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Review

Residual Agroforestry Biomass Supply Chain Simulation Insights and Directions: A Systematic Literature Review

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Abstract: Residual biomass is a reliable source of energy and hence requires effective supply chain management for optimal performance and sustainability. While there are various studies on this recent trend, a comprehensive review of the literature on simulation-based modeling of the supply chain for residual agroforestry biomass is lacking. This study aims to present a systematic review of relevant literature surrounding residual agroforestry supply chain simulation insights and directions. The systematic literature review was carried out in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 standards and intends to answer the research questions based on (1) Key Performance Indicators (KPI); (2) Simulation techniques; and (3) Efficient supply chain. A search of the Science Direct, SCOPUS, and UA EBSCO databases was conducted using the appropriate keywords combination. The databases were searched, and a total of 1617 papers were appraised automatically. Subsequently, the titles, keywords, and abstracts of 172 papers were examined. Following the full-text analysis, 20 papers in addition to 27 articles taken from other sources matched the requirements for study inclusion. The publications accessed reveals that simulation-based techniques will optimize the supply chain for residual biomass when applied.

Keywords: agroforestry; decision support; Key Performance Indicators; simulation; supply chain; residual biomass

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1. Introduction

Due to its minimal negative environmental impact in terms of CO_2 emissions, which account for most greenhouse gas emissions, residual biomass has emerged as an attractive renewable and sustainable energy source [1–3]. Residual biomass, which is obtained from specific energy crops, supports the circular economy, and promotes the sustainability of the energy supply without interfering with food production [4]. A crucial step in creating sustainable societies and efficiently controlling greenhouse gas emissions is the effective utilization of residual biomass for energy [5]. The rising demand for agroforestry residual products and the dwindling supply from natural forests has made agroforestry attract more attention from the industry, the producers, and policymakers [6]. The network of residual agroforestry biomass from the land to their final use in the production of biomass energy is referred to as residual agroforestry biomass supply chain. For the effective utilization of the residual biomass energy on a large scale, it is necessary to design a sustainable supply chain that is readily available, economical, reduces environmental hazards, and enhances social benefits [7]. The achievement of the desired supply chain is made possible by implementing choices derived from a simulation-based optimization decision support system.

Simulation models are used to explore disruption propagation and the ripple effect across many stages. The benefits of simulation models include evaluating in-the-moment operations, incorporating, and gaining visibility into the dynamic interactions between supply chain components, infuses randomization into a range of supply chain inputs and procedures to ascertain the true behavior of the supply chain and get insight into it [8].

1.1. Agroforestry Residual Biomass

The remnant organic material that is still present after agroforestry operations like thinning, trimming, or harvesting is referred to as agroforestry residual biomass. Residual biomass is a significant consequence of agriculture, a type of land use management that blends trees with crops or cattle on the same site [9–11].

Branches, leaves, twigs, and other plant materials that are not used for the primary goal of the agroforestry activity can be considered residual biomass raw materials. These residues can be used for a number of purposes, such as generating energy through combustion, serving as a feedstock for the manufacturing of biofuels, or being added to the soil to enhance its fertility and quality [12–14].

Residual biomass can be used to produce renewable energy, reduce waste, lower greenhouse gas emissions, and promote local economic growth, among other environmental and financial advantages. To prevent detrimental effects on soil health, ecosystems, and other ecological functions, the sustainable use of agroforestry residual biomass must be closely monitored [15–17].

1.2. Agroforestry Residual Biomass Supply Chain Management

Agroforestry residual biomass needs to be moved from the source to the end user in an effective and sustainable manner. Hence, supply chain management for this resource must include planning, designing, implementing, and monitoring a system for doing so. This covers the planning of tasks including gathering, transporting, storing, and processing as well as other similar tasks [18–20].

The prompt and economically feasible delivery of biomass to the end user, as well as ensuring that the biomass is of the requisite quality and quantity, are all dependent on good supply chain management for residual biomass. At each stage throughout the supply chain, possible obstacles and problems must be identified and eliminated. Also, the supply chain must be made socially and environmentally friendly [21,22].

1.3. Simulation as a Supply Chain Management Tool

The analysis of complex systems is made possible by simulation methods and models, which give information on how the system would behave in various scenarios. Various companies, notably the bioenergy sector, have made extensive use of simulation tools to optimize their supply chains [23–27]. Simulation is a crucial tool for creating planning and exploratory models in order to maximize decision-making as well as the design and operation of complex and intelligent manufacturing processes [28]. Investors and suppliers in the biomass industrial sector can use simulation models to establish long- and short-term schedules to manage the biomass supply chain in a timely, economical, and sustainable manner [29]. Additionally, it might aid companies in evaluating the costs, risks, difficulties associated with implementation, impacts on operational performance, and strategy.

This study aims to present a systematic review of relevant literature surrounding residual agroforestry supply chain simulation insights. The review was implemented by applying the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines of systematic literature review [30,31]. It intends to answer the following research questions:

- What set of KPIs (Key Performance Indicators) should be considered for the decision support in the dynamic evaluation of decision levels of the agroforestry residual biomass supply chain?
- How can efficiency be achieved in an agroforestry residual biomass supply chain through simulation techniques?
- What are the factors that make for a resilient residual biomass supply chain?

The remaining part of this paper is organized as follows: Section 2 describes the materials and methods employed in conducting the review. Section 3 presents the descriptive and quantitative results as it relates to the bibliometric analysis. Section 4 presents a discussion on the enabling technology, the scientific and technological barriers, and the current trends with reference to the simulation approaches of residual biomass supply chain. Finally, Section 5 emphasizes the overall work done, the deductions and suggest directions for further studies.

2. Materials and Methods

2.1. Literature Search

In this review, the University of Aveiro research database was surfed through the EBSCO host database. Also, the Scopus and Science direct databases were accessed. In order to compile a comprehensive list of all original literature relevant to the research topics, search criteria were devised that took into account the demographic and desired objectives. The search algorithm used included the following terms: "Decision-support AND Simulation" AND "Supply chain" AND "Residual" AND "Biomass" AND Agroforestry. The keywords were applied in the search engine of all 3 databases used for this study. The search for articles was restricted to those published between January 2011 to March 2023.

2.2. Eligibility Criteria

The study was conducted in line with the pre-determined exclusion and inclusion criteria as formulated by the researchers. The articles included for review are peer reviewed articles published in English Language within the year of 2011 to 2023. Also, for accessibility only open access articles were reviewed.

2.3. Data Extraction

The articles retrieved from the database searches were downloaded and exported into the StArt software (version 3.3 Beta 03) with the following data columns: title, authors, publication, year of publication and status selection. Next, the studies were evaluated for inclusion or exclusion at the selection stage by evaluating the title, keywords and abstract. Furthermore, for the final extraction, the papers were critically evaluated to ascertain their level of relevance for inclusion in the present review, focusing on the research questions.

2.4. Study Selection

The title, keywords, and abstract of articles selected through the electronic databases were reviewed in the study to determine their eligibility for selection and extraction using preset eligibility criteria as stated in Section 2.2. Data extraction tools and procedures were developed, tested, and implemented using a state-of-the-art review software (StArt-version 3.3 Beta 03).

On 27 March 2023, a search was carried out on the University of Aveiro (UA) EBSCO host research database using the predefined key words, while Science direct and Scopus databases were accessed on 28 March 2023.

A total of 1617 literatures were identified in the initial search in the following order: 1432 from UA EBSCO database, 79 from SCOPUS and 106 from Science Direct. Following the application of filters on the individual databases, and using the preset criteria for inclusion, 192 papers were retrieved, downloaded, and exported in RIS format to the appropriate software for bibliometric analysis and review. The full text of the remaining 192 articles was properly screened and evaluated in line with the eligibility criteria. As a result, a total of 172 papers were excluded leaving 20 papers to be included in the review. Judging by the low volume of articles for the review, an additional 27 papers were gotten from other articles sourced from specific searches. Overall, a total of 47 papers were considered for the final review. In accordance with PRISMA 2020 guideline, a flow diagram was generated to depict and display the information in this section, see Figure S1. The study characteristics table: Table A1 shows the authors, the research study design applied in the work and the most likely end user and beneficiary of the study.

3. Results

The overall quantitative and descriptive analysis of the 47 studies selected through the review are presented in this section. The section emphasizes the research trends in terms of publications throughout the years, the geographical application area, the distribution of papers evaluated by journals, and the thematic enabling advancements.

3.1. Publication over Time

The authors conducted a plot of the volume of publications over a period of 2011 to 2023, to monitor the progression of research interest. The goal of this analysis was to ascertain the year-by-year progress on the research area. It was observed that the research theme experienced an upward trend in the past 7 years, see Figure 1. From 2016 there was a significant increase that slowed down completely with no publication in 2017 and later experience a growth in 2018.

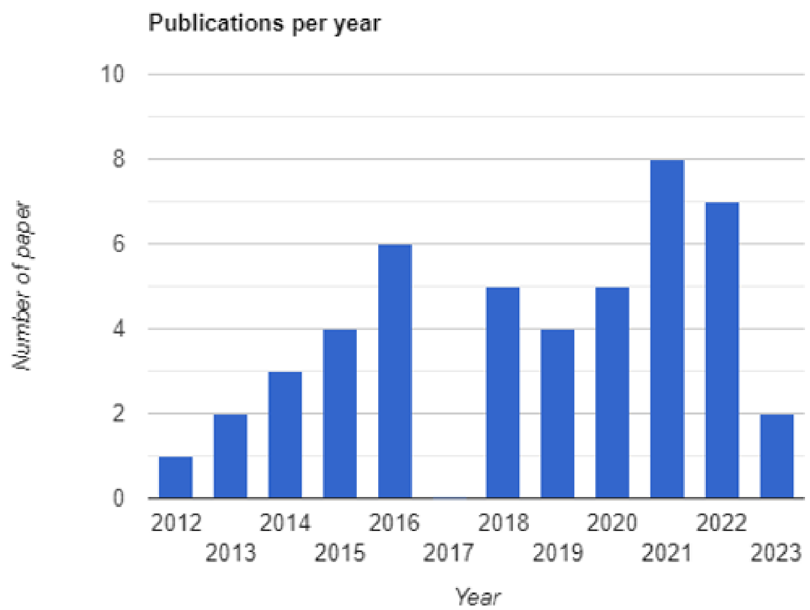

Figure 1. Graphical representation of publications per year.

This indicates that residual agroforestry supply chain simulation is a developing research area because more academics and industry professionals are becoming aware of it. Moreover, it is possible to anticipate that research in this area will keep expanding as more firms are focusing on the digitalization of their supply chains.

3.2. Geographical Application Area

The geographical analysis reveals that the research spans across a total of 29 countries worldwide. The geographical location of authors that conducted the studies analyzed, are presented in the pie chart, see Figure 2.

From the chart, it can be clearly seen that majority of the articles retrieved were carried out in Portugal and Canada with 5 articles each. This shows that residual agroforestry supply chain simulation is gaining recognition in these two countries followed by Italy which had the total of 4 articles reviewed. China had 3 articles while Mexico, France, India, Australia, and Finland have 2 publications each. The remaining 20 articles accessed spans 20 countries with 1 article each. In general, the authors deduced that the thematic study still needs more research attempts and implementation on the topic.

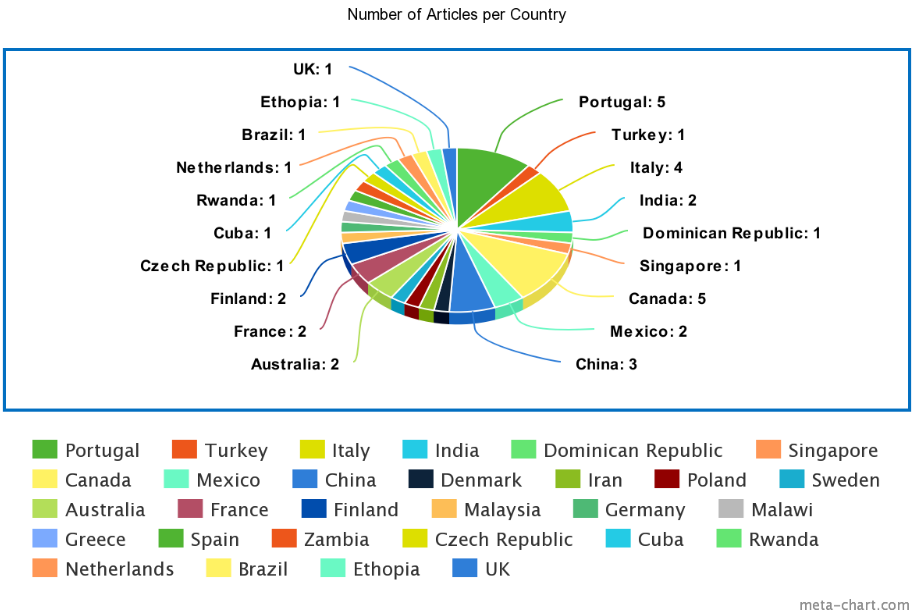

Figure 2. Representation of countries participation in the research area.

3.3. Journal Distribution

The range of any journal's coverage reflects the expansion of the field of study. Examining the current journals that had published research articles was the goal of the journal-wise distribution study. The selected 47 research publications were distributed in 26 journals. This implies that the study has a wide range of scope and research application areas. The researchers evaluated the rankings provided by the SCImago Journal Rank (SJR) platform to gauge the publications' impact on science by taking into consideration the number of citations a journal receives over a period of three years and the significance of the journals that produce those citations. The rating was made based on Scopus database as of April 2022. In doing so, we observed that all the journals that had the most (at least 3) papers published through them had a Q1 ranking except for IFAC online that had a Q3 rating. Also, most of the other journals having 1 publication were rated Q1. This discovery shows that the research area is suitable for publications with a scientific focus. Table 1 presents the first eleven journals with highest number of paper distribution and their SJR rankings.

The other 15 journals have one publication each. Some very reputable journals in this class are Agronomy, Industrial & Engineering Chemistry Research, Internal Journal of Geo—Information.

3.4. Keywords Analysis

The occurrence of the keywords was analyzed to identify the essential study areas of the topic and the direction to which the recent trend is going. Figure 3 displays the keywords as generated from wordart.com. The bolder the words, the more frequently it appeared in the articles.

According to the diagram, biomass energy and agroforestry have the highest number of appearances. Due to the limited number of related literature available, all 169 keywords generated were considered for the analysis with at least 2 occurrences. 24 words fulfilled this criterion. Table 2 and Figure 4 shows the keywords co-occurrence network, and 5 clusters were classified and identified.

The colors show the words that are clustered in a group. The words in red belong to the first cluster which are Energy, biofuel, gasification, uncertainty and biomass supply chain. Using the cluster density visualization, each cluster of items was displayed with its corresponding keyword density. The color of a point in the visualization was determined by blending the colors of various clusters, as shown in Figure 5. The weight assigned to a particular cluster's color was based on the number of items in that cluster within the vicinity of the point.

Table 1. Top eleven (11) journal distribution.

Journal	SJR	Number of Articles
Energies	Q1	4
Renewable Energy	Q1	4
Biomass & Bioenergy	Q1	3
IFAC online	Q3	3
Journal of Clean Technology	Q1	2
Applied Energy	Q1	2
Forest Policy & Economics	Q1	2
Renewable and Sustainable Energy	Q1	2
Agricultural Systems	Q1	2
Sustainability	Q1	1

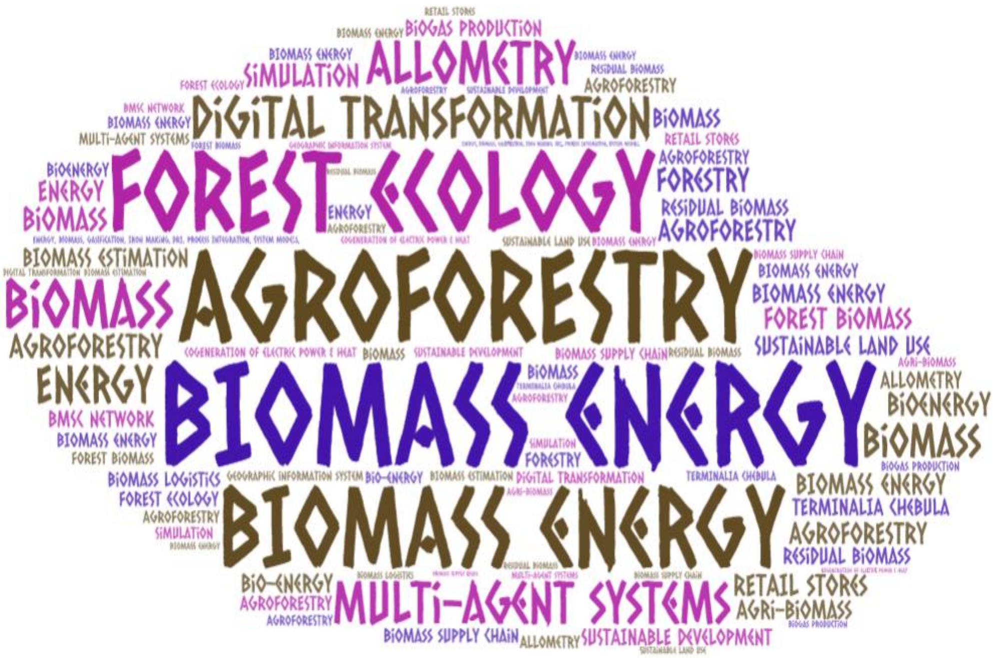

Figure 3. Keywords occurrence.

Table 2. Cluster identification from keywords analysis.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster_5
Biofuel	Biomass	Advanced biofuels	Agroforestry	Bioenergy
Biomass supply chain	Decision support systems	Biomass energy	Allometry	Sensitivity analysis
Energy	Logistics	Optimization	Modeling	Supply chain optimization
Gasification	Modelling	Residual biomass	Simulation	
Sustainability	Supply chain	Supply chain design	Supply chain management	
Uncertainty				
Sustainability	Supply chain	Supply chain design	Supply chain management	
Uncertainty				

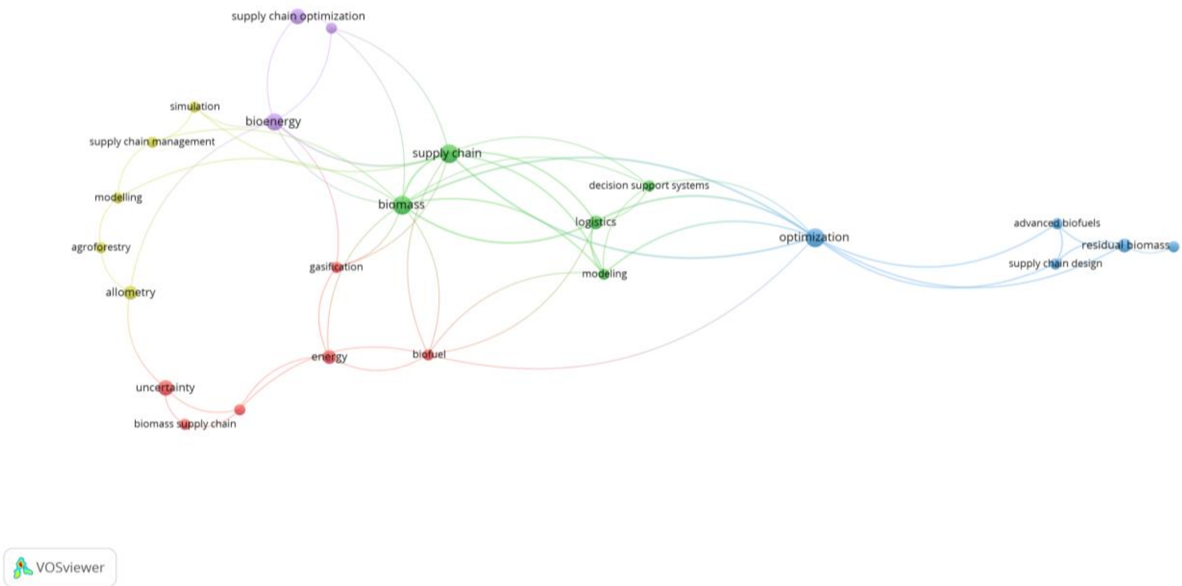

Figure 4. Keyword co-occurrence network.

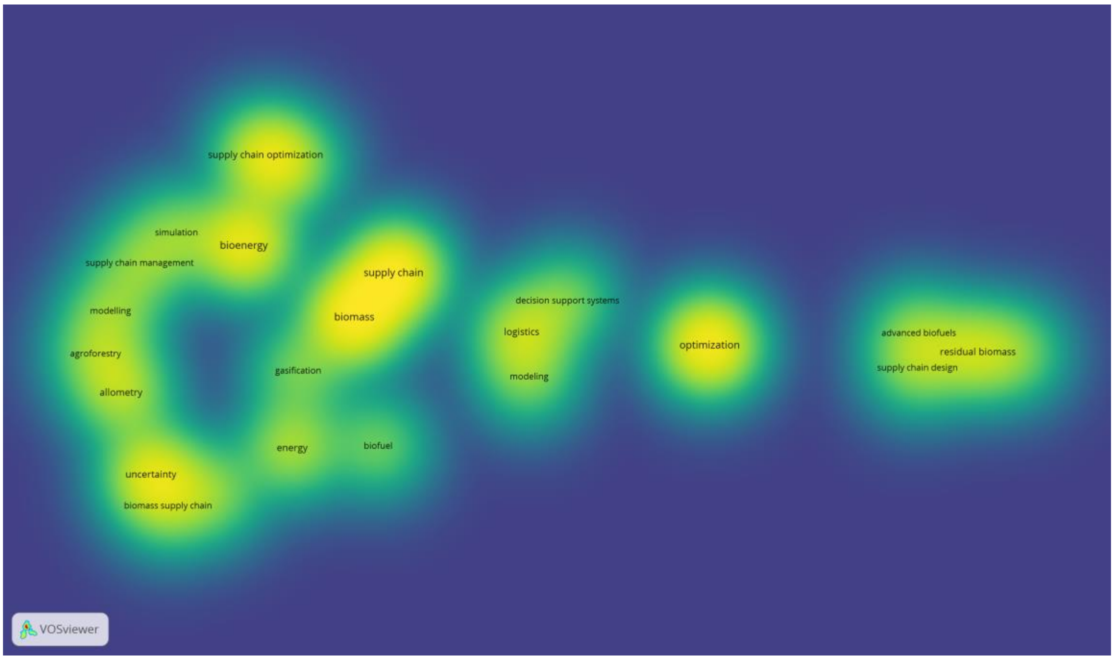

Figure 5. Keywords co-occurrence visualization.

3.5. KPI Definition According to Biomass Supply Chain

In the context of residual biomass supply chain, Key Performance Indicator (KPI) refers to quantifiable metrics used to assess the efficiency of the biomass supply chain at various points in the industry [32,33]. With numerous levels of decision-making, the supply chains for agroforestry residual biomass involved in the utilization of biomass, whether for the provision of raw materials or the recovery of energy, can be complicated [34]. Key performance indicators (KPIs) can be used to gauge and assess the effectiveness of various supply chain components [35]. 80% of the articles included for the review treated KPIs with respect to the level of decision to be made. For instance, in order to make the best decision of where to locate an agroforestry biomass cogeneration venture, an evaluation criteria system is created, with metrics such as societal demands, resource availability, and economic considerations [36]. Decision making process can be based on a couple of risk factors or uncertainty [37]. The literature accessed highlights the essence of data-driven measured outcomes for decision-making to optimize the performance of any supply chain.

Simulation methods have been employed in 75% of the articles accessed. Allometric methods have been used to model accurate biomass estimation through scaling of tree diameter, wood density and various tree species [38–40]. A simulation model was created to examine the possibilities for establishing a sustainable biomass energy sector through widespread agroforestry adoption [41]. To determine the worth of information, discrete-event simulation and a scheduling method based on simulation are employed as decision-support models. According to the findings, the value of the information increases with the density of the logistical process [42]. A multi-criteria simulation method with the combination of mathematical programming and GIS optimizes the operations of a residual biomass processing system [43].

Sustainable supply chain model incorporates leanness, agility, resilience and circular economy in the design and optimization process [44]. Mathematical model enhances the complete supply chain process [45].

4. Discussion

4.1. Results Analysis and Interpretations

Making decisions at the strategic, tactical, and operational levels is frequently a part of managing and optimizing biomass supply networks [46,47]. Supply chain uncertainties such as biomass availability, biomass quality, transportation costs, market demand, and material price volatility have previously been considered in the evaluation to produce more precise and dependable feasibility estimates [48]. Nonetheless, it is essential to create models that take these underlying uncertainties into account. In order to offer more practical answers to challenges encountered in everyday life, these models should also include a variety of objectives and criteria that take into account economic, technical, environmental, and social factors [49,50].

According to Ahmadvand S. et al., if the inventory level differs from the safety stock, a maximum of 18% in cost savings may be achieved. KPIs are total costs of the upstream supply chain and negative deviations of monthly inventory from the safety stock [51].

In the context of residual forestry biomass to bioelectricity production, KPIs for strategic decisions such as the best choice for biomass amounts and sources, the choice of transportation modalities, and the establishment of links necessary for the delivery of biomass products to markets are considered [52]. The harvesting of the biomass, transportation to the biorefinery, including intermediate storage facilities, and the biodiesel plant are all taken into account through simulation approaches [53].

A resilient residual biomass supply chain is influenced by a number of variables. Precise supply chain network models need to be developed so as to efficiently predict and enhance its performance. These models concentrate more on three decision levels; the strategic level, which includes location/allocation decisions, demand planning, distribution channel planning, etc.; the tactical level, which covers inventory control, production distribution coordination, and risk mitigation; and the operational level, including vehicle routing/scheduling, workforce scheduling, record keeping, and customer support [54,55].

Operations involving energy densification can streamline transportation-related logistics, allowing the use of residual biomass in place of fossil fuels. As a result, supply chain design and modeling is crucial for the success of effective utilization of residual biomass energy in place of second-generation biofuels [56]. Effective biomass storage techniques are crucial, especially when the supply of the biomass is seasonal [57]. There are several barriers and enablers of forest biomass and bioenergy supply chain resilience, which can be applied as a basis for the comprehension and optimization of the supply chains structure in the forest biomass and bioenergy industries. These can be analyzed from the social, economic, technical, strategic and environmental dimensions [58–61].

Through the use of simulation techniques, a virtual supply chain environment can be created. Hence, this virtual setup can be utilized to evaluate various situations and improve the supply chain operations for greater effectiveness [62]. To solve supply chain issues, scholars use a variety of techniques such as mathematical programming, multi-criteria decision-making, simulation modeling, and systematic modeling [63–65].

Simulation can be regarded as an optimization method in biomass supply chain management [66].

Optimization models include network design problems, scheduling problems, facility location problems, vehicle routing problem, and technology selection problem are methods for biomass supply chains management [67]. In the work of Noeldeke B. et al., an agent-based simulation model and different decision-making models focusing on an agroforestry system with various tree species in Sub-Saharan Africa and coming up with decisions made based on theory of planned behavior, random choice, econometric approach, bounded rationality, and perfect rationality [68].

To determine the worth of information, discrete-event simulation and a simulation-based scheduling method based can be employed as decision-support tools [69]. To determine workable facility locations for supply chains based on residual biomass and feasible regions to site biomass processing systems facilities, a simulation tool based on geographic information systems in order to involve environmental, social and geographic restrictions is utilized [70,71]. Possible environmental features that can be measured are omission of protected areas, vegetation type in accordance with human activities, and water bodies location [72].

4.2. Technical and Scientific Barriers Associated with Biomass Supply Chain Simulation

Simulation of a biomass supply chain that uses agricultural and forestry residue entails modeling and dissecting the operations and elements of the chain. This kind of simulation can offer useful insights into the potential of agroforestry biomass as a renewable energy source and assist in recognizing the scientific and technological obstacles that might prevent its mainstream adoption. In the simulation of the supply chain for agroforestry residual biomass. During this study, we identified a couple of technological and scientific obstacles such as:

Biomass Collection and Harvesting: Given the variety of agricultural and forestry leftovers, efficient biomass collection and harvesting can be difficult. These residues may differ in size, density, and moisture content, which have an impact on how they are handled and transported. It is crucial to create collecting and harvesting methods that are both creative and economical [57].

Storage and Preprocessing of Residual Biomass: To preserve the quality of residual biomass and make it easier to convert it into energy products, it is necessary to store and preprocess it effectively. Methods of storage must stop deterioration, moisture absorption, and pest infestation. To prepare the biomass for next conversion operations, preprocessing methods including chipping, grinding, and drying could be necessary [73].

Supply Chain Logistics: Addressing logistical issues is necessary to design a reliable supply chain for residual agroforestry biomass. To cut costs and guarantee a consistent supply of biomass to conversion plants, it is necessary to strategically locate the facilities for biomass collecting, transportation, and storage. Within the supply chain, routing, scheduling, and inventory management must all be optimized [74].

Technologies for converting biomass: Residual biomass can be transformed into a variety of energy sources, such as heat, electricity, and biofuels. However, there are scientific and technological difficulties in creating and implementing effective and affordable conversion technologies. To increase overall efficiency and lower costs, improvements in biomass gasification, pyrolysis, anaerobic digestion, and biochemical conversion technologies are required [75].

Sustainability: Sustainability and environmental impacts are important factors for agroforestry biomass supply chains. The potential environmental effects of biomass production, harvesting, and conversion must be considered with Important metrics including minimizing emissions, trash production, and water use, as well as guaranteeing ethical land management techniques [76].

Economic Viability and Policy Support: A key element in the widespread adoption of residual agroforestry biomass supply chains is their economic viability. It's important to evaluate how profitable and cost-effective it is to produce, collect, and convert biomass. Additionally, encouraging policies like incentives, subsidies, and laws that support biomass consumption can significantly contribute to removing obstacles and promoting the growth of this industry [33,77].

Data Availability and Quality: For supply chain simulation, accurate and thorough data on biomass resources, including their availability, properties, and spatial distribution, is essential. However, acquiring trustworthy data at the necessary scale and granularity can be difficult. To increase the quantity and caliber of data linked to biomass, data collection and standardization activities must be made [78].

4.3. Recent Trends in the Simulation of Residual Biomass Supply Chain

The most current trend in technological and policy advancement in the research area is presented in this section.

Integration of Spatial Analysis: Spatial analysis methods are increasingly being used in biomass supply chain simulation to take the geographic distribution of biomass resources, biomass conversion facilities, and transportation networks into consideration. By taking into account variables like distance, transportation costs, and resource availability, this integration enables more precise modeling of biomass sourcing, logistics optimization, and infrastructure planning [79,80].

Analysis of Uncertainties and Risks: Simulation models are being improved to include stochastic and probabilistic methods to account for the inherent uncertainties and risks in biomass supply chains. Decision-makers can evaluate the robustness and risk exposure of various supply chain configurations and management techniques using these approaches, which evaluate variations in biomass yields, weather, market pricing, and other factors [81,82].

Multi-objective Optimization: Simulation models are being created to facilitate multi-objective optimization, which considers a few competing goals, including minimizing costs, reducing greenhouse gas emissions, and maximizing social effect. These models make use of optimization algorithms that can spot trade-offs and Pareto-optimal solutions, assisting decision-makers in navigating challenging decision environments and selecting efficient and sustainable supply chain designs [83,84].

Lifecycle Assessment and Sustainability indicators: To examine the environmental and social effects of biomass consumption, biomass supply chain modeling is increasingly using lifecycle assessment (LCA) approaches and sustainability indicators. The quantification of greenhouse gas emissions, energy use, water use, land-use change, and other sustainability indicators is made possible by this integration. These insights can be used by decision-makers to find supply chain topologies that are socially and environmentally responsible [85].

Real-time optimization and digital twins: The biomass supply chains are being modelled using digital twins, which are virtual versions of physical systems. Simulation models can dynamically optimize supply chain operations, monitor performance, and spot areas for improvement by incorporating real-time data and sensor inputs. This strategy provides more effective and quick supply chain management and real-time decision-making [86–88].

These patterns answer most of the barriers highlighted in this study. It also draws attention to the ongoing work being done to improve the precision, realism, and sustainability evaluation capabilities of models simulating the biomass supply chain. It is crucial to keep in mind that the simulation industry is always changing, and new trends and advancements will keep emerging.

4.4. Limitations of the Study

To select papers for this systematic review, the authors followed the recommended PRISMA 2020 guidelines. However, there is a possibility that some relevant papers may have been missed during the selection process. The field of study has various designations and terminology, which might have caused the authors to overlook papers with different keywords that are not commonly used. Additionally, the search was restricted to peer-reviewed published papers in English, which limited the search results 20 articles.

5. Conclusions

To highlight the distributions and trends in publications, a systematic review study is conducted. This work examines a thorough systematic literature review of each important component throughout the thematic area. To carefully answer our research questions, the review results are comprehensively analyzed with regards to residual biomass from three main viewpoints including (1) Key Performance Indicators (KPI); (2) Simulation techniques; and (3) Efficient supply chain. In each component, the primary research directions and representative references are offered. Additionally, several common approaches and concerns, as well as the research trends, are explored and compiled in the review. The findings from the review guided the authors come to the following deductions:

- An agroforestry residual biomass supply chain can be made more efficient with the use of simulation approaches.
- The most efficient supply chain processes can be found and put into place by clearly determining the scope of the supply chain as this will inform the choice of KPIs to be considered.
- The data to be collected and evaluated is a function of the KPI identified. The data retrieved is used to develop a simulation framework and should include all the relevant components of the supply chain, including but not limited to collection of residues, biomass production, transportation, processing, and distribution.
- To obtain an optimal supply chain, it is pertinent to run different scenarios to determine the best supply chain processes to improve efficiency. The supply chain operations can be put into practice in the real world following their optimization to accomplish the required degree of efficiency.

Residual agroforestry biomass supply chain simulation is a vital tool for comprehending the potential of agroforestry biomass as a renewable energy source and identifying scientific and technological obstacles that can prevent its broad use. The supply chain logistics, biomass conversion technologies, environmental impacts and sustainability, commercial viability and policy support, stakeholder engagement and collaboration are the main challenges in residual agroforestry biomass supply chain simulation.

Interdisciplinary study, teamwork, and ongoing development of simulation models and approaches are crucial to overcoming these difficulties. Improving the usefulness and applicability of residual agroforestry biomass supply chain simulation requires addressing data shortages, improving modeling methods, including uncertainty analysis, and taking policy and market dynamics into account.

In conclusion, the outcome of this study implies that simulation modeling methods can be utilized to enhance the effectiveness of supply chains for agroforestry residual biomass for the purpose of bioenergy generation. Eventually, policy makers can make better decisions when the findings of this study are applied.

However, for futuristic purposes, subsequent studies should concentrate on creating comprehensive structures that enable the operational, strategic, and tactical optimization of residual biomass supply chains. Also, an integrative simulation technique that should depict how people and machines interact, taking into account things like manpower capabilities, advances in automation, and collective decision-making should be considered. Furthermore, for a better circular economy, sustainability criteria should be introduced into the simulation model such as water usage, production of waste, energy efficiency, and greenhouse gas emissions in order to manage and recycle waste and reduce carbon emissions through the optimization of transport paths.

Supplementary Materials: The following supporting information can be downloaded at: www.prisma-statement.org and https://www.mdpi.com/article/10.3390/su15139992/s1, Figure S1: Studies Selection PRISMA flow diagram.

Author Contributions: Conceptualization, B.C.C. and A.L.R.; methodology, B.C.C. and A.L.R.; software, B.C.C.; validation, B.C.C., A.L.R., J.V.F. and L.P.F.; formal analysis, B.C.C.; investigation, B.C.C.; data curation, B.C.C.; writing—original draft preparation, B.C.C.; writing—review and editing, B.C.C., A.L.R. and L.P.F.; visualization, B.C.C.; supervision, A.L.R., J.V.F. and L.P.F.; project administration, A.L.R. and J.V.F.; funding acquisition, B.C.C. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No additional datasets have been used.

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

Appendix A

Table A1. Studies characteristics table.

Author, Year & Reference	Country	Study Design	End User
Nunes L J et al. (2023) [33]	Portugal	Qualitative study	Bioenergy industry
Dominguez & Carnella (2020) [56]	Spain	Literature review	Bioenergy policy makers and researchers
Balaman & Selim (2015) [49]	Turkey	Quantitative analysis	Policy makers and researchers
Santibañez-Aguilar J E et al. (2019) [43]	Mexico	Qualitative study	Bioenergy industry policy maker
Moretti L et al. (2021) [60]	Italy	Conceptual and Quantitative design	Italian bioenergy sector
Sarkar B et al. (2021) [64]	South korea	Qualitative study	Biofuel and biogas policy makers
Guzman-Bello H et al. (2022) [45]	Dominican Republic	Literature review	Bioenergy policy makers and researchers
Sun & Fan (2020) [67]	Singapore	Literature review	Policy makers and researchers
Piqueiro G H et al. (2022) [18]	Portugal	Case study	Industry policy makers and researchers
Mobini M et al. (2013) [42]	Canada	Conceptual and case study	Canadian bioenergy industry
Wu J et al. (2022) [2]	China	Qualitative study	Agric-biomass policy makers and researchers
Ahmadvand S et al. (2021) [51]	Canada	Qualitative study	Bioenergy policy makers
Salehi S et al. (2022) [7]	Iran	Conceptual and case study analysis	Policy makers SATBA Iranian bioenergy
Zahraee S M et al. (2021) [29]	Malaysia	Quantitative and case study	Malaysian bioenergy company
Peter B & Niquidel K (2016) [13]	Canada	Quantitative study	Bioenergy sector
Santibañez-Aguilar et al. (2018) [70]	Mexico	Case study analysis	Bioenergy industry policy makers
Grip C E et al. (2015) [65]	Sweden	Quantitative studies	Forestry an steel industry
Akhtari S et al. (2015) [47]	British Colombia	Quantitative analysis	Bioenergy policy makers
Acuna M et al. (2019) [46]	Australia	Literature review	Researchers and bioenergy policy makers
Zandi N et al. (2016) [1]	France	Literature review	Bioenergy policy makers and researchers
Ba B et al. (2016) [26]	France	Operations research study	Bioenergy policy makers and researchers
Torreiro Y et al. (2020) [16]	Portugal	Conceptual study	Bioenergy & Agroforestry industry
Natarajan K et al. (2014) [72]	Finland	Quantitative study	Bioenergy decision makers in Finland
De Menna F et al. (2018) [71]	Italy	Quantitative study	Agri-biomass policy makers
Hong B H et al. (2016) [44]	Malaysia	Conceptual and quantitative analysis	Bioenergy policy makers and researchers
Basile F et al. (2022) [3]	Sweden	Quantitative study	Forestry and bioenergy industry
Paulo H et al. (2015) [52]	Portugal	Quantitative and case study analysis	Researchers and bioenergy policy makers
Den Herder M et al. (2012) [50]	Finland	Qualitative and case study analysis	Bioenergy policy makers
Jazinaninejad M et al. (2022) [63]	Canada	Literature review of quantitative analysis and study	Bioenergy policy makers and researchers
Enes T et al. (2019) [5]	Portugal	Quantitative	Bioenergy policy makers and researchers
Kraft et al. (2021) [62]	Germany	Review	Policy makers
Schuenemann F et al. (2018) [41]	Malawi	Qualitative	Policy makers
Manolis E N et al. (2016) [39]	Greece	Qualitative design	Bioenergy policy makers
Al Mashalah H et al. (2022) [61]	Canada	Literature review and conceptual study	Policy makers and researchers in the industry
Sileshi G W (2014) [40]	Zambia	Review	Forestry policy makers
Králík T et al. (2023) [27]	Czech Republic	Case study	Agroforestry policy makers and researchers
Kang K et al. (2021) [17]	Canada	Conceptual and qualitative study	Policy makers
Casau M et al. (2022) [4]	Portugal	Case study	Bioenergy policy makers and researchers

Table A1. *Cont.*

Author, Year & Reference	Country	Study Design	End User
Bascietto M et al. (2020) [9]	Italy	Quantitative study	Ecosystem services and policy makers
Zhou X Y et al. (2020) [37]	China	Hybrid research studies	Policy makers
Wu Y et al. (2019) [36]	China	Case study analysis	Bioenergy generation policy makers and researchers
Nunes L J R et al. (2020) [57]	Portugal	Review	Policy makers and researchers
Panwar P et al. (2014) [25]	India	Quantitative study	Agroforestry plantations
Noeldeke B et al. (2020) [68]	Rwanda	Quantitative study	Agroforestry sector
Viet N Q et al. (2018) [69]	Netherland	Quantitative study	Agrofood industrial sector
Chen Q et al. (2015) [38]	Brazil	Quantitative study	Agroforestry industry
Negash & Kanninen (2015) [35]	Ethopia	Quantitative study	Agroforestry industry

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