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Methodology of Economic Assessment of Forest Resources, Concerning Forest Conditions and Their Impact on Wood Quality

Mei Lu, Irina Volkova[1] and Irina Petunina[2]*

New York University, New York, United States
[1]Department of Social and Economic Geography, Institute of Geography RAS, Moscow, Russia
[2]Department of Higher Mathematics, Federal State Budgetary Educational Institution of Higher Education "Kuban State Agrarian University named after I.T. Trubilin", Krasnodar, Russia
✉ petuninair@rambler.ru

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Abstract: The present study aims to develop a methodology for forest economic assessment using forest protection strips as an example. Environmental (soil composition) and biological factors (tree species) effecting the wood quality in the south European part of Russia are taken into account. The studies were conducted from 2010 to 2017 in six regions of the south European part of Russia. In this area, a total of eight dominating tree species lying in forest shelterbelts were examined. The wood price in different natural zones was determined by two factors: stem wood volume (maximum volume and price in the forest-steppe, minimum in the dry steppe) and edaphic conditions. Stand wood compared to the forest have a high price, since the former consists mainly of one species that dominates in the upper tier whereas the forest usually includes a minimum of two to four species. The natural zone is of paramount importance for the formation of the economic potential of eight species studied. We observed maximum indices for oak and larch under conditions of a forest-steppe, two to eight times greater compared to the species present in the steppe. The same type of plant (oak), depending on conditions, can produce wood of different values based on different natural zones, with a difference in prices varying two to five times than the original price.

Key words: Economic effect, forest belts, forest ecosystems, tree species, wood.

Introduction

An adequate assessment of the economic development rates of various regions with significant forest areas includes aspects such as characterisation of forest potential (Ackerman et al., 2014; Acuna et al., 2012; De Foresta et al., 2013). At the same time, the distance between the forest area and the roads, along which transportation plays one of the leading roles determines the price of the wood (Jürgensen et al., 2014). However, this already outdated approach does not take into account the fact that well-developed infrastructure such as oil and gas fields, various hydraulic engineering facilities (dams), and mineral processing plants facilities can also be located in the forest areas from which timber is exported. All these factors make wood from such regions noticeably more expensive compared to wood harvested in remote, "empty" regions. The quality of wood ultimately determining its price is primarily affected by such factors as follows: a) forest species

*Corresponding Author

composition; b) trees' age (Cwiertnia et al., 2014; Deere and Co, 2010; Klun et al., 2009, 2016; Kosir et al., 2015; Strokov et al., 2017). In assessing the forest plot value and its resource (timber), a purely economic approach is in use (Kosir and Spinelli, 2015; Nemestothy et al., 2014). In reality, the forest is a dynamic ecosystem in constant development (Pilz and Erler, 2017). Accordingly, the quantitative (forest composition) and qualitative (tree age, wood quality) characteristics of the forest change over time (Sperandio, 2010). All this affects the cost of the wood as the final product, which is often underestimated in Russia in comparison with other countries (Bobylev, 2017).

The resources provided by forests include not only wood but also medicinal herbs, which are collected on the forest territory and serve as the basis for creating drugs in medicine. Forest essentials useful for mankind also include wild fruits and berries (strawberries, lingonberries, blueberries, nuts), as well as mushrooms, which are also of high value (Triplat et al., 2013, 2015; WCM WoodChainManager, 2018). Animals as wild boars, deer, various species of birds can be objects of hunting within the limits of the country's legislation (Jürgensen et al., 2014). This is confirmed by specific data. In 2001, in Russia, the income from the timber sale was 98% in the forest industry. In 2010, these indicators decreased to 88% (Tsvetkov, 2015). At the same time, tourism, health and recreation businesses held second place in profitability (about 9%), according to the Federal State Statistics Service. The remaining 4% falls on the procurement of raw materials from medicinal herbs, the collection of edible mushrooms and berries, as well as hunting (Bobylev, 2017).

European countries with highly developed forest industries include Finland, Sweden, and Canada in the Western World (European Commission, 2018; Sorrenti, 2017). Russian Federation has more than half of its territory forested (65%, or 1172 million ha). The development of the forest industry is low compared to its neighbours, as well as there's a lack of a unified methodology for forests. In Russia, the level of payment under the purchase and sale agreement for forest plots is 15-20 times lower compared with the aforementioned Western countries (%) (Tsvetkov, 2015). The same situation is with forest income per 1 ha. A specific feature of Russia is the fact that forests are state-owned while private individuals can use forest land only in the form of leases. Therefore, there is no forest land market. But an adequate assessment of the country's forest resource is vital. Appraisers often do not have full access to information, which makes it difficult to analyse the market value of a forest resourcefully. In particular, it is not always clear what the timber average price is including its harvesting cost. The information about the volume of forest resources and their renewability is always accurate. There is a tendency to increase the number of private owners leasing forest land. In this regard, the market for cadastral forest resources valuation is developing (Strokov et al., 2017). However, there are certain difficulties. Firstly, there is no short-term benefit from the valuation of the cadastral forest, because the resource harvesting (such as timber) is carried out in separate sections of vast forest lands. This is a consequence of the fact that forest plots are currently unprofitable, where logging work is possible. Often local budgets, that provide the funding, have no money to carry out such work. No cadastral valuation of these lands is carried out. Private organizations tend to use diametrically opposite approaches that differ in market price. The final price may vary by 3-6 times (Bobylev, 2017). Such image and price losses lead to a natural unattractiveness for the business (especially foreign) of the Russian forest industry. There is another negative consequence of such assessments: forest prices and their valuation in different regions of Russia can also vary greatly. The fragmentation of forests is also not taken into account. Their price difference depends on the composition of trees, their age and condition and can vary by 3-5 times even within single forestry. Assessment is made at the district level. In other words, there is no clear differentiation between the price category and the state of the forest. Large areas may have the same status and the same price for wood or per unit area if this plot is to be leased. The consequence of this is the ill-conceived and illiterate management of the forest fund, which in the long run can lead to degradation and extinction of forests, and wood as a valuable resource. This determines the relevance of this work. It is necessary to develop an assessment methodology applicable to other forest territories, which can become an adequate alternative to existing ones, using the example of a separate model territory.

In addition to the forest plots, forest shelter belts remain underestimated, widely represented in the European part of Russia. They land on slopes with an angle of 2 to 6 degrees in order to protect agricultural land. Thus, a more efficient landscape use is created, due to the presence of agricultural areas and typically forest areas, even in areas with a predominance of steppes. In favourable conditions, wood mass growth rates are moderate, sometimes even more, than in forest areas of natural origin in the same region.

This present work is devoted to the study and development of a methodology for the economic assessment of forest belts in the south European part of Russia. In the future, data unification for all forestries in Russia will allow conducting an economic assessment of the potential of the world's largest wood supplier, which is adequate to the world level.

The main goal of this work is to develop a methodology for the economic assessment of forests using the model territory as an example, taking into account environmental and biotic factors and their impact on wood quality.

The main hypothesis of this study is that wood of the same plant species growing under different climatic and edaphic conditions of natural zones (forest-steppe, steppe and dry steppe) in the south European part of Russia (as a model territory) has different economic value.

Materials and Methods

The studies were conducted in 2010-2017 in the south European part of Russia: Adygea, Kalmyk Republics, Krasnodar Territory, and Astrakhan, Volgograd, as well as Rostov regions. Within the specified region there are two natural zones: forest-steppe and steppe (dry steppe and chernozem steppe). Grey forest soils prevail in the northern regions and chestnut soils in the southern regions. Forests are not typical for the region. They are present only along river beds, occupying watersheds only in the north.

Economic assessment of the resources of forest shelter belts was carried out following the developed formula:

$$NP = \frac{\sum_1^t qt \frac{1}{(1+r)^t}}{q_{\max} \sum_1^t \frac{1}{(1+r)^t}} \sum_1^t (PW_1 + PW_2 + PNW_n + CW_{1t} - CW_{2t} - CNW_T) \quad (1)$$

where NP – is the total value of net profit; q is the expected effect of profit in a given (t) year; $q_{\max}$ – indicators of the maximum economic effect, calculated for forest stands that have reached the height laid down in the project; PW_1 – total cost of all the timber of the afforestation; PW_2 – wood cost that can be used at the moment; PNW – resource value of other afforestation components (mushrooms, herbs, berries); CW_1 – expenses for timber harvesting in a given year; CW_2 – similarly for wood, which appeared as a result of sanitary felling and other forest protection measures; CNW – similarly for secondary resources (tree bark, etc.); r – is the discount rate; T – is the estimated life of the forest belt.

For each type of natural zone, we proposed to distinguish between two agroforest landscapes, which differ in the composition of tree species. The first type includes forest shelterbelts consisting of short-lived but fast-growing tree species (early ripening), and the second type includes plantations of long-lived tree species. Changes were estimated on sample plots of 1000 per 1000 m in forest stands during wood and other resources harvesting, taking erosion degree into account. In total, we made a record for 500 plots and 347 shelterbelts. The composition of forest belts as the dominant trees in the tier consisted of 8 species (see Table 1). In addition to field trips carried out in June-August 2010-2017, a parallel analysis of trial plots and forest shelterbelts was carried out using Google Maps. For each area, a system of forest shelter belts was considered to regulate rainfall runoff. Each plantation is conventionally considered for two soil types: eroded and not eroded. To identify soil types, standard studies of soil sections were carried out according to methods generally accepted in edaphology. Depending on the angle of inclination, the first group includes plantations on non-eroded soils with slope angles of 1-3 degrees. The second group includes plantations growing on eroded soils on slopes of 3 to 6 degrees steep. Calculations of market value and profit are given in rubles.

Processing of the results was carried out using Microsoft Excel 2010. Differences between traits (for example, wood cost of a given tree species in different natural zones of the south European part of Russia) were calculated using the t-test for independent samples. The differences are significant at $p \leq 0.05$.

Results

Forest protection strips in the forest-steppe are leading according to all indicators: the volume of stem, industrial wood and firewood (Table 1). As a consequence of this, here are the maximum indicators of net profit.

The minimum yield of wood and its derivatives (firewood) are in the dry steppe. The difference between the steppe plots and the forest-steppe in the yield of wood and profit can reach 2-6 times ($p \leq 0.001$). The natural zone is the main factor determining the yield of wood and profit. For dry steppes, the use of tree stands is the least profitable and may be more directed towards erosion control. Another important factor is the species

Table 1: Assessment of plantations that have reached ripeness, according to the productivity indicators of the main tree species for different natural zones of the south European part of Russia (in thousand rubles per 1 ha)

Natural area and tree species	*General indicators of stem wood volume, m^3 per 1 ha*	*Volume indicators of commercial wood, m^3 per 1 ha*	*Volume indicators of wood of economic importance (firewood), m^3 per 1 ha*	*Net profit indicators, in thousands of rubles per 1 ha*
Forest steppe				
Betula pendula (birch)	320	255	74	819
Populus nigra (poplar)	343	111	241	431
Quercus robur (oak)	361	256	109	1121
Larix decidua (larch)	402	252	154	1034
Steppe				
Betula pendula (birch)	297	186	116	641
Populus nigra (poplar)	309	102	210	391
Quercus robur (oak)	318	201	127	888
Larix decidua (larch)	300	193	118	762
Dry steppe				
Robinia pseudoacacia, *Gleditsia* sp. (locust, honeylocust)	122	60	66	205
Ulmus sp. (elm)	107	49	60	176
Quercus robur (oak)	169	109	61	478
Fraxinus excelsior (ash)	101	49	54	193

composition of dominant tree species. Thus, larch, oak and birch are the most profitable in all three natural zones. The minimum cost of oak in the dry steppe is two times lower compared to the forest-steppe ($p \leq 0.05$). This confirms that the natural zone determines the price category of wood, including the same tree species. There is also a significant price difference between tree species. Ash and acacia are the cheapest, their wood costs 2-5 times less ($p \leq 0.01$) than other species.

Smaller differences were recorded when analyzing the amount of wood that can be obtained from each tree species during sanitary felling (Table 2).

Thus, annual wood growth is minimal for poplar, elm and ash, maximum for oak and larch by 0.5 times ($p \leq 0.05$). Given that sanitary felling or thinning felling is carried out on a smaller scale than felling, and with less change for forest ecosystems, lower profits should be expected. Indeed, profits from sanitary felling are 8–10 times less than in terms of marketable productivity ($p \leq 0.001$). However, the use of the annual resources of forest belts will fully pay for the marketable productivity of the entire plantation over 8-10 years. Sanitary felling maintains the same pattern: the maximum values for each tree species in the forest-steppe zone, the minimum—in the dry steppe, the cost of wood and its derivatives is high for oak and larch, and 5-8 times lower for ash and robinia ($p \leq 0.01$).

We have developed regression equations that reflect the raw material potential for the main stock of wood (stem wood), for the secondary stock of wood (firewood, brushwood) and from products of by-product origin (medicinal herbs, etc.) (Table 3).

Forest belts durability (species composition of the main tree species) plays a key role in calculating the resource potential. Next, we have considered the patterns observed when trees of different species grow on soils of different types in different natural zones (Table 4).

In the forest-steppe zone, the maximum economic effect of trees of all species growing on gray forest soils shows their indicators to be 1.3-1.5 times higher than those on leached chernozems ($p \leq 0.05$). The difference between the chernozems in the steppe and the forest-steppe is not significant, although compared with the gray forest soils in the forest-steppe; the steppe chernozems are almost 2 times lower in performance ($p \leq 0.01$). The effect of gledia and elm is minimal in the dry steppe on chestnut soils. A positive economic effect is from the planting of long-lived tree species on eroded soils. They have a maximum economic effect in

Table 2: Assessment of the afforestation resources in which sanitary felling carried out for different natural zones of the south European part of Russia (in thousand rubles per 1 ha)

Natural area and tree species	*General indicators of stem wood volume, m^3 per 1 ha*	*Volume indicators of commercial wood, m^3 per 1 ha*	*Volume indicators of wood of economic importance (firewood), m^3 per 1 ha*	*Brushwood, m^3 per 1 ha*	*Net profit indicators, in thousands of rubles per 1 ha*
Forest steppe					
Betula pendula (birch)	103	23	36	49	93.4
Populus nigra (poplar)	71	16	26	32	50.4
Quercus robur (oak)	122	31	35	61	145.2
Larix decidua (larch)	135	36	37	67	139.4
Steppe					
Betula pendula (birch)	90	20	30	43	84.3
Populus nigra (poplar)	61	13	23	28	44.6
Quercus robur (oak)	101	27	25	51	133.3
Larix decidua (larch)	118	32	31	55	122.5
Dry steppe					
Robinia pseudoacacia, *Gleditsia* sp. (locust, honeylocust)	84	9	13	64	30.4
Ulmus sp. (elm)	70	9	11	51	29.5
Quercus robur (oak)	77	14	19	47	64.8
Fraxinus excelsior (ash)	70	9	11	53	33.3

Table 3: Mathematical equations for calculating the raw material potential in forest protection stands

Indicator	*Regression*
Expected output of the main stock of wood	$y = 693.2x + 19.1a - 705.1$
	$R^2 = 0.91$
Expected yield from a minor stock of wood (firewood)	$y = 41.9x + 3.7a - 89.6$
	$R^2 = 0.87$
Expected yield from by-products	$y = 95.9x + 0.19a + 7.9$
	$R^2 = 0.97$
Sum of all characteristics	$y = 831.2x - 23.0a - 802.6$
	$R^2 = 0.92$

Note: y – expected yield from the stock of wood (in thousands of rubles per 1 ha), x – ratio of the total rainfall in this region to the moisture evaporation; a – design durability of forest belts (in years).

all-natural zones that exceed the indicators of short-lived tree species on non-eroded soils by a factor of 2.0 ($p \leq 0.001$, between larch and birch in the forest-steppe and steppe). The gap in the dry steppe is minimal: between ash and gledia, elm, the difference in economic effect is unreliable. This is because the steppe, especially dry, is not a favourable habitat for trees.

In addition to wood, in every forest ecosystem, there are non-woody resources. We have attempted to evaluate them comprehensively (Figure 1).

In the conditions of the forest-steppe, maximum is obtained by the collection of medicinal herbs, mushrooms, and berries. The lesser effect has the production of beekeeping and the increase in biomass of wild animals and birds. Figure 1 shows that in the dry steppe there are also minimal indicators of the economic effect of non-woody components of the forest ecosystem, which is a consequence of unfavourable climatic conditions for trees. Since the trees that make up the main tiers in this ecosystem are dominant here

Table 4: Total economic effect of forest belts resources that have reached a mature state in terms of height in the south European part of Russia, in thousands of rubles per 1 ha of landscape per 1 year

Name of the natural area	*Fast-growing tree species on non-erosive soils*	*Long-lived tree species on non-erosive soils*	*Fast-growing tree species on eroded soils*	*Long-lived tree species on eroded soils*
Forest-steppe zone, gray soils	*Betula pendula, Populus nigra*	*Quercus robur*	*Betula pendula, Populus nigra*	*Larix decidua*
Output	25.0	40.2	35.7	55.1
Forest-steppe zone, leached chernozems	*Betula pendula, Populus nigra*	*Quercus robur*	*Betula pendula, Populus nigra*	*Larix decidua*
Output	17.4	28.1	27.5	42.8
Steppe zone, chernozems	*Betula pendula, Populus nigra*	*Quercus robur*	*Betula pendula, Populus nigra*	*Larix decidua*
Output	14.3	22.9	22.1	32.6
Dry steppe, chestnut soils	*Ulmus* sp., *Robinia pseudoacacia, Gleditsia* sp.	*Quercus robur*	*Ulmus* sp., *Robinia pseudoacacia, Gleditsia* sp.	*Fraxinus excelsior*
Output	10.0	11.4	13.6	14.5

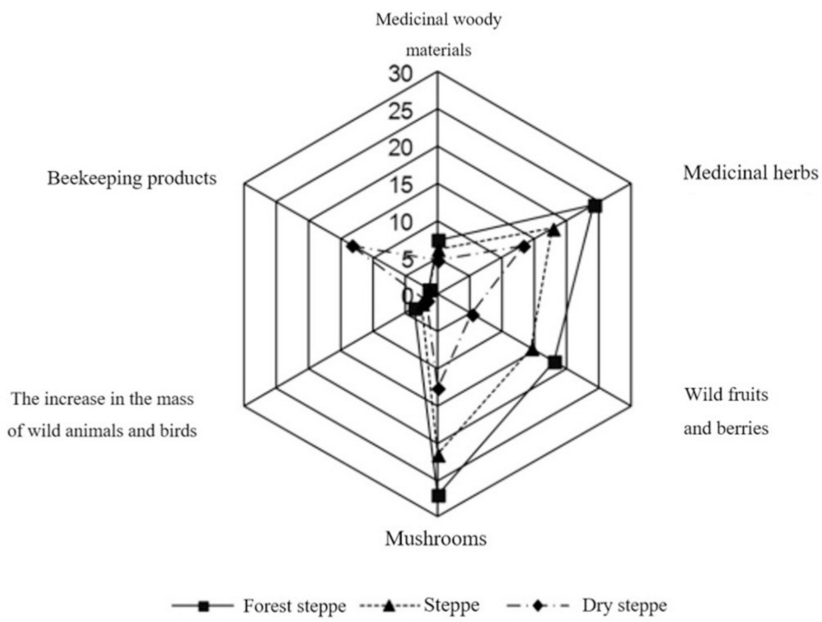

Figure 1: Expected economic effect of the forest shelter belts resources of non-timber origin, thousand rubles per 1 ha.

and give the main increase in biomass, the productivity of the forest ecosystem, including the economic one, will depend on their condition and species composition.

Discussion

When forest shelter belts are created, factors such as soil type and tree species composition are of primary interest (Winkel, 2017). If the soil is eroded, then only a limited number of tree species can grow normally on them. The quality of the land with the forest shelter belts created on it and the local climatic conditions will determine planting dynamics and the expected profit (Giurca and Spath, 2017; Nijnik et al., 2016; Pettenella et al., 2007). The data showed that birch is a suitable species for the conditions of the forest-steppe and steppe (not dry), which is an early ripe tree species and can produce high-value wood by the time of renewable felling. Similarly, poplar can be counted, but in case of sufficient regime of moisture. For species such as oak, growing conditions, in particular, soil erosion, can be of decisive importance. Values of oak wood in the forest-steppe and dry steppe can vary by 2-5 times. Therefore, it is necessary to select suitable conditions for oak in which it will eventually produce the highest quality of wood. The most suitable replacement for oak on eroded soils is larch.

The latter is a fast-growing breed that is undemanding to soil conditions, and, like oak, is a long-living tree species (de Arano et al., 2018; Grêt-Regamey et al., 2017). Thus, the use of precocious tree species is justified for all natural zones and soil types, while specific conditions are required for oak.

Over the years of growth, forest shelter belts can accumulate significant reserves of wood, which makes them economically valuable. The price of timber is determined by such factors as its quality, wood species and the conditions in which the final product is obtained (Marusakova et al., 2019). According to the results obtained, oak is the most valuable on non-eroded soils, while larch is the most valuable on eroded soils. Both species belong to long-living tree species. The cost of these two species in the forest-steppe can reach 1.3 million rubles per 1 ha. The value of these tree species is also known from other data.

The calculation obtained in the research allows us to expressly assess the economic value and profits of not only forest protection strips but also of any forest areas in territories with a similar climate. The main parameters are enough: the area of the solid wood, the cost of this type of wood, etc. In this work, the edaphic factors determining the growth rate of wood are considered for the first time and a comparative economic assessment of the cost of tree species in different natural zones is carried out. The same species of trees can have a significantly different cost of wood in different natural zones. Other studies primarily focus on forest areas in one natural area and tend not to consider the edaphic factor (Klun et al., 2016; Pilz and Erler, 2017).

Plantings compared to the forest can have a high price, because they consist mainly of one species dominating in the upper tier, while in the forest there are usually at least 2-4 species. Some species of trees in the forest will have one price, while others will have a different one. This makes it difficult to quickly assess the resource potential of forests in comparison with forest shelter belts.

Regular sanitary felling and thinning play an important role in the formation of the forest ecosystem. Thanks to felling, the quality and presentation of wood increases, and its reserves have increased in all natural zones. This is, especially, true for long-lived tree species. Thinning and sanitary felling can provide farmers with the necessary supply of low-quality wood for fuel, soil fertilisers, obtaining bedding material and feed for cattle and small cattle.

In addition to wood and its derivatives, there are other more quickly reproducible resources in forest shelter belts. These include berries, mushrooms, and medicinal herbs. Robinia species, which are of little value in terms of wood, but are excellent honey plants for beekeeping (Ministry of Agriculture of the Czech Republic, 2008).

Thus, forest shelter belts in the long-term forecast provide economic benefits in a variety of areas: production of wood and its derivatives; production of other resources.

Conclusions

The natural zone is of paramount importance for the formation of the economic potential of all eight species of trees studied. The maximum indices were observed for oak and larch for forest-steppe, 2-8 times greater compared to the steppe. The same type of plant (oak), depending on conditions, can produce wood of different values in different natural zones, with a 2-5 times difference in price. Long-lived tree species are more suitable for the forest-steppe zone, with oak for soils not affected by erosion, and larch for erosive ones. For trees of all types growing on gray forest soils, price indices are 1.3-1.5 times higher than those on leached chernozems. Steppe chernozems are two times lower in terms of wood value compared with grey forest soils in the forest-steppe.

References

Ackerman, P., Belbo, H., Eliasson, L., De Jong, A., Lazdins, A. and J. Lyons (2014). The COST model for calculation of forest operation costs. *International Journal of Forest Engineering*, **25(1):** 75–81.

Acuna, M., Bigot, M., Guerra, S., Hartsough, B., Kanzian, C., Karha, K., Lindroos, O., Magagnotti, N., Roux, S., Spinelli, R., Talbot, B., Tolosana, E. and F. Zormaier (2012). Good practice guidelines for biomass production studies. COST Action FP0902 and CNR IVALSA, Siesto Fiorentino, Italy.

de Arano, I.M., Muys, B., Topi, C., Pettenella, D., Feliciano, D., Rigolot, E., Lefèvre, F., Prokofieva, I., Labidi, J., Carnus, J.M., Secco, L., Fragiacomo, M., Follesa, M., Masiero, M. and R. Llano-Ponte (2018). A Forest-Based Circular Bioeconomy for Southern Europe: Visions, Opportunities and Challenges. Reflections on the Bioeconomy. European Forest Institute, Joensuu, Finland.

Bobylev, S.N. (2017). Sustainable development: Paradigm for the future. *World Economy and International Relations*, **61(3):** 107–113. (In Russian)

Cwiertnia, O., Hauer, H., Nemestothy, N. and Preier, P. (2014). NEWFOR - BFW - Online-Forstmaschinendatenbank. Bundesforschungszentrum fur Wald (BFW): Bundesforschungs - und Ausbildungszentrum fur Wald, Naturgefahren und Landschaft (BFW). Available at: https://bfw.ac.at/fmdb/maschinen.web?kat=AB&lang=1 (Accessed 15 August 2018).

Deere and Co. (2010). TimberCalc – Machine Cost Web Calculator. Available at: http://ebus.eame.deere.com/timbercalc/index.php?language=ENGLISH (Accessed 20 August 2018).

European Commission (2018). A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment. Updated Bioeconomy Strategy. Brussels, Belgium: European Commission.

de Foresta, H., Temu, A., Boulanger, D., Feuilly, H. and M. Gauthier (2013). Towards the assessment of trees outside forests: A thematic report prepared in the Framework of the Global Forest Resources Assessment 2010. Food and Agriculture Organization of the United Nations.

Giurca, A. and P. Spath (2017). A forest-based bioeconomy for Germany? Strengths, weaknesses and policy options for lignocellulosic biorefineries. *Journal of Cleaner Production*, **153:** 51–62.

Grêt-Regamey, A., Altwegg, J., Sirén, E.A., Van Strien, M.J. and B. Weibel (2017). Integrating ecosystem services into spatial planning – A spatial decision support tool. Landscape and Urban Planning, **165:** 206–219.

Jürgensen, C., Kollert, W. and A. Lebedys (2014). Assessment of Industrial Roundwood Production from Planted Forests. *In:* Planted Forests and Trees Working Paper. Food and Agriculture Organization of the United Nations, Rome.

Klun, J., Robek, R., Piskur, M. and B. Kosir (2016). Estimation of timber transport costs with a forestry tractor semitrailer. *Forestry Journal*, **75(3):** 119–135. (In Slovenian)

Klun, J., Sinjur, I. and M. Medved (2009). Forestry machinery costs catalog 2009. Ljubljana: Forestry Institute of Slovenia. Available at: http://www.gozdis.si/data/katalog_kalkulacij/Katalog_stroskov_gozdarske_mehanizacije_linki.pdf (Accessed 15 April 2018). (In Slovenian)

Kosir, B. and R. Spinelli (2015). Views on the study of work in the field of forest technology. *Forestry Journal*, **73(9):** 369–391. (In Slovenian)

Kosir, B., Magagnotti, N. and R. Spinelli (2015). The role of work studies in forest engineering: Status and perspectives. *International Journal of Forest Engineering*, **26(3):** 160–170.

Marusakova, L., Sallmannshofer, M., Kaspar, J., Schwarz, M., Tyrvainen, L. and N. Bauer (2019). Human Health and Sustainable Forest Management. *In:* L. Marusakova and M. Sallmannshofer (eds.), Forest Europe – Liaison Unit Bratislava, Zvolen, Slovakia, pp. 58–97.

Ministry of Agriculture of the Czech Republic (2008). National Forest Programme for the Period until 2013. Praha, Czech Republic: Ministry of Agriculture of the Czech Republic.

Nemestothy, N., Czwiertnia, O., Frutig, F. and O. Thees (2014). English glossary for estimating the costs of cable crane operations with "HeProMo", the wood harvesting productivity model from WSL. Costs and benefits, Workpackage.

Nijnik, M., Nijnik, A. and I. Brown (2016). Exploring the Linkages between multi-functional forestry goals and the legacy of spruce plantations in Scotland. *Canadian Journal of Forest Research*, **46:** 1247–1254.

Pettenella, D., Secco, L. and D. Maso (2007). NWFP&S marketing: Lessons learned and new development paths from case studies in some European countries. *Small-Scale Forestry*, **6(4):** 373–390.

Pilz, S. and J. Erler (2017). Cost calculation to determine the forest operations costs. Brasov: Technische Universitat Dresden. Available at: https://www.formec.org/images/proceedings/2017/C4/C42_Sebastian_Pilz_et_al.pdf (Accessed 15 April 2018).

Sorrenti, S. (2017). Non-Wood Forest Products in International Statistical Systems. *In:* Food and Agriculture Organization of the United Nations, Rome. Non-Wood Forest Products Series (no. 22). FAO, Rome (Italy).

Sperandio, G. (2010). Costing forest machinery: Available methods, recurrent problems. *In:* Harvesting forest biomass: A global state of the art. COST Action FP0902, Trento, Italy.

Strokov, A.S., Yakubovich, E.N. and P.V. Krasil'nikov (2017). Economic and ecological evaluation of land use change: Evidence from Karelia. *Economy of Region*, **13(2):** 422–433. (In Russian)

Triplat, M., Krajnc, N. and R. Robek (2013). Choice of technological model in the production of green wood chips. Forestry Institute of Slovenia, Ljubljana. (In Slovenian)

Triplat, M., Prislan, P. and N. Kranjc (2015). Decision-making tool for cost-efficient and environmentally friendly wood mobilisation. *South-East European Forestry*, **6(2):** 179–190.

Tsvetkov, V.F. (2015). Systematization, zoning and typology of forests: A monograph. SAFU Publ., Arkhangelsk. (In Slovenian)

WCM (WoodChainManager) (2018). Web portal WoodChainManager. Available at: http://wcm.gozdis.si (Accessed 20 August 2018).

Winkel, G. (2017). Introduction. *In:* Towards a Sustainable European Forest-Based Bioeconomy. Assessment and the Way forward. European Forest Insitute, Joensuu, Finland, pp. 15–18.