass and bioenergy industries, as well as relevant global and local SCNs. Even though there is a significant research gap on forest biomass and bioenergy SCR, the implication of the mentioned capability from environmental, economic, social, technical, and strategic aspects was investigated, and relevant barriers and enablers were identified.

Through a systematic review of the literature on forest biomass and bioenergy SCR within a 20-year time frame (2009–2020 directly and 2000–2009 indirectly), the concept was discussed. In this way, a comprehensive definition for forest biomass and bioenergy SCR was presented that indicates the complexity of resilience in this sector. Moreover, the timeline and framework were presented in order to recognize the resilience barriers and enablers that transpired as the findings of the reviewing process. It is hoped that the findings of this SLR will prepare an inclusive cornerstone for researchers and practitioners in their future works.

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References

1. McKendry, P. Energy production from biomass (part 1): Overview of biomass. *Bioresour. Technol.* **2002**, *83*, 37–46. [CrossRef]
2. Letcher, T.M. Introduction with a Focus on Atmospheric Carbon Dioxide and Climate Change. In *Future Energy*; Elsevier: Amsterdam, The Netherlands, 2020; pp. 3–17.
3. Fischer, G.; Schrattenholzer, L. Global bioenergy potentials through 2050. *Biomass Bioenergy* **2001**, *20*, 151–159. [CrossRef]
4. Rogers, J.N.; Stokes, B.; Dunn, J.; Cai, H.; Wu, M.; Haq, Z.; Baumes, H. An assessment of the potential products and economic and environmental impacts resulting from a billion ton bioeconomy. *Biofuels Bioprod. Biorefining* **2017**, *11*, 110–128. [CrossRef]
5. Thiffault, E.; Hannam, K.D.; Paré, D.; Titus, B.D.; Hazlett, P.W.; Maynard, D.G.; Brais, S. Effects of forest biomass harvesting on soil productivity in boreal and temperate forests—A review. *Environ. Rev.* **2011**, *19*, 278–309. [CrossRef]
6. Röser, D.; Asikainen, A.; Raulund-Rasmussen, K.; Stupak, I. *Sustainable Use of Forest Biomass for Energy: A Synthesis with Focus on the Baltic and Nordic Region*; Springer Science & Business Media: Berlin, Germany, 2008; Volume 12.
7. Liu, W.; Hou, Y.; Liu, W.; Yang, M.; Yan, Y.; Peng, C.; Yu, Z. Global estimation of the climate change impact of logging residue utilization for biofuels. *For. Ecol. Manag.* **2020**, *462*, 118000. [CrossRef]
8. Nguyen, T.H.; Jones, S.D.; Soto-Berelov, M.; Haywood, A.; Hislop, S. Monitoring aboveground forest biomass dynamics over three decades using Landsat time-series and single-date inventory data. *Int. J. Appl. Earth Obs. Geoinf.* **2020**, *84*, 101952. [CrossRef]
9. Maier, J.M.; Sowlati, T.; Salazar, J. Life cycle assessment of forest-based biomass for bioenergy: A case study in British Columbia, Canada. *Resour. Conserv. Recycl.* **2019**, *146*, 598–609. [CrossRef]
10. Rosillo-Calle, F. The role of biomass energy in rural development. *Proc. Third Encontro Energ. Meio Rural* **2000**, *3*, 12–15.
11. Ölz, S. *Renewable Energy Policy Considerations for Deploying Renewables*; International Energy Agency (IEA): Paris, France, 2011.
12. Wang, H.; Zhang, S.; Bi, X.; Clift, R. Greenhouse gas emission reduction potential and cost of bioenergy in British Columbia, Canada. *Energy Policy* **2020**, *138*, 111285. [CrossRef]
13. Berger, A.L.; Palik, B.; D'Amato, A.W.; Fraver, S.; Bradford, J.B.; Nislow, K.; King, D.; Brooks, R.T. Ecological impacts of energy-wood harvests: Lessons from whole-tree harvesting and natural disturbance. *J. For.* **2013**, *111*, 139–153. [CrossRef]
14. Shabani, N.; Akhtari, S.; Sowlati, T. Value chain optimization of forest biomass for bioenergy production: A review. *Renew. Sustain. Energy Rev.* **2013**, *23*, 299–311. [CrossRef]
15. Cambero, C.; Sowlati, T. Assessment and optimization of forest biomass supply chains from economic, social and environmental perspectives—A review of literature. *Renew. Sustain. Energy Rev.* **2014**, *36*, 62–73. [CrossRef]
16. Kamalahmadi, M.; Parast, M.M. A review of the literature on the principles of enterprise and supply chain resilience: Major findings and directions for future research. *Int. J. Prod. Econ.* **2016**, *171*, 116–133. [CrossRef]
17. Sangari, M.S.; Dashtpeyma, M. An integrated framework of supply chain resilience enablers: A hybrid ISM-FANP approach. *Int. J. Bus. Excell.* **2019**, *18*, 242–268. [CrossRef]
18. Dashtpeyma, M.; Ghodsi, R. Developing the resilient solar energy management system: A hybrid qualitative-quantitative approach. *Int. J. Ambient Energy* **2019**, 1–20. [CrossRef]
19. de Bikuña, K.S.; Garcia, R.; Dias, A.C.; Freire, F. Global warming implications from increased forest biomass utilization for bioenergy in a supply-constrained context. *J. Environ. Manag.* **2020**, *263*, 110292. [CrossRef]
20. Lattimore, B.; Smith, C.T.; Titus, B.D.; Stupak, I.; Egnell, G. Environmental factors in woodfuel production: Opportunities, risks, and criteria and indicators for sustainable practices. *Biomass Bioenergy* **2009**, *33*, 1321–1342. [CrossRef]
21. Adams, P.; Hammond, G.P.; McManus, M.C.; Mezzullo, W.G. Barriers to and drivers for UK bioenergy development. *Renew. Sustain. Energy Rev.* **2011**, *15*, 1217–1227. [CrossRef]
22. Sherrington, C.; Bartley, J.; Moran, D. Farm-level constraints on the domestic supply of perennial energy crops in the UK. *Energy Policy* **2008**, *36*, 2504–2512. [CrossRef]
23. Akhtari, S.; Sowlati, T.; Day, K. Economic feasibility of utilizing forest biomass in district energy systems—A review. *Renew. Sustain. Energy Rev.* **2014**, *33*, 117–127. [CrossRef]

24. Skoulou, V.; Zabaniotou, A. Investigation of agricultural and animal wastes in Greece and their allocation to potential application for energy production. *Renew. Sustain. Energy Rev.* **2007**, *11*, 1698–1719. [CrossRef]
25. Manolis, E.; Zagas, T.D.; Karetsos, G.K.; Poravou, C.A. Ecological restrictions in forest biomass extraction for a sustainable renewable energy production. *Renew. Sustain. Energy Rev.* **2019**, *110*, 290–297. [CrossRef]
26. Dafis, S. *Forest Ecology*; Ghiahoudi and Ghiapouli Publications: Thessaloniki, Greek, 1986.
27. Rentizelas, A.; Melo, I.C.; Junior, P.N.A.; Campoli, J.S.; do Nascimento Rebelatto, D.A. Multi-criteria efficiency assessment of international biomass supply chain pathways using data envelopment analysis. *J. Clean. Prod.* **2019**, *237*, 117690. [CrossRef]
28. Cambero, C.; Sowlati, T. Incorporating social benefits in multi-objective optimization of forest-based bioenergy and biofuel supply chains. *Appl. Energy* **2016**, *178*, 721–735. [CrossRef]
29. Perdue, J.H.; Stanturf, J.A.; Young, T.M.; Huang, X. A geospatial biomass supply model adjusted for risk from natural disasters. *Scand. J. For. Res.* **2019**, *34*, 598–606. [CrossRef]
30. Tuomasjukka, D.; Martire, S.; Lindner, M.; Athanassiadis, D.; Kühmaier, M.; Tumajer, J.; Vis, M.; Spinelli, R.; Dees, M.; Prinz, R.; et al. Sustainability impacts of increased forest biomass feedstock supply—A comparative assessment of technological solutions. *Int. J. For. Eng.* **2018**, *29*, 99–116. [CrossRef]
31. Brewer, P.C. Using the balanced scorecard to measure supply chain performance Brewer, Peter Cspeh, Thomas W. *J. Bus. Logist.* **2000**, *21*, 75.
32. Nunes, L.; Causer, T.; Ciolkosz, D. Biomass for energy: A review on supply chain management models. *Renew. Sustain. Energy Rev.* **2020**, *120*, 109658. [CrossRef]
33. Rijal, B.; Gautam, S.H.; LeBel, L. The impact of forest disturbances on residual biomass supply: A long-term forest level analysis. *J. Clean. Prod.* **2020**, *248*, 119278. [CrossRef]
34. Rijal, B.; Raulier, F.; Martell, D.L. A value-added forest management policy reduces the impact of fire on timber production in Canadian boreal forests. *For. Policy Econ.* **2018**, *97*, 21–32. [CrossRef]
35. Rauch, P. Developing and evaluating strategies to overcome biomass supply risks. *Renew. Energy* **2017**, *103*, 561–569. [CrossRef]
36. Fedorova, E.; Pongrácz, E. Cumulative social effect assessment framework to evaluate the accumulation of social sustainability benefits of regional bioenergy value chains. *Renew. Energy* **2019**, *131*, 1073–1088. [CrossRef]
37. Liu, W.-Y.; Lin, C.-C.; Yeh, T.-L. Supply chain optimization of forest biomass electricity and bioethanol coproduction. *Energy* **2017**, *139*, 630–645. [CrossRef]
38. Meyer, J.; Hobson, P.; Schultmann, F. The potential for centralised second generation hydrocarbons and ethanol production in the Australian sugar industry. In Proceedings of the 34th Conference of the Australian Society of Sugar Cane Technologists, Cairns, QLD, Australia, 1–4 May 2012.
39. Mirkouei, A.; Haapala, K.R.; Sessions, J.; Murthy, G.S. A review and future directions in techno-economic modeling and optimization of upstream forest biomass to bio-oil supply chains. *Renew. Sustain. Energy Rev.* **2017**, *67*, 15–35. [CrossRef]
40. Gold, S.; Seuring, S. Supply chain and logistics issues of bio-energy production. *J. Clean. Prod.* **2011**, *19*, 32–42. [CrossRef]
41. Kanzian, C.; Holzleitner, F.; Stampfer, K.; Ashton, S. Regional energy wood logistics–optimizing local fuel supply. *Silva Fenn.* **2009**, *43*, 113–128. [CrossRef]
42. Mitigation, C.C. IPCC special report on renewable energy sources and climate change mitigation. *Renew. Energy* **2011**, *20*, 1–41.
43. De Meyer, A.; Cattrysse, D.; Rasinmäki, J.; Van Orshoven, J. Methods to optimise the design and management of biomass-for-bioenergy supply chains: A review. *Renew. Sustain. Energy Rev.* **2014**, *31*, 657–670. [CrossRef]
44. Akhtari, S.; Sowlati, T.; Griess, V.C. Integrated strategic and tactical optimization of forest-based biomass supply chains to consider medium-term supply and demand variations. *Appl. Energy* **2018**, *213*, 626–638. [CrossRef]
45. Akhtari, S.; Sowlati, T.; Day, K. The effects of variations in supply accessibility and amount on the economics of using regional forest biomass for generating district heat. *Energy* **2014**, *67*, 631–640. [CrossRef]
46. Gan, J. Supply of biomass, bioenergy, and carbon mitigation: Method and application. *Energy Policy* **2007**, *35*, 6003–6009. [CrossRef]
47. Gao, E.; Sowlati, T.; Akhtari, S. Profit allocation in collaborative bioenergy and biofuel supply chains. *Energy* **2019**, *188*, 116013. [CrossRef]
48. Ramaekers, K.; Verdonck, L.; Caris, A.; Meers, D.; Macharis, C. Allocating collaborative costs in multimodal barge networks for freight bundling. *J. Transp. Geogr.* **2017**, *65*, 56–69. [CrossRef]
49. Welfle, A.; Gilbert, P.; Thornley, P. Increasing biomass resource availability through supply chain analysis. *Biomass Bioenergy* **2014**, *70*, 249–266. [CrossRef]
50. Wood, S.M.; Layzell, D.B. *A Canadian Biomass Inventory: Feedstocks for a Bio-Based Economy-Final Report*; BIOCAP Canada Foundation: Kingston, ON, Canada, 2003.
51. Malladi, K.T.; Sowlati, T. Biomass logistics: A review of important features, optimization modeling and the new trends. *Renew. Sustain. Energy Rev.* **2018**, *94*, 587–599. [CrossRef]
52. Gronalt, M.; Rauch, P. Designing a regional forest fuel supply network. *Biomass Bioenergy* **2007**, *31*, 393–402. [CrossRef]
53. Sowlati, T. Modeling of forest and wood residues supply chains for bioenergy and biofuel production. In *Biomass Supply Chains for Bioenergy and Biorefining*; Holm-Nielsen, J.B., Ehimen, E.A., Eds.; Elsevier, Woodhead Publishing: Amsterdam, The Netherlands, 2016; pp. 167–190.

54. Gunnarsson, H.; Rönnqvist, M.; Lundgren, J.T. Supply chain modelling of forest fuel. *Eur. J. Oper. Res.* **2004**, *158*, 103–123. [CrossRef]
55. Thiffault, E.; Béchard, A.; Paré, D.; Allen, D. Recovery rate of harvest residues for bioenergy in boreal and temperate forests: A review. *Wiley Interdiscip. Rev. Energy Environ.* **2015**, *4*, 429–451. [CrossRef]
56. Mansuy, N.; Thiffault, E.; Lemieux, S.; Manka, F.; Paré, D.; Lebel, L. Sustainable biomass supply chains from salvage logging of fire-killed stands: A case study for wood pellet production in eastern Canada. *Appl. Energy* **2015**, *154*, 62–73. [CrossRef]
57. D'amours, S.; Rönnqvist, M.; Weintraub, A. Using operational research for supply chain planning in the forest products industry. *INFOR Inf. Syst. Oper. Res.* **2008**, *46*, 265–281. [CrossRef]
58. Kangas, A.S.; Kangas, J. Probability, possibility and evidence: Approaches to consider risk and uncertainty in forestry decision analysis. *For. Policy Econ.* **2004**, *6*, 169–188. [CrossRef]
59. Shabani, N.; Sowlati, T. Evaluating the impact of uncertainty and variability on the value chain optimization of a forest biomass power plant using Monte Carlo Simulation. *Int. J. Green Energy* **2016**, *13*, 631–641. [CrossRef]
60. Mobini, M.; Sowlati, T.; Sokhansanj, S. Forest biomass supply logistics for a power plant using the discrete-event simulation approach. *Appl. Energy* **2011**, *88*, 1241–1250. [CrossRef]
61. Prinz, R.; Väätäinen, K.; Laitila, J.; Sikanen, L.; Asikainen, A. Analysis of energy efficiency of forest chip supply systems using discrete-event simulation. *Appl. Energy* **2019**, *235*, 1369–1380. [CrossRef]
62. Karttunen, K.; Lättilä, L.; Korpinen, O.J.; Ranta, T. Cost-efficiency of intermodal container supply chain for forest chips. *Silva Fenn.* **2013**, *47*, 1–24. [CrossRef]
63. Ahl, A.; Eklund, J.; Lundqvist, P.; Yarime, M. Balancing formal and informal success factors perceived by supply chain stakeholders: A study of woody biomass energy systems in Japan. *J. Clean. Prod.* **2018**, *175*, 50–59. [CrossRef]
64. Ooba, M.; Hayashi, K.; Fujii, M.; Fujita, T.; Machimura, T.; Matsui, T. A long-term assessment of ecological-economic sustainability of woody biomass production in Japan. *J. Clean. Prod.* **2015**, *88*, 318–325. [CrossRef]
65. Keefe, R.; Anderson, N.; Hogland, J.; Muhlenfeld, K. Woody biomass logistics [Chapter 14]. In *Cellulosic Energy Cropping Systems*; Karlen, D., Ed.; John Wiley and Sons: West Sussex, UK, 2014; pp. 251–279.
66. Martire, S.; Castellani, V.; Sala, S. Carrying capacity assessment of forest resources: Enhancing environmental sustainability in energy production at local scale. *Resour. Conserv. Recycl.* **2015**, *94*, 11–20. [CrossRef]
67. Costanza, R. Science and ecological economics: Integrating of the study of humans and the rest of nature. *Bull. Sci. Technol. Soc.* **2009**, *29*, 358–373. [CrossRef]
68. Sánchez-García, S.; Athanassiadis, D.; Martínez-Alonso, C.; Tolosana, E.; Majada, J.; Canga, E. A GIS methodology for optimal location of a wood-fired power plant: Quantification of available woodfuel, supply chain costs and GHG emissions. *J. Clean. Prod.* **2017**, *157*, 201–212. [CrossRef]
69. Delivand, M.K.; Cammerino, A.R.B.; Garofalo, P.; Monteleone, M. Optimal locations of bioenergy facilities, biomass spatial availability, logistics costs and GHG (greenhouse gas) emissions: A case study on electricity productions in South Italy. *J. Clean. Prod.* **2015**, *99*, 129–139. [CrossRef]
70. Lin, B.; Ge, J. To harvest or not to harvest? Forest management as a trade-off between bioenergy production and carbon sink. *J. Clean. Prod.* **2020**, *268*, 122219. [CrossRef]
71. Zetterholm, J.; Pettersson, K.; Leduc, S.; Mesfun, S.; Lundgren, J.; Wetterlund, E. Resource efficiency or economy of scale: Biorefinery supply chain configurations for co-gasification of black liquor and pyrolysis liquids. *Appl. Energy* **2018**, *230*, 912–924. [CrossRef]
72. Gautam, S.; LeBel, L.; Carle, M.-A. Supply chain model to assess the feasibility of incorporating a terminal between forests and biorefineries. *Appl. Energy* **2017**, *198*, 377–384. [CrossRef]
73. Akhtari, S.; Sowlati, T.; Siller-Benitez, D.G.; Roeser, D. Impact of inventory management on demand fulfilment, cost and emission of forest-based biomass supply chains using simulation modelling. *Biosyst. Eng.* **2019**, *178*, 184–199. [CrossRef]
74. Axsäter, S. *Inventory Control*; Springer: Berlin, Germany, 2015; Volume 225.
75. Windisch, J.; Väätäinen, K.; Anttila, P.; Nivala, M.; Laitila, J.; Asikainen, A.; Sikanen, L. Discrete-event simulation of an information-based raw material allocation process for increasing the efficiency of an energy wood supply chain. *Appl. Energy* **2015**, *149*, 315–325. [CrossRef]
76. Simioni, F.J.; de Almeida Buschinelli, C.C.; Moreira, J.M.M.Á.P.; dos Passos, B.M.; Girotto, S.B.F.T. Forest biomass chain of production: Challenges of small-scale forest production in southern Brazil. *J. Clean. Prod.* **2018**, *174*, 889–898. [CrossRef]
77. Rauch, P. Stochastic simulation of forest fuel sourcing models under risk. *Scand. J. For. Res.* **2010**, *25*, 574–584. [CrossRef]
78. Lattimore, B.; Smith, C.T.; Titus, B.; Stupak, I.; Egnell, G. Woodfuel harvesting: A review of environmental risks, criteria and indicators, and certification standards for environmental sustainability. *J. Sustain. For.* **2013**, *32*, 58–88. [CrossRef]
79. Routa, J.; Asikainen, A.; Björheden, R.; Laitila, J.; Röser, D. Forest energy procurement: State of the art in Finland and Sweden. *Wiley Interdiscip. Rev. Energy Environ.* **2013**, *2*, 602–613. [CrossRef]
80. Pérez, A.T.E.; Camargo, M.; Rincón, P.C.N.; Marchant, M. Key challenges and requirements for sustainable and industrialized biorefinery supply chain design and management: A bibliographic analysis. *Renew. Sustain. Energy Rev.* **2017**, *69*, 350–359. [CrossRef]
81. Hanafizadeh, P.; Sherkat, M.H. Designing fuzzy-genetic learner model based on multi-agent systems in supply chain management. *Expert Syst. Appl.* **2009**, *36*, 10120–10134. [CrossRef]

82. Ghaffariyan, M.R.; Brown, M.; Acuna, M.; Sessions, J.; Gallagher, T.; Kühmaier, M.; Spinelli, R.; Visser, R.; Devlin, G.; Eliasson, L.; et al. An international review of the most productive and cost effective forest biomass recovery technologies and supply chains. *Renew. Sustain. Energy Rev.* **2017**, *74*, 145–158. [CrossRef]
83. Balaman, Ş.Y.; Selim, H. A fuzzy multiobjective linear programming model for design and management of anaerobic digestion based bioenergy supply chains. *Energy* **2014**, *74*, 928–940. [CrossRef]
84. Alsaleh, M.; Abdul-Rahim, A.; Mohd-Shahwahid, H. Determinants of technical efficiency in the bioenergy industry in the EU28 region. *Renew. Sustain. Energy Rev.* **2017**, *78*, 1331–1349. [CrossRef]
85. Falcone, P.M.; Tani, A.; Tartiu, V.E.; Imbriani, C. Towards a sustainable forest-based bioeconomy in Italy: Findings from a SWOT analysis. *For. Policy Econ.* **2020**, *110*, 101910. [CrossRef]
86. Mirata, M.; Nilsson, H.; Kuisma, J. Production systems aligned with distributed economies: Examples from energy and biomass sectors. *J. Clean. Prod.* **2005**, *13*, 981–991. [CrossRef]
87. Shabani, N.; Sowlati, T.; Ouhimmou, M.; Rönnqvist, M. Tactical supply chain planning for a forest biomass power plant under supply uncertainty. *Energy* **2014**, *78*, 346–355. [CrossRef]
88. Gan, J.; Smith, C. Optimal plant size and feedstock supply radius: A modeling approach to minimize bioenergy production costs. *Biomass Bioenergy* **2011**, *35*, 3350–3359. [CrossRef]
89. Vukasinovic, V.; Gordic, D.; Zivkovic, M.; Koncalovic, D.; Zivkovic, D. Long-term planning methodology for improving wood biomass utilization. *Energy* **2019**, *175*, 818–829. [CrossRef]
90. Awudu, I.; Zhang, J. Uncertainties and sustainability concepts in biofuel supply chain management: A review. *Renew. Sustain. Energy Rev.* **2012**, *16*, 1359–1368. [CrossRef]
91. Strandgard, M.; Turner, P.; Mirowski, L.; Acuna, M. Potential application of overseas forest biomass supply chain experience to reduce costs in emerging Australian forest biomass supply chains—A literature review. *Aust. For.* **2019**, *82*, 9–17. [CrossRef]
92. Becker, D.R.; Moseley, C.; Lee, C. A supply chain analysis framework for assessing state-level forest biomass utilization policies in the United States. *Biomass Bioenergy* **2011**, *35*, 1429–1439. [CrossRef]
93. Herbert, G.J.; Krishnan, A.U. Quantifying environmental performance of biomass energy. *Renew. Sustain. Energy Rev.* **2016**, *59*, 292–308. [CrossRef]
94. Kim, J.; Realff, M.J.; Lee, J.H.; Whittaker, C.; Furtner, L. Design of biomass processing network for biofuel production using an MILP model. *Biomass Bioenergy* **2011**, *35*, 853–871. [CrossRef]
95. Malladi, K.T.; Quirion-Blais, O.; Sowlati, T. Development of a decision support tool for optimizing the short-term logistics of forest-based biomass. *Appl. Energy* **2018**, *216*, 662–677. [CrossRef]
96. Ba, B.H.; Prins, C.; Prodhon, C. Models for optimization and performance evaluation of biomass supply chains: An Operations Research perspective. *Renew. Energy* **2016**, *87*, 977–989. [CrossRef]
97. Hugos, M.H. *Essentials of Supply Chain Management*; John Wiley & Sons: Hoboken, NJ, USA, 2018.
98. Abrams, J.; Becker, D.; Kudrna, J.; Moseley, C. Does policy matter? The role of policy systems in forest bioenergy development in the United States. *For. Policy Econ.* **2017**, *75*, 41–48. [CrossRef]
99. Lim, C.H.; How, B.S.; Ng, W.P.Q.; Lam, H.L. Debottlenecking of biomass element deficiency in a multiperiod supply chain system via element targeting approach. *J. Clean. Prod.* **2019**, *230*, 751–766. [CrossRef]
100. Ladanai, S.; Vinterbäck, J. *Global Potential of Sustainable Biomass for Energy*; Swedish University of Agricultural Sciences: Uppsala, Sweden, 2009.
101. Pokharel, R.; Grala, R.K.; Grebner, D.L.; Grado, S.C. Factors affecting utilization of woody residues for bioenergy production in the southern United States. *Biomass Bioenergy* **2017**, *105*, 278–287. [CrossRef]
102. Anderson, N.; Mitchell, D. Forest operations and woody biomass logistics to improve efficiency, value, and sustainability. *Bioenergy Res.* **2016**, *9*, 518–533. [CrossRef]
103. Neary, D.G. Best practices guidelines for managing water in bioenergy feedstock production. In *Report 2015: TR02. International Energy Agency (IEA) Bioenergy Task 43*; USDA Forest Service: Washington, DC, USA, 2015; 124p.