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ACCOUNTING FOR CARBON AS A FOREST INNOVATION: A SYSTEMATIC REVIEW

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Abstract:

(1) Background: Carbon accounting, provides society with accurate and reliable information on the production and capture of carbon, as well as its costs and revenues. Carbon accounting is also important for product quality control, safety management and environmental compliance. This systematic review aims to respond to the objective of analyzing carbon accounting as a forestall innovation, in order to support the forestry industry in the economic-financial evaluation of the reducing greenhouse gas emissions. (2) Methods: Articles were selected based on Systematic Reviews and Meta-Analyses (PRISMA). Regarding the eligibility of the reviews, the PICOS strategy (population, interventions, comparators, outcomes and study design) was used from 347 articles scientifically identified in the Web of Science Journal Citation Report databases. Eleven articles were included in the literature review phases. (3) Results: The results of the present review propose to standardize the methodology of accounting for the total amount of greenhouse gases (GHG) emitted during the life cycle of goods and services, based on Life Cycle Assessment (LCA). (4) Conclusions: Carbon accounting and its principles, models and Methodology are used to measure and value the environmental impacts and climate risks of economic activities and investments. (4) Conclusions: The principles, models and Methodology in Carbon Accounting are

used individually or in combination to provide a more complete and accurate view of the management of environmental impacts and climate risks in an organization or a project. (4) Conclusions: Carbon accounting is dynamic, will improve and evolve every day, based on the environmental impact of carbon production and capture.

Keywords: carbon accounting; principles; models; accounting errors; Methodology; Forest Innovation

1. Introduction

Carbon accounting refers to the processes used to measure the amount of carbon dioxide equivalent emitted and/or captured by an organization [1, 2,3].
Carbon accounting can include measuring the quantity of carbon emitted and/or captured [4, 5]; determining its quality and assessing emitted and/or captured costs [6, 7], accounting for the carbon emitted un transportation processes [8, 9], as well as accounting for investments and sustainable mining operations [10, 11, 12].
Carbon accounting also takes over the management of carbon in the biosphere [13, 14, 15]. An example of this is plant growth, carbon dioxide is removed from the atmosphere through photosynthesis, but can then be partially or fully re-emitted to the atmosphere at different stages of the life cycle [16].
Keeping in mind that carbon management in the biosphere differs from fossil carbon management in that biogenic carbon is emitted and sequestered in the biosphere [17].
It is highlighted as a problem for the environment that energy is generated from fossil fuels, because this increases the total carbon in the biosphere-atmosphere system and is essentially permanent [18]. Another problem is marine ecosystems, such as kelp forests and unvegetated tidal flats, specifically with carbon sequestration and storage by these ecosystems, the question arises as to whether they meet the rigorous standards required to be accounted for [19].
There are indeed different standards, methodologies, and principles to be followed to manage carbon in the biosphere (among others: international standard ISO 14064 and the Corporate Accounting and Reporting Standard (GHG Protocol) of the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)). The Greenhouse Gas (GHG) Protocol [20]. It classifies greenhouse gas emissions into three groups or Scopes [21,22,23]. This classification allows organizations to identify and prioritize their greenhouse gas emissions to effectively address them and reduce their impact on the climate. It is important to note that scopes 1 and 2 are usually the easiest to measure and address, while scopes 3 can be more difficult to measure and address due to the complexity and scale of the emissions [24, 25,26], leading to errors in their accounting registration. It is important to note that errors in carbon accounting can negatively affect the ability of organizations to address their greenhouse gas emissions effectively and reduce their impact on climate [27,28,29]. Therefore, it is critical that rigorous and accurate methodologies are used for measuring and accounting for greenhouse gas emissions [30,31,32].

The objective of this review is to analyze carbon accounting as a forestry innovation, to support the forestry industry in the economic-financial evaluation of the reducing greenhouse gas emissions, taking as a reference published reviews that consider carbon accounting and logging. It seeks to reveal how carbon accounting can provide accurate and reliable information on greenhouse gas emissions and carbon fluxes to inform and support decision making on climate change mitigation and adaptation. Carbon accounting can also be used to assess progress in emission reductions and to monitor compliance with international climate change commitments [33,34,35].

2. Materials and Methods

In this review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used, applying the items: 1 (title), 2 (structured abstract), 3 (rationale), 4 (objective), 5 (protocol and registry), 6 (eligibility criteria), 7 (sources of information), 8 (search), 9 (study selection), 10 (data extraction process), 11 (data list), 16 (additional analyses), 17 (study selection), 18 (study characteristics), 20 (individual study results), 21 (synthesis of results), 23 (additional analyses), 24 (summary of evidence), 25 (limitations), 26 (conclusions), and 27 (funding) [36,37]. The following items were excluded from the PRISMA guidelines because of their inapplicability to the objective of this review: 12 (risk of bias in individual studies), 13 (outcome measures), 14 (synthesis of results), 15 and 22 (risk of bias between studies), 19 (risk of bias in studies). The reading of the articles begins with the analysis of the abstracts, using the framework called PICOS, Problem or topic of interest (P), Intervention (I), Comparison (C), Outcome (O) and Study Design (S) [38,39,40]. The criteria applied in this study were: P= Carbon accounting, I= principles, models, ac-counting errors, and Methodology for managing greenhouse gases, C= non-comparator, O= Re-interpretation of results, S= Systematic reviews on carbon accounting.

The information was approached inductively, i.e., without predefined categories of analysis, except those included in carbon accounting, from the Web of Science (WoS) core collection, avoiding the difficulty of comparing indexing databases that use different criteria to calculate the impact factor of journals [41,42,43]. From the WoS core collection, the researchers selected articles published in journals indexed by WoS in Science Citation Index Expanded (SCI-EXPANDED); Social Sciences Citation Index (SSCI); Conference Proceedings Citation Index-Science (CPCI-S); Emerging Sources Citation Index (ESCI); Book Citation Index (BKCI-S) and Conference Proceedings Citation Index - Social Science & Humanities (CPCI-SSH). From the search vector "Carbon accounting" (All Fields) and Forestry or forestry (All Fields), they obtained 347 records in the identification phase. In the verification phase they obtained 301 records after eliminating duplicate documents. A total of 286 records were excluded because they were not classified in the WoS database as reviews. Similarly, 1 record was excluded because it was not an article review, being a book review. Moving on to the eligibility phase, 13 articles were obtained. Finally, 2 articles were eliminated for not considering Carbon Accounting. As a result of the 347 records initially retrieved, 11 records were included (see Figure 1), of which 7 records are scientific articles and 4 records are systematic reviews. The review was conducted on February 08, 2023 and all selected articles were published in English.

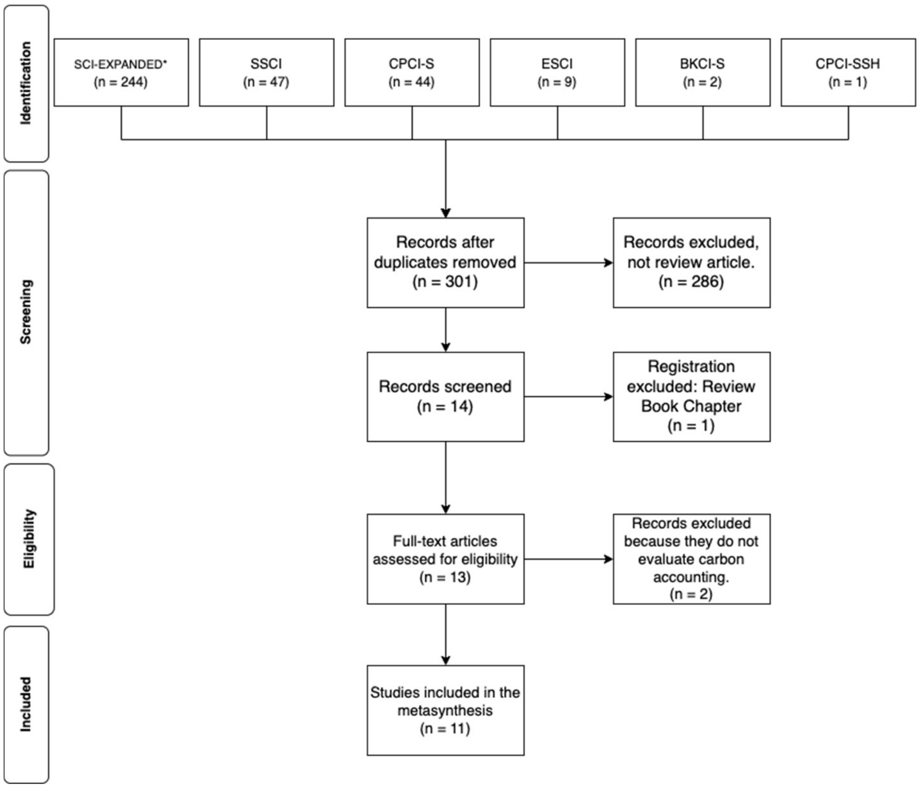

Figure 1. Analysis flow of preferred reporting items for systematic reviews and meta-analyses. (PRISMA). SCI-EXPANDED*= Science Citation Index Expanded; SSCI= Social Sciences Citation Index; CPCI-S= Conference Proceedings Citation Index-Science; ESCI= Emerging Sources Citation Index; BKCI-S= Book Citation Index; CPCI-SSH= Conference Proceedings Citation Index – Social Science & Humanities.

3. Results

The eleven articles that met the eligibility criteria were reviewed at the full-text level to determine precisely whether their characteristics offered homogeneous criteria (carbon accounting and its principles, models, accounting errors and Methodology for managing greenhouse gases), which would make them comparable (Appendix A). Table 1 shows the main identification and retrieval information obtained from the WoS database.

Table 1. Articles included in the Systematic Review

Authors	Article Title	Source Title	DOI	Publication Year	Citations in WoS Core Collection	WoS Categories
Miner, RA; Abt, RC; Bowyer, JL; Buford, MA; Malmsheimer, RW; O'Laughlin, J; Oneil, EE; Sedjo, RA; Skog, KE [44]	Forest Carbon Accounting Considerations in US Bioenergy Policy	JOURNAL OF FORESTRY	10.5849/jof.14-009	2014	61	Forestry
Ter-Mikaelian, MT; Colombo, SJ; Chen, JX [18]	The Burning Question: Does Forest Bioenergy Reduce Carbon Emissions A Review of Common Misconceptions about Forest Carbon Accounting	JOURNAL OF FORESTRY	10.5849/jof.14-016	2015	86	Forestry
Fain, SJ; Kittler, B;	Managing Moist Forests of	FORESTS	10.3390/f9100618	2018	3	Forestry

Chowyuk, A. [45]	the Pacific Northwest United States for Climate Positive Outcomes					
Tellnes, LGF; Ganne-Chedeville, C; Dias, A; Dolezal, F; Hill, C; Escamilla, EZ. [16]	Comparative assessment for biogenic carbon accounting methods in carbon footprint of products: a review study for construction materials based on forest products	IFOREST-BIOGEOSCIENCES AND FORESTRY	10.3832/ifor2386-010	2017	26	Forestry
Smith, P; Nabuurs, GJ; Janssens, IA; Reis, S; Marland, G; Soussana, JF; Christensen, TR; Heath, L; Apps, M; Alexeyev, V; Fang, JY; Gattuso, JP;	Sectoral approaches to improve regional carbon budgets	CLIMATIC CHANGE	10.1007/s10584-007-9378-5	2008	19	Environmental Sciences; Meteorology & Atmospheric Sciences

Guerschman, JP; Huang, Y; Jobbagy, E; Murdiyarso, D; Ni, J; Nobre, A; Peng, CH; Walcroft, A; Wang, SQ; Pan, Y; Zhou, GS. [46]						
Liu, WG; Yu, Z; Xie, XF; von Gadow, K; Peng, CH. [47]	A critical analysis of the carbon neutrality assumption in life cycle assessment of forest bioenergy systems	ENVIRONMENTAL REVIEWS	10.1139/er-2017-0060	2018	17	Environmental Sciences
Bandyopadhyay, S; Maiti, SK. [41]	Steering restoration of coal mining degraded ecosystem to achieve sustainable development goal-13 (climate action): United Nations decade of ecosystem	ENVIRONMENTAL SCIENCE AND POLLUTION RESEARCH	10.1007/s11356-022-23699-x	2022	0	Environmental Sciences

	restoration (2021-2030)					
Thomas, SC; Martin, AR. [48]	Carbon Content of Tree Tissues: A Synthesis	FORESTS	10.3390/f3020332	2012	283	Forestry
Davidson, SJ; Daze, E; Byun, E; Hiler, D; Kangur, M; Talbot, J; Finkelstein, SA; Strack, M. [49]	The unrecognized importance of carbon stocks and fluxes from swamps in Canada and the USA	ENVIRONMENTAL RESEARCH LETTERS	10.1088/1748-9326/ac63d5	2022	3	Environmental Sciences; Meteorology & Atmospheric Sciences
Vanderklift, MA; Herr, D; Lovelock, CE; Murdiyarso, D; Raw, JL; Steven, ADL [19]	A Guide to International Climate Mitigation Policy and Finance Frameworks Relevant to the Protection and Restoration of Blue Carbon Ecosystems	FRONTIERS IN MARINE SCIENCE	10.3389/fmars.2022.872064	2022	0	Environmental Sciences; Marine & Freshwater Biology
Harmon, ME; Fasth, BG; Yatskov,	Release of coarse woody detritus-	CARBON BALANCE AND	10.1186/s13021-019-0136-6	2020	47	Environmental Sciences

M; Kastendick, D; Rock, J; Woodall, CW. [50]	related carbon: a synthesis across forest biomes	MANAGEMENT

Of the 11 articles included in the present study, 4 articles are systematic reviews [16,41,48,49], while 7 of the studies included in the present systematic review are articles [18,19,44,45,46,47,50], although all of them are classified as reviews in the WoS database.
The eleven articles reviewed were published between 2008 and 2022. The work of Smith et al [46], entitled Sectoral approaches to improve regional carbon budgets, which to date has been cited by 17 productions in which a publication of the same authorship dated 2010, entitled Measurements necessary for assessing the net ecosystem carbon budget of croplands, stands out.
The research by Thomas and Martin [48], entitled Carbon Content of Tree Tissues: A Synthesis, is the most cited research to date, counting 287 citations. In 2015 Ter-Mikalian [18], published a paper entitled The Burning Question: Does Forest Bioenergy Reduce Carbon, which has been cited 86 times, highlights flawed methodologies for accounting for forest carbon fate in the absence of bioenergy demand for forests harvested on a sustained yield basis. In 2022, Davidson et al [49], published a paper entitled The Unrecognized Importance of Carbon Stocks and Fluxes from Swamps in Canada and the USA, has 3 citations and is notable for studying uncertainty about the role of swamps in carbon capture and release.
In terms of WoS Categories, 5 of the 11 publications reviewed were indexed in the Forestry category, demonstrating the importance of Carbon Accounting for Forestry studies, 3 publications indexed in Environmental Sciences, 1 publication in Environmental Sciences; Marine & Freshwater Biology and 2 publications indexed in Environmental Sciences; Meteorology & Atmospheric Sciences.
An evaluation was carried out on the principles, models, accounting errors and Met-hodology to manage greenhouse gases occupied by Carbon Accounting, present in the studied articles (Table 2).

Table 2. Management of greenhouse gases in the framework of Carbon Accounting.

Authors	Article Title	Principles	Models	Accounting errors	Methodology
Miner, RA; Abt, RC; Bowyer, JL; Buford, MA; Malmsheimer, RW;	Forest Carbon Accounting Considerations in US Bioenergy Policy	X			

O'Laughlin, J; Oneil, EE; Sedjo, RA; Skog, KE [44]						
Ter-Mikaelian, MT; Colombo, SJ; Chen, JX [18]	The Burning Question: Does Forest Bioenergy Reduce Carbon Emissions A Review of Common Misconceptions about Forest Carbon Accounting			X		
Fain, SJ; Kittler, B; Chowyuk, A. [45]	Managing Moist Forests of the Pacific Northwest United States for Climate Positive Outcomes	X			X	
Smith, P; Nabuurs, GJ; Janssens, IA; Reis, S; Marland, G; Soussana, JF; Christensen, TR; Heath, L; Apps, M; Alexeyev, V; Fang, JY; Gattuso, JP; Guerschman, JP; Huang, Y; Jobbagy, E; Murdiyarso, D; Ni, J; Nobre, A; Peng, CH; Walcroft, A; Wang, SQ; Pan, Y; Zhou, GS. [46]	Sectoral approaches to improve regional carbon budgets		X			
Liu, WG; Yu, Z; Xie, XF; von	A critical analysis of the carbon neutrality assumption in life cycle			X		

Gadow, K; Peng, CH. [47]	assessment of forest bioenergy systems				
Vanderklift, MA; Herr, D; Lovelock, CE; Murdiyarso, D; Raw, JL; Steven, ADL [19]	A Guide to International Climate Mitigation Policy and Finance Frameworks Relevant to the Protection and Restoration of Blue Carbon Ecosystems	X			X
Harmon, ME; Fasth, BG; Yatskov, M; Kastendick, D; Rock, J; Woodall, CW. [50]	Release of coarse woody detritus-related carbon: a synthesis across forest biomes		X		

The research entitled Forest Carbon Accounting Considerations in US Bioenergy Policy [44], explains that some proposals for biogenic carbon accounting are based on a limited analysis of the direct and short-term impacts of GHG emissions using forest biomass. The study proposes to consider in Carbon Accounting the recording of biomass residues from manufacturing, as these produce low or negative Greenhouse Gas (GHG) emissions [51,52,53], biogenic in relatively short timescales and essentially instantaneous benefits by displacing fossil fuels [54, 55, 56]. However, accountants should take into consideration that the benefits of forest bioenergy depend on the evaluation of forest management options [18].

Ter-Mikaelian, among others [18], highlight in their research common errors in the principles used in carbon accounting. Notable among them are: Renewable equals carbon neutral; Sustained yield equals carbon neutral [57]; Diversion of traditional wood products [58]; Dividend then debt [59]; Plantations used for bioenergy have no carbon debt [60]; Abandoned plantations have no carbon debt [61]; Use of the carbon debt payment approach to carbon accounting and indirect LUC (refers to land use changes occurring elsewhere as a consequence of harvesting for bioenergy) [62]. The objective of the research was to promote accurate accounting of the atmospheric effects of bioenergy, not to argue against the use of forest biomass for energy generation.

As for the research by Liu et al [47], they also present an analysis of errors recorded by Carbon Accounting. For example, when analyzing a specific bioenergy product, treating carbon emissions from biomass combustion as neutral is misleading because life cycle analysis (LCA) results always indicate less greenhouse gas (GHG) emissions from bioenergy products than from fossil fuels. The researchers highlight the following errors: Emissions in the supply chain; Effects of land use change and forest carbon change; Loss of carbon captured; and Negative effect of forest residue removal.

Research by Fain et al [45] explores the life-cycle assessment methodology for tracking forest carbon. This methodology allows decision-makers to assess the impacts of carbon transfer within regional forest sectors. Other elements highlighted in the research of Fain et al [45], as well as the study of Ter-Mikaelian, among others [18], propose principles involved in carbon accounting, such as: On-site Forest carbon pools; Off-site Forest carbon pools, Substitution, Carbon transfer, Leakage. On the other hand, Vanderklift et al [19], conduct research where they point out that the reduction of greenhouse gas emissions must be real, measurable, and credible.

The research of Smith et al [46], presents models for modeling the pre-supposition and dynamics of forest carbon, highlighting among them: Process-based models and Hybrid models. The authors point out that hybrid approaches can be useful in bridging the gap between empirical forest carbon accounting and process-based carbon balance models.

The research of Harmon et al [50], discusses a synthesis of forest biomes. The present research highlights how coarse woody debris-related carbon release models can be classified into three groups: (1) forest models that are generally used to specifically simulate forest development, including management [63], (2) vegetation or land-use models [64], and (3) soil models, sometimes run as part of a larger framework or as a module within another model [65]. While several models currently used for carbon accounting and land use/climate change assessment could potentially capture some changes such as: in species, positions, sizes, and microclimate following disturbance in carbon fluxes and balances, many do not.

In the systematic reviews studied [16,41,48,49] (Table 3), the primary source used by Tellnes et al [16] was ISI Web of Knowledge and Google Scholar, while in the case of Thomas and Martin [48] the primary sources used were Web of Science, Web of Knowledge and Google Scholar. In both reviews the research method was a literature review. The systematic review by Bandyopadhyay and Maiti [41] used Web of Science (WoS) Core Collection (SCIE, SCI, SSCI) as the primary source. Bandyopadhyay and Maiti [41], do not disclose the method they used to conduct the research; however, they note that the study focuses exclusively on the potential of carbon captured in reclaimed coal mine sites to achieve the goal of sustainable development. Davidson et al [49] used the Web of Science database as a primary source for their review.

Table 3. Primary source in the systematic reviews studied.

Authors	Article Title	Primary source
Tellnes, LGF; Ganne-Chedeville, C; Dias, A; Dolezal, F; Hill, C; Escamilla, EZ. [16]	Comparative assessment for biogenic carbon accounting methods in carbon footprint of products: a review study for construction materials based on forest products	ISI Web of Knowledge y Google Scholar
Bandyopadhyay, S; Maiti, SK. [41]	Steering restoration of coal mining degraded ecosystem to achieve sustainable	Web of Science (WoS) Core Collection .

	development goal-13 (climate action): United Nations decade of ecosystem restoration (2021-2030)	
Thomas, SC; Martin, AR. [48]	Carbon Content of Tree Tissues: A Synthesis	Web of Science, Web of Knowledge, Google Scholar
Davidson, SJ; Daze, E; Byun, E; Hiler, D; Kangur, M; Talbot, J; Finkelstein, SA; Strack, M. [49]	The unrecognized importance of carbon stocks and fluxes from swamps in Canada and the USA	Web of Science

The study entitled Comparative Assessment for Biogenic Carbon Accounting Methods in Carbon Footprint of Products: A Review Study for Construction Materials Based on Forest Products by Tellnes et al [16], presents a summary of existing methodologies and standards to be used for carbon accounting, specifically with relevance to construction materials and biogenic carbon. Among the methodologies, the following stand out: Dynamic Life Cycle Assessment [66]; Approach based on the global carbon cycle [67]; Flexible parametric model for forests [68] and Characterisation factors for biogenic CO2 emissions with atmospheric decay [69]. As for the normative listed by the systematic review are: EN-15804 (2012); ISO/DIS-21930 (2015); EN-15804 (2012) + A1:2013; CEN/TR-16970 (2016); EN-16485 (2014); PEF Pilot Guide v2.2 February 2016; ISO/TS-14067 (2013) and PAS-2050 (2011). The study concludes by noting that there is currently no scientific consensus on which method is the most appropriate to use for the life cycle of goods and services (LCA) applied in an environmental product declaration (EPD). In addition, the results of the review of technical standards show that there are differences between those for all products and those covering building materials.

Bandyopadhyay and Maiti [41] present a systematic review entitled Steering Restoration of Coal Mining Degraded Ecosystem to Achieve Sustainable Development Goal-13 (climate action): United Nations decade of ecosystem restoration (2021-2030), they pose the following research question How could sustainable management (restoration) of post-mining ecosystem be essential to achieve the post-2020 framework target of SDGs (SDG-13)? In answering it, it is evident that the mining sectors have the potential to combat the global climate crisis and assess the carbon budget by implementing sustainable land management (such as forest restoration). Ensuring that mining industries are engaging with concerns such as carbon emissions mitigation and carbon accounting to govern a rhetorical shift towards sustainable mining [70,71].

On the other hand, Thomas and Martin [48], in their systematic review shows a compilation of associated data, providing fractions of carbon that can be easily incorporated into carbon accounting and can correct for systematic errors similar to 1.6-5.8 % in carbon assessments.

Davidson et al [49], in their research in their review entitled the unrecognized im-portance of carbon stocks and fluxes from swamps in Canada and the USA. As a result, the researchers point out that robust measurements of vertical accumulation rates from swamp soils and associated long-term carbon accumulation rates, along with measurements of carbon losses from swamps, are needed for emerging frameworks for carbon accounting.

4. Discussion

The objective of this systematic review, based on the PRISMA system, was to analyze carbon accounting as a forest innovation, with the aim of supporting forestry industry in the economic-financial evaluation of the reducing greenhouse gas emissions. For this purpose, two reviews were carried out. First, the review of seven articles in which the principles, models, accounting errors and Methodology to manage greenhouse gases, which occupies the Carbon Accounting, were analyzed.

With respect to the principles governing Carbon Accounting, the researches [19,44,45], set out principles in their research, which are not far from the principles set out in Corporate Accounting and Reporting Standard [72], that accounting should be based on relevance, completeness, consistency, transparency and accuracy.

On the other hand, models for modeling forest bioenergy were addressed by research [46,50], demonstrating that forest bioenergy is the way to mitigate climate change, however, it is not instantaneous. Another model that is recommended to be analyzed and is not considered by the researchers studied, is the scenario model; it is based on strategic planning that simulates possible future scenarios for climate change and the transition to a low-carbon economy [73,74].

Regarding accounting errors, these were studied in the research [18,47], recognizing as an error, the assessments of greenhouse gases (GHG) at the level of projects, corporations, nations, and individuals that mostly represent direct GHG emissions, disregarding indirect emissions. It is a relevant error to presume that emissions from biomass combustion are carbon neutral and should not be included in a national GHG inventory. However, a critical error in climate accounting is the inclusion of indirect emissions, such as power generation, in an accounting scope that is not relevant or adequate.

For example, if an organization includes indirect emissions from its supply chain in its Scope 1, rather than including them in its Scope 3 [5,75], its carbon footprint and climate impact will be inflated.

From the methodological point of view, research [19,45] highlights that methods that can measure the carbon fixed in one place and captured in another is the pending task of carbon accounting. In addition, it is proposed as a methodology to account for the total amount of greenhouse gases (GHG) emitted during the life cycle of goods and services, based on Life Cycle Assessment (LCA), this method being called Carbon Footprint.

The second review allowed a meta-synthetic analysis [16, 41,48,49], highlighting the standards used for biogenic carbon accounting in the carbon footprint [16]. However, the study of the international standard ISO 14064 and the corporate accounting and reporting standard (GHG

Protocol) of the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) remains pending in these reviews. The present study detects a gap in relation to accounting standards for greenhouse gas emissions, what we have to date is the withdrawal by the International Financial Reporting Interpretation Committee of a draft of the Emission Rights (IFRIC 3), there is still no accounting standard related to emissions. Therefore, there is currently no scientific consensus on the standard to be applied by accountants in carbon accounting.

Another aspect evaluated by the reviews were the errors made by Carbon Accounting [48], however, the study of the error of underestimation or overestimation of greenhouse gas emissions was missed [76]. This can occur due to poor estimation of emissions or poor measurement methodology. Whereas, if an organization underestimates carbon dioxide (CO2) emissions resulting from burning fossil fuels, its carbon footprint will be underestimated and its impact on climate will be underestimated [48].

5. Conclusions

Carbon Accounting as a forest innovation will be possible when forest bioenergy is used; researchers note that when greenhouse gas (GHG) emissions from forest biomass from living trees used to generate energy are properly accounted for, they exceed those from fossil fuels over periods ranging from a few years to more than a century [18]. Although much evidence has been collected, additional efforts are still needed to accurately and comprehensively account for the impacts of bioenergy use on climate change [47]. For this reason, methods, models should be harmonized [46].

It is important to note that critical errors in carbon accounting can negatively affect the ability of organizations to effectively address their greenhouse gas emissions and reduce their impact on the climate. Therefore, it is critical that rigorous and accurate methodologies for measuring, value and accounting for greenhouse gas emissions are used.

In this regard, it is recommended to study other methods and techniques used by Carbon Accounting to measure and value the environmental impacts and climate risks of economic activities and investments. Some examples: Emissions inventory, a systematic record of greenhouse gas emissions by an organization or project [77]; Climate risk assessment, an assessment of financial risks related to climate change and the transition to a low-carbon economy [78,79]; Carbon footprint indicator, a tool for monitoring and analyzing the greenhouse gas emissions of an organization or product [80,81]; Life cycle analysis: an assessment of environmental impacts throughout a product's life cycle, including raw material extraction, production, transportation, use, and end-of-life [82,83]; Sustainability reporting: a report that provides information on an organization's management of environmental impacts and climate risks [84].

Finally, carbon accounting is dynamic, it will improve and evolve every day, based on the environmental impact of carbon emitted and capture, so it is necessary for carbon accounting to take into account environmental costs.

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Conflicts of Interest: The authors declare that they have no conflict of interest.

Appendix A

The Appendix shows the digital object identifiers (DOIs) for the fifteen articles selected for metasynthesis: DO=((10.5849/jof.14-009 OR 10.5849/jof.14-016 OR 10.3390/f9100618 OR 10.3832/ifor2386-010 OR 10.1007/s10584-007-9378-5 OR 10.1139/er-2017-0060 OR 10.1007/s11356-022-23699-x OR 10.3390/f3020332 OR 10.1088/1748-9326/ac63d5 OR 10.3389/fmars.2022.872064 OR 10.1186/s13021-019-0136-6)).

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