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Carbon balance in harvested wood products in Slovakia

Bilancia uhlíka v drevných produktoch na Slovensku

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Abstract
The forests in Slovakia are managed according to the forest management plans. The limits for cuttings are prescribed according to the rules of sustainable forest management. Thus, the produced timber becomes the sustainable natural resource. The purpose of wood use has implications for the carbon balance. Wood products for long term use represent a carbon pool from which carbon is released according to decay of products. The method for calculation and results of carbon balance of harvested wood products in Slovakia are provided in this paper. According to the results, the total amount of carbon stored in the harvested wood products in Slovakia have had an increasing trend in the last years and reached almost 15 Tg. The calculation follows the methods and good practice guidance arising from the Kyoto Protocol.

Key words: harvested wood products; carbon balance; wood use; carbon pool; Kyoto Protocol

Abstrakt
Lesy sú na Slovensku obhospodarované podľa programov starostlivosti o lesy. Limity pre objem ťažby sú predpísané na základe pravidiel trvalo udržateľného obhospodarovania lesov. Týmto spôsobom sa produkované drevo stáva obnoviteľnou surovinou s trvalo udržateľnou produkciou. Následné využitie dreva má vplyv na bilanciu uhlíka a produkty z dreva určené na dlhodobé využívanie predstavujú zásobáreň uhlíka, z ktorej sa uhlík uvoľňuje pri rozklade dreva po ukončení životnosti drevného produktu. V práci je prezentovaný metodický postup výpočtu a výsledky bilancie uhlíka v produktoch z dreva na Slovensku. Podľa výsledkov je celkové množstvo uhlíka uloženého v drevných produktoch odhadnuté na 15 Tg a doteraz malo stúpajúci trend. Metodický postup je spracovaný podľa metód a praktických návodov spracovaných v súvislosti s postupmi navrhnutými pre hodnotenie plnenia záväzkov vyplývajúcich z Kjótskeho protokolu.

Kľúčové slová: produkty z dreva; bilancia uhlíka; využitie dreva; zásobáreň uhlíka; Kjótsky protokol

1. Introduction

Europe produces significant amount of roundwood, reaching almost 600 million cubic metres in 2010. The wood is used for products of long term use and as a wood fuel, for which the demand is increasing at a high rate (Forest Europe et al. 2011). The volume of fellings in Slovakia varies, on average reaching 5 million m^3 $year^{-1}$ in nineties, almost 8 million m^3 $year^{-1}$ in the first decade of new millennium and almost 9 million m^3 $year^{-1}$ in the period 2010–2013. This trend indicates increasing demand for wood due to the growth of wood based industry, which is reflected also in the rules for carbon accounting under Kyoto Protocol in its second commitment period, when balance of carbon in harvested wood products (HWP) becomes mandatory. The increasing concentration of greenhouse gases in the atmosphere and the climate change stimulate interests for carbon sequestration (Konôpka 2007). Contrary to the firewood and energetic use of wood, the long-term used HWP represent a carbon pool. The term HWP is based on a concept of two separate elements – forest harvesting and wood products (Brown et al. 1998) and for the carbon balance purposes the roundwood category is split to the industrial roundwood and fuelwood subcategories. While the instantaneous oxidation applies to fuelwood, the accounting of carbon from sawn wood, wood-based panels and paper (including paperboard) as defined in the Decision 2 of the seventh Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (2/CMP.7) shall be based on the change in the harvested wood products pool during the second and subsequent commitment periods, estimated using the first-order decay function with default half-lives of two years for paper, 25 years for wood panels and 35 years for sawn wood (UN FCCC 2012). The methods, calculation and results of carbon balance of harvested wood products in Slovakia are provided in this paper. The paper provides an overview of the situation and the first step in assessing HWP in Slovakia. Further development of input databases, used factors and applied methods is expected in the future as a response to the trends in other countries (e.g. Ellison et al. 2011; Dymond 2012).

2. Methodology

The forests in Slovakia are managed according to the forest management plans. The limits for cuttings are prescribed according to the rules of balanced wood production over time and sustainable forest management (Regulation no. 453/2006 Z. z.). Thus way, the produced timber becomes

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the sustainable resource. The purpose of wood use has implications for the carbon balance as the wood used for long-term products represents the carbon pool from which carbon is released over time during the product decay. The calculation follows the methods and good practice guidance arising from the Kyoto Protocol, where accounting of HWP is confined to products in use manufactured from the wood derived from domestic harvest. For the HWP from deforestation (D), woody products at solid wood disposal sites and wood used for energy purposes the instantaneous oxidation shall be applied, i.e. the release of carbon is considered in the year of felling. It is a good practice to estimate the change in carbon stocks separately for each of the HWP fractions originating from afforestation/reforestation (AR) and from forest management (FM) according to the first-order decay (FOD) function as presented in Equation 1.

$$C(i+1) = e^{-k} * C(i) + ((1-e^{-k})/k) * Inflow(i) \quad [1]$$

where
i – year,
$C(i)$ – the carbon stock in the particular HWP category at the beginning of year i, Gg C,
k – decay constant of FOD for each HWP category,
k – $ln(2)/HL$, where HL is half-life,
$Inflow(i)$ – the inflow to the particular HWP category during year i, Gg C.yr^{-1}.

The carbon stock change of the HWP category during year i is calculated by Equation 2.

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

The data on the production and trade statistics on HWP can be found in the public database of the Food and Agriculture Organization of the United Nations (FAO) at http://faostat.fao.org/. The data are available since 1961, however, the data for Slovakia (SK) and the Czech Republic (CZ) were aggregated before the dissolution of Czechoslovakia (CS) in 1993. To calculate the shares of SK and CZ on individual HWP in the period 1961–1992, the CS figures were multiplied by country specific share on the sum of figures for both countries in the period of five years 1993–1997, i.e., correspondingly as applied earlier in the CZ (Cienciala & Palán 2014).

The shares of CK and SK on production, import and export quantities of main HWP categories, calculated as an average of country specific shares according to FAO data in the period 1993–1997, are provided in Table 1.

The FOD function represents a flux data method, where decay is calculated as continuous loss of stored carbon, reducing the initial amount of stored carbon by one half in the period of half-life. Half-life time represents the number of years required to lose one-half of the material currently in the carbon pool, while the remaining carbon is again reduced by one half in the next half-life period, etc. Thus, for valid estimates of recent years it is recommended that inputs to and outputs from HWP stocks since 1900 are used. The HWP production, imports and exports before the year 1961 can be estimated using Equation 3, assuming continuous rate U of change in industrial roundwood consumption in the region.

$$V_i = V_{1961} * e^{[U*(i-1961)]} \quad [3]$$

where
V_i – annual production, imports or exports of a solid wood or paper product in year t,
i – year,
U – estimated continuous rate of change in industrial roundwood consumption for the region between 1900 and 1961, (0.0151 yr^{-1} for Europe).

At this stage of the assessment, the default conversion factors according to the IPCC guidelines from 2014 (Hiraishi et al. 2014) provided in Table 2 are used for conversion of technical units of HWP to the carbon amount and default half-lives (Table 1) are applied for decay. The alternative conversion factors for HWP subcategories are provided in IPCC guidelines from 2006 (Eggleston et al. 2006) or country specific factors can be used.

According to Decision 2/CMP.7, accounting for HWP contribution is restricted to carbon in HWP from activities in forests of the country, while carbon in imported HWP is to be excluded. The share of carbon in HWP originating from domestic forests is estimated applying Equation 4, calculated for industrial roundwood and for pulp separately.

$$f_{IRW}(i) = (IRW_P(i) - IRW_{EX}(i)) / (IRW_P(i) + IRW_{IM}(i) - IRW_{EX}(i)) \quad [4]$$

where
$fIRW(i)$ – share of industrial roundwood for domestic production of HWP originating from domestic forests in year i,
$IRWP(i)$ – production of industrial roundwood in year i,
$IRWIM(i)$ – import of industrial roundwood in year i,
$IRWEX(i)$ – export of industrial roundwood in year i.

The fractions of HWP that are derived from domestic forests under activities (forest management, afforestation/reforestation, deforestation) are estimated using Equation 5.

$$f_j(i) = harvest_j(i) / harvest_{Total}(i) \quad [5]$$

where
$fj(i)$ – share of harvest originating from the particular activity j in year i,
j – activity FM, AR or D in year i.

In Slovakia, all forest areas (registered as forest areas in cadastre) are subjects to forest inventory, planning and management according to forest management plans. Domestic wood production is continuously registered in the mandatory process of forest management evidence (Regulation no. 297/2011 Z. z.), structured by forest management units, tree species and type of felling. The fellings in initial stages of forests after AR activities practically do not occur, thus total wood production is attributed to the activities FM and D. The areas for deforestation are subject of state authority permission and a corresponding levy has to be paid, thus this activity is limited to strategic constructions and the area of deforestation is officially recorded. Timber volume from deforestation is estimated on the base of the deforested area and an average volume of forest stands. The records of forest management evidence on explicit wood volume cut at deforested areas represent an alternative source, however, since the area is claimed as non-forest it is no more subject to forest evidence and there is a risk of omission error.

Table 1. The shares of Czech Republic and Slovak Republic on the HWP in the period 1993–1997 and default half-lives.

Wood product	FAO code	Production		Import		Export		Default half-life [yr]
		CR	SR	CR	SR	CR	SR	
Sawn wood	1872	0.834	0.166	0.868	0.132	0.723	0.277	35
Wood based boards	1873	0.716	0.284	0.719	0.281	0.851	0.149	25
Paper and paperboards	1876	0.655	0.345	0.772	0.228	0.598	0.402	2

Table 2. Default conversion factors used for HWP adopted by IPCC (Hiraishi et al. 2014).

Factor	Sawnwood aggregated (coniferous; non-coniferous)	Wood-based panels (HDF; particle board)	Paper and paperboard
Density D (oven-dry tonnes per m^3 or per air dry tonne of pulp or paper)	0.458 (0.450; 0.560)	0.595 (0.788; 0.596)	0.900
Carbon fraction CF (tonnes carbon per oven-dry tonne of wood material)	0.500 (0.500; 0.500)	0.454 (0.425; 0.451)	0.500
Carbon factor (D * CF) (tonnes carbon per m^3 or per air-dry tonne of paper product)	0.229 (0.225; 0.280)	0.269 (0.335; 0.269)	0.386

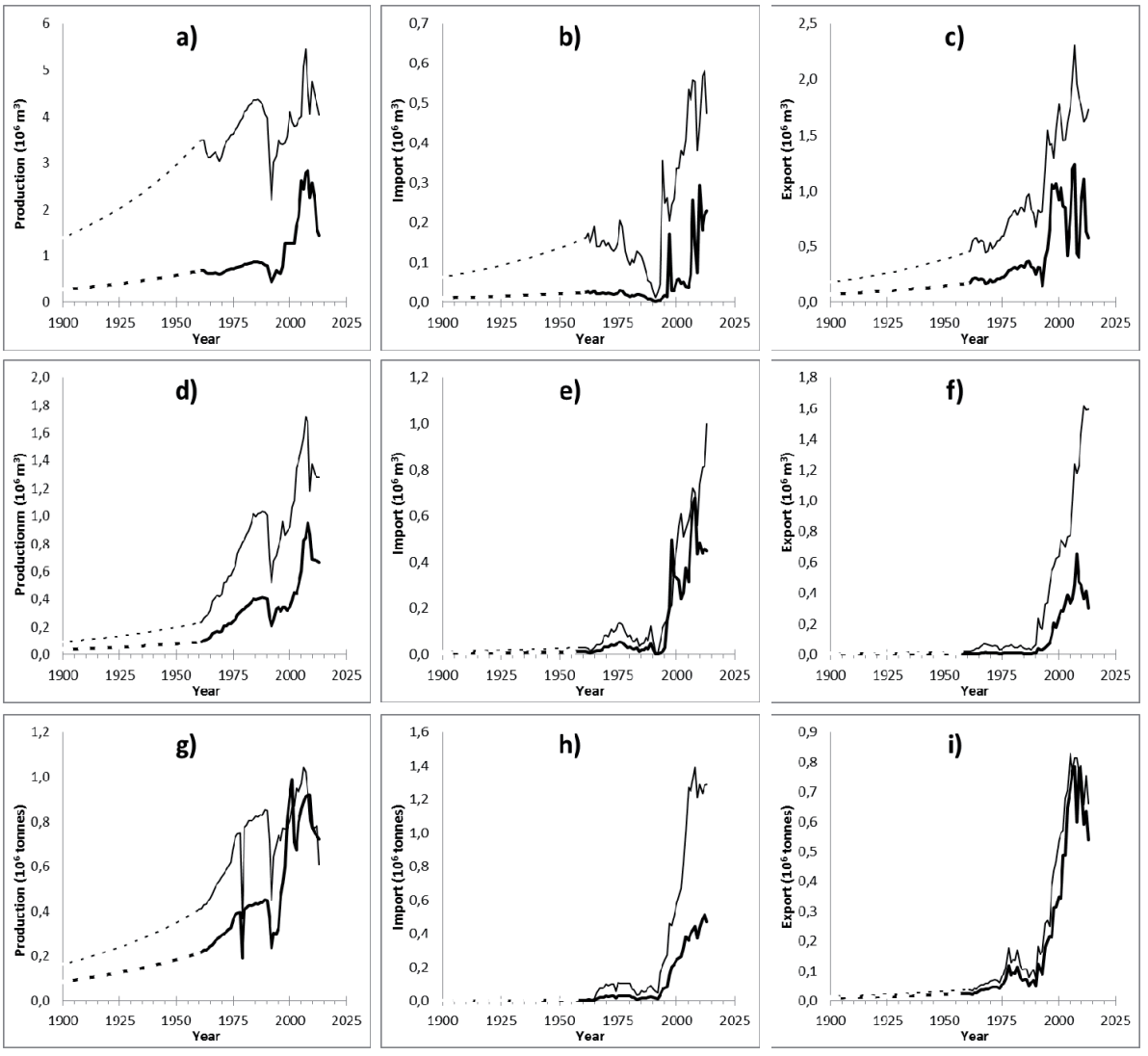

Fig. 1. Production (*a, d* and *g*), import (*b, e* and *h*) and export (*d, f* and *i*) of sawn wood, wood-based boards and paper & paperboard respectively. Thick lines represent data of Slovak Republic, thin lines the data of the Czech Republic, dashed parts are the outputs of Equation 3.

To obtain the annual HWP fraction from domestic harvest associated with the particular activity Equation 6 should be used.

$$HWPj(i) = HWPP(i) * fDP(i) * fj(i) \quad [6]$$

where

j – activity FM, AR or D,

fDP(i) – *fIRW(i)* for HWP categories sawnwood and wood-based panels, and

fDP(i) – *(fIRW(i) * fPULP(i))* for paper & paperboard HWP category.

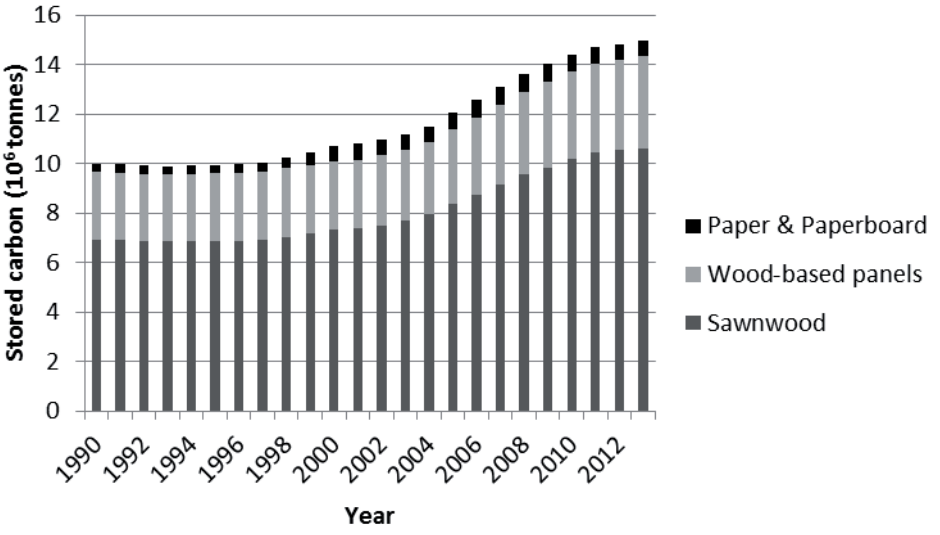

Fig. 2. Carbon stored in HWP from forest management in Slovakia.

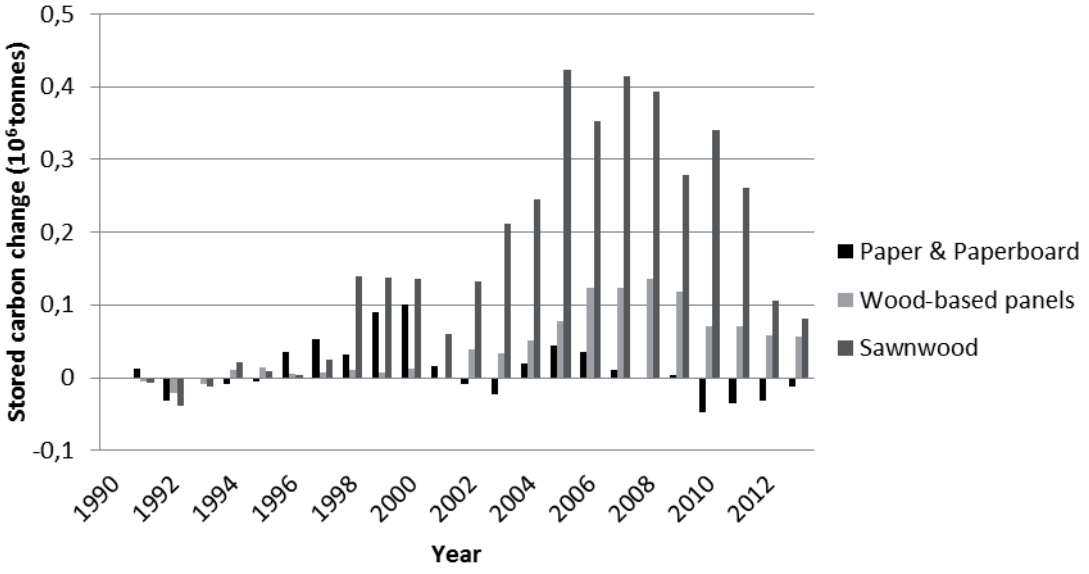

Fig. 3. Annual changes of carbon stored in HWP from forest management in Slovakia.

In order to consider HWP half-lives and to produce an estimate of the existing carbon pool by means of Eq. 1, the historic inflow to HWP has to be included. If we assume that the HWP pools are in a steady state at the beginning of the period of interest, this steady carbon stock can be approximated by means of Equation 7.

$$C(t0) = Inflowaverege / k \quad [7]$$

where

$Inflow_{average}$ is an average of specific HWP carbon inflow in the first 5 years of period.

3. Results

An overview of the production, import and export of main HWP categories in CZ and SK is provided in Fig. 1, while the data for the period 1900–1960 were calculated by Eq. 3, for the period 1961–1992 the CS data in the FAO database were split using coefficients in Table 1, and for the period 1993–2013 active data from the FAO database were used.

The default conversion coefficients in Table 2 were used for conversion of HWP technical amounts to carbon content. The amount of carbon in HWP pool was estimated since 1990, applying Eq. 7 to estimate the initial state and Eq. 1 to estimate the annual changes in HWP pool. Fig. 2 displays the amounts of carbon stored in HWP corresponding to domestic wood production from forest management in Slovakia.

The annual changes of carbon in individual HWP calculated according to Eq. 2 are displayed in Fig. 3.

The carbon balance follows the production approach, and the real use of wood products in the country can differ due to trade with wood products. The HWP production structure in countries differs based on the wood industry structure, examples of some European countries with developed forestry and wood processing sectors are displayed in Fig. 4.

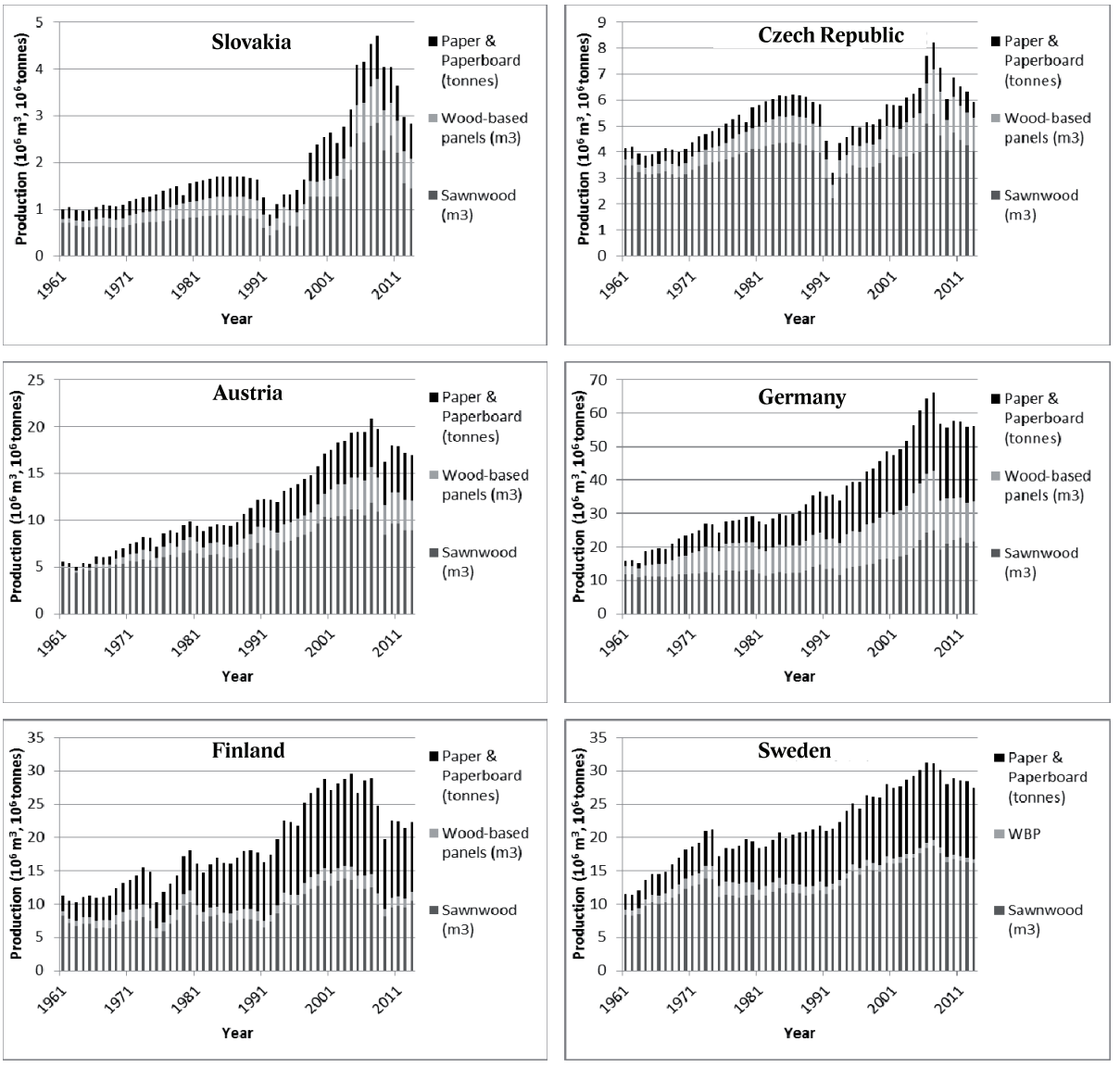

Fig. 4. Comparison of HWP production in selected European countries with developed forestry and wood processing sectors (Source: http://faostat3.fao.org/download/F/FO/E).

There is an obvious culmination of HWP production in the years 2006–2007 (see Fig. 4) corresponding to the pre-crisis period, in Slovakia the production of sawnwood accelerated also due to higher availability of wood processed after the destruction of spruce stands by windstorm in November 2004. Another feature visible in Fig. 4 is that while production of wood-based panels, paper and paperboard is more stable, sawnwood shows higher fluctuations.

4. Discussion

The absolute amounts of production, import and export of all three wood products (sawn wood, wood-based panels, paper & paperboard) in both countries (as displayed in Fig. 1) show large variability in time with a positive trend in last decades and decrease in last years. This indicates that wood production and processing sectors in our relatively small countries are sensitive to disturbances, e.g. the availability of wood due to disturbances in forests, technological processes in wood processing factories, and situation in the market with wood products. Considering this change of trend in last years, the liability of possible prediction based on historic data would be limited (see also Pilli et al. 2015) The course of carbon stored in HWP pool (Fig. 2) shows that according to the applied FOD method, the first decennium since 1990 is characterised by balanced losses and gains of carbon in the pool, the trend of increasing carbon gains in sawn wood and paper is better visible in Fig. 3. The next decennium is characterised by the growth of sawn wood and wood-based panels production (Fig. 1), increasing carbon gains in these HWP (Fig. 3). Last years are characterised by the drop of production in all HWP categories (Fig. 1), this is reflected also in the annual changes of carbon stored in HWP (Fig. 3) and the year 2008 (start of economic crisis) can be identified as a break point when the trend of increasing gains in HWP carbon pool turned to decrease. The noteworthyfact is that in the last years since 2008 the fellings in Slovakia have been higher than in the

previous period (as mentioned in Introduction), indicating increase in an alternative (energetic) use of wood. The results indicate, that HWP pool is a carbon sink, however, if the market does not recover and the production stagnates or drops down, the HWP pool may become a source of carbon emissions due to decay of higher gains accumulated in the past years. This first assessment of carbon balance in HWP in Slovakia uses default conversion coefficients applied to the aggregated HWP categories and the collection of country specific conversion factors. More detailed structure of HWP and corresponding half-lives could contribute to further improvement of the assessment of carbon balance in this pool. More detailed analysis of wood products and their use at a national scale would support more realistic assessment as these factors can differ due to national traditions in wood use, e.g. the estimate for wood housing in U.S. half-life is 100 years (Skog & Nicholson 1998). To reduce the uncertainties in determining the lifespan of wood material after harvesting, a substantial effort was also given in the framework of Cost Action E31 Management of recovered wood (Valentini & Miglieta 2015). Our results indicating the increase of the carbon pool in HWP in Slovakia correspond to the assessments of global trends (e.g. Skog & Nicholson 1998). Global carbon pool of forest products is estimated to be growing by 150 Mt of carbon per year (Miner & Perez-Garcia 2007). There are also different approaches for carbon balance assessment (e.g. atmospheric-flow) considering diverse inputs and providing different results (Winjum et al. 1998).

5. Conclusions

The First order decay method was applied to the production and trade data from FAO database on the production, import and export of harvested wood products in Slovakia. The source data since 1961 to 1992 available only for the former Czechoslovakia were disaggregated between Slovakia and the Czech Republic. The data showed large fluctuations with an overall positive trend and the decrease of production of all three HWP categories (sawn wood, wood-based panels, paper and paperboards) in the last years. In Slovakia the HWP pool is a carbon sink, specifically sawn wood has large contribution and potential as a carbon sink as shown by the data from the pre-crisis period. The overall trend of carbon sequestration in HWP is positive what corresponds with the global trend of increasing use of wood products.

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