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Assessing the Effects of Accounting Methods for Carbon Storage in Harvested Wood Products on the National Carbon Budget of Lithuania

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Abstract: Forests and the forest-based sector play important roles in mitigating climate change through carbon sequestration and storage in living biomass and soil. In Europe, the forest sector is the only sector that positively affects atmospheric carbon balance. After the forest harvest, a large share of carbon is removed together with the wood. This wood carbon might be stored for centuries if in the form of long-lived wood products. In 2011, the United Nations decided that countries should account for and report carbon balance not only in forests but also in harvested wood products (HWP), followed by very general guidelines on methods for carbon accounting in HWP. The Intergovernmental Panel on Climate Change (IPCC) proposed three methodological levels called tiers for estimating carbon stock and its changes in HWP. The first reporting period revealed that countries applied different carbon accounting methods (tiers), therefore comparing the carbon budgets of HWP and the effect of climate change mitigation among different countries is difficult. In order to test the differences between carbon accounting methods proposed by the IPCC guidelines, we applied two carbon accounting methods and used different data sources in the case of Lithuania. The methods applied were the IPCC Tier 2 method (data on HWP from statistics or the literature, default half-life values, and default HWP categories) and material flow analysis, which is compatible with the IPCC Tier 3 method (material flow data on HWP, country-specific half-life values, and country-specific HWP categories). Depending on the availability of historical data from different sources for the purpose of this study, three study periods were defined: 1992–2015 Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) data, 1960–1991 data from the literature, and 1940–1991 data from national statistics. The study findings show that carbon stock in HWP significantly differed when different data sources and methods were applied. The highest carbon stock in HWP (19.5 Mt) at the end of the study period was observed when FAOSTAT data from 1992–2015 were used and the Tier 3 method was applied. The lowest carbon stock in HWP (11.2 Mt) at the end of the study period was observed when data from national statistics from 1940–1991 were used and the Tier 2 method was applied. The carbon inflow into the pool of HWP in all cases was estimated to be 40% higher when material flow analysis was applied compared to the IPCC default (Tier 2) method. These findings suggest that in general it is more reasonable to apply the Tier 3 method for carbon accounting of HWP in Lithuania.

Keywords: HWP; carbon; country-specific values; material flow analysis

1. Introduction

Carbon storage in harvested wood products (HWP) is an internationally recognized measure for mitigating climate change. When a forest is harvested, a significant amount of carbon is removed from it and can continue to be stored in the HWP, e.g., in wood as a building material, furniture, paper, etc. Recently, the contribution from EU forests, including wood products, comprised 13% of total EU emissions [1]. About 10% of this carbon amount can be accumulated in HWP [2]. Nevertheless, if the EU Member States do not take additional measures to increase forest felling and/or produce longer, more durable HWP, the carbon content currently stored in HWP eventually will decline [2]. The accurate carbon accounting in HWP is a challenging task because reliable data on production, import, and export are lacking in some cases. The Intergovernmental Panel on Climate Change (IPCC) has published guidelines on default carbon accounting methods and data sources for assessing carbon stocks and stock changes in HWP [3,4]. Carbon accounting methods and data sources are chosen by the reporting party depending on data availability; nevertheless, the basic principles laid down in the United Nations (UN) decision/resolution must be respected [5].

The latest IPCC guidelines [4], based on the decisions of the Durban conference, propose estimating carbon stocks for the three default HWP categories—paper and paperboard, wood-based panels, and sawn wood—but carbon stocks can also be accounted for in other HWP categories if reliable data are available.

One of three accounting methodological levels, Tier 1, 2, or 3, can be used depending on the availability of country-specific activity data and methodology [4]. The Tier 1 method assumes that the HWP carbon stock is constant over time; this is equivalent to assuming instantaneous oxidation of HWP resulting in zero annual net emissions from the pool, as the annual stock change is zero. This method makes the simplistic assumption of no carbon stock in HWP. It should be mentioned that the Tier 1 method can be applied by developing countries only. The Tier 2 method suggests using default HWP categories and Food and Agriculture Organization (FAO) activity data on HWP. The Tier 3 method should use reliable country-specific HWP activity and is a transparent method for estimating carbon stock changes in HWP.

For any accounting method, the main factors influencing carbon stock in HWP and its changes are domestic wood supply and product half-life [6]. The results of carbon accounting in HWP could be significantly affected depending on the method used and data availability [7,8]. We analyzed the national carbon accounting reports and studies from Canada, Czech Republic, Denmark, Germany, Latvia, Finland, and Slovakia, focusing on their problems and possible solutions [9]. Denmark has encountered discrepancies between national and FAO Corporate Statistical Database (FAOSTAT) data, and Germany estimated that about 20% of wood is not included in the statistics for unregistered but legal fellings [10]. Slovakia carried out a stock flow analysis, which showed that wood consumption was 16% higher than reported in the statistics because the use of industrial wood waste in the production of new HWP had not been evaluated [11]. In Finnish accounting, two carbon accounting methods (Tier 2 for paper products and Tier 3 for other products) are combined. Carbon stock in hard wood products is calculated on the basis of national inventory data for wood products, which is carried out every five years [12]. In 2012, a study was conducted to calculate the balance of wood resources in wood products and energy production in the EU, using a wood flow analysis that covered many wood products [13]. The study showed that the use of a local wood flow analysis can significantly improve the results of carbon accounting. The analyses of other countries' experiences with carbon accounting in HWP showed that the choice of accounting method significantly affects the accounting results.

Forestry and the forest industry are important branches of the Lithuanian economy. There are 2.2 million ha of forestland in Lithuania, 33.5% of the country's territory [14]. Coniferous stands cover the main part (55.6%) of the forest area, followed by softwood deciduous forests (40.9%) and hardwood deciduous forests (3.5%). The average forest area per capita is 0.77 ha. Total growing stock volume is 542.7 million m^3, and the average growing stock volume in all forests is 256 m^3/ha. Commercial forests make up 72.3%, while the rest is under some level of protection.

Around half of all forests in Lithuania are state forests, and the remaining forests are private. Forests sequester nearly 25% of all of Lithuania's CO_2 emissions. Annually, Lithuanian forests accumulate about 1.8 million tons of carbon (6.5 million tons of CO_2 equivalent) or about 0.8 t/ha (C). Mandatory reforestation of clear-cuts and expansion of forest areas through afforestation of abandoned lands are among the core principles of Lithuanian forest policy.

The forest certification process began in 2001. Currently, more than 1 million ha of Lithuanian forest is certified according to the FSC (forest stewardship council) standard [15]. All state forests in Lithuania are certified under this system, but the majority of private forest holdings are still not.

The aim of this study was to investigate how the use of different carbon accounting methods in HWP and different data sources affect the results of national HWP carbon stocks. In the case of Lithuania, we tested two carbon accounting methods proposed by the IPCC guidelines, Tier 2 and Tier 3, by using different data sources.

2. Materials and Methods

For carbon accounting in harvested wood products (HWP), 2 methods, Tier 2 and Tier 3, were applied to compare the results and consider which is appropriate to use in Lithuania. The IPCC Tier 2 method (data on HWP from statistics or literature, default half-life values, and default HWP categories) and the material flow analysis, which is compatible with the IPCC Tier 3 method (material flow data on HWP, country-specific half-life values, and country-specific groups of HWP) were applied. In both cases, to estimate carbon stock in HWP and its annual changes, equations and default carbon conversion factors proposed by the latest IPCC guidelines were used [4]. The main differences of methods applied are shown in Table 1.

Table 1. Main characteristics of the Tier 2 and Tier 3 methods applied in this study.

Characteristics	Tier 2	Tier 3
Data source	FAOSTAT *: HWP ** production, and trade	Wood flow analysis taken from a survey for wood processing companies in Lithuania [16]; data on forest harvest and trade derived from national statistics [17]
Carbon conversion factors	Default factors [4]	Default factors [4]
Half-life values	Default values [4]	Country-specific values derived from survey results for sawnwood short-life (EURO pallets) and cross laminated timber (CLT); default values for wood-based panels, sawnwood long-life and paper [4] as they are consistent with the country-specific values
Categories of HWP	Default categories: wood-based panels, sawnwood and paper	Country-specific categories: wood-based panels, sawnwood long-life, sawnwood short-life (for EURO pallets), cross laminated timber (CLT) and paper

* FAOSTAT—Food and Agriculture Organization of the United Nations, Statistics Division. ** HWP—Harvested wood products.

For estimating carbon stocks and annual carbon stock changes in HWP pool, Equations (1) and (2) were used:

$$C(i+1) = e^{-k} \times C(i) + \left[\frac{\left(1-e^{-k}\right)}{k}\right] \times Inflow(i) \quad (1)$$

$$\Delta C(i) = C(i+1) - C(i) \quad (2)$$

where i = year; $C\ (i)$ = the carbon stock in the particular HWP category at the beginning of year i, Gg C; k = decay constant for each HWP category given in units yr^{-1} (k = ln(2)/HL, where HL is half-life of the HWP pool in years); *Inflow (i)* = the inflow to the particular HWP category (HWPj) during year i, Gg C yr^{-1}; and $\Delta C\ (i)$ = carbon stock change of the HWP category during year i, Gg C yr^{-1}.

Default conversion factors for the default HWP categories and their subcategories applied in this study are shown in Table 2. For country-specific wood products, such as cross laminated timber or EURO pallets, aggregated conversion factors for sawn wood were applied.

Table 2. Default conversion factors for the default harvested wood products (HWP) categories, adapted from [4].

HWP Categories	Density (Oven Dry Mass Over Air Dry Volume), Mg m^{-3}	C Conversion Factor (per Air Dry Volume), Mg C m^{-3}
Sawn wood (aggregate)	0.458	0.229
Coniferous sawnwood	0.450	0.225
Non-coniferous sawnwood	0.560	0.280
Veneer sheets	0.505	0.253
Plywood	0.542	0.267
Particle board	0.596	0.269
Hardboard	0.788	0.335
Medium-density fibreboard	0.691	0.295
Fibreboard compressed	0.739	0.315
Insulating board	0.159	0.075
	(oven dry mass over air dry mass), Mg Mg^{-1}	(per air dry mass), Mg C Mg^{-1}
Paper and paperboard (aggregate)	0.900	0.386

Depending on the availability of historical data from different sources for the purpose of this study, 3 study periods were defined: 1992–2015 FAOSTAT data, 1960–1991 data from the literature, and 1940–1991 data from national statistics. The country-specific data on the use of industrial residues and half-life for 4 commodities were also gathered during this study.

Data on wood material flow was not available in Lithuania. Therefore, data from a previous study in Lithuania were adapted and used [16]. In that study, a survey for wood processing companies was developed to collect data on the commodities entering and leaving the production processes in the wood processing industry. During the study, the country-specific data on wood flow, including the use of industrial residues for HWP, and country-specific half-life of 4 commodities were obtained (Table 3). The material flow data corresponded to 63% of domestic industrial roundwood used by local industries in Lithuania. It should be noted that the material flow analysis included only domestically harvested industrial roundwood. Imported wood flows were excluded from the system. As a limitation, data for only 1 year (2013) were used for the material flow analysis.

Table 3. Half-life of harvested wood products (HWP) categories.

HWP Category	Source	Half-life (years)	Proportion of Carbon Inflow (Year 2013)
Wood-based panels	IPCC * default	25	46
Sawnwood long-life	IPCC default	35	43
Sawnwood short-life (for EURO pallets)	Estimates, this study	3	8 **
Cross laminated timber (CLT)	Estimates, this study	45	3 **
Paper (applied for historical flows until 1999, when wood pulp was manufactured)	IPCC default	2	0

* IPCC—Intergovernmental Panel on Climate Change. ** Use of wood for certain products has only a limited history as, for example, EURO pallets or CLT production have only recently expanded to a larger scale. The CLT production in Lithuania started in the late 1970s and the EURO pallets production in the early 1990s. Those features are integrated in carbon stock estimates by changing historical shares of the main HWP categories.

Available historical data from different sources for the purpose of this study were collected, defining 3 study periods: 1992–2015 FAOSTAT data, 1960–1991 data from the literature, and 1940–1991 data from national statistics [17–20]. Historical FAOSTAT data are not available prior to 1992, as Lithuania was in the Soviet Union at that time. It should be noted that the available data for some periods were very fragmented. The fragmented data from the literature and national statistics were interpolated to fill the gaps in lost data. All sources provided data as default values for HWP semifinished product categories (paper, wood-based panels, and sawn wood).

The carbon stocks in HWP and their changes were accounted for in accordance with IPCC requirements. The IPCC guidelines stipulate that the Tier 2 method involves the accounting of carbon in HWP made from roundwood only, but in reality, HWP such as wood-based panels and paper are made from secondary raw materials such as sawdust, wood shavings, and waste paper.

The use of secondary raw materials for the production of HWP predominates in different countries [21,22]. Using the data flow analysis (comparable to the Tier 3 method), it is possible to follow wood (carbon) in the forest sector [23,24]. Wood flow analysis is an important element in assessing existing carbon HWP flows, which is often ignored due to lack of data [25].

The IPCC guidelines propose that carbon can be accounted for only for HWP made from domestic harvest [4]. Carbon in imported HWP is excluded from the national carbon budget. Carbon in HWP originating from deforested areas and in exported domestic industrial roundwood is considered as a national carbon loss. According to an international agreement, carbon in exported industrial roundwood is uncountable due to the lack of data on the use of this wood. However, carbon could be attributed to the national carbon budget if reliable data on the exported wood use were available.

3. Results

The results of this study show that carbon stock in harvested wood products (HWP) differs significantly when different data on HWP are used and different carbon accounting methods are applied. The difference in carbon stocks varied in a range from 4.6 to 5.6 of Mt between Tier 2 and Tier 3 methods during the period from 1992 to 2015 (Figure 1). The applied Tier 3 method showed 1.4 times higher carbon stock values during the entire period. The highest carbon stock (19.5 Mt) at the end of the study period (2015) was observed when FAOSTAT data were used and the Tier 3 method was applied. On the other hand, a total carbon stock of 13.9 Mt was observed when national statistical data were used and the Tier 2 method was applied.

Different combinations of methods and activity data sources were chosen to analyze the impacts on the results. FAOSTAT data for many Eastern European countries are available only since their independence. In the case of Lithuania, FAOSTAT data are available since 1992. According to the IPCC guidelines, countries can choose activity data series as well as verifiable and transparent methods.

3.1. Effects of Different Accounting Methods

The carbon inflow into the pool of HWP was estimated to be 40% higher when applying the material flow analysis (Tier 3) compared to the IPCC default (Tier 2) method. For the years 2014–2015, historical carbon inflow by applying the IPCC Tier 2 method was 0.53 Mt of C, and by applying the Tier 3 it was 0.74 Mt of C (Figure 2a).

Higher carbon inflow resulted in higher carbon stock over the study period (Figure 2). During the years 1992–2015, three periods showing differences of carbon inflow between Tier 2 and Tier 3 could be defined: the difference of 0.04–0.09 Mt in 1992–1994; 0.11–0.15 Mt in 1995–2002; and 0.17–0.21 Mt in 2003–2015. The inflow appeared to be higher mainly because of industrial residue usage in the production of semifinished HWP, which was not considered in the Tier 2 method. However, in this study, material flow was tracked for one year only. The carbon inflow differences found in the study year were assumed to be equal for the historical period. This might be seen as a shortcoming of the comparative analysis; however, for estimating current carbon stock, historical data are needed despite the method used. It should be mentioned that material flow analysis of HWP in Lithuania was never done in the past; therefore, in order to compare different methods, simplification was needed. This simplification is necessary in order to be able to estimate carbon stocks and compare them across different accounting methods. If in the future a similar study on material flow analysis is done, missing periods could be interpolated.

The observed decline of carbon inflows in 1990–1992 was fixed due to local political (Lithuania re-established its independence) and economic reasons, which significantly reduced the production.

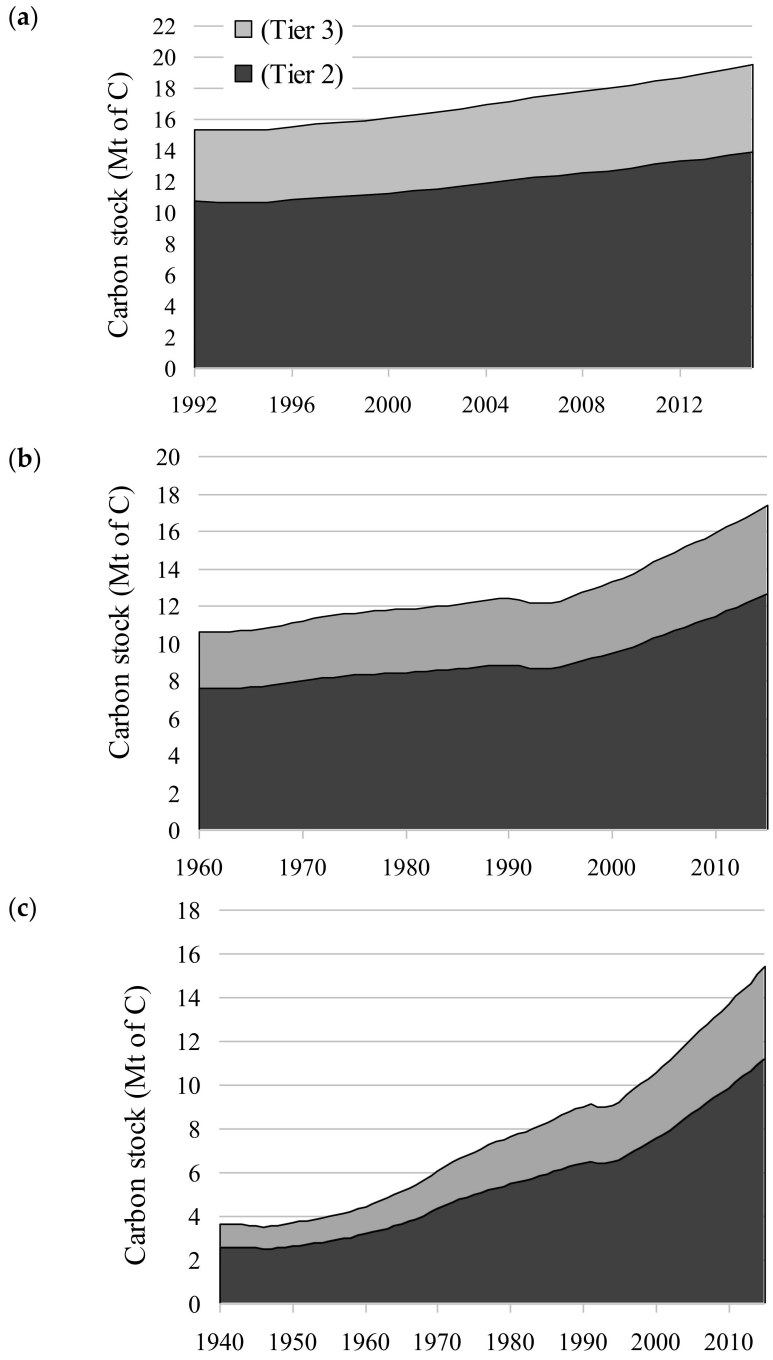

Figure 1. Total carbon stocks in harvested wood products (HWP) under the Intergovernmental Panel on Climate Change (IPCC) Tier 2 and Tier 3 methods: (**a**) Estimates based on available Food and Agriculture Organization (FAO) data (1992–2015); (**b**) estimates based on available literature data (1960–1991) and FAO data (1992–2015); (**c**) estimates based on data obtained from national statistics (1940–1991) and FAO data (1992–2015).

The carbon stock in Lithuania could be even higher if carbon in exported roundwood were tracked and attributed to the national budget. On average, about 1.7 million m^3 of industrial roundwood was exported annually from 2010 to 2014. This corresponds to 33% of country-produced industrial round timber [19]. Thus, a large proportion of local carbon in the roundwood is exported. However, currently there is no methodology to evaluate the exported wood-related carbon flows and HWP half-life. According to the requirements of carbon accounting [4,5], if it is not possible to obtain data,

the country's roundwood exports are assessed as a national carbon loss. It is clear that the principles and guidelines for carbon budget calculations are not favorable to Lithuania, because the country acts more as an exporter than an importer. No international methodology for calculating carbon stocks in exported roundwood exists. In a case of reliable data and available methodology for assessing carbon-based roundwood, it would be possible to provide higher values for national carbon stocks in HWP. Therefore, studies on determining carbon in exported wood would be required.

3.2. Effects of Different Data Sources on HWP

When comparing carbon stock using data from different sources, the total carbon stock obtained by Tier 3 differed from that obtained by Tier 2 (Figure 1). Using FAOSTAT data and the Tier 3 method showed, on average, 42% higher carbon stock compared with the Tier 2 method and other data sources. Using combined scientific literature and FAOSTAT data and applying the Tier 3 method showed, on average, 39.7% higher carbon stock compared with the Tier 2 method and the same data sources.

When comparing carbon stock changes in HWP using different data sources, changes varied significantly between the Tier 2 and Tier 3 accounting methods (Figure 3). The results show the largest carbon inflow in HWP when using FAOSTAT data and the Tier 3 method. This is mainly because of increased forest fellings in Lithuania after 1991. Statistical FAOSTAT data on production of HWP are available only since 1992.

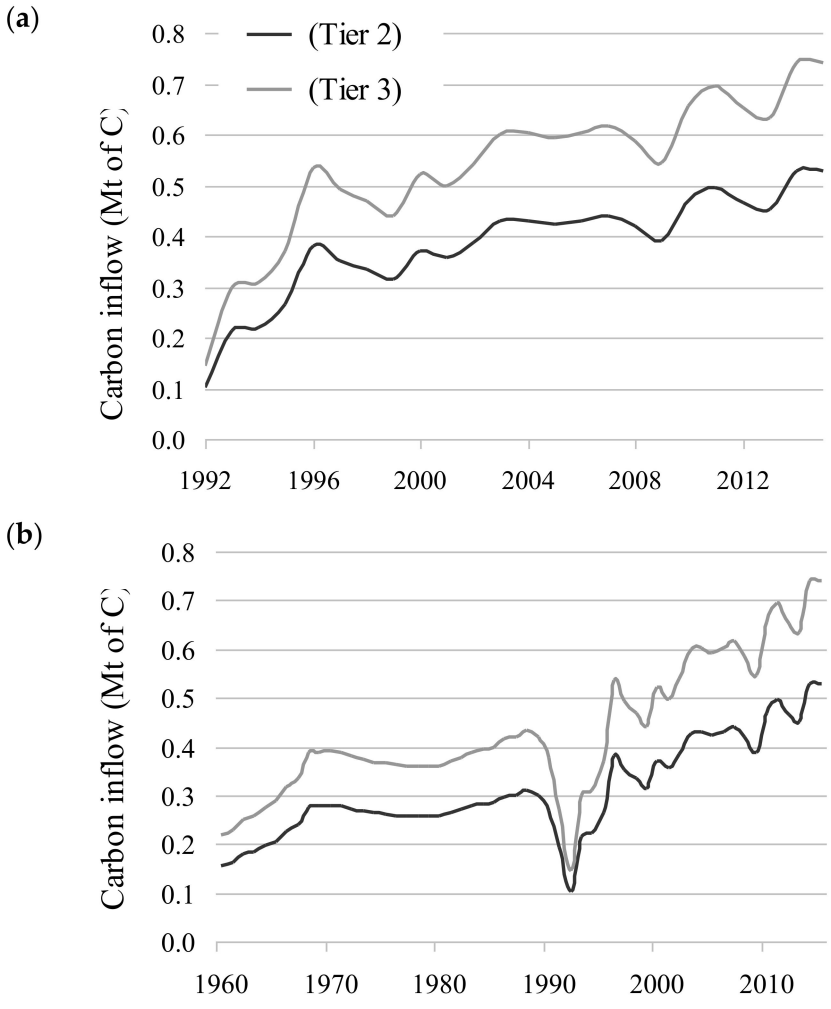

Figure 2. *Cont.*

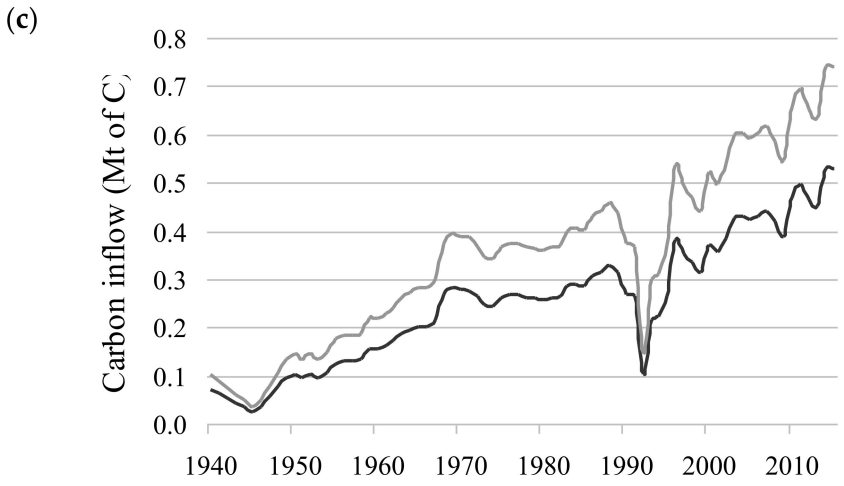

Figure 2. Historical carbon inflows by applying the IPCC Tier 2 and Tier 3 methods: (**a**) estimates based on available FAO data (1992–2015); (**b**) estimates based on available literature data (1960–1991) and FAO data (1992–2015); (**c**) estimates based on data obtained from national statistics (1940–1991) and FAO data (1992–2015).

Using combined scientific literature and FAOSTAT data, the Tier 3 method showed, on average, 34% higher carbon stock changes than the Tier 2 method. Using the combined data from the statistics department and FAOSTAT, the carbon stock changes calculated by the Tier 3 method were, on average, 36.6% higher than by the Tier 2 method. The negative change in carbon stocks was recorded in the periods 1942–1947 and 1990–1992 for political and economic reasons that drastically reduced the extent of production (Figure 3). The first historical period coincides with the Second World War, and the second one was when Lithuania regained its independence.

The findings of this research-based study do not suggest using any particular accounting method. To make it clear, carbon accounting methods do not increase carbon stocks in HWP, and additional measures will need to be taken if Lithuania decides to contribute to mitigating climate change by increasing carbon stocks in HWP.

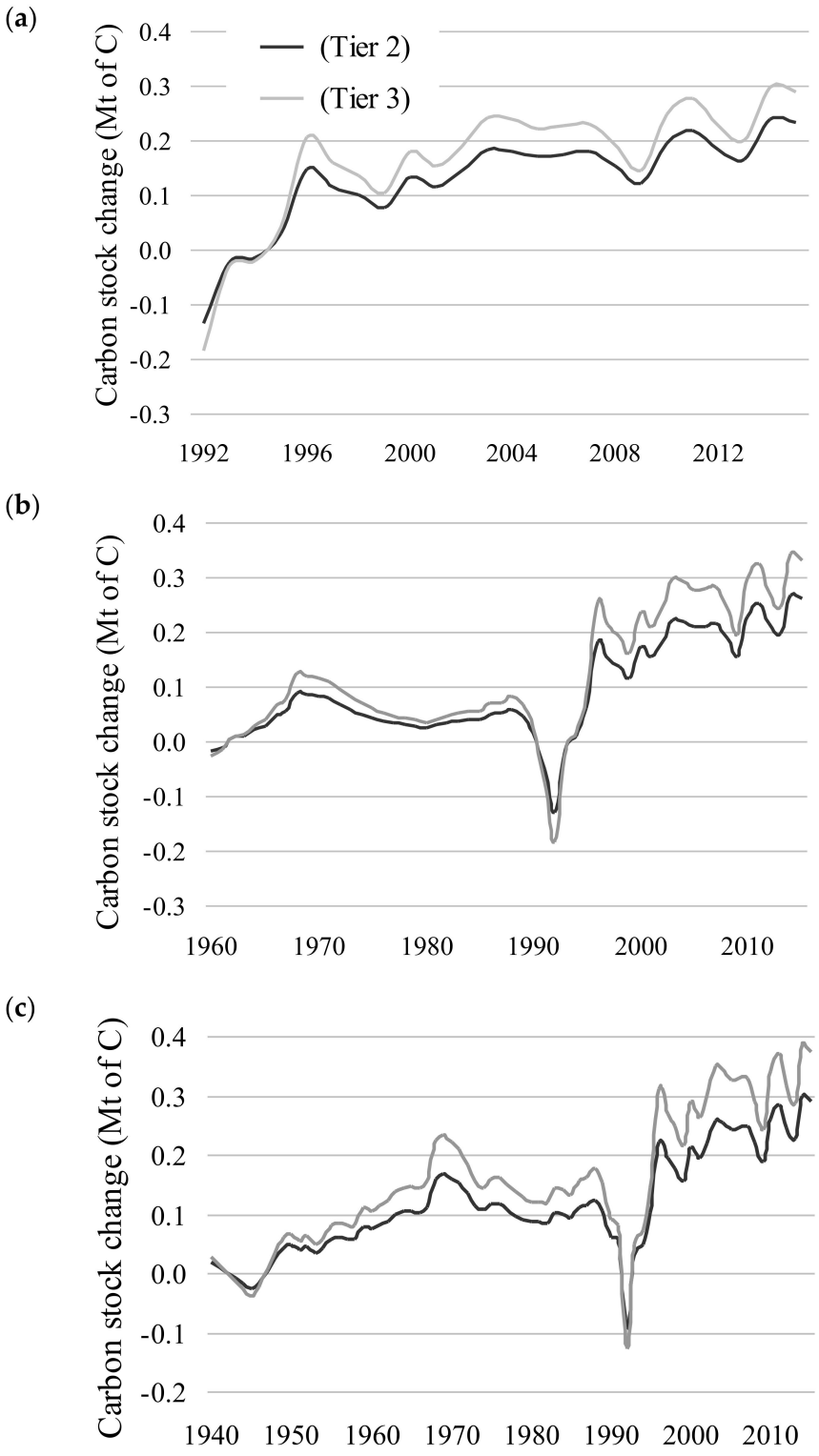

Figure 3. Historical carbon stock changes by applying the IPCC Tier 2 and Tier 3 methods. (**a**) estimates based on available FAO data (1992–2015); (**b**) estimates based on available literature data (1960–1991) and FAO data (1992–2015); (**c**) estimates based on data obtained from national statistics (1940–1991) and FAO data (1992–2015).

4. Conclusions

The aim of this study was to reveal the impacts of using different carbon accounting methods for harvested wood products (HWP) and different data sources on national HWP carbon stocks. Three data sources from different periods were used to estimate the carbon stocks in HWP: FAOSTAT (1992–2015), scientific literature (1960–1991), and national statistics (1940–1991).

Between the two alternative computing methods (Tier 2 and Tier 3), the carbon stock levels with the Tier 3 method were significantly higher than with the Tier 2 method. The main advantages and disadvantages of the material flow method (Tier 3) are as follows: local and imported carbon are separated in all timber flows, thus completely eliminating the possibility of accounting for carbon in imported wood; and carbon in industrial residues (chips and particles) is included in the carbon stock, taking into account the processes in the wood industry. This was the main reason for the carbon increase. In Lithuania, more than half of wood-based panels are made from industrial wood waste. Despite the advantages of this method, the material flow data in this study are based on only one year, because this type of research was carried out for the first time in Lithuania. Since the material flow analysis is based on data for Lithuania referring to one year only, the results could be compared when comparing similar study results in the future.

If further research is carried out, missing data in intermediate years could be interpolated. In this case, results with higher reliability could be used in national carbon accounting and reporting. It is advisable to apply the Tier 3 method for carbon accounting of HWP in Lithuania. We suggest that the data needed for this method could be updated every five years to avoid compromising accounting reliability.

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References

1. Nabuurs, G.J.; Delacote, P.; Ellison, D.; Hanewinkel, M.; Lindner, M.; Nesbit, M.; Ollikainen, M.; Savaresi, A. *A New Role for Forests and the Forest Sector in the EU Post-2020 Climate Targets*; European Forest Institute: Joensuu, Finland, 2015; p. 29.
2. Pilli, R.; Fiorese, G.; Grassi, G. EU Mitigation potential of harvested wood products. *Carbon Balance Manag.* **2015**, *10*, 1–16. [CrossRef] [PubMed]
3. IPCC. *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme*; Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., Eds.; Institute for Global Environmental Strategies (IGES): Hayama, Japan, 2006.
4. IPCC. *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*; Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M., Troxler, T.G., Eds.; IPCC: Geneva, Switzerland, 2014.
5. UNFCCC. *Land Use, Land-use Change and Forestry*; Decision 2/CMP.7, FCCC/KP/CMP/2011/10/Add.1; United Nations Framework Convention on Climate Change: Bonn, Germany, 2012; Available online: https://unfccc.int/resource/docs/2011/cmp7/eng/10a01.pdf (accessed on 25 November 2018).
6. Pingoud, K.; Pohjola, J.; Valsta, L. Assessing the integrated climatic impacts of forestry and wood products. *Silva Fenn.* **2010**, *44*, 155–175. [CrossRef]
7. Skog, K.E. Sequestration of carbon in harvested wood products for the United States. *For. Prod. J.* **2008**, *58*, 56–72.

8. Dias, A.C.; Arroja, L.; Capela, I. Carbon storage in harvested wood products: Implications of different methodological procedures and input data—A case study for Portugal. *Eur. J. For. Res.* **2012**, *131*, 109–117. [CrossRef]
9. UNFCCC. National Inventory Submissions, 2016. Available online: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php (accessed on 6 November 2018).
10. Jochem, D.; Weimar, H.; Bösch, M.; Mantau, U.; Dieter, M. Estimation of wood removals and fellings in Germany: A calculation approach based on the amount of used roundwood. *Eur. J. For. Res.* **2015**, *134*, 869–888. [CrossRef]
11. Parobek, J.; Paluš, H.; Kaputa, V.; Šupín, M. Analysis of wood flows in Slovakia. *BioResources* **2014**, *9*, 6453–6462. [CrossRef]
12. Greenhouse Gas Emissions in Finland 1990–2014, National Inventory Report under the UNFCCC and the Kyoto Protocol. Available online: https://www.stat.fi/static/media/uploads/tup/khkinv/fi-nir_eu_2016_2018-03-15.pdf (accessed on 25 November 2018).
13. Mantau, U. *Wood Flows in Europe (EU27)*; Project Report; CEPI Confederation of European Paper Industries, CEI-Bois European Confederation of Woodworking Industries: Celle, Germany, 2012; p. 24.
14. Lithuanian Statistical Yearbook of Forestry. Ministry of Environment, State Forest Service, 2017. Available online: http://www.amvmt.lt/Images/Veikla/STAT/MiskuStatistika/2017/Metrastis_2017_CD.pdf (accessed on 6 November 2018).
15. Forest Stewardship Council. FSC Facts & Figures October 1, 2018. Available online: https://ic.fsc.org/en/facts-and-figures (accessed on 6 November 2018).
16. Jasinevičius, G.; Lindner, M.; Cienciala, E.; Tykkyläinen, M. Carbon accounting in harvested wood products: Assessment using material flow analysis resulting in larger pools compared to the IPCC default method. *J. Ind. Ecol.* **2018**, *22*, 121–131. [CrossRef]
17. Lithuanian Statistical Yearbook of Forestry. Ministry of Environment, State Forest Service, 2015. Available online: http://www.amvmt.lt/index.php/leidiniai/misku-ukio-statistika/2015 (accessed on 15 September 2018).
18. Brukas, A.; Kairiūkštis, L. Miško kirtimai ir bendras naudojimas (Forest fellings and general use of forests). In *The Chronicle of Lithuanian Forests*; Juodvalkis, A., Kairiūkštis, L., Ozolinčius, R., Eds.; Petro Ofsetas: Vilnius, Lithuanian, 2003. (In Lithuanian)
19. Morkevičius, A. *Wood Industry in Lithuania: From the Beginning until 2000*; Association "Lithuanian Wood": Vilnius, Lithuania, 2001; p. 442. (In Lithuanian)
20. FAOSTAT. Food and Agriculture Organization of the United Nations, Statistics Division. Forestry Production and Trade. Available online: http://faostat3.fao.org/browse/F/*/E (accessed on 12 February 2018).
21. Rüter, S.; Diederichs, S. LCA Basic Data for Construction Products Made of Wood. Available online: http://literatur.vti.bund.de/digbib_extern/dn050490.pdf (accessed on 5 October 2018).
22. Wilson, J.B. Life-cycle inventory of particleboard in terms of resources, emissions, energy and carbon. *Wood Fiber. Sci.* **2010**, *42*, 90–106.
23. Binder, C.R.; Hofer, C.; Wiek, A.; Scholz, R.W. Transition towards improved regional wood flows by integrating material flux analysis and agent analysis: The case of Appenzell Ausserrhoden, Switzerland. *Ecol. Econ.* **2004**, *49*, 1–17. [CrossRef]
24. Korhonen, J.; Wihersaari, M.; Savolainen, I. Industrial ecosystem in the Finnish forest industry: Using the material and energy flow model of a forest ecosystem in a forest industry system. *Ecol Econ.* **2001**, *39*, 145–161. [CrossRef]
25. Jasinevičius, G.; Lindner, M.; Pingoud, K.; Tykkyläinen, M. Review of models for carbon accounting in harvested wood products. *Int. Wood Prod. J.* **2015**, *6*, 198–212. [CrossRef]