Analysis of Wood Flows in Slovakia

Ján Parobek,* Hubert Paluš, Vladislav Kaputa, and Mikuláš Šupín

This paper describes the analysis of raw wood flows in Slovakia. Material flow analysis was used to reveal and quantify relations between the resources and the primary uses of wood. In particular, two approaches to wood flow modelling were utilised - wood balance and wood resource balance. Wood balance was introduced to illustrate a global view of the resources and primary uses of roundwood in Slovakia without analysing internal flows or individual roundwood assortments, respectively. The wood resource balance, as a more detailed analysis, takes into account the uses of wood as a material and also the by-products and waste generated by the production that could be used as inputs for further uses in wood processing or energy sectors. The latter balance was compiled using available official statistics supplemented by a questionnaire to estimate missing data for waste streams. With a total consumption of 11.964 mil. m^3 roundwood equivalents, the value of the overall cascade factor was 1.11. Over 84% of all resources were used for industrial purposes, and nearly 16% were used for energy generation.

Keywords: Wood flows; Wood balance; Wood resource balance; Cascade use of wood

*Contact information: Technical University in Zvolen, Faculty of Wood Sciences and Technology, T. G. Masaryka 24, 960 53 Slovakia; *Corresponding author: parobek@tuzvo.sk*

INTRODUCTION

The principles of sustainable forest management and the continuous and regular production of raw wood material are based on the general requirements of society to meet its environmental, economic, social, cultural, and spiritual needs. The path of raw wood material from its production to giving the final product to a consumer is relatively long, as it passes several stages of production and different types of markets until the final product fulfils the needs of the consumers. Before reaching the end-user, these stages include leaving the forest, primary wood processing, secondary wood processing, and subsequent wood-using industries. Within these stages, raw wood material is transformed into primary processed intermediate products (sawn wood, pulp), secondary processed products (furniture, construction, and joinery), and then has a role in the final production of different industries related to the use of wood (*e.g.*, construction). The domestic wood processing industry in the Slovak Republic is the major customer of the products of the forestry sector, and roundwood represents the main material input for this sector (Parobek and Paluš 2008). Similar links exist between the wood processing industry and other sectors that are dependent on wood products. To use existing resources optimally, it is therefore necessary to explain and quantify such complex relationships in detail. Material flow analysis (MFA) can be used for the quantification and modelling of wood flows. The analysis process includes the gathering of information and requires market experience and recognition of mutual relations in the "forest - wood – end-user" chain.

The objective of this work was to analyse raw wood material flows to reveal and quantify relations between the resources and primary uses of wood in Slovakia. For these purposes, two particular approaches were used - wood balance and wood resource balance.

Resource management and environmental quality have been improving in line with the increasing implementation of the principles of sustainable forest management. Economy-wide material flow analysis and balances and the indicators derived from them are descriptive tools that aim to provide information on the material and energy coming into and leaving the society and economy. They are conceptually based on a simple environment-economy model, where the latter is embedded into the former. The economy is connected with the surrounding environment *via* material and energy flows (Binder *et al*. 2004). Fisher-Kowalski (1998) argue that the material flow analysis is one of the most effective tools to control the consumption of resources and their conservation for future generations. Hinterberger *et al.* (2003) points out that material flow analysis builds on earlier concepts of material and energy balances. Zhou and Sun (2008) argue that MFA can be used to quantify material flows in a certain situation or for a certain time period.

In general, material flows can be explained in three basic dimensions. EUROSTAT (2001) defines a so-called territorial dimension that indicates the origin and direction of individual flows, which is either the domestic processing or exports of the country. Domestic flows are obtained from the natural resources of the country. The second dimension represents the view of the product chain or life cycle, in which the calculation of direct and indirect flows is taken into account. Direct flows enter the national economy as a direct physical input. Indirect flows occur in the opposite direction during the production process. If the national economy is seen as a black box comprising the entire economy, then it is not necessary to evaluate the indirect material flows. The third dimension is the product dimension, which describes whether the material enters the economic system or not, *i.e.*, whether or not the material is used. Extracted materials that do not enter further processing represent unused flows. Bringezu (2003) considers the analysis of material flows from resource extraction to final waste disposal as the key factor for understanding the structure, quantity, and quality of industrial metabolism. MFA can be also used as an analytical and modelling tool for different areas and sectors *e.g.*, material balances of corporations and urban regions in industrialised countries (Baccini and Bader 1996), regional wood management (Müller 1996), and the generation of waste in regional systems (Schwarzenbach *et al.* 1999).

The planning of strategic development in sectors related to the production and use of wood requires information on material flows in the complete supply chain, including raw wood production, processing, and usage. The analysis of wood flows enables one to determine a balance between the production and the use of wood in the country. The analysis results reveal relationships between the production, quality, and availability of data, the balance of foreign trade, and the importance of wood in domestic consumption. Additionally, it also helps to determine deviations from the officially reported statistics. Wood flow analysis is focused on all uses of wood and takes into account by-products and waste generated by processing the material input for further use. Both sides of the balance, the resources and the use side, are specific, as they incorporate different markets and products; therefore, it is necessary to examine each side individually. The overall structure of the balance is not constant and may vary depending on the uses of wood and wood products. In most cases, the balance includes such uses of wood for which there are no official statistics available, and the total consumption therefore cannot be simply

calculated. Consequently, the consumption of wood may be much higher than indicated by official statistics.

In recent years, the wood balances and material flow analyses have been developed in a number of countries (Hekkert *et al.* 2000; Binder *et al.* 2004; Piškur and Krajnc 2007; Knaggs and O'Driscoll 2008) and have served as the basis either for development plans or as a tool for quantifying volumes of illegal felling. Hekkert *et al.* (2000) analysed material flows of wood and paper in the economic system of the Netherlands using the STREAMS method. This method utilises available statistical data from supply and use tables and provides detailed information about the final consumption of wood and paper in the country. Binder *et al.* (2004) presented wood flow analysis for forests, wood processing industries, and consumption in a selected region of Switzerland. The model defined six processes and 20 material flows, including external flows. The aim of the analysis was to define and quantify the main wood flows between the processes to identify influencing factors. The synthesis included proposals for improving the efficiency of the flow system, such as increased domestic roundwood production and elimination of import dependency. A different approach was adopted by Piškur and Krajnc (2007), who carried out a material flow analysis as a part of the life cycle model. The applied analysis showed the correlation between resources, uses, and flows, and the results were then verified through the wood balance, which consisted of wood material and waste streams.

In general, wood flow analysis is focused more on resources than on products. Official data are not recorded for individual distribution channels in different sectors and products purchased by individual consumers. For these reasons, the analysis of wood flows highlights the need for empirical research and the use of empirically collected data. The balance can either be simply constructed as "wood balance," or it can reflect a complicated structure of market and material flows as "wood resource balance". This easily helps analysts to obtain the missing information and integrates information from the forestry sector, wood processing industry, and energy sector. The approach thus enables one to control and monitor wood flows at a national and international level. Emerging and developing ways of using wood can be easily integrated into the existing flows (Mantau *et al.* 2010).

EXPERIMENTAL

A single wood balance presents a global view of the resources and primary uses of roundwood in Slovakia without analysing internal flows or individual roundwood assortments, respectively. The main categories of resources are represented by the domestic roundwood production and imports, and the main uses by the domestic roundwood consumption and exports. The resource side is complemented by the recycled material and stock decrease, and the use side by the stocks increase. An increase in stocks causes a decrease in consumption, and *vice-versa*. The availability and consistency of data represent a limiting factor for the construction of the wood balance. Available data for 2011 from the FAOSTAT database (FAO 2013) and the reports on forestry in Slovakia (MARD 2013) were used. To achieve the state of wood balance, the resources should equal the uses. However, there were no data available on domestic consumption; therefore, it was deducted from the volumes of roundwood production and foreign trade.

The wood resource balance provides a detailed analysis of wood and wood products flows. Unlike the wood balance, which takes into account only uses of wood as a material,

the wood resource balance is focused on different uses within the internal environment of the sector. First of all, it takes into consideration by-products and waste generated by the production for use as inputs in wood processing or in the energy sector. The categories of resources and uses for the wood resource balance are shown in Table 1.

Table 1. Categories of Resources and Uses Defined in Slovakia

Woody biomass		Wood products and waste	
Sources		Uses	
Forest woody biomass	Coniferous roundwood (logs, pulp wood, other industrial wood, wood fuel)	Sawmill industry	Wood processing industry
	Non-coniferous roundwood (logs, pulp wood, other industrial wood, wood fuel)	Veneer and plywood industry	
	Forest chips	Particleboard and fibre board industry	
		Wood fuel industry	
	Other logging residues		
Used material (paper and other)	Post-consumer fibres	Pulp and paper industry	
Other woody biomass	Woody biomass outside forests	Power and heat	Energy users
Wood processing residues	Sawmill residues (sawdust, chips, particles)		
	Pulp production co-products	Industrial internal	
Processed wood fuel	Processed wood fuel	Private households	
Total			Total

The quality of the final wood resource balance depends directly on the quality and availability of data on wood production and use in individual sectors. Generally, the availability of data on consumption is usually poor, and detailed data do not exist. Empirical research and expert estimations based on the available production data are commonly used to obtain the missing data. Under current conditions, wood resource balance data can be compiled as a mix of officially published and empirically collected data. Official statistics are available for highly concentrated sectors such as the pulp and paper industry. However, certain sectors of the wood processing industry, such as the sawmill industry, are poorly concentrated; thus, access to data is complicated. Therefore, to obtain data on the major material inputs to different wood processing sectors as well as various kinds of wood waste, estimates can only be gained from data produced from a questionnaire. In particular, a questionnaire was carried out to gain additional data not included in the official statistics (production of other logging residues, use of sawmill, and other production co-products and waste, use of energy wood for internal use within the industry, stocks changes). A questionnaire containing questions adapted to individual sectors was used to quantify the missing volumes. Available business databases and trade registers were used to identify the primary wood processing companies in each sector (sawmilling, panel industry). In total, 430 questionnaires were sent to the primary wood

processors in the sawmilling and panel production sectors. During the two rounds of surveying, 68 responses were received (56 from sawmills and 12 from wood based panels producers). Knowing the aggregated volumes of production of wood products from the official statistics, responses were used to identify the average rates of residues and waste produced by each sector. In the case of the sawmilling industry, the returned questionnaires covered approximately 30% of the total coniferous sawn wood and 21% of the non-coniferous sawn wood production. In the wood panels industry, all primary producers responded. In the pulp and paper sector, the responses were analysed with the use of official statistics as well as the sector using wood fuel for power and heat generation. All data were aggregated to quantify the respective wood flows. To quantify flows and balances in a single measurement unit (m^3), the UNECE/FAO (2010) official input/output ratios for Slovakia were used (Table 2).

Table 2. Ratios of Raw Material Input to the Output of Wood Products

Product	Coniferous sawnwood	Non-coniferous sawnwood	Particle board	Fibreboard	Plywood	Veneer	Mechanical pulp	Chemical pulp	Semi-chemical pulp	Newsprint	Oth. paper and paperboard	Recovered paper
Ratio	1.80	1.70	1.40	1.80	2.90	2.20	2.50	4.50	2.90	3.20	4.00	3.40

As wood is a universal material and can be used in multiple production processes, to calculate volumes of individual wood flows, it was necessary to identify on both sides of the balance whether the products were final or intermediate products entering the opposite site of the balance to be used again. When considering this multiple use of wood material, we were able to calculate the cascade coefficient pointing out the volumes repeatedly entering the resource side of the balance. However, such a cascade approach neither overvalued nor undervalued the final balance; it only broadened the scope of products or product groups included in the analysis. Thus, the final balance included the flows of intermediate products; *i.e.*, it also comprised indirect wood flows.

RESULTS AND DISCUSSION

The primary wood resources are represented by the domestic roundwood production of 9.268 mil. m^3. This volume represents the actual felling and is relatively stable from a long-term perspective, though a share of accidental felling is quite high (up to 70%). The resource side is complemented by the import of roundwood (0.808 mil. m^3), which accounts for only 9.5% of the domestic wood consumption and is represented mostly by the import of non-coniferous pulpwood used for pulp production, and by the recycled material (0.706 mil. m^3) calculated as the domestic production plus import and reduced by export.

The total resources were 10.782 mil. m^3 roundwood equivalents. The use side of the balance is represented by the roundwood export, which was 2.289 mil. m^3. The share of roundwood exports for is relatively high (25%) and significantly reduces the domestic availability of certain roundwood assortments. The volume of domestic consumption

(8.493 mil. m^3) was deducted from the volumes of roundwood production and foreign trade. The wood balance presents a global view of the resources and primary uses of roundwood in Slovakia and is illustrated in Table 3. Because of the unavailability of data, we do not consider the stock changes.

Table 3. Wood Balance in Slovakia (m^3)

Sources		Use	
Roundwood production	9,268,556		
Import	807,703	Export	2,289,330
Used paper*	706,187		
		Consumption	8,493,116
Total sources	10,782,446	Total uses	10,782,446

* Roundwood equivalents

The wood resource analysis shows that the total resources were 11.96 mil. m^3 roundwood equivalents (Table 4). Roundwood volume on the resource side is supplemented by wood processing residues consisting mainly of sawmill residues and black liquor. These residues account for 16% of the total resources. The majority of residues (1.3 mil. m^3 roundwood equivalents) was produced by the sawmill industry.

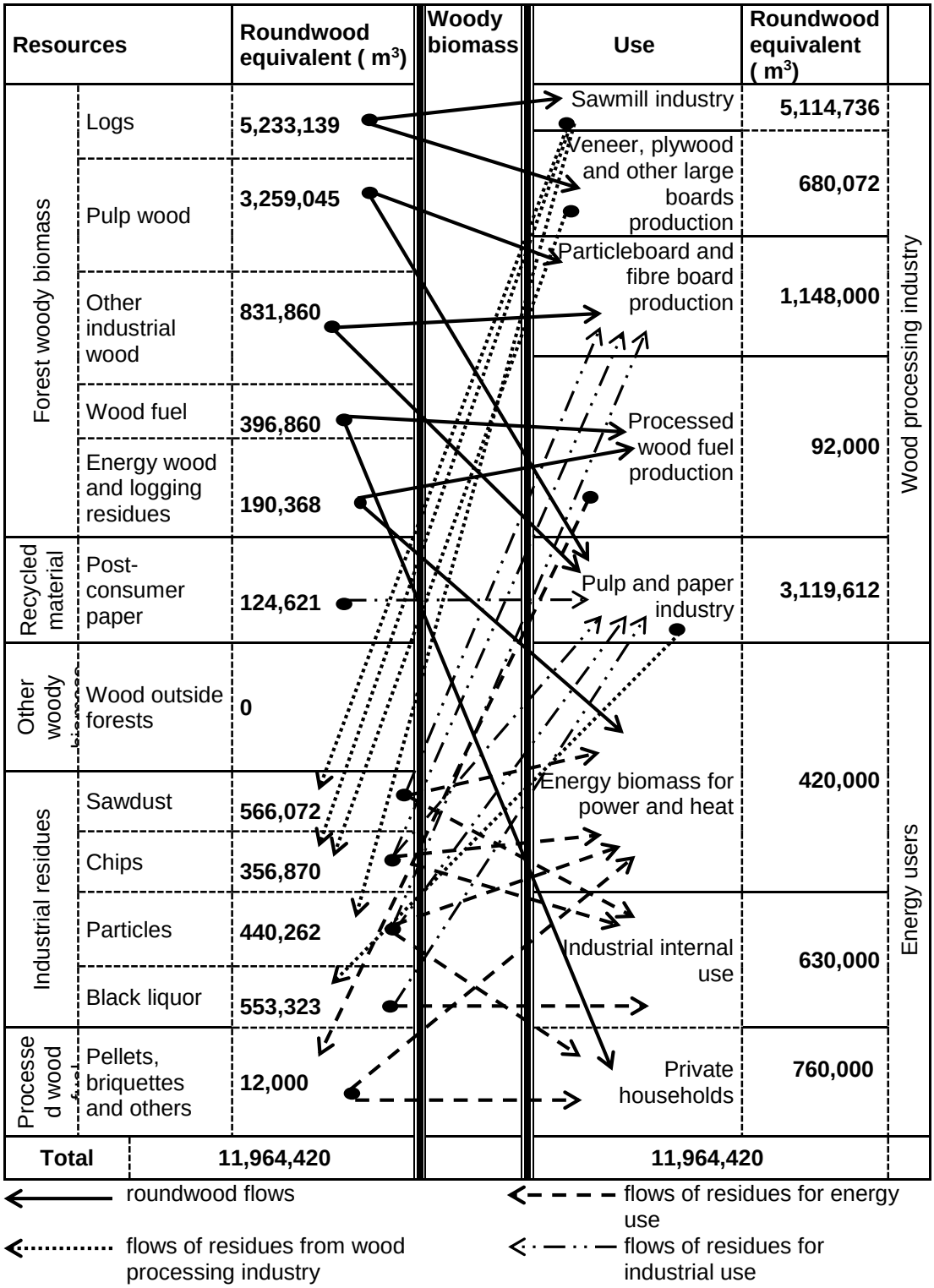
Taking into account the overall estimated data, almost 83% of all resources used in Slovakia originated in forest biomass, 16.1% were from industry waste, and only 1% came from used paper. On the other hand, over 84% of resources were used industrially, while nearly 16% were used for energy purposes.

At the same time, the sawmill industry is the key producer of wood products on the use side of the balance, followed by the production of pulp and wood-based panels. The consumption of energy wood in its different forms was estimated to be 1.8 mil. m^3 roundwood equivalents. This overall estimate comprises energy wood for households, power, and heat production, as well as direct consumption in the wood processing industry. Wood fuel industry is a very specific sector, with the production of 92,000 m^3 roundwood equivalents. Most of this production, however, is exported from the country, and only a small portion (12,000 m^3 roundwood equivalents) occurs on the resource side.

The sawmill industry with its production of 5.11 mil. m^3 roundwood equivalents represents the main consumer of roundwood as well as the main producer of wood products in Slovakia. The final volume of production by the pulp and paper industry is relatively small. However, because of the intensive material input/output ratio, the final production was 3.1 mil. m^3 roundwood equivalents. Most of this production is represented by chemical pulp, where the input/output ratio is the highest (4.5).

On the other hand, the lowest ratio (1.4) was determined for roundwood needed for the production of particleboard. The industry produced an output of 1.1 mil. m^3 roundwood equivalents, and from the viewpoint of raw material utilisation, it belongs to the industries with the lowest rates of residue production.

Table 4. Wood Resource Balance



Wood residues and by-products are produced during industrial processing of wood. The waste stream is represented by different types of waste generated during the logging operations (*e.g.,* logging residues) as well as the waste generated during primary mechanical and chemical processing of wood (sawdust, chips, black liquor), which can be

used either industrially or for the production of energy. The primary source of wood residues used for production of agglomerated wood-based panels, processed fuel wood, and energy generation is the sawmilling industry. Most of the volumes of residues flows were calculated on the basis of questionnaire results. Indirect wood flows can be expressed by a cascade factor, which considers the repeated use of wood originating on the use side and returning back to the resource side, and *vice-versa*. Considering the actual total consumption of wood was 11.9 mil. m^3 and the volume of external resources was 10.7 mil. m^3 (domestic wood resources, imports and used paper), the value of the cascade factor was 1.11.

Wood balance is primarily used to estimate domestic consumption, regardless of the further use of wood; unlike the wood resource balance, it considers foreign trade in wood products. Taking into account roundwood classification, the wood resource balance distinguishes wood flows for individual sectors according to the intended use of assortments. Logs are primarily processed by sawmills, and only a small portion is consumed by plywood or veneer producers. As a paradox, in spite of the large proportion of broadleaved forests in Slovakia, coniferous logs are the primary raw material used by sawmills. Non-coniferous pulp wood and other industrial roundwood is used by the pulp and paper industry for the production of pulp, or alternatively for the production of particleboard and fibre board.

The importance of wood for energy production has been increasing recently. Wood fuel is used for energy production in either internal or external facilities. At the same time, it represents a significant source for heat energy in households.

The same roundwood assortments and wood residues can, at the same time, be used for the production of different wood products, thus acting as substitutes. The present market conditions for roundwood producers are significantly regulated by available wood resources, legislative regulations, voluntary international agreements, and global initiatives and politics of sustainable forest management (Paluš and Parobek 2013). As a result of these determinants, the supply of renewable wood resources is changing. The primary drivers of demand for energy wood are policies favouring the use of renewable materials (Šupín 2011; 2013). Wood, which was traditionally utilised as material for the production of wood products, is presently in demand for energy production. The increasing direct or derived demand for energy wood causes an increase in energy wood prices.

As already stated above, the main difference between the wood balance and wood resource balance is in the calculated consumption, as wood resource balance comprises the wood waste stream, giving total resources of 12 mil. m^3. The results of this analysis can be compared to those derived by Mantau (2010). In his work, he estimated the total wood resources potential to be at the level of 14.8 mil. m^3, as the sum of domestic resources in and imports to Slovakia. The primary differences can be found in the estimates of wood waste derived from the questionnaire. In our research, the production of black liquor, for example, was lower by 0.8 mil. m^3. Similarly, the production of sawn wood and pulp wood in our research was estimated at lower levels (by approximately 1 mil. m^3) compared to those found by Mantau (2010).

CONCLUSIONS

1. The wood market in Slovakia is continually developing, and the demand for roundwood is changing depending on the possibilities of its use. There are many specifics

influencing production and consumption patterns in the domestic market. On one hand, timber production is subject to available resources, which are the result of long-term forest management and long-term planning. Timber production has been recently influenced by the high proportion of accidental felling. On the other hand, timber production tries to adapt to rapidly changing market conditions and the requirements of wood processing sectors that vary over a relatively short period of time.

2. The applied material flow analysis can reveal the actual consumption of wood in its various forms. The principal outcome of the analysis of raw wood material flows in Slovakia is the balance between the resources and the primary uses of wood. The analysis describes in detail the relationships between resources, basic production indicators, foreign trade relations, and the use of raw wood material in the domestic market from the viewpoint of the wood balance and wood resource balance.
3. The determined estimates and described causalities are based on official statistics and additional primary data collected with the use of the questionnaire. This approach also suggested the vulnerability of revealed relationships occurring due to the limited wood resources and existing regulatory as well as supporting measures.

ACKNOWLEDGMENTS

The authors are grateful for the support of the Scientific Grant Agency of the Ministry of Education, Science, Research, and Sport of the Slovak Republic, and the Slovak Academy of Sciences, Grant No. 1/0385/13, "Modelling substitution changes in timber market under the increasing demand for renewable energy sources," and Grant No. 1/0387/13, "A comprehensive model of wood chain comparative advantages."

REFERENCES CITED

Baccini, P., and Bader, H. P. (1996). *Regionaler Stoffhaushalt. Erfassung, Bewertung und Steuerung*, Spektrum, Heidelberg, Germany.

Binder, C. R., Hofer, C., Wiek, A., and Scholz, R. W. (2004). "Transition towards improved regional wood flows by integrating material flux analysis and agent analysis: The case of Appenzell Ausserrhoden, Switzerland," *Ecological Economics* 49(1), 1-17.

Bringezu, S. (2003). "Industrial ecology and material flow analysis. Basic concepts, policy relevance and some case studies," in: *Perspectives on Industrial Ecology*, D. Bourg and E. Suren (eds.), Greenleaf Publishing, Sheffield, UK, pp. 24-30.

EUROSTAT (2001). "Economy-wide material flow accounts and derived indicators: A methodological guide," retrieved from http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-34-00-536/EN/KS-34-00-536-EN.PDF.

FAO (2013). "FAOSTAT - Forestry," retrieved from http://faostat.fao.org.

Fisher-Kowalski, M. (1998). "Society's metabolism, the intellectual history of material flow analysis," *Journal of Industrial Ecology* 2(1), 61-78.

Hekkert, M. P., Joosten, L. A. J., and Worrell, E. (2000). "Analysis of the paper and wood flow in the Netherlands," *Resources, Conservation and Recycling* 30(1), 29-48.

Hinterberger, F., Giljum, S., and Hammer, M. (2003). "Material flow accounting and analysis (MFA): A valuable tool for analyses of society-nature interrelationships," retrieved from http://seri.at/wp-content/uploads/2009/09/Material-Flow-Accounting-and-Analysis-MFA.-Encyclopaedia-of-the-International-Society-for-Ecological-Economics-ISEE.pdf.

Knaggs, G., and O'Driscoll, E. (2008). "Estimated woodflow for the Republic of Ireland in 2007," retrieved from http://www.coford.ie/media/coford/content/publications/projectreports/cofordconnects/woodflow.pdf.

Mantau, U., Saal, U., Prins, K., Steierer, F., Lindner, M., Verkerk, H., Eggers, J., Leek, N., Oldenburger, J., Asikainen, A., and Anttila, P. (2010). "EUwood real potential for changes in growth and use of EU forests," retrieved from http://ec.europa.eu/energy/renewables/studies/doc/bioenergy/euwood_final_report.pdf.

MARD (2013). "Zelená správa 2013," retrieved from http://mpsr.sk/sk/download.php?fID=7840.

Müller, D. (1996). "Szenarien zur nachhaltigen regionalen Holzbewirtschaftung," *Schweizerische Zeitschrift für Forstwesen* 147(11), 873-885.

Paluš, H. and Parobek, J. (2013). "Changing patterns of roundwood deliveries in Slovakia," in: *Markets for Wood and Wooden Products*, WoodEMA, Zagreb, pp. 77-91.

Parobek, J., and Paluš, H. (2008). "Modelling of wood and wood products flow in the Slovak Republic," in: *A European Wood Processing Strategy: Future Resources Matching Products and Innovations*, Ghent University, Belgium, pp. 93-99.

Piškur, M., and Krajnc, N. (2007). "Roundwood flow analysis in Slovenia," *Croatian Journal of Forest Engineering* 28(1), 39-46.

Schwarzenbach, R. C., Heitzer, A., Stäubli, B., Grossmann, B., and Scholz, R. W. (1999). "A regional perspective on contaminated site remediation - Fate of materials and pollutants," *Environmental Science and Technology* 33(14), 2305-2310.

Šupín, M. (2011). "The measurement of globalization influence on pulp and paper products international trade flows in Slovakia," *Intercathedra* 27(1), 63-68.

Šupín, M. (2013). "Slovak and EU market with wood pellets," *Intercathedra* 29(2) 74-81.

UNECE/FAO. (2010). *Forest Product Conversion Factors for the UNECE Region*, ECE/TIM/DP/49, UN, Geneva.

Zhou, Z., and Sun, L. (2008). "Preliminary research on regional material flow analysis: A case study of Chengyang District in Qingdao," *Journal of Northeast Agricultural University* 15(2), 41-47.

Article submitted: April 30, 2014; Peer review completed: August 24, 2014; Revised version received and accepted: August 28, 2014; Published: September 9, 2014.