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REVISTĂ TEHNICO-ŞTIINŢIFICĂ EDITATĂ DE SOCIETATEA „PROGRESUL SILVIC”

Fotografii copertă:
Copertă față și spate exterior:
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Copertă interioară :
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ISSN: 1583-7890
Varianta on-line :
www. revistapadurilor. ro
ISSN 2067-1962

Indexare în baze de date:
CABI
DOAJ
Google Academic
Index Copernicus (ID 7538)
RePEc
SCIPIO

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50th Anniversary of the International Symposium on Forestry Mechanization, Brașov, Romania, 25th - 29th September 2017

Stelian Alexandru BORZ

Intro

In the context of the Paris COP21 agreement that calls for a more environmental friendly and climate-resilient economy, **Transilvania University of Brașov - Faculty of Silviculture and Forest Engineering** is pleased to host the **Jubilee Edition of the International Symposium on Forestry Mechanization (FORMEC)** between 25th and 29th September 2017, in Brașov (Romania).

Building up on the previous experience of the Forest Engineering Community, and following the 48th and 49th FORMEC editions held in Austria and Poland, the motto of the conference is:

Remembering the 49th FORMEC Conference, Warsaw, Poland, 2016. © formec.org

"Innovating the competitive edge: from research to impact in the forest value chain"

The 50th FORMEC anniversary brings together leading researchers, practitioners and high-level officials from countries worldwide to share state-of-the-art knowledge and debate the most critical issues on how innovation should enhance sustainable wood mobilization and forest value chain competitiveness.

This year, the conference addresses key topics, such as timber logging and transport, forest road engineering, use of biomass for bioenergy, ergonomics and work safety of forest operations and other wood supply chain challenges, including innovative forest equipment and emerging forest technology.

Held for the first time in Romania, the symposium is organized in two days of technical sessions that will address new developments in forest engineering, followed by one-day field trip in the Romanian forests – FOREST ROMANIA FAIR – to watch traditional and innovative harvesting technology at work.

Changing the lead between the FORMEC organizers. © formec.org

Remembering the 1st FOREST ROMANIA FAIR

Organizers

Transilvania University of Brașov - Faculty of Silviculture and Forest Engineering, Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements has teamed up with the Forest Engineering Scientific Community and Association for Development and Innovation in Green Economy (ADIGE) to organize the event. The opening ceremony, plenary and technical sessions as well as the poster session will be held in the facilities of the Transilvania University of Brașov - Aula Sergiu T. Chiriacescu.

Faculty of Silviculture and Forest Engineering, Transilvania University of Brașov, host of the 50th Symposium on Forestry Mechanization.

Attendance and contributions

More than 150 contributions were received and will be presented during the event as oral presentations and posters.

Scientists and practitioners coming from all over the world will attend the jubilee edition of the International Symposium on Forestry Mechanization (FORMEC). A number of 30 countries will be represented by their scientists and practitioners during the symposium, bringing together the international high-lead science, experience and know-how.

Keynote speakers and support

High-level keynote speakers are expected to participate and give presentations on current and perspective topics related to forestry and forest engineering, science, technology, financing, and forestry-related political agendas.

The event is supported by the local community, national & international companies and organizations, associations and the state forest management.

To support the anniversary edition of FORMEC, four journals joined the partnership and will release special numbers on the event's topics: **Annals of Forest Research**, **Bulletin of the Transilvania University of Braşov - Series II - Forestry**, **Croatian Journal of Forest Engineering** and **Revista Pădurilor** - one of the oldest forestry journals.

Looking forward for an excellent event!

FORMEC Romania 2017

Univ.Prof.Dr.Eng. Stelian Alexandru BORZ
Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements,
Faculty of Silviculture and Forest Engineering,
Transilvania University of Braşov, Şirul Beethoven No.1, 500123, Braşov, Romania,
President of the Organizing Committee,
FORMEC 2017
e-mail: stelian.borz@unitbv.ro

Economic Balances and GHG Emissions of Forest Biomass Utilization in Kanuma Area of Tochigi Prefecture, Japan

Kazuhiro ARUGA

1. Introduction

Following the Great East Japan Earthquake, the supply capacity of electricity has been reduced, because the operation of many nuclear power plants has been suspended. In this context, the Japanese Government proposed to promote the introduction in use of renewable energy sources including biomass (***, 2012a). In August 2011, the "Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities" was adopted in the Diet for the introduction of the "Feed-in Tariff Scheme for Renewable Energy" starting from July 2012. In the Feed-in Tariff (FIT), the purchase price (without tax) of electricity sourced by unused materials such as thinned wood and logging residues was of 32 JPY/kWh, that sourced by general materials such as sawmill residues was of 24 JPY/kWh, and that sourced by recycled material such as construction waste wood was of 13 JPY/kWh (***, 2012b). Furthermore, a price of 40 JPY/kWh for unused materials having a generation capacity less than 2 MW was set in order to promote the use of wood coming from thinning operations and logging residues from a large number of small, fragmented, and scattered forests, starting with April of 2015. Incentives have promoted the use of power generated from unused materials, and they are expected to increase the use of wood sourced by thinning operations and logging residues from 2 million m^3 in 2014 to 8 million m^3 in 2025 based on the forest and forestry basic plan of Japan established in May 2016 (Forestry Agency of Japan, 2016).

In order to utilize forest biomass resources for bioenergy, it is crucial to find out the relationship between the annual available amounts and the procurement (harvesting and transporting) costs. Yoshioka *et al.* (2005a), Kinoshita *et al.* (2009), and Yamamoto *et al.* (2010) have carried out detailed analyses of supply potential based on Geographic Information Systems (GIS).

Nord-Larsen and Talbot (2004), Aruga *et al.* (2006a), Rørstad *et al.* (2010), and Aruga *et al.* (2011) discussed long-term feasibility of timber and forest biomass resources by predicting future forest resources using growth models while optimizing the allocation of fuel wood by Linear Programming or Random Search. Yagi *et al.* (2007), Aruga *et al.* (2006b), and Panichelli *et al.* (2008) discussed the scales and locations of bio-energy facilities based on the relationship between the supply potential and the procurement costs of forest biomass resources, whereas Ranta (2005), Möller and Nielsen (2007), and Viana *et al.* (2010) developed methods for expressing them at a national level. Furthermore, Yamaguchi *et al.* (2010), Yamaguchi *et al.* (2014), Nakahata *et al.* (2014), and respectively Aruga and Uemura (2015) have developed a method to estimate harvesting volumes and costs of logging residues by considering the economical balances estimated from revenues and costs of both timber and logging residues in the region as a unit of sub-compartments while Kinoshita *et al.* (2010) and Kamimura *et al.* (2012) have developed a similar method as a unit of cities and towns. However, these studies have not considered the regeneration expenses, which are important for conducting the forest management, especially in plantation forests such as Japanese cedar and Japanese cypress from Japan. In contrast, Aruga *et al.* (2014) developed a method to extract production forests based on economic balances that considered also the regeneration expenses. Their study defined the production forests as those forests where the expected revenues surpass all costs from planting to final harvesting. The revenue and costs were estimated based on forest registration and GIS data. However, the study just estimated the annual available amount of forest biomass resources with total revenues and costs during a 60-year rotation. The estimation should be conducted by considering the current situation of forest resources, forestry, forest and energy industries and by projecting their future context while discounting the future revenues and costs to the present net values although the study of Aruga *et al.* (2014) did not.

Therefore, this study estimated the annual available amount of forest biomass resources from profitable sub-compartments in Kanuma Area of Tochigi Prefecture, Japan while considering the regeneration expenses for the sustainability of forest management and by discounting the future revenues and costs to the present net values using the long-term relationship between the supply potential and the procurement cost of forest biomass resources established in a previous study (Aruga *et al.*, 2011). In addition to the economic balances, this study estimated the greenhouse gas (GHG) emissions including CO_2, CH_4, and N_2O while the studies of Yoshioka *et al.* (2005b) and Aruga *et al.* (2011) estimated only CO_2 emissions.

2. Materials and methods

2.1. The General Approach

Forest biomass resources can be categorized into several categories including logging residues, wood sourced by thinning operations, and broadleaved trees (Yoshioka *et al.*, 2005a). GIS layers of forest resource, slope, public and forest roads were obtained from Tochigi Prefectural Government in order to estimate the supply potential and the procurement costs of timber and forest biomass resources.

In order to analyze the long-term relationship between the supply potential and the procurement cost of timber and forest biomass resources, in this study, future forest resources on each stand were predicted using the system yield Table, Local Yield Table Construction System (LYCS, Shiraishi 1985). Then, the stand harvesting schedules were planned by balancing the supply potential of forest biomass resources using random search while minimizing the procurement costs. Annual available amounts of forest biomass resources were estimated as the supply potential from profitable sub-compartments.

2.2. Study Site

The site chosen for this study is located in Kanuma area, consisting of Kanuma city and Nishikata town (Aruga *et al.*, 2011). This area encompasses 52,000 hectares, of which about 65% are covered by forests. Most of forests are man-made (79%) of which tree species are conifers; Japanese cedar (Sugi) and Japanese cypress (Hinoki) account for 54% and 23% of the trees, respectively. Most of conifers are within 45-50 years old. As for the site slope, most of forests are relatively steep, 30 degrees or more. The density of the road network in the Kanuma area is of 18 m/ha.

2.3. Procurement Costs

Harvesting and transporting systems for forest biomass resources were classified into two types depending on the parts of a tree used to recover energy wood (logging residues or the whole tree sourced by thinning operations and broadleaved trees). Logging residues are considered as a byproduct of conventional forestry while the wood coming from thinning operations and broadleaved trees are assumed to be felled for energy utilization. Therefore, the system boundary of logging residues starts with comminuting logging residues at the landing by a mobile chipper while the system boundary of thinning operations and broadleaved trees starts with felling operations in the forests (Aruga *et al.*, 2011).

In this study, cable skidders, swing yarders, tower yarders, and conventional yarders are assumed to be used for the skidding/yarding operations. Cable skidders could be used for slopes below 11 degrees for uphill skidding and for slopes below 19 degrees for downhill skidding. In this study, one machine from the described types is assumed to be selected for each stand so that the skidding/yarding costs are minimized within the topographic condition of each stand (Aruga *et al.*, 2011).

The harvesting and transporting costs of timber and forest biomass resources were estimated in relation to slope θ (degree), average stem volume V_n (m^3/stem), harvested volumes per ha V (m^3/ha), the number of trees harvested per ha N_F (stem/ha), skidding/yarding distance L_Y (m), and transporting distance L_T (m). In addition to the direct costs of labor, machine, and fuel, the indirect costs of labor (55% of the direct cost of labor), machine moving cost (50,000 JPY/each), overhead costs (14% of the total direct cost), piling costs in the log market (700 JPY/m^3), handling fees associated with the logging contractor (5% of timber and forest biomass prices) and the log market (5% of timber prices), and consumption tax (5% of the direct cost) are considered herein.

Thinning operations are subsidized in Japan. In this study, subsidies were estimated using the standard unit costs, areas, assessment coefficients, and the subsidy rate of Tochigi Prefectural Government (2010). Standard unit costs were determined by age and thinning rates (Table 1).

Table 1
Standard unit costs (JPY/ha) for thinning operations

Age (year)	Thinning rate	
	Less than 30%	More than 30%
26-35	400,792	600,612
36-45	381,288	571,935
46-59	386,176	579,261

The assessment coefficient and the subsidy rate were assumed to be 1.7 and 4/10, respectively. In addition to subsidies given to conduct thinning operations, subsidies to develop strip roads for thinning operations are also received in Japan. These subsidies were also estimated using standard unit costs, areas, assessment coefficients, and the subsidy rate of Tochigi Prefectural Government (2010). Standard unit costs for construction of strip roads were determined on slope categories (Table 2).

Table 2
Standard unit costs for construction of strip roads

Slope	Standard unit costs (JPY/m)
< 5 degrees	159
6 to 10 degrees	191
11 to 15 degrees	230
16 to 20 degrees	276
21 to 25 degrees	477
26 to 30 degrees	850

In addition to these timber extraction costs, regeneration expenses including site preparation, planting, weeding, vine cutting, pruning, and forest inventory were estimated by labor expenses and the number of people necessary in each operation, non-personnel expenses, and insurance expenses (Okawbata, 2003). Regeneration expenses were estimated as 2,512,376 JPY/ha for Japanese cedar and 2,892,365 JPY/ha for Japanese cypress, respectively. This study considered the subsidy for regeneration. Similar to the thinning operations, subsidies were estimated using the standard unit costs, areas, assessment coefficients, and the subsidy rate of Tochigi Prefectural Government. Subsidies were estimated as 1,227,400 JPY/ha for Japanese cedar and 1,219,240 JPY/ ha for Japanese cypress, respectively. Therefore, the net regeneration expenses were estimated as 1,284,976 JPY/ha for Japanese cedar and 1,673,125 JPY/ ha for Japanese cypress, respectively.

2.4. Revenues

The current supply potential of timber and forest biomass resources can be estimated from the stem volume recorded in the forest register and the coefficients such as the thinning ratio, ratio of the top and branches' volume to stem volume, and tree density (Aruga *et al.*, 2011). To estimate the future available amounts of timber and forest biomass resources, the yield system Table, LYCS (Shiraishi, 1985) was applied to the forest register. Time interval was set to five years. In order to ensure a steady yet continuous work of the energy conversion plants, forest biomass resources should be steadily and continuously supplied. In this study, the stand harvesting schedules were planned for sixty years by balancing the supply potential of timber and forest biomass resources using the random search approach set to minimize the procurement costs (Aruga *et al.*, 2011). Revenues were estimated using the supply potential and log prices which were set to 10,000 JPY/m^3 and forest biomass resources prices which were set to 3,000 JPY/ton of dry matter (tDM). After the estimation of revenues, the available amounts of forest biomass resources from profitable sub-compartments were also estimated. In addition to these figures, sensitivity analyses were conducted with various log prices such as 8,000 and 12,000 JPY/m^3, and forest biomass resources prices such as 6,000 and 10,000 JPY/tDM, respectively. Forest biomass resources prices (6,000 JPY/tDM) were estimated with the additional subsidy and an amount of 10,000 JPY/tDM was estimated according to the FIT introduced in Japan.

2.5. Economic Balances

Two types of energy-conversion technology were considered in this study. One was the direct combustion and the other was the small-scale gasification (Aruga *et al.*, 2011). Under the

FIT program, the price of electricity was set to 40 JPY/kWh for less than 2 MW produced and 32 JPY/kWh for more than 2 MW produced. Furthermore, this study assumed that the steam could be sold to houses at a price of 0.5 JPY/kg. Then, the economic balances of direct combustion and small-scale gasification were estimated.

2.6. GHC Emissions

GHG emissions coming from all the processes of the system were examined using the method described by Yoshioka *et al.* (2005b), Aruga *et al.* (2011), and Ministry of the Environment (2005). In addition to those described in Yoshioka *et al.* (2005b) and Aruga *et al.* (2011), dismantlement of a power generation plant was estimated as 5% of the construction costs.

3. Results and Discussions

3.1. Economic Balances

The maximum supply potential of forest biomass resources was estimated to 28,872 tDM/year, which was enough to meet the fuel requirement of a 5 MW direct combustion power plant (Aruga *et al.* 2011). According to the procurement costs of forest biomass resources excluding the subsidies and regeneration costs, logging residues were the cheapest (9,271 JPY/tDM), followed by broadleaved forests (12,995 JPY/tDM); wood coming from thinning operations incurred the greatest costs with 15,325 JPY/tDM (Aruga *et al.*, 2011). However, by including the subsidies and the regeneration costs, procurement of such wood was the cheapest (6,960 JPY/tDM), followed by logging residues (9,330 JPY/tDM). Broadleaved forests incurred the greatest costs with 13,143 JPY/tDM (Figure 1).

According to the supply potential of forest biomass resources including subsidies and regeneration costs, logging residues were assumed to be harvested based on the harvesting schedule while the broadleaved forests and wood sourced by thinning operations were assumed to be harvested to meet sufficient volumes if the forest biomass resources were not sufficient (Figure 2).

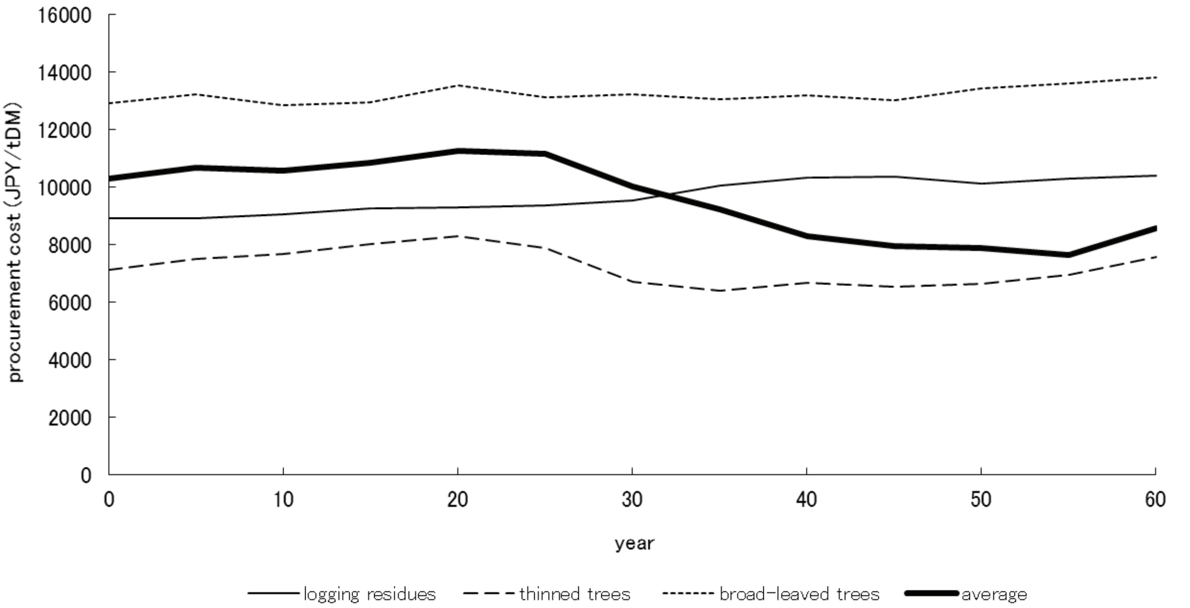

Fig. 1. Procurement cost including the subsidies

The trend shown in Figure 2 was similar to the results of a previous study (Aruga *et al.*, 2011). For timber, the maximum supply potential and the procurement cost were of 86,657 m^3/year and 5,564 JPY/m^3 without subsidies and regeneration costs, while the same Figures were of 82,729 m^3/year and 5,565 JPY/m^3 with subsidies and regeneration costs.

In a previous study (Aruga *et al.*, 2011), the average price of electricity sold to power grids in Japan was assumed to be 8 JPY/kWh. Since the generation costs specific to direct combustion and small-scale gasification were more than 24 and 13 JPY/kWh, the economic balances of electricity generation were in deficit. If the steam

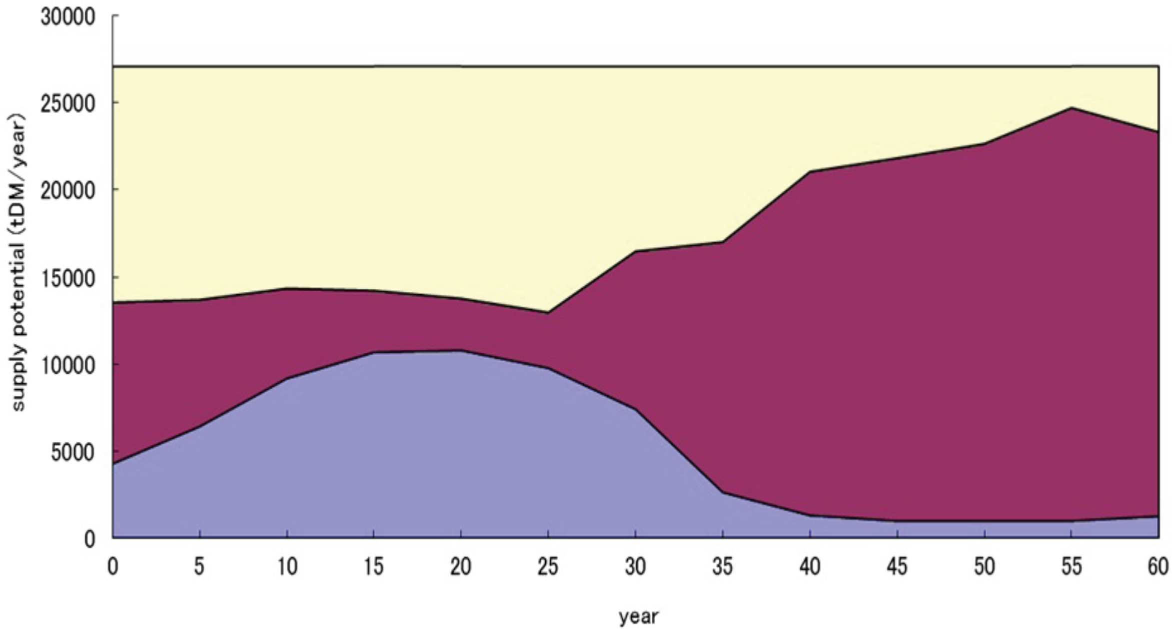

Fig. 2. Supply potential with subsidy

could be sold to houses at a price of 0.5 JPY/kg, the economic balance of small-scale gasification would be positive whereas the economic balance of direct combustion would remain negative (Aruga *et al.*, 2011).

Under the FIT program, the price of electricity was set on 40 JPY/kWh for those plants producing less than 2 MW and to 32 JPY/kWh for those producing more than 2 MW.

Therefore, if the steam could be sold to houses at a price of 0.5 JPY/kg, then the economic balances of both direct combustion and small-scale gasification would be positive (Figure 3). The economic balances would be improved by the subsidies, especially for direct combustion in which the procurement costs contributed significantly.

3.2. Annual Availability of Timber and Forest Biomass Resources

With log prices set to 10,000 JPY/m^3 and forest biomass resources prices set to 3,000 JPY/tDM,

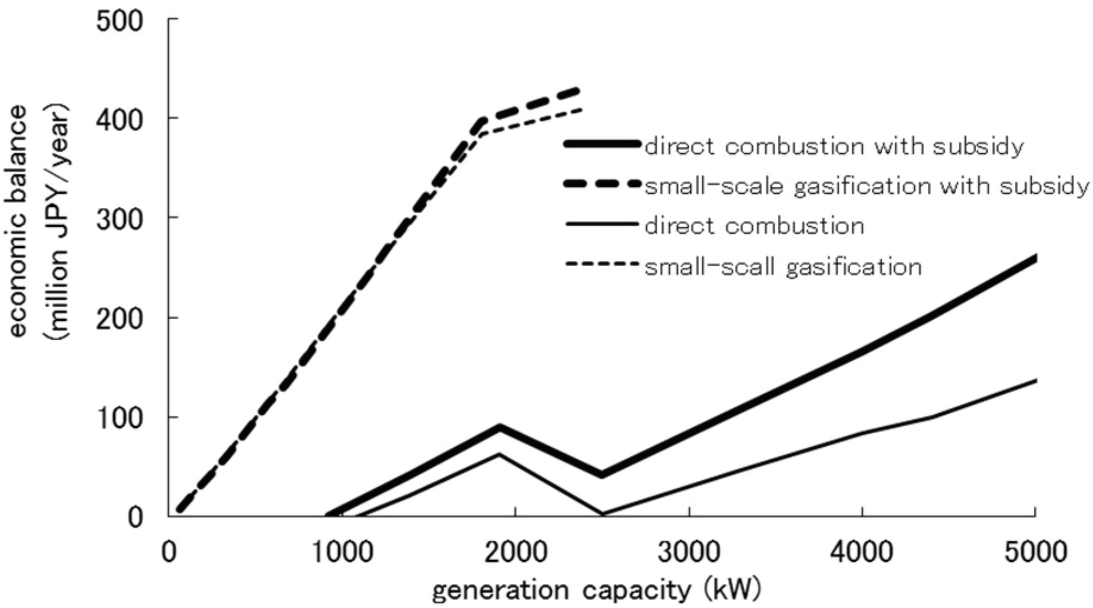

Fig. 3. Generation capacity and economic balance

the annual available amount of forest biomass resources from profitable sub-compartments including subsidies and regeneration costs was estimated at 12,044 tDM/year.

It consisted of logging residues (3,999 tDM/year) and thinned trees (8,045 tDM/year) as shown in Table 3.

especially in the Kyushu Island (Tsuduki, 2006). Therefore, sensitivity analyses were conducted to discuss the effects of subsidies and regeneration operations on the annual available amounts and procurement costs of forest biomass resources.

Without subsidies and with regeneration costs, the annual available amount of forest biomass resources from profitable sub-compartments was estimated at only 2,710 tDM/year. It consisted of logging residues (2,068 tDM/year) and the wood sourced by thinning operations (642 tDM/year), as shown in Table 3. Only 9% of the maximum supply potential of forest biomass resources was available.

Table 3

Availability of forest biomass resources and timber and the procurement costs with and without subsidies and regeneration costs for log prices of 10,000 JPY/m^3 and forest biomass resources prices of 3,000 JPY/tDM

Source	Subsidy		No Subsidy	
	Regeneration	No Regeneration	Regeneration	No Regeneration
Total	12,044 tDM/year 6,571 JPY/tDM	15,056 tDM/year 6,161 JPY/tDM	2,710 tDM/year 8,531 JPY/tDM	6,022 tDM/year 8,510 JPY/tDM
Logging residues	3,999 tDM/year 8,010 JPY/tDM	4,484 tDM/year 8,216 JPY/tDM	2,068 tDM/year 7,897 JPY/tDM	5,107 tDM/year 8,148 JPY/tDM
Thinned Trees	8,045 tDM/year 5,856 JPY/tDM	10,572 tDM/year 5,290 JPY/tDM	642 tDM/year 10,577 JPY/tDM	915 tDM/year 10,531 JPY/tDM
Broadleaved Trees	0 tDM/year --- JPY/tDM	0 tDM/year --- JPY/tDM	0 tDM/year --- JPY/tDM	0 tDM/year --- JPY/tDM
Timber	57,003 m^3/year 5,116 JPY/m^3	63,958 m^3/year 5,233 JPY/m^3	29,470 m^3/year 4,922 JPY/m^3	72,830 m^3/year 5,170 JPY/m^3

With these prices, only 42% of maximum supply potential of forest biomass resources was available and no broadleaved forests were assumed to be harvested. Also, due to the limited prices, the procurement cost of forest biomass resources was reduced from 9,093 JPY/tDM (see Figure 1) to 6,571 JPY/tDM (see Table 3) because the procurement cost of logging residues was reduced from 9,391 JPY/tDM to 8,010 JPY/tDM and that of thinned trees was reduced from 6,711 JPY/tDM to 5,856 JPY/tDM.

For timber, the annual available amount and the procurement cost were of 57,003 m^3/year and 5,116 JPY/m^3 respectively, accounting for 69% and 92% of the maximum supply potential and procurement costs of timber.

Subsidies play important roles on economic balances of regeneration and thinning operations in Japan. However, subsidies would be reduced due to limited budget of the Japanese government. Since the revenues from clear cutting operations cannot cover the regeneration costs in the current conditions, forest owners would not conduct planting operations even on unsuitable natural regeneration sites after clear cutting. This situation is spread in Japan,

No broadleaved forests and almost no wood coming from thinning operations were harvested in this scenario.

With these limited prices, the procurement cost of forest biomass resources (8,531 JPY/tDM) was higher than that with subsidies because the procurement cost of wood coming from thinning operations increased from 5,856 JPY/tDM to 10,577 JPY/tDM while the cost of logging residues without subsidies were similar to those with subsidies. For timber, the annual available amount and the procurement cost were also reduced to 29,470 m^3/year and 4,922 JPY/m^3 due to no subsidies for regeneration costs.

Without regeneration costs, the annual available amount and the procurement cost of timber were significantly higher, especially without subsidies. Subsequently, the annual available amount of logging residues was higher. However, the increment was small with subsidies. The annual available amount of wood coming from thinning operations with subsidies was increased whereas that without subsidies was decreased significantly. Therefore, it was confirmed that subsidies play an important role in thinning operations. If subsidies would be reduced due to the limited budget of Japanese government, regeneration and procurement costs should be reduced by developing new harvesting systems and by enhancing the forest road network in order to ease the extraction of timber and forest biomass resources.

According to the increment of log price, the annual available amounts of forest biomass resources from profitable sub-compartments were increased because the profitable sub-compartments were increased (Table 4).

However, no broad-leaved forests were still harvested in this scenario. Then, the forest biomass resources prices were increased (Table 5).

As a result, the annual available amounts of broadleaved trees from profitable sub-compartments were increased in direct relation to increment of forest biomass resources price.

3.3. GHC Emissions

The GHG emission of the direct combustion power generation facilities with a capacity of 5 MW was of 68 gCO_2eq/kWh. On the other hand, the GHG emission of a small-scale gasification power plant with a capacity of 2.4 MW was 52 gCO_2eq/kWh (Figure 4).

These values were higher than the CO_2 emission namely 46 gCO_2/kWh for the direct combustion and 41 gCO_2/kWh for a small-scale gasification. Komata *et al.* (2017) estimated the GHG emissions to be about 80 gCO_2eq/kWh for direct combustion power generation facilities having a capacity of 5.7 MW. Ministry of Environment (2013) estimated GHG emissions as 195 gCO_2eq/kWh for a small-scale gasification facility.

The results of Komata *et al.* (2017) were similar to those from this study. Ministry of Environment

Table 4

Availability of forest biomass resources and timber and the procurement costs with subsidy and regeneration according to different log prices and for 3,000 JPY/tDM forest biomass resources prices

Source	8,000 JPY/m^3	10,000 JPY/m^3	12,000 JPY/m^3
Total	9,033 tDM/year 5,960 JPY/tDM	12,044 tDM/year 6,571 JPY/tDM	15,054 tDM/year 6,501 JPY/tDM
Logging residues	2,358 tDM/year 7,875 JPY/tDM	3,999 tDM/year 8,010 JPY/tDM	4,780 tDM/year 8,124 JPY/tDM
Thinned Trees	6,675 tDM/year 5,284 JPY/tDM	8,045 tDM/year 5,856 JPY/tDM	10,274 tDM/year 5,745 JPY/tDM
Broadleaved Trees	0 tDM/year --- JPY/tDM	0 tDM/year --- JPY/tDM	0 tDM/year --- JPY/tDM
Timber	33,595 m^3/year 4,707 JPY/m^3	57,003 m^3/year 5,116 JPY/m^3	68,162 m^3/year 5,426 JPY/m^3

Table 5

Availability of forest biomass resources and timber, and procurement costs with subsidy and regeneration according to 10,000 JPY/m^3log prices and different forest biomass resources prices

Source	3,000 JPY/tDM	6,000 JPY/tDM	10,000 JPY/tDM
Total	12,043 tDM/year 6,571 JPY/tDM	27,096 tDM/year 8,713 JPY/tDM	30,108 tDM/year 9,040 JPY/tDM
Logging residues	3,999 tDM/year 8,010 JPY/tDM	4,862 tDM/year 8,652 JPY/tDM	5,007 tDM/year 8,689 JPY/tDM
Thinned Trees	8,045 tDM/year 5,856 JPY/tDM	13,749 tDM/year 6,444 JPY/tDM	15,023 tDM/year 6,348 JPY/tDM
Broadleaved Trees	0 tDM/year --- JPY/tDM	8,485 tDM/year 12,425 JPY/tDM	10,077 tDM/year 13,228 JPY/tDM
Timber	57,003 m^3/year 5,116 JPY/m^3	69,495 m^3/year 5,142 JPY/m^3	71,577 m^3/year 5,143 JPY/m^3

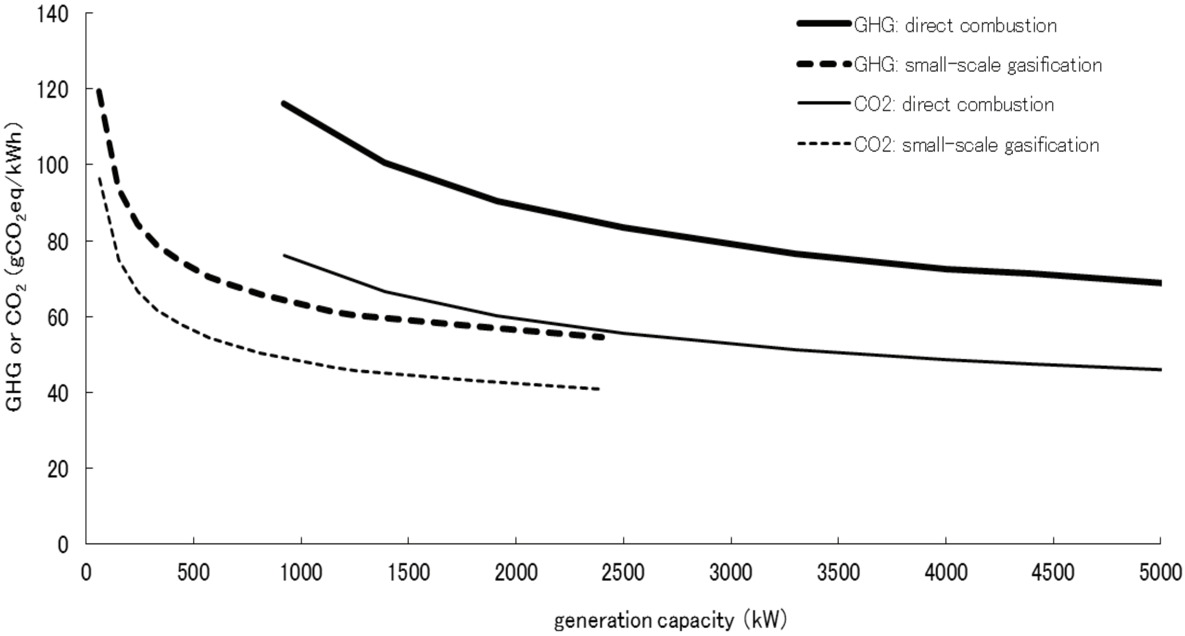

Fig. 4. GHG and CO_2 emissions related to the production capacity

(2013) estimated the GHG emissions from more detailed processes compared to the approach of Yoshioka *et al.* (2005b) and Aruga *et al.* (2011) whose methods were used in this study.

4. Conclusions

This study estimated the annually available amount of forest biomass resources from profitable sub-compartments in Kanuma Area of Tochigi Prefecture, Japan. It included the regeneration expenses as a prerequisite of the forest management sustainability as well as discounting the future revenues and costs to the present net values. In addition to the economic balances, this study estimated the GHG emissions including CO_2, CH_4, and N_2O. Under the FIT program, the economic balances of both, direct combustion and small-scale gasification, would be positive if the steam could be sold to households.

However, it is difficult to use the steam generated from power production plants in Japan because the infrastructure for a district heating system has not been established yet. Therefore, power plants should be constructed on the saw mills or near those factories that use the heat.

For log prices of 10,000 JPY/m^3 and forest biomass resources prices of 3,000 JPY/tDM, the annual available amount of forest biomass resources with subsidy and regeneration costs was estimated at 12,043 tDM/year. Since subsidies play important roles on economic balances of regeneration and thinning operations in Japan, the annual available amount of forest biomass resources without subsidies was reduced to 2,710 tDM/year. However, subsidies would be reduced due to the limited budget of Japanese government. Therefore, low-cost forest operations should be developed by increasing the mechanization level and by developing further the forest road networks.

The GHG emissions of the direct combustion facilities having a capacity of 5 MW was of 68 gCO_2eq/kWh. On the other hand, the GHG emission of a small-scale gasification power plant having a capacity of 2.4 MW was of 52 gCO_2eq/kWh.

The result was similar to that of Komata *et al.* (2017), but not to that of Ministry of Environment (2013) because the later estimated the GHG emissions from more detailed processes compared to Yoshioka *et al.* (2005b) and Aruga *et al.* (2011) whose methods were used in this study. Therefore, more detailed analyses should be conducted by implementing future studies.

Acknowledgements

This study was supported by JSPS KAKENHI grant number 15H04508 and 16KK0168.

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Kazuhiro ARUGA
Associate Professor, Department of Forest Science, Faculty of Agriculture,
Utsunomiya University, 350 Mine, Utsunomiya 321-8505, Japan.
Tel. +81-28-649-5537, Fax. +81-28-649-5545, aruga@cc.utsunomiya-u.ac.jp

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Economic Balances and GHG Emissions of Forest Biomass Utilization in Kanuma Area of Tochigi Prefecture, Japan

Abstract

This study estimated the annual available amount of forest biomass resources from profitable sub-compartments in the Kanuma Area of Tochigi Prefecture, Japan, by considering the regeneration expenses incurred by the sustainability of forest management and by discounting the future revenues and costs to the present net values. In addition to the economic balances, this study estimated the GHG emissions including CO_2, CH_4, and N_2O. Under the Feed-in-Tariff program, the economic balances of both, direct combustion and small-scale gasification facilities would be positive. For log prices of 10,000 JPY/m^3 and forest biomass resources prices of 3,000 JPY/tDM, the annual available amount of forest biomass resources with subsidies and regeneration costs was estimated at 12,044 tDM/year. Since subsidies play important roles on economic balances of regeneration and thinning operations in Japan, the annual available amount of forest biomass resources without subsidies was reduced to 2,710 tDM/year. In relation to log price increments, the annual available amounts of forest biomass resources were increased. The GHG emission of the direct combustion plants having a capacity of 5 MW was of 68 gCO_2eq/kWh. On the other hand, the GHG emission of a small-scale gasification power plants having a capacity of 2.4 MW was 52 gCO_2eq/kWh. Further studies should be undertaken for detailed analyses.

Keywords: available amount, economic balance, forest biomass resource, GHG emission, supply potential

Balanţa economică şi emisiile de gaze cu efect de seră relaţionate cu utilizarea biomasei forestiere în zona Kanuma, Tochigi, Japonia

Rezumat

Prezentul studiu estimează cantitatea de biomasă forestieră disponibilă anual în unități amenajistice considerate a fi profitabile, localizate în zona Kanuma, Tochigi, Japonia prin luarea în considerare a cheltuielilor de regenerare cauzate de menținerea sustenabilității managementului forestier și prin raportarea veniturilor și costurilor previzionate la valoarea actuală netă. Pe lângă balanțele economice, studiul estimează emisiile de gaze cu efect de seră incluzând aici emisiile de CO_2, CH_4, și N_2O. Sub programul de tarifare a energiei, atât balanța economică a facilităților de combustie directă cât și cea a facilităților de producție a gazului la scară mică ar fi pozitive. Pentru preţuri ale masei lemnoase sub formă de buștean de 10.000 yeni/m^3 și preţuri ale resurselor forestiere de biomasă de 3.000 yeni/tonă masă uscată, cantitatea de biomasă forestieră disponibilă anual în scenariul includerii subvențiilor și a costurilor de regenerare a fost estimată la 12.044 tone masă uscată/an. Din moment ce subvențiile joacă roluri importante în balanța economică a lucrărilor de regenerare și a aplicării răriturilor în Japonia, cantitatea de biomasă forestieră disponibilă anual în scenariul excluderii subvenților a fost redusă la 2.710 tone masă uscată/an. În relație directă cu creşterea preţului masei lemnoase a fost și cantitatea de biomasă forestieră disponibilă anual. Emisiile de gaze cu efect de seră specifice facilităților de combustie directă caracterizate de o capacitate de 5 MW a fost de 68 gCO_2eq/kWh pe când, emisiile de gaze cu efect de seră specifice unor facilități de producție a gazului la scară mică caracterizate de capacități de 2,4 MW au fost de ordinul a 52 gCO_2eq/kWh. Necesitatea unor analize de detaliu trebuie adresată prin realizarea de noi studii.

Cuvinte cheie: cantitate disponibilă, balanţă economică, resursă forestieră de biomasă, emisii de gaze cu efect de seră, potenţial de aprovizionare

Using Sound Pressure Sensors to Monitor the Performance of Manually Operated Circular Saws: What Parameters and to What Extent Can They Be Inferred?

Marius CHEȚA
Daniel ȘERBAN
Gheorghe IGNEA
Rudolf Alexandru DERCZENI
Victor SFECLĂ
Stelian Alexandru BORZ

1. Introduction

Delivery of various wood products to final consumers spans a wide supply chain composed of operational processes developed in the forest, on the transportation infrastructure, in the primary timber processing facilities (Oprea, 2008) and in the final wood product development facilities.

Timber harvesting and its subsequent industrial processing contributes to a significant extent to the Romanian GDP (Gligoraș and Borz, 2015) and it has a lot of potential in the creation of jobs.

Timber harvesting operations in Romania are characterized by the use of rather low-level mechanization systems usually making use of motor-manual tree felling and processing, horse logging and cable skidding (Borz and Ciobanu, 2013; Borz *et al.*, 2013; Borz *et al.*, 2015). At the same time, it is reasonable to assume that it is also the case of primary wood processing facilities as most of them are configured and are working as small-medium scale businesses. For instance, there were more than 7000 primary wood processing facilities in Romania as of 2007 (Sbera, 2007) with wood processing capacities ranging from 8-10 to thousands of m^3 per day.

Most of the product-oriented industries use to some extent equipment and tools that are designed to fulfill their production needs. To cope with market requirements and customer satisfaction, production managers are concerned with their product development processes, insurance of production quality and timing of their product release on the market. Similar to small-scale harvesting operations (Talagai *et al.*, 2017; Spinelli *et al.*, 2012), small-scale entrepreneurs working into wood processing industry do not have the necessary resources to acquire large-scale fully automated equipment which is far too expensive for their economic context and market segment. At the same time, it is rather difficult for them to cooperate in order to develop large-scale business and wood processing applications since they are competitors within the frame of wood processing industry and on the processed wood products market. Therefore, they are using affordable tools and equipment and are struggling to save money in order to remain competitive.

Meanwhile, one of the current problems of the Romanian wood related industry is that related to the training level of the personnel (Rauch *et al.*, 2015). This situation may come as a result of limited financial resources to keep on-the-job highly-trained professionals in the industry as well as an effect of a lack of dedicated training programs. On the other hand, by their competences and expertise, such professionals may contribute significantly to the increment of the operational efficiency including here an improved operation of the tools and of the time management in their jobs.

Wood sawing mills use different equipment configurations to convert the logs into sawn timber and other primary processed wood products depending on their marketed products. The main equipment is that converting the logs into lumber or other primary products. Among the existing options for such operations are the band saws (Gligoraş and Borz, 2015; Ištvanić *et al.*, 2009). Then, depending on the processing level as well as on the manufactured products, some of the wood processing facilities use equipment for trimming operations. Such equipment is used to make transversal cuts and helps in obtaining shorter wood pieces which are further integrated into different wood-based products. Most commonly, the equipment used in the wood processing facilities is powered by electricity which comes from the national grid, while the maintenance tools (*i.e.* blade sharpening equipment) use the same energy inputs. Since in such production facilities work, more or less simultaneously, several equipment and tools, a general system optimization should aim, among other things, to enhance the electrical energy savings, resulting also in lower product releasing costs, that could be attained by an adequate work organization, especially by removing delays and by increasing the utilization level of machines. To this end, forest production studies represent a valuable tool in the overall system's optimization as they can be used to experiment, observe, model and compare options (Spinelli and Magagnotti, 2012). Such studies may include the measurement of energy inputs required by the product development. For such attempts, studies can be implemented at different resolutions (Spinelli and Magagnotti, 2012) and the use of modern approaches such as those making use of sensors have a lot of potential in reducing the resources required by their implementation (Borz, 2016; Talagai and Borz, 2016).

The goal of this study was to test to what extent the sensors used to measure the sound pressure level can be used to monitor and collect data for manually operated wood trimming equipment.

2. Materials and Methods

2.1. Study Location, Equipment Description and Data Collection Procedures

This study was carried out in a wood processing facility located in Brașov, Romania which wished to remain anonymous.

They use primary processed wood to develop a series of wood products from resinous lumber. In particular, they are manufacturing wood boxes

Fig.1. Storage boxes - a typical product of the studied wood processing facility

(Figure 1) which are sold to various customers that use them to store other products. Most of the product design involves the use of otherwise short wood pieces, produced from regular lumber, that are part of the final assemblies.

Therefore, an important part of the operations carried on in the wood processing facility are shaped around trimming operations of the lumber which are carried on using a manually driven circular saw (Figure 2). As mentioned, in such operations, energy inputs come from the national electricity grid. At the same time, in small wood processing facilities, energy

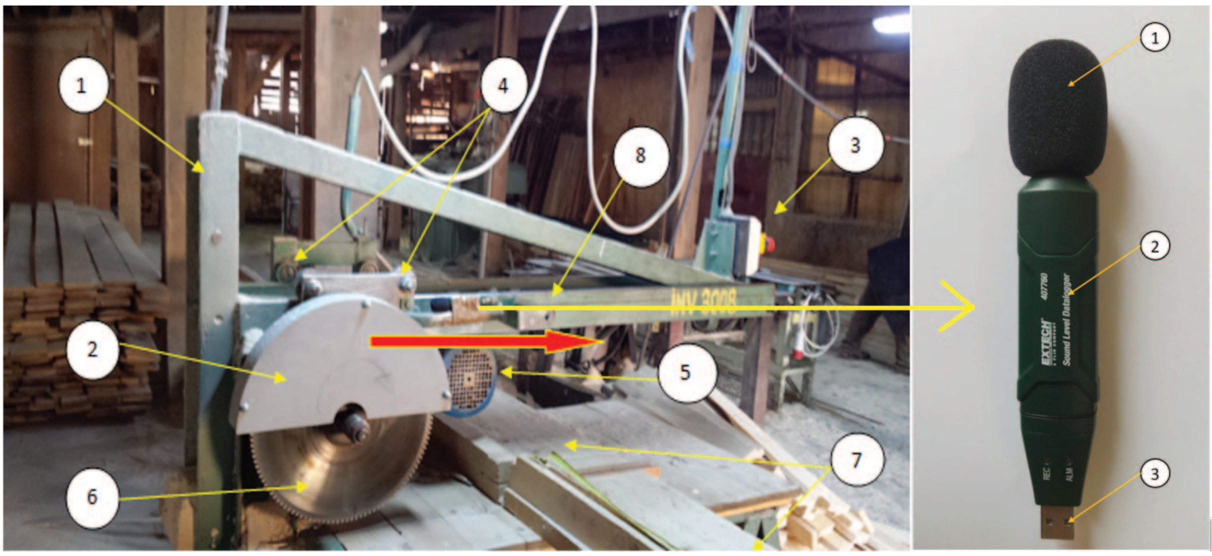

Fig.2. Description of the studied circular saw and of the used datalogger. Legend: right: 1 - main steel spar, 2 - blade protection, 3 - starting/stopping control, 4 - retracting mechanism, 5 - engine, 6 - blade, 7 - sawing Table, 8 - steel frame; left: 1 - protected microphone, 2 - case of the datalogger, 3 - USB port

savings are particularly important in order to maintain the wood processing costs as low as possible. This comes forth also as a result of quite expensive raw woody material as being characteristic lately in Romania. Therefore, the equipment running time should be planned based on the production requirements and it should be kept to the minimum required to process the wood. Nevertheless, the equipment such as that taken into study has no monitoring capabilities due to the low technological integration. It is constructed to align the power saw capabilities with that of manual handling of the wood pieces to be trimmed and the switch-off functions are manually controlled rather than in an automatic way, while the running time depends greatly on the operational behavior of the workers. Therefore, the effective trimming time always overlaps with the engine running time but it is reasonable to assume that the two are never the same.

The circular saw taken into study (Figure 2) was built by the wood processing facility's employees and it is powered by a 1.75 kW electrical engine being equipped with a circular blade of 400 mm and having a number of 99 sawing teeth. The saw ensures a cutting height of 110 mm and a transversal movement across the sawing table of 700 mm. The equipment is manually driven during the active sawing time and it retracts mechanically following such actions.

To monitor the behavior of the studied equipment we used a sound pressure level datalogger (Figure 1) developed and produced by Extech ®, able to collect data at high sampling rates and to export it in native format of the producer as well as MS Excel ® spreadsheets. It enables the setup of various sampling rates starting from 50 milliseconds for a computer-based data capture setup, respectively half of a second for externally conducted applications. The device configuration is done using the dedicated software that enables the choice of specific sampling parameters including the sampling rate.

For this study, we have setup and used sampling parameters such as the minimum available sampling rate for external applications (500 milliseconds), slow recording mode and the dB(A) scale. These settings were done in the office phase of the study following that the datalogger start to be made manually after its placement on the studied trimming equipment. Then, the datalogger was placed on the equipment in a place that avoided any interference with the usual way of doing the trimming work, near the electrical engine and the trimming blade (Figure 2).

To observe the real events during the operations we have used the video-camera of a smartphone that was setup to record files in real time. It was placed at approximately 2 meters away of the saw as specified in Figure 3.

Then the datalogger was manually set to collect

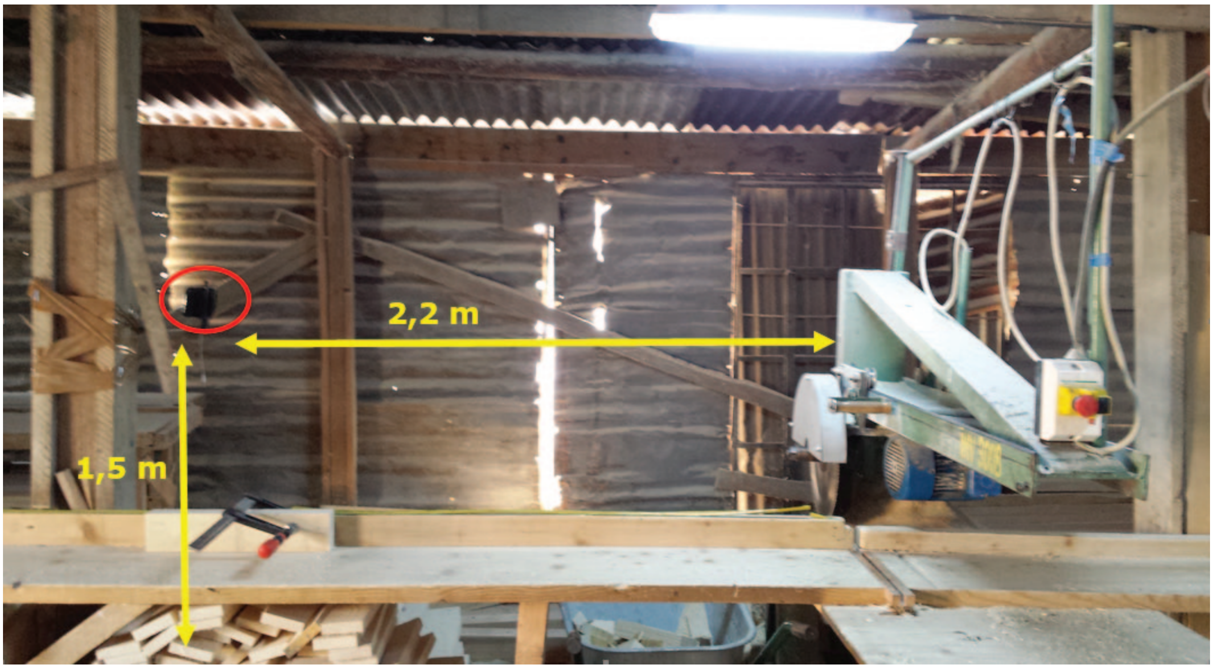

Fig.3. Video camera setup

data and the real operations were recorded by both devices for a usual working day.

2.2. Data Processing and Analysis

Data captured by both devices was downloaded into a computer using different approaches. Video data was transferred from the internal memory of the video-camera using regular procedures and it was stored in a folder containing the video collected files in their natural succession. Then the data stored on internal memory of the datalogger was downloaded via its dedicated software (Figure 4).

While on a first glance such software may help operational regimes the data was exported into MS Excel ® sheets, a function that is enabled by the datalogger's software.

The exported data comes with date and time stamps for each observation taken at the selected sampling rate, a feature that helps in further assessments that use the time as a variable.

To pair the information from video-collected data with that from the used sensor, a traditional approach of using freely available video software was not feasible given the sampling rate of the sensor. Therefore, this study used freely-available video-editing software to broke the files into frames captured at 500 milliseconds.

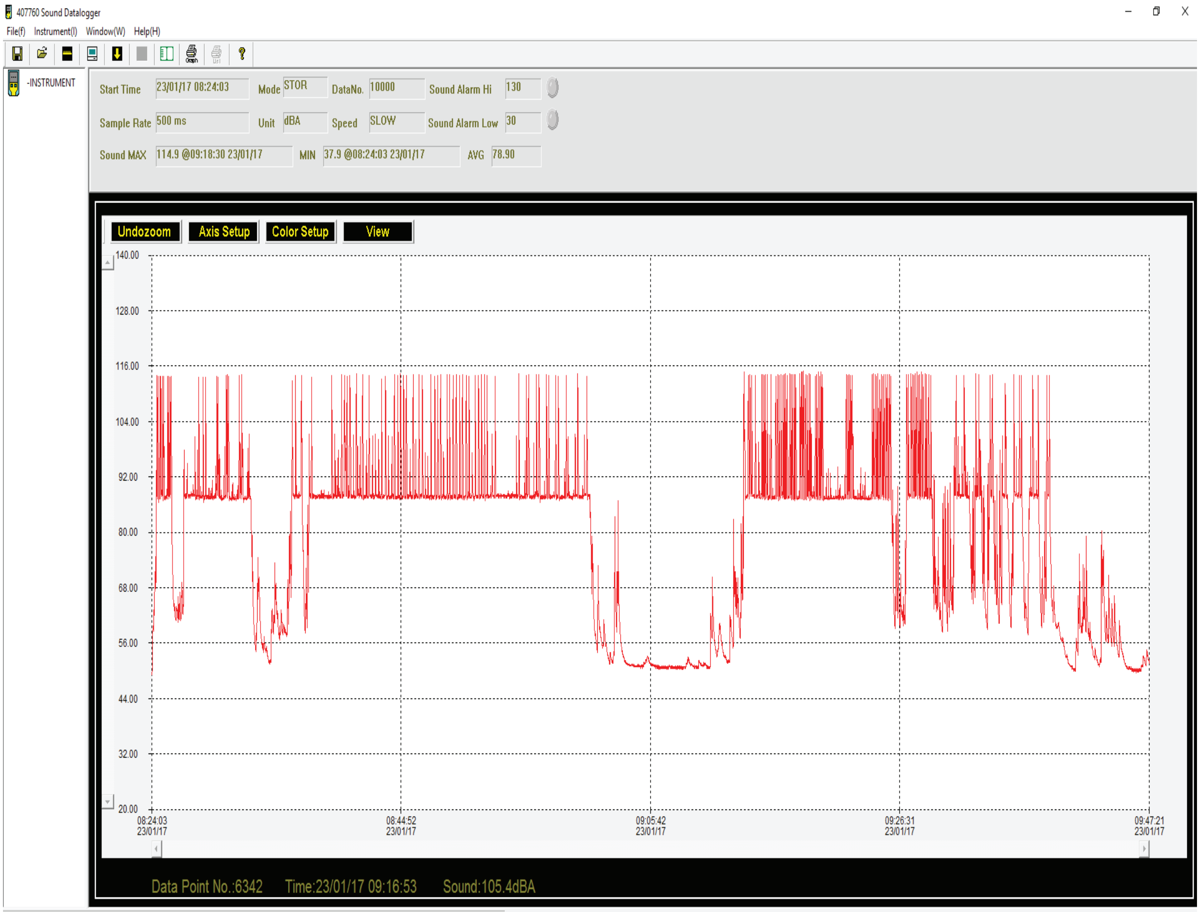

Fig.4. Data vizualization in the dedicated software

the researchers to distinguish between certain patterns and to see the behavior of the studied equipment in terms of sound pressure level it does not allow any kind of data segmentation based, for instance, on specified thresholds. However, one can easily see three distinct patterns within the data pool as being specific to the studied working regimes.

In order to be able to separate the specific Then, we have synchronized the video files and frames with the data collected by the sensor. Afterwards, a MS Excel ® database has been built to contain the information coming from the two approaches. To this end, each of the produced and synchronized frames was carefully analyzed to deduct the operational behavior of the studied equipment. This approach was particularly useful for those time segments characterizing the effective sawing (S) time as well as the retraction (R) time that were grouped into the operating (O) time. At the same time, the running time without effective sawing (RUN) as well as down time (STOP) were observed on the images. For each of the 500-millisecond extracted frame, data coming from the sensor was paired with codes following the image analysis. The resulted database was used further for analysis that assumed computations and time separation based on user-defined thresholds. After a careful analysis of the data, a threshold value was taken into consideration to separate the running and downtime regimes. It was set to 86.5 dB(A). Obviously, this was specific to the experimental design that was used in this study, knowing that the sound pressure level may be affected by sound attenuation as a function of the distance from the emitting source as well as by sound reflection due to indoor measurements which adds to the regular sound pressure level.

Nevertheless, in other kind of setups one can infer such a threshold based on the data plotted by the sensor's software or that plotted against time using external software such as MS Excel ®. On the other hand, in studies such as that described herein, it is rather unrecommended to place sound pressure level sensors far away of the emitting source as sound or noise produced by other equipment or activities may interfere with that of the studied one. The effective sawing and retracting regimes were rather difficult to separate. This can be related to the size of trimmed wood pieces as the time needed and the emitted noise depend on such characteristics. Figure 4 shows such a behavior in the first part of the data pool collected by the sensor. Therefore, it was typically to obtain a pattern specific to certain dimensions of the trimmed wood pieces but as their size decreased, lower sound pressure level peaks appeared in the plotted data pool. To this end, we assumed a low recognition ability for the number of undertaken trims and we used a threshold able to detect only the trims made on larger wood pieces. It was setup at 110 dB(A) that enabled the detection of a single value for each of the trimmed pieces resulting this way into a counter. Due to the same reasons, we did not attempt to separate the effective sawing time by a threshold-based extraction from the data pool as the size of the trimmed wood pieces and the sampling rate did not allow for such an endeavor.

For demonstration purposes, we have selected a time interval of 10 minutes where we found the greatest variability of the studied parameters and we ran the analysis using the mentioned thresholds on that part of the data pool.

3. Results and Discussion

Our results indicate that the approach used in this study has a lot of potential in the attempt to monitor the operational behavior including here the performance of the small tools and equipment used in primary wood processing facilities.

One of the key issues here is that related to the running *vs.* downtime because, if no trimming operations are actually carried out then keeping the engine running is counterproductive from the energy saving point of view. To this end, the threshold set for the sound pressure level corresponding to the two behavioral states (down *vs.* running) succeeded to separate the time spent into the two with a recognition accuracy of almost 100%.

As a fact, when comparing the running time as extracted from the sensor-collected data with that captured by the video-surveillance approach we have obtained a difference of -0.24% (Table 1). The same applied to the extraction of down time where the difference was of +0.54%. Most probably, these small differences are the effect of a rapid transition of the sound pressure level when switching between the two states (Figure 5) that could not be observed using the sampling rate described herein.

Conventionally (Figure 5), the running behavior was plotted as 85 dB(A) for the "ON" state and as 80 dB(A) for the "OFF" state.

In what concerns the automatic recognition of the number of trimmed wood pieces, the things were different. Here, the threshold set for the extraction of those events failed to give accurate results. This was an effect of scale as mentioned before as the obtained recognition accuracy of the used threshold was of only 66.67% resulting into a large difference (-33.33%) compared to the video-surveillance approach (Table 1).

To this end, by using the same type of sensor, one may take a look into the data plotted against time to observe the number of wood pieces that were processed. Another approach is that of linking the sensor to a computer by an external

Table 1

Comparison ov video-extracted and sensor collected data

Parameter	Extracted from video files	Extracted from sound pressure level data	Recognition accuracy [%]
Trimmed pieces	30	20	- 33.33
Running time - *RUN* (s)	414.5	413.5	-00.24
Down time - *STOP* (s)	186.0	187.0	+00.54

cable to take measurements to a higher sampling rate that could solve this inconvenient by sampling the data in real-time and storing it on a computer drive.

Nevertheless, the energy inputs in such operations depend on that time in which the equipment runs instead of that in which the equipment is actually used to process the wood. From this point of view, the obtained results were consistent and the approach could be used to monitor in an effective way such operations to take measures for improvement.

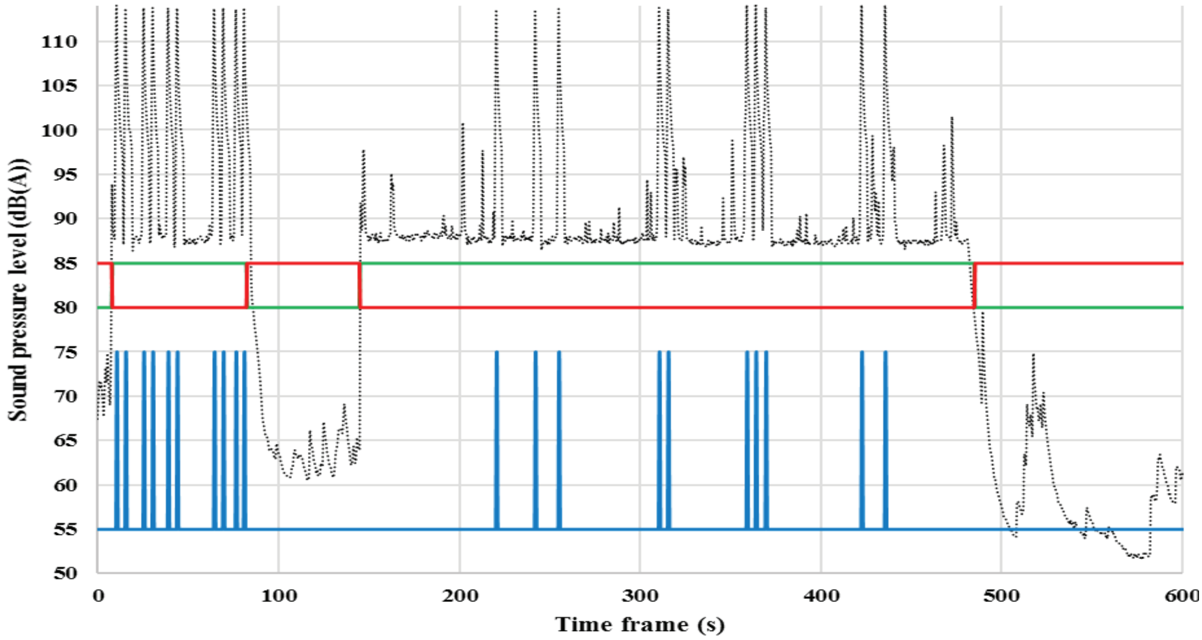

Fig.5. Separation of operational regimes of the studied equipment using thresolds. Legend: dotted black line - sound pressure level dB(A) as downloaded from the datalogger, continuous green line - running regime; continuous red line - stopped regime, continuous blue line - number of recognized cuts

4. Conclusions

This study aimed to test to what extent the sound pressure level sensors may be used to monitor and collect data for small-scale manually driven sawing equipment. The results were rather encouraging because such an approach can accurately separate the two most important operational regimes related to the energy saving. It is possible to get more accurate results by adjusting the sample rate to a higher one, an option that should be explored further. Nevertheless, a full automation of data collection and analysis is still not achievable as some "eye observation" and "human intelligence" by supervised training of the used thresholds and algorithms is still needed to be able to accurately separate the regimes. This is the effect of the size of processed lumber as well as of the sensor placement. On the other hand, such supplementary actions are needed to a less extent compared with what could be achieved following the setup of adequate thresholds.

Acknowledgements

The authors of this paper would like to thank to the Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements of the Faculty of Silviculture and Forest Engineering, Transilvania University of Braşov, for the logistics and support in carrying out this study. This study is a synthesis of the MSc thesis of Mr. Eng. Daniel Şerban that has been defended in the Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements - Study Program Management and Technical Systems in Forest Engineering. The authors acknowledge the support of the wood processing facility in carrying out this study.

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Eng. Marius CHEŢA

Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Braşov, Şirul Beethoven No.1, 500123, Braşov, Romania

e-mail: marius.cheta@unitbv.ro

Eng. Daniel ŞERBAN

Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Braşov, Şirul Beethoven No.1, 500123, Braşov, Romania

e-mail: dannys_92@yahoo.com

Prof.dr.eng. Gheorghe IGNEA

Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Braşov, Şirul Beethoven No.1, 500123, Braşov, Romania

e-mail: igneagh@unitbv.ro

Assoc.prof.dr.eng. Rudolf Alexandru DERCZENI
Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Braşov, Şirul Beethoven No.1, 500123, Braşov, Romania
e-mail: derczeni@unitbv.ro

Assist.prof.eng. Victor SFECLĂ
Department of Forestry and Public Gardens, Faculty of Horticulture, State Agrarian University of Moldova, Mirceşti, 44, Chişinău, MD-2049
e-mail: v.sfecla@uasm.md

Prof.dr.eng. Stelian Alexandru BORZ
Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Braşov, Şirul Beethoven No.1, 500123, Braşov, Romania
e-mail: stelian.borz@unitbv.ro

Using Sound Pressure Sensors to Monitor the Performance of Manually Operated Circular Saws: What Parameters and to What Extent Can They Be Inferred?

Abstract

Operational performance and energy inputs are key issues when designing and implementing product-oriented systems because such systems make use of tools and equipment to deliver their products. In small-scale wood processing facilities energy savings and an improved time management are crucial in order to stay competitive. This often results in the necessity to reconfigure operational processes or to train the personnel to improve its skills, but in order to do that, it is required to monitor how the operations are implemented. This study tests the possibility to use sound pressure level sensors to monitor the operational behavior of manually-operated circular saws in wood trimming operations. Following a comparative design, the results indicate a good potential to use a threshold-setting approach in monitoring the equipment, as the separation between the running and down time was possible and accurate. Nevertheless, the extraction of effective sawing time as well as of the number of trimmed wood pieces that indicate the production, was rather difficult and inaccurate for the time being but it would be possible to infer such parameters by using higher sampling rates.

Keywords: wood processing, monitoring, energy saving, sound pressure level, sensor, automation

Utilizarea senzorilor de măsurare a nivelului de presiune acustică la monitorizarea performanțelor ferăstraielor circulare acționate manual: ce parametri pot fi estimați și în ce măsură pot fi aceștia estimați?

Rezumat

Performanța operațională și consumul de energie reprezintă aspecte cheie în dezvoltarea și implementarea sistemelor orientate pe generarea de produse deoarece astfel de sisteme utilizează unelte și echipamente în manufacturarea de produse. În facilitățile de prelucrare primară a lemnului, economisirea energiei și un management îmbunătățit al timpului sunt cruciale pentru asigurarea competitivității, fapt ce conduce la necesitatea reconfigurării proceselor operaționale și la training pentru îmbunătățirea competențelor muncitorilor. Pentru a fi realizabile cele menționate, este necesară monitorizarea modului de implementare a operațiilor. Acest studiu testează posibilitatea de a utiliza senzori de măsurare a nivelului de presiune acustică pentru a monitoriza comportamentul operațional al ferăstraielor circulare acționate manual. Rezultatele studiului indică că, prin utilizarea unor valori prag, separarea timpului de funcționare în diferite regimuri este posibilă și suficient de precisă. Cu toate acestea, extragerea timpului consumat efectiv cu tăierea precum și a numărului de tăieturi au fost mai greu de realizat iar rezultatele obținute au fost mai puțin precise. Totuși, utilizarea unor rate de eșantionare mai mari ar putea să îmbunătățească aceste rezultate.

Cuvinte cheie: prelucrarea lemnului, monitorizare, economisirea energiei, nivel de presiune acustică, senzor, automatizare

Irish Wood Fuel Database - A WEB Based Database of Wood Fuel Parmeters

Enda COATES
Brian CRONIN
Christopher MCGURREN
Nicholas MOCKLER
Eleanor OWENS
Maeve KENNEALY
Tom KENT

1. Introduction

Ireland is required to produce 16% of its energy from renewable sources by the year 2020 (***, 2010). Wood fuel is the second largest source of renewable energy in Ireland after wind (Coford, 2014). It is estimated that due to EU directives, the demand for forest based biomass for energy in Ireland will be 3,084,000 m^3 per annum by the year 2020 (***, 2011). However, it is estimated that only 1,453,000 m^3 of forest biomass will be available for the bioenergy market from currently employed supply chains (Phillips, 2011). This forecast of supply only estimates stem wood, and does not take into account the biomass that may be mobilized from branches and tree tops. There is a relatively new category that has been introduced by the Department of Agriculture's afforestation scheme to support the planting of new species of trees to help bridge this gap. This new category, Forestry for Fibre, aims to introduce fast growing species such as poplar, eucalyptus, and alder specifically for fibre to be used in wood fuel supply chains and to also feed panel board mills. As these biomass streams from forest residues and new species develop, data on the wood fuel parameters of the materials is needed, in order for biomass users to decide if the material is suitable in their combustion systems. In an effort to inform the industry on the makeup of these biomass feedstocks, the database described in this study has been created.

2. Materials and Methods

2.1. Field Sampling

A number of specimen trees of each genus were felled by chainsaw: alder (*Alnus glutinosa*), ash (*Fraxinus excelsior* L.), birch (*Betula pendula & B. pubescens*), lodgepole pine (*Pinus contorta Dougl.*), Norway spruce (*Picea abies* (L.) Karst.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), hybrid poplars (*Populus sp.*), *Eucalyptus delegatensis,* and *Eucalyptus nitens.*

Each tree was cross cut at the height where the stem measured 7 cm in diameter, and the top was removed and weighed. The branches along the stem were removed and separated into live and dead branches and each partition was weighed. Three branches from each category, (a large, medium, and small branch) were then

Fig. 1. Collection of stem discs from a *Eucalyptus delegatensis* specimen

selected as representative samples and bagged. The remaining live and dead branches, and the tree top, were then chipped separately with a TP200 chipper, and three woodchip samples (each approx. 1000 g) were collected, bagged, and weighed. Diameter measurements were taken at 1 m intervals along the stem. Discs of 25 - 30 mm thickness were cut by chainsaw approx. every 3 m along the stem. These disks were weighed and bagged for analysis (Figure 1). The analysis procedures are described below.

2.2. Determination of Moisture Content

Sample moisture content was determined on three replicates using the oven dry method at 105 °C for 48 hours, according to EN 14774-3 (***, 2009a), and expressed as a percentage of total weight. Moisture content, expressed as a percentage of total weight, was calculated according to Equation 1.

$$Moisture\ content\ \% = \frac{(W_m - D_m)}{W_m} \times 100 \quad (1)$$

where: W_m is the wet mass, in grams, of the sample, D_m is the dry mass in grams, of the sample.

2.3. Determination of Basic Density

Basic density was estimated using the stem disks sampled in the field. The samples were placed under water for 24 hours in order to become fully saturated. A bucket of water was placed on a mass balance and a weight reading was recorded. The saturated discs were then submerged below the water level in the bucket using teasing needles to hold the disc in place just below the surface. Then a new reading on the mass balance was taken again.

The difference between the reading before submersion and during submersion was converted from weight to volume.

2.4. Preparation of Sampled Material

Prior to the determination of ash content, calorific value, and chemical contents, the samples were comminuted to a particle size of less than 1 mm. Each sample was dried in an oven, and then comminuted using a Fritsch Universal Cutting Mill Pulverisette 19. Stem discs and some branch material which were too large to comminute in the cutting mill were first reduced in particle size by splitting and chipping.

2.5. Determination of Ash Content

Ash content was determined according to EN 14775:2009. Briefly, approximately 1 g of the comminuted sample was weighed in a porcelain dish and burned to a temperature of 550 ± 10 °C using a Mason Technology Nabertherm muffle furnace. The sample analyses were replicated three times and the results were expressed on a dry basis according to EN 14775 (***, 2009b) (Equation 2).

$$A_d = \left(\frac{m_3 - m_1}{m_2 - m_1} \times 100 \times \left(\frac{100}{100 - M_{ad}}\right)\right) \quad (2)$$

where: m_1 is the mass, in grams, of the empty dish, m_2 is the mass, in grams, of the dish plus the test sample, m_3 is the mass, in grams, of the dish plus ash and M_{ad} is the % of moisture content of the test sample used for the determination.

2.6. Determination of Gross Calorific Value (GCV)

Gross Calorific Value (*GCV*) at constant volume was determined according to EN 14918 (***, 2009c). Briefly, 1 g of sample was combusted using a Parr 6300 automated isoperibol bomb calorimeter calibrated with benzoic acid. All sample analyses were replicated three times and were expressed on a dry basis according to EN 14918 (***, 2009c) (using Equation 3).

$$q_{v,gr,d} = q_{v,gr} \times \frac{100}{100 - M_{ad}} \quad (3)$$

where: $q_{v,gr,d}$ is the gross calorific value at constant volume of the dry (moisture free) fuel, in megajoules per kilogram, M_{ad} is the moisture content in the analysis sample, in percentage by total mass, $q_{v,gr}$ is the gross calorific value at constant volume of the fuel as analyzed, in joules per gram.

2.7. Determination of Carbon, Hydrogen, Nitrogen, Chlorine and Sulphur Contents

Samples were sent to the Microanalytical lab of the University College Dublin, Ireland for CHN, Cl and S analysis. CHN and S were measured using an Exeter Analytical CE 440 elemental analyzer. Cl was determined through a titrimetric method.

2.8. Determination of Metal Content

The samples were analyzed for minor elements arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb) and zinc (Zn) and were prepared by using an adapted method of EN 15297:2011. 400 - 500 mg of the sample (≤ 1 mm nominal top size) was weighed and mixed with 8 ml 69% Puriss HNO_3 and 2 ml 35% H_2O_2. Samples were digested in a closed vessel using a CEM Mars 5 Station using a specific temperature profile:

- temperature increased to 190 °C over 15 minutes;
- temperature was kept at 190 °C for 15 minutes;
- samples were allowed to cool down for 20 minutes.

Samples were filtered using Whatman 42 70 mm filter paper and diluted up to 25 ml using 2% HNO_3 and stored at 4° C in polypropylene sample bottles. Metal analysis was carried out using a Varian 710-ES Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES).

Single element standards were prepared for As, Cd, Cr, Cu, Pb, Hg, Ni and Zn using 2% HNO_3. Concentrations of the standards solutions are listed in Table 1. Wavelengths were chosen for each element according to the following:

- best interference free line;
- greatest intensity with lowest background noise and,
- the best correlation coefficient (≥ 0.9950).

Table 1

Metal standard concentrations (mg/l) with selected wavelengths (nm)

Element	Wavelength λ (nm)	Std 1	Std 2	Std 3	Std 4	Std 5	Std 6
As	188.980	0.1	1.0	10.0	---	---	---
Cd	226.502	0.0007	0.0015	0.004	0.007	0.01	---
Cr	267.716	0.001	0.005	0.01	0.025	0.04	---
Cu	327.395	0.005	0.1	0.2	0.3	0.4	---
Hg	253.652	0.1	1.0	10.0	---	---	---
Ni	231.604	0.004	0.02	0.04	0.05	---	---
Pb	220.353	0.1	1.0	10.0	---	---	---
Zn	213.857	0.01	0.05	0.1	1.0	2.0	3.0

Determined sample values were the mean metal content of three replicates (mg/kg) (db) ± standard deviation which were calculated using the Equation 4.

$$w_i = \frac{(c_i - c_{i,o}) \times V}{m} \times \frac{100}{(100 - M_{ad})} \quad (4)$$

where: w_i was the concentration of the element in the sample, on a dry basis, in mg/kg, c_i was the concentration of the element, in the diluted sample digest, in mg/l, $c_{i,o}$ was the concentration of the element, in the solution of the blank experiment, in mg/l, V was the volume of the diluted sample digest solution, in ml, m was the mass of the test portion used, in g and M_{ad} was the moisture content in the analysis test sample in % m/m.

2.9. Instrumentation for Metal Content

A Varian 710-ES Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) equipped with a SPS3 autosampler was used for the analysis of the samples.

Instrumental conditions and sample introduction settings are listed in Table 2**.**

2.10. Limit of Detection and Limit of Quantification Determination

The limit of detection (*LOD*) and limit of quantification (*LOQ*) for each element was determined by analyzing ten blank solutions using the standards and wavelengths listed in Table 3. *LOD* and *LOQ* values were determined using the calculations below provided by the Varian ICP instrument:

LOD = (3 × the average of the standard deviation results of 10 blank replicates);

LOQ = (10 × the average of the standard deviation results of 10 blank replicates).

Table 2

Varian 710-ES operating parameters

Operating parameters	Value
Power (kW)	1.0
Plasma flow (L/min)	15.0
Auxiliary flow (L/min)	1.5
Nebulizer pressure (kPa)	200.0
Replicate read time (s)	5.0
Instrument Stabilization delay (s)	15.0
Sample introduction settings	
Sample uptake delay (s)	30.0
Pump rate (rpm)	15.0
Rinse time (s)	10.0
Fast pump (sample delay/rinse)	On
General settings	
Replicates	3.0
Correlation coefficient	≥0.9950

2.11. Certified Reference Material

Method accuracy was determined using a certified reference material (CRM). Measured metal content was compared to the certified

Table 3

***LOD* and *LOQ* determined for each element analyzed (mg/kg)**

Element	Wavelength, λ (nm)	LOD (mg/kg)	LOQ (mg/kg)
As	188.980	0.1297	0.4323
Cd	226.502	0.0018	0.0062
Cr	267.716	0.0034	0.0114
Cu	327.395	0.0040	0.0135
Hg	253.652	0.0019	0.0066
Ni	231.604	0.0043	0.0143
Pb	220.353	0.0370	0.1230
Zn	213.857	0.0019	0.0066

Table 4

Details of the recovery of the elements from the certified reference material

Element	CRM (mg/kg)	Obtained (mg/kg db)	% Recovery
As	0.112 ± 0.004	ND*	0
Cd	1.52 ± 0.04	1.18 ± 0.14	77.42
Cr	1.99 ± 0.06	2.11 ± 0.05	106
Cu	4.7 ± 0.14	3.66 ± 0.13	77.88
Hg	0.034 ± 0.004	ND*	0
Ni	1.59 ± 0.07	1.53 ± 0.20	96.38
Pb	64 ± 4	43.08 ± 3.55	67.32
Zn	30.9 ± 0.7	29.18 ± 2.46	94.42

Note: *ND - not detected

value and was expressed as a recovery percentage (Table 4).

A combination of Tomato leaves (1573 a), Sea lettuce (BCR - 279) and Aquatic plant (BCR - 060) were used. Each CRM was digested and analyzed in the same way as the samples.

3. Results and Discussion

The results of the analysis were compiled into spreadsheets to form the dataset for the database. A data visualization software package, Tableau (Tableau Software), was used to develop an online tool for users to interact with the data (Figure 2). Users may access the database and query the data under two headings: parameter or species. Under the parameter heading, a given parameter can be selected and filtered by species and partition. The results for this parameter are then presented, and can be further filtered to show all or only specified results. The tool is available online at *www.forestenergy.ie*.

The parameters that are presented in the database are known to be important in forest biomass supply chains. By having the net calorific value on a dry basis, and the basic density, the actual energy content of any fuel quantity at any moisture content can be calculated. This is useful for practitioners who are seasoning stacks of forest biomass and want to estimate the energy per stack / per load they are delivering. A high content of ash means that less of the biomass is combustible as a fuel and there is more ash to be utilized/disposed at the end of the combustion process, and so quantifying this for tree partitions is useful. It is also important to characterize the biomass ash melting behavior as the ash deposition causes slagging and fouling of the boiler system (Karampinis and Grammelis, 2016; Obernberger, 2009). Slagging is the deposition of sticky, molten ash on the furnace walls and on hottest parts of the boiler system which experience radiant heat transfer directly from the flames from combustion; fouling takes place in the relatively cooler parts of the system where flue gas and fly ash cool down and form deposits, often on the heat exchanger tubes. The chemical composition of biomass can determine usability of biomass as a fuel in terms of emissions and suitability for combustion in certain conditions. Chlorine, Sulphur and Nitrogen contents should be quantified and any biomass feedstock having high concentrations of these elements should be highlighted and omitted from the fuel mix.

Chlorine content is a concern for boiler operators, as a high Chlorine content can cause corrosion of the boiler. Sulphur itself is corrosive, but a certain ration of Sulphur to Chlorine will reduce the corrosive effects. While maintaining this ratio is important to reduce corrosion, a

Gross Calorific Value (dry basis) MJ/kg

	Species (Common)	Species (Latin)	Stem	Wood	Branch	Bark	Wholetree	Foliage	
Broadleaf	Alder	*Alnus glutinosa*	19.66	19.40	20.51	20.36		21.21	1
	Ash	*Fraxinus excelsior L.*	19.24	19.10	19.39	18.98		20.23	1
	Birch	*Betula pendula*							
		Betula pubescens							
		Betula sp.	19.73	19.45	20.69	21.70		21.18	1
	Eucalyptus	*Eucalyptus delegatensis*		19.80	19.80	18.85		22.30	
		Eucalyptus nitens	19.32	19.28	19.68	17.00	19.54	22.71	2
	Hybrid poplar	*Populus spp.*	19.45	19.43	19.50	19.55		19.53	1
Conifer	Lodgepole pine	*Pinus contorta Dougl.*	20.01	19.98	20.76	21.39		21.52	1
	Norway spruce	*Picea abies (L.) Karst.*	19.89	19.87	20.82	20.01		20.54	1
	Sitka spruce	*Picea sitchensis (Bong.) Carr.*	19.95	19.85	20.66	20.66		21.41	1

Fig. 2. Output of online database for gross calorific value

Note: Users can filter the results according to species and partition, and download the underlying data.

high concentration of either Sulphur or Chlorine could lead to emission issues (Obernberger *et al.*, 2006). Carbon, Hydrogen and Nitrogen are also important elements to quantify for carbon accounting purposes, and life cycle analysis of biomass supply chains. This is where the carbon released in the harvesting, chipping and transportation of the wood fuel is evaluated to see if there is a net benefit using the wood fuel in terms of carbon offsetting from fossil fuels.

4. Conclusions

The developed database tool has the potential to serve practitioners, planners, and researchers working with biomass supply chains.

As more data is becoming available, it can be added to the database to further extend the knowledge in the industry. The underlying data stored in the developed tool, can be displayed or downloaded, so that users can perform their own data analyses.

The tool is freely available online at *www.forestenergy.ie*.

Acknowledgements

This study was carried out under the SHORTFOR Project, which was funded by the Department of Agriculture, Food and the Marine, under the COFORD Forest Research Programme.

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Enda COATES
Waterford Institute of Technology
e-mail: ecoates@wit.ie
Brian CRONIN,
Waterford Institute of Technology
Christopher MCGURREN
Waterford Institute of Technology
Nicholas MOCKLER
Waterford Institute of Technology
Maeve KENNEALY
Waterford Institute of Technology
Eleanor OWENS
Waterford Institute of Technology
Tom KENT
Waterford Institute of Technology

Irish Wood Fuel Database - A WEB Based Database of Wood Fuel Parameters

Abstract

An online database has been developed which details the wood fuel characteristics of many Irish grown tree species. The database includes values for Moisture Content at felling, Basic Density, Ash, Ash melting behavior, Calorific value, Carbon, Hydrogen, Nitrogen, Chlorine, Sulphur, Oxygen, Arsenic, Cadmium, Chromium, Copper, Mercury, Nickel, Lead and Zinc. The information that populates the database has been collected from the felling and destructive sampling of specimen trees. It is presented in an online web-based format, where users can query parameters to view specific data as graphics, download figures, and also tables of the underlying data, which is all freely available. The species currently represented in this database are alder (*Alnus glutinosa*), ash (*Fraxinus excelsior L.*), birch (*Betula pendula* & *B. pubescens*), lodgepole pine (*Pinus contorta* Dougl.), Norway spruce (*Picea abies* (L.) Karst.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.), hybrid poplars (*Populus sp.*), *Eucalyptus delegatensis*, and *Eucalyptus nitens*. For each species, data is presented separately for the stem, wood, top, bark, branch, and foliage. The database can be accessed at *www.forestenergy.ie*.

Keywords: Biomass, biomass characterization, fuel quality, database

Irish Wood Fuel Database - O bază de date WEB pentru parametrii combustibililor lemnoși

Rezumat

Lucrarea de față prezintă metodologia de dezvoltare a unei baze de date ce conține detalii legate de caracteristicile combustibililor lemnoși pentru mai multe dintre speciile forestiere caracteristice Irlandei. Baza de date include valori ale umidității la recoltare, densității, conținutului de cenușă și a parametrilor de topire a cenușei, valorii calorifice, conținutului în carbon, hidrogen, azot, clor, sulf, oxigen, arsenic, cadmiu, crom, cupru, mercur, nichel, plumb și zinc. Informația care populează baza de date a fost colectată prin doborâre și eșantionare destructivă a specimenelor de arbori. Informația este prezentată în format disponibil online, în care utilizatorii pot interoga parametrii disponibili pentru a vizualiza datele sub formă de grafice și de unde pot descărca grafice și tabele conținând informația în cauză, informație ce este disponibilă gratuit. Speciile disponibile în prezent în baza de date sunt aninul (*Alnus glutinosa*), frasinul (*Fraxinus excelsior* L.), mesteacănul (*Betula pendula & B. pubescens*), pinul (*Pinus contorta* Dougl.), molidul (*Picea abies* (L.) Karst.), molidul de Sitka (*Picea sitchensis* (Bong.) Carr.), plopii hibrizi (*Populus sp.*), și eucaliptul (*Eucalyptus delegatensis, E. nitens*). Pentru fiecare specie, datele sunt prezentate separat pentru lemnul din trunchi și vârf, coajă, crăci și masa foliară. Baza de date dezvoltată poate fi accesată la *www.forestenergy.ie*.

Cuvinte cheie: biomasă, caracterizarea biomasei, calitatea combustibililor lemnoşi, bază de date

A New M.S. Excel - V.B.A. Tool for Postural Data Processing and Analysis in Forest Operations

Mădălina FORNEA

1. Introduction

To stay competitive on a dynamic market, nowadays industries tend to automate most of their specific processes as a result of the constant pressure to reduce the products and services development cycle time, enabling this way an improved customer satisfaction, as well as to reduce the development and market releasing costs with obvious benefits in terms of competitiveness. Nevertheless, many industries are still relying on manual labor either as a consequence of underdeveloped technology in their fields or due to the lack of such technology in the underdeveloped countries.

In particular, forest operations may be characterized by an important contribution of manual and motor-manual labor. That's because the mechanization level depends to a great extent on factors such as forest type, management approach, terrain and climate conditions (Vusic *et al.*, 2013). At the same time, there is a number of harvesting systems that are currently used around the world in forest operations (Oprea, 2008), but many of them still make a substantial use of manual labor. For instance, motor-manual tree felling and processing is a practice well spread across the globe both, in the traditional forestry (Borz and Ciobanu, 2013; Ghaffariyan *et al.*, 2013; Ghaffariyan and Sobhani, 2007; Ignea *et al.*, 2017; Jourgholami *et al.*, 2013) and short rotation coppice (Talagai *et al.*, 2017). In forestry, it aims to convert the standing trees into logs that are then extracted to the roadside using other kind of forest equipment. Examples of operations that involve manual labor are those of animal logging (Borz and Ciobanu, 2013; Jourgholami *et al.*, 2010), manual bunching (Borz and Ciobanu, 2013), manual splitting, manual stacking, cable yarding (Gaffariyan *et al.*, 2010; Spinelli *et al.*, 2010), cable skidding (Borz, *et al.*, 2013; Borz *et al.*, 2015), chute logging (Eroglu and Acar, 2007), cable rigging (Ottaviani *et al.*, 2011; Stampfer *et al.*, 2006) etc. Excepting few harvesting systems such as those coupling harvesters with forwarders, most of the equipment used in timber harvesting operations still involves, under operational point of view, manual labor. On the other hand, forest work is particularly difficult (Alexandru, 1997) and dangerous. First of all, forest workers are required to cope with difficult terrain, rigors of open sky work and to handle heavy equipment and tools while wearing also heavy and, sometimes, uncomfortable protective equipment. Secondly, they are required to work with or near hazardous equipment that sometimes needs to be handled in very steep terrain or at considerable heights above the ground (Corella-Justavino *et al.*, 2015; Stampfer *et al.*, 2006). In addition, they often disregard the best practices in operations (Borz *et al.*, 2014c) a fact that may have serious consequences.

The U.S. report on "*National Census of Fatal Occupational Injuries in 2015*" classifies the logging work as one of the most dangerous due to its difficulty level and high risk to which the workers falling in this industry are exposed to (Bureau of Labor Statistics, 2016). Obviously, the technical procedures are quite complex in this industry, requiring a high level of physiological (Oprea, 2008) and physical workload and exposing the workers to musculoskeletal disorders (MSD) (Calvo, 2009). In addition, the work with power tools (Alexandru, 1997; Tsioras *et al.*, 2014), and with other kind of forest equipment such as skidders, forwarders and chippers (Poje *et al.*, 2015) exposes the workers to other stressors such as vibration (Axelsson, 1998; Bovenzi, 1996; Bovenzi and Betta, 1994; Rottensteiner *et al.*, 2013; Tsioras *et al.*, 2011) and noise (Humann *et al.,* 2012; Poje *et al.*, 2015; Rottensteiner *et al.,* 2013).

Therefore, one of the most important scientific parts and concerns of forest operations engineering and management as a discipline is the forest operations ergonomics (Heinimann, 2007).

Ergonomic studies are often carried on with the purpose to evaluate, classify and, if necessary, to take corrective actions related to postural behavior during work, aiming to find the most convenient way to balance the two main parts of a work system - the human capabilities and the work conditions - without affecting work productivity or increasing significantly the labor costs (Vieira and Kumar, 2004). Therefore, an ergonomic assessment of postures taken by the workers during their production tasks can give valuable information for those concerned to design or re-design work places and tools that will help in the attempt to maximize work performance while not exceeding the safety level of musculoskeletal workload.

The international literature on ergonomic methods developed and used in the assessment of work postures is characterized by a wide variety, with methods specifically designed for certain research objectives (Chiasson, 2011; David, 2005). The main advantages of these methods are that they can be easily adapted to specific industries, depending on the scope of the ergonomic assessment.

OWAS (Ovako Working Analysis System) is only one of the methods currently used in postural assessment for certain industries or jobs. This method is used to analyze, classify and undertake corrective actions for the most frequent work postures including the force exertion during the work tasks based on an analysis carried on four components (Karhu *et al.*, 1977). It has been used for assessments in various industries, including forest operations (Calvo, 2009; Corella-Justavino *et al.,* 2015), where it still has a lot of potential.

As the work science and the work system itself evolved, researches and professionals concerned with finding the right combination between the capabilities of a worker and his job requirements, have tried by the development and use of certain assessment methods to test and analyze the implications of workload and posture on worker's health. Initially, all the developed methods used pen-and-paper approaches to collect the needed data. Examples are described in studies of Karhu *et al.* (1977), Keyserling *et al.* (1992), McAtamney and Corlett (1993). At the same time, in work science applied to forest operations, the pen-and-paper approach usually involves a great amount of resources to collect data and there is a need to automate as much as possible data collection activities with obvious benefits in terms of resource allocation (Borz, 2016). The same applies to data processing and analysis where computers have a lot of potential in automating some of the tasks and producing reliable results. Such an approach may be used, for instance to process video-collected data. To this end, video-collected data has several advantages over the traditional approaches because it enables the reproduction of field operations as they were carried out (Borz *et al.,* 2014a), gives the possibility to review the data at any time and, most importantly, enables an adequate data treatment for different purposes with virtually no restrictions related to the separation on work tasks (Muşat *et al.*, 2016). Therefore, the variability of postures taken during the operations can be addressed properly. This is particularly useful in the research of that job tasks characterized by rapid changes in terms of work postures, dynamism and variability of movements, as described in Corella-Justavino *et al.* (2015). Variability in time of such tasks often comes from the variability in size of the work object and variability of operational conditions. For instance, the time spent in a given posture when felling trees will vary in direct relation to the tree size (Borz and Ciobanu, 2013; Ghaffariyan and Sobhani, 2007; Jourgholami *et al.*, 2013) while the time spent in winching operations will vary in direct relation to the winching distance, slope and direction (Borz *et al.*, 2014b). For this reason, a work cycle or activity in the forest operations industry may not be characterized by a constant duration between the replications as it may be the case of other industries (Beheshti *et al.*, 2015). Therefore, *in situ* sampling at regular periods of time that is further characterized by large time intervals between the replications, as well as data analysis based on such measurements, may produce biased results and constitutes yet another reason to collect data by video-recording. On the other hand, postural data collection by video-recording can sometimes be impaired due to some reasons such as the gaps in the continuously collected data reasoned by observer's safety or by the work conditions. Following this idea, in the traditional pen-and-paper approach of postural data analysis, an observer may need to remake the observations until a proper level of data accuracy is reached while in the video-collected data approach he (she) only needs to set an adequate sampling rate.

At the same time, processing and analysis of video-collected data may be challenging (Borz and Adam, 2015; Muşat *et al.,* 2016) supporting the idea of developing software tools able to process such or derived data while the postural assessment using software tools should automate operations to a certain extent. Among the capabilities and functionalities of existing software tools that implement the OWAS method are the code identification and matching of the intervention categories. In some cases, the software tools can give recommendations based on the results (de Anchieta Messias and Okuno, 2012; Ketan and Al-Zuheri, 2008; Costa *et al*., 2015).

The postural assessment may also be eased by the integration of sampled pictures for each posture in the evaluation window. This is particularly important to save time and effort as presented in this study. Nevertheless, such capabilities were not identified in the existing software tools. Then, the developed tools should cope with and treat the limitations of the video-collected data approach, they should be able to produce the relevant statistics as well as to build databases to enable further analysis if needed.

By considering the above mentioned, the development of software products to integrate the premises and specifications of a certain method or theory, can save a lot of time and money and also can provide a better data management. There are many examples of simple tools coming from the forest industry (*i.e.* cost calculation tools) that support forest practitioners and scientists in their work. On the other hand, such tools need to step up by adding value and by improving the existing capabilities and functionalities. This often means that new capabilities and functionalities need to be developed and aligned to the newly identified needs as being specific to science and practice.

The added value is sometimes referred as the improvement of scientific research by easing its resource management. Therefore, the transposition of a certain theory or method in computational code represents a path for the development of scientific research (Lane and Gobet, 2012) while important science relies on models and the software implementing them (Joppa *et al*., 2013) meaning that a professional end-user (Segal, 2004) needs to cope with modern requirements of the scientific world by adapting classical methods and theories to tools that can ease the scientific research in a comprehensive way. To this end, Segal *et al.* (2005) define the so-called „*reflective practitioners*" as those people concerned with the improvement of their discipline by developing software tools.

The aim of this study was to develop and test in terms of added value a software tool for video-collected data work posture processing and analysis by implementing the OWAS method.

2. Materials and Methods

In order to develop a software tool for the ergonomic assessment of work postures based on OWAS specifications, it was mandatory to carry on a bibliographical research that aimed to build knowledge and a better understanding related to the needs of such a tool.

In particular, the industries that use such methods in the ergonomic assessment, pros and contras, as well as the existing software tools were benchmarked in a comprehensive approach. The literature survey included also those problems related to forest operations and wood processing industry. The issues related to the traditional approaches were addressed, and the existing software capabilities and functionalities were assessed. This part of the methods section was used to build the background of this paper and also to sketch the targeted capabilities and functionalities of the software product to be developed. Based on the identified needs, and for convenience (since many people use Microsoft Office applications), the software tool was developed using the Visual Basic for Applications - V.B.A. ® development environment running under Microsoft Excel - MS Excel ®, version 2013.

While the added value can be measured in a number of ways, including the newly integrated capabilities and functionalities, one key issue is that of resource management, especially time consumption in data processing activities. To this end, following the release of the first functional version of the software tool, a comparative study was designed and implemented to test the added value in terms of time resources requirements. For this purpose, the comparison was made between the traditional way of doing an ergonomic evaluation and that implementing the developed tool (FORERGO).

Therefore, this paper was organized differently compared to classic research papers. Firstly, it gives an overview on the developed tool's interface, capabilities and functionalities, then it develops and discuss the results of comparative study and, finally, it concludes on the added value of the product.

3. Description of Key Capabilities and Functionalities

3.1. Initial Data Window

The software tool was built to work with frames extracted at a certain (equal) time interval from video files, a capability that is aligned to the OWAS method specifications that analyses the postures at a given time interval. Usually, the video files can be broken into a number of frames that stand for images sampled at a given time interval from the original video file. To this end, there is a number of freely available tools able to undertake such conversions and to code sequentially the extracted frames. Therefore, the accuracy requirements of a given study can be met by extracting the frames at a sampling rate that is aligned to the study goal.

The tool is simply initialized by opening the containing Excel workbook. As it was developed in order to be included also other ergonomic assessment methods, the first screen (not given herein) introduces the user into the available evaluation sub-tools. Here, the user may choose the method used in the evaluation. If the OWAS evaluation method is selected then the next window pops up (Figure 1). It allows the user to define a project name that has to be unique (otherwise the tool pops up a message instructing the user to choose another name) as well as to define up to 10 tasks (work elements) and their corresponding abbreviations.

This functionality is particularly helpful when observing forest operations tasks where the number of work elements within a work cycle can reach such numbers (Borz *et al.*, 2014a). Then the user proceeds to the project data validation that is transposed into the creation of a new sheet named by the project name and fully formatted for the evaluation. This sheet serves as a data storage database for the evaluations made according to those presented in Figure 2. It is fully updated based on the actions undertaken by the user and it also serves to build statistics and to allocate the action categories specific to the method. The third step to be undertaken under the window shown in Figure 1 is the input of a value for the number of frames per second. This is particularly helpful for those projects aiming to derive also the time spent in different work postures, work elements, work cycles and work postures.

The time spent is such subdivisions is actually calculated by using the value set for the *fps* variable, the number of digital images falling into a specific category and the declared and attributed work phases to each analyzed image. Based on the comments added by the user in the next window and the updated database, one may choose to conduct externally other detailed analyses as being specific to time and motion studies.

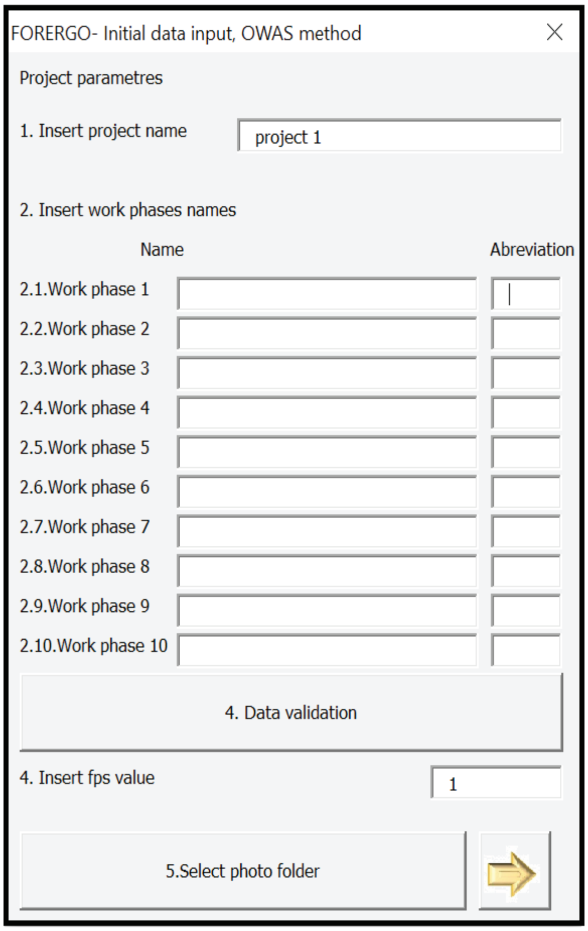

Fig.1. FORERGO's initial data window

The last step in this window is the one corresponding to the selection of a folder containing the digital images to be analyzed. Once the folder was selected, the user needs to click on the arrow button located to the bottom right corner to move on to the evaluation window.

This action builds a list of strings into the database that is used afterwards to locate the user between the analyzed images each time a given image is shown on the screen.

3.2. The Evaluation Window

The evaluation window enables the users to perform a number of tasks that are specific to most of the software products implementing the OWAS method, but it gives also newly built capabilities and functionalities. Firstly, when the window is shown, the upper part indicates in green the path and the name of the first or current image that is shown within the main window. This functionality helps the user to go back or forth to a given image and to analyze (reanalyze) it as mentioned below.

Depending on the clarity and the visibility of the image, the user may choose to magnify it or to reduce its size using the controls placed in the upper right corner. One of the new functionalities is that allowing the user to navigate between the images loaded using the previous window. This functionality is supported by a dedicated code written to characterize the clicking events of the two arrow buttons located in the lower left side corner of the window. This way, the user may navigate between the loaded images, may choose his options based on the evaluation buttons and may reconsider some already processed images by searching them.

The database behind the window is dynamic, in the sense that once the user chooses and validates given parameters they are written in the corresponding space until the user chooses to modify them. In addition to the possibility to select a work phase and a work cycle for each of the analyzed images using the combo and the text boxes located in the left bottom corner, the user is enabled also to make observations or comments to each of the analyzed body segments using the corresponding text boxes. Once a decision is made on a given image that was analyzed, the user validates the data using the "*Validate image data*" button. This event triggers the modification of the background database.

It should be montioned here that FORERGO was specifically designed in order to cover other situations that may occur, based on those described by Corella-Justavino *et al.* (2015). An example is that specific to those images that may be interpreted as being not valid as they are incomplete or are showing only a part of the worker's body. For this purpose, FORERGO implements a special value for each body segment as well as a special action category named "*0*".

They enable the user to partially evaluate an image, as it can be used, for instance, in a time and motion study but also it helps to exclude those images form the ergonomic postural analysis.

For convenience, most of the buttons were

Fig.2. FORERGO's evaluation window

built as suggestive as possible. The images used to represent typical postures as being specific to OWAS analysis, were built using the free software tool MakeHuman (available at: *www.makehumancommunity.org/*), based on the description provided in Helander (2005). As shown in Figure 2, each body segment was included as typical for an OWAS analysis and a supplementary button was added to cover the above-mentioned problems related to inconsistent images.

3.3. Building Statistics and Showing Results

FORERGO also provides a simple way to build, compute and show basic statistics of the ergonomic postural assessment under the framework of OWAS. For a more detailed analysis, the user may work on the database that is automatically built and updated in the background (MS Excel sheets).

For basic statistics on the ergonomic assessment, FORERGO provides functionalities to build and show category frequencies, proportions and time percentages only by selecting the appropriate buttons and chart types.

Frequency of a given category is the result of identifying and counting the number of identical entries, from 0 to 4 (Figure 3). The proportions are computed by dividing the frequency value for each category by total number of category entries and multiplying the result by 100.

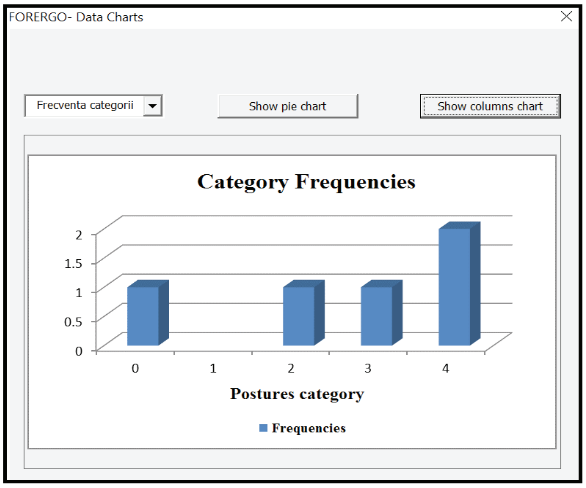

Fig.3. FORERGO's statistics building function

Time consumption for each postural category is computed by multiplying two numerical values, namely the category frequencies and the time for each postural category followed by the result's division by 100.

4. FORERGO's Added Value in Terms of Time Consumption

4.1. Design of the Comparative Study

In order to emphasize the FORERGO's added value in terms of time consumption, a comparative study has been designed and implemented in two experimental setups: FORERGO as a modern approach *vs.* pen-and-paper as a traditional approach.

By this study, time consumption was used as the main variable describing the resource requirement intensity. For this purpose, a set of 500 digital images characterizing the work tasks specific to traditional manual handling of wood were selected randomly from a set containing more than 5000 images. A number of 50 images were randomly selected from the initial selection set and were used in the analysis that followed the specific paths of both approaches: modern *vs.* traditional. Therefore, the pen-and-paper traditional approach took into consideration all of the phases required by postural assessment including the development of paperwork needed to gather and analyze the data. The paperwork needed to analyze the data was developed prior to the implementation of the comparative study, therefore this step was not included in the study even if, for given setups, it could take additional time and resources such as paper sheets. Basically, in this setup, one researcher analyzed the images shown on a computer screen, wrote the codes for each body segment on a paper sheet, then concluded the study by identifying the action categories in a printed matrix and by writing down all the codes on the sheets. Statistical analysis was excluded from the traditional study as the FORERGO builds those statistics in an automated way and the comparison did not make any sense as the statistics are built in few time.

In the modern approach, the same images were analyzed following the analysis and computational steps presented in this paper.

In both experimental setups, the time needed to analyze each image was counted at a one second accuracy by a continuous timing method (Björheden *et al.*, 1995) using a professional stopwatch. In addition, the time needed to synthetize the codes and to extract the action values for each category were separately timed for the pen-and-paper approach. Timing results of each approach were translated and processed into a MS Excel sheet by applying basic operations to compute the time differences, to develop descriptive statistics and to plot graphically the results.

4.2. Results of the Comparative Study

The results showing the added value of using FORERGO compared to the traditional approach are shown in Figure 4 and in Table 1. The descriptive statistics shown in Table 1 stand for obvious differences in terms of time consumption between the two approaches. For instance, individual analysis of each image took in average almost 13 seconds when using FORERGO and almost 30 seconds in the traditional approach. This indicates that using the traditional approach would take, in average, more than 2.3 times more time to analyze individual images. Standard deviations in both cases indicate the variability in this task suggesting that in the case of FORERGO this task is less variable in terms of time compared to the traditional approach as a result of automation. The same may be observed in the data ranges as being specific to the two approaches. In the case of FORERGO it was of 29 seconds while in the case of traditional approach it was of 49 seconds (not shown in the Table 1). Both, minimum and maximum time consumptions to analyze a given image were smaller when using FORERGO.

On the other hand, the individual image analysis was responsible for a share of about 38% of the total analysis time in the traditional approach. Also, matching the intervention categories took between 3 and 66 seconds, as this activity was fully manual. Obviously, here may be one of the greatest benefits of using the developed tool as it automatically assigns and extract the intervention categories.

Altogether, image analysis and category matching took more than 50% of the total study time in the traditional approach. Globally, the time consumption in the traditional approach was almost 4 times higher compared to the modern approach as shown in Figure 4, a result that clearly shows the benefits of using the developed software tool. If only the time spent in image analysis is taken into consideration then the traditional approach took almost 2.3 times more time resources than the modern approach.

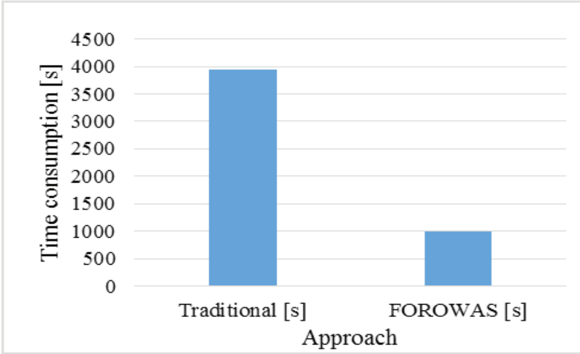

Fig.4. Comparison of the time consumption as being specific to the two tested approaches

As the experiment was setup and conducted by the author of this study, most of the differences found in the presented figures come from the time needed to alternatively focus the researcher's attention to the computer screen to identify the posture of each body segment followed by the focus of attention to the paper sheet to write down the results.

While it is a pure speculation, as this study covered the analysis and processing of only 50 digital images, it is possible for a researcher using the traditional approach to get tired very soon as a consequence of the frequent refocus of his (her) attention between a computer screen or other media to the paper sheets. Also, the results of this comparative study are indicative. To this end, for conclusive results and improved estimations,

Table 1

Results of the comparative study

Undertaken task	Traditional approach					Modern approach				
	tmin	tmax	Sum	Average±St. dev.	%	tmin	tmax	Sum	Average±St. dev.	%
Image analysis (s)	11	60	1477	29.54 ± 10.55	37.6	1	30	630	12.60 ± 6.22	-
Matching intervention categories (s)	3	66	542	10.84 ± 9.36	13.8	-	-	-	-	-
Other Activities (s)	-	-	-		48.7	-	-	-	-	-
Total analysis and processing time (s)	3933					988				

the two approaches should be tested by a greater sample of users to cover other variability factors including their perception as described in Mușat *et al.* (2016).

5. Conclusions

In this study, a tool for postural evaluation as being specific to ergonomic assessment was developed and tested. The main purpose of FORERGO as a software tool was to provide an improved resource management by easing the process of data processing and analysis while incorporating also other functionalities and capabilities aligned to the current needs in the field.

As a significant step up, with obvious benefits in research tasks in terms of resource allocation, it allows digital image integration in the assessment window. This capability removes the necessity to switch the researcher's attention and focus from the screen or other media to paper sheets or other tools to process the data. Also, it has the capability to use specific parameters such as the number of frames per second enabling this way the computation of the time spent by a worker in a certain posture, work element or task.

Relative to the traditional approach, another benefit of using FORERGO was the automation of those time-consuming activities such as identifying the postures codes, matching the intervention categories, computing the category frequencies, proportions and time percentages. In addition, FORERGO builds and dynamically maintains a background database that can be used for further, detailed analyses.

Another advantage is that related to the possibility to partially analyze problematic images, enabling their inclusion or exclusion from the analysis depending on the intended goal of the study. This functionality as well as the possibility to view the image in the main window add value to the tool and tasks undertaken by using the tool, unlike the other methodologies or assessment means (tools).

All of these newly built capabilities and functionalities help at least in time saving as shown in this study. As a fact, time resources needed to carry on postural assessments may be reduced by a factor of almost 4 compared to the traditional pen-and-paper approach. This can be translated, for instance, in the possibility to analyze bigger datasets in the same time, with obvious benefits in terms of results accuracy.

Acknowledgements

The author would like to thank prof. Stelian Alexandru Borz for support and assistance in carrying out this study. The author would like to thank also to the Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements of the Faculty of Silviculture and Forest Engineering, Transilvania University of Braşov for providing the infrastructure needed in this study. This paper is a synthesis of the author's MSc thesis developed within the frame of Master Program - Management and Technical Systems in Forest Engineering.

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Eng. Mădălina FORNEA

Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, *Transilvania* University of Braşov, Șirul Beethoven No. 1, Braşov 500123, Romania

e-mail:fornea.madalina@unitbv.ro

A New M.S. Excel - V.B.A. Tool for Postural Data Processing and Analysis in Forest Operations

Abstract

As described by many studies, forest operations have always been ones of the most difficult and hazardous jobs, requiring a careful design of tools, workplaces and technical procedures. Postural assessment of a job is an important field of ergonomics. The ergonomic assessment of work postures may require a great amount of data to be collected, processed and analyzed, involving significant resources. To ease such tasks, IT applications may be developed and used to process and analyze data in less time and to increase the accuracy of results. OWAS

(Ovako Working Posture Analysis System) is one of the most used methods aiming to evaluate the risks to work-related disorders. In the last years, a number of applications framed around OWAS have been developed but the field of forest operations requires more specific parameters. With the help of Microsoft Excel's Visual Basic component (VBA), an application (FORERGO) was developed in order to facilitate the postural analysis in such jobs. Based on frames extracted from video files, the application may be used to compute also the time spent in different postures. After describing the main capabilities of the developed software tool, this paper presents the results of a comparative study, mainly focused on resource requirements for two approaches of the OWAS method such as the traditional pen-and-paper and FORERGO emphasizing obvious benefits of using the tool instead of the traditional approaches.

Keywords: forest operations, ergonomics, postural assessment, efficiency, data processing, automation

Unealtă M.S. Excel - V.B.A. pentru procesarea şi analiza datelor de natură posturală în operaţii forestiere

Rezumat

După cum se descrie în multe studii, operațiile forestiere au fost întotdeauna unele dintre cele mai dificile și periculoase activități, necesitând un design atent al uneltelor, locurilor de muncă și a procedeelor tehnice. Evaluarea posturală a unui tip de muncă reprezintă o latură importantă a ergonomiei care poate necesita colectarea, procesarea și analiza unor seturi mari de date, implicând resurse substanțiale. Pentru a ușura astfel de activități, pot fi dezvoltate și utilizate aplicații software pentru a procesa și analiza datele în timp mai scurt, precum și pentru a crește acuratețea rezultatelor. OWAS (Ovako Working Posture Analysis System) este una dintre cele mai utilizate metode ce vizează evaluarea nivelului de expunere la riscuri de îmbolnăvire profesională. În ultimii ani, s-a dezvoltat un număr de aplicații software ce implementează metoda OWAS, dar pentru analizele specifice operațiilor forestiere, astfel de aplicații necesită includerea unor capabilități suplimentare. Utilizându-se Microsoft Excel și componenta V.B.A. specifică acestuia, s-a dezvoltat o aplicație (FORERGO) pentru a se facilita analiza posturilor de muncă în astfel de activități. Pe baza unor imagini extrase din înregistrări video, aplicația poate fi utilizată pentru a calcula inclusiv timpul consumat în diferite posturi de muncă. După descrierea principalelor funcționalități ale uneltei software dezvoltate, lucrarea de față prezintă rezultatele unui studiu comparativ care s-a realizat pentru a se identifica consumul de resurse pentru două abordări ce utilizează metoda OWAS precum cea tradițională și cea bazată pe utilizarea aplicației FORERGO, punând în evidență beneficiile evidente ale utilizării aplicației dezvoltate în locul abordării tradiționale.

Cuvinte cheie: operații forestiere, ergonomie, evaluare posturală, eficiență, procesarea datelor, automatizare

Application of PERT & CPM for Forest Utilization Planning

Majid LOTFALIAN
Mahboobe SABZI
Ali Hosseini YEKANI
Saba PEIROV

1. Introduction

Increase of technical, economic, political and social complexity is one of the important aspects in the technology development. Projects usually involve a collection of extensive, costly and highly risky commitments which should be finished with a defined budget during a certain time and according to an expected efficiency level (Williams, 1995), therefore, a project manager should be able to identify and then evaluate the uncertainties of the project and ultimately control them in order to achieve success in the project (Amiri, 2013).

Working in forest is very difficult and overwhelming and it is also associated with frequent limitations including shortage of human force, loss of trained subjects, loss of professional machines, high costs of buying machines, duration limitation for working in forest, ruggedness of some tracks, topography, costly procedures etc. On the other hand, while performing all the forest utilization projects, consideration of timetable and accurate scheduling of operational phases causes timely utilization and valuable time, cost and financial and human resources saving, so that the longer the project time period, the less certainly the finishing time and costs could be estimated.

Thus, optimum and helpful management planning methods, scheduling, assessment and coordination should be used in the field of management for utilization procedures. In this context, modern methods such as PERT and CPM could be used (Soltani *et al.*, 1999). PERT and CPM are majorly designed for planning and control purposes (Chizari and Amirnezhad, 2000). PERT was designed to use a statistical method for estimating the possible time of doing a task (Haj Shir Mohammadi, 1999). It is the fastest and the most common method in large-scale projects planning and control (Azaron *et al.*, 2005, Chen and Chang, 2001).

PERT was developed in 1950 so as to help managers with planning and managing large scale and important projects. These days, it is widely used in various industrial and service units. Using this method, managers could gain the following capabilities (Azaron *et al.*, 2006; Stevenson, 2002):
- appropriate networks graphs expressing the situation of doing tasks;
- acceptable estimation of project finishing time;
- analysis of critical activities;
- delay analysis of project tasks without affecting total time of the project.

The Critical Path Method (CPM) is one of the important tools applicable in project planning and control. It includes the determination of critical path, critical activities and critical incidents in a project network by considering the earliest possible finishing time of the project. In project management and control, when the time of activities is certain, application of classic techniques such as CPM will be an appropriate tool in project planning and control (Krajewski and Ritzman, 2005).

Chen and Hsueh (2008) provided an algorithm for forward and backward pass calculation in a CPM network. In this algorithm, the project critical path was determined based on a linear programming model and a number as a criticality level was attributed to each available path in the CPM network.

Chizari and Amirnezhad (2000) investigated the application of PERT and CPM in project management for planning, understanding of management responsibilities and determination of the realistic time. Results showed how much extra cost should be paid according to the definition of critical paths using PERT and CPM in order to reduce the time of doing different activities.

Asghari *et al.* (2004) carried out a study about project planning, control and coordination between time and cost using the Critical Path Method (CPM). In their study, besides the investigation of characteristics related to Critical Path Method (CPM) and the determination of critical activities, a cost-time curve was also suggested, and subsequently, the minimum cost limit (*i.e.* direct and indirect costs) was obtained. The results indicated that, in any conditions, cost would not be reduced with increasing time, since when time increases, effect of indirect costs would be greater and thereafter would lead to improved total project cost.

Jebel Ameli and Saeedi (2007) examined the development of an information system in project planning and control by applying the CPM. They obtained results such as help in a fast implementation (without reworking) of CPM by project planning and control sector; possibility of adding and updating the date; determination of project starting activities and updating buffers situation in system and following up their situation; creation of a context in order to facilitate informative and operational performance of CPM.

In timber harvesting operations, Oprea and Borz (2007) used the CPM and MPM (Metha Potential Method) to allocate, distribute and operationalize timber harvesting operations based on time constraints respectively activity timing and overlapping for timber harvesting blocks.

Yousefi-Nezhad Attari and Neishabouri Jami (2009) mentioned that the lack of a valid critical method to limit the resources not only has disturbed the extensive use of principal path programming software in management procedures, but also has made the basis of any sophisticated investigation, cost or base time analysis of CPM unstable in the structure research planning. Therefore, it seems necessary to develop an initiated and totally automated method for CPM with limit resources which is called a simulated-base planning system.

Considering that forest logging is an important part which links biological to industrial production, in this study, we have tried to manage the forest utilization operations costly and timely using PERT and CPM methods, and we have also tried to determine those operations acting as bottlenecks based on these methods.

2. Materials and Methods

2.1. Study Location

The studied forest, called district 1 - Darab-Kola is located about 15 km east of Sari city. We have selected a parcel for this study in which the team included one chainsaw-man, two chainsaw-man assistants, one supplier and a machine deriver. The harvested volume and the number of trees were 1600 m^3 and 311, respectively.

The used equipment included a rubber-tired skidder, a tracked skidder, a tractor and GMC machines. In this study, common project planning methods such as the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) were used (Sadri and Sakaki, 2004). Different tasks as being specific to forest operations are shown in the Table 1.

Table 1

Tasks taken into study

No.	Code	Activity	No.	Code	Activity
1	A1	Workers' safety tools and provision of work tools	23	C6	Marking logs and cut waste
2	A2	Workers' planning	24	C0	Volume re-measurement
3	A3	Official request for sending out the tree marking team	25	D1	Official administration procedures, reporting volume re-measurement proceedings to administrator
4	A4	Sending out the administrative tree marking team to determine the harvesTable volume	26	D2	Determining the contractor and providing tender offer time
5	A5	Presentation time of tree marking team	27	D3	Provision of bucking license
6	A6	Adjusting the marking documents	28	D4	Providing the equipment
7	A7	Going through official administration procedures	29	D5	Workers' planning
8	A8	Going through official procedures	30	D0	Bucking
9	A9	Issuance of cutting license	31	E1	Adjusting the bucking proceedings
10	A10	Cutting permission	32	E2	Reporting the proceedings to the administrator
11	A11	Tender offer time	33	E3	Providing the tools
12	A12	Determining the contractor	34	E0	Extraction
13	A0	Tree cutting	35	F1	Providing the machines
14	B1	Determination of skid trails	36	F2	Personnel
15	B2	Map surveying	37	F0	Primary transportation
16	B3	Constructing the trails in the field	38	G0	Sales and marketing
17	B0	Mapping	39	H1	Temporary storage at landing
18	C1	Reporting cutting to the administrator	40	H0	Loading
19	C2	Providing operation team equipment	41	I1	Providing the personnel and equipment
20	C3	Mission tab	42	I2	Issuance of transportation permission
21	C4	Providing vehicles	43	I0	Secondary transportation
22	C5	Landowner's share payment			

2.2. Solving the Question Using CPM Parameter in QSB Software

In QSB software, input data were completed by “SELECT CPM DATA FIELD” option and then by solving the question in CPM environment. The next step used the outputs of critical path program such as the earliest start time and the latest start time to calculate the earliest finish time and the latest finish time.

2.3. Solving the Question Using PERT Parameter in QSB Software

To solve the problem by using the PERT parameter and to estimate the required time for each activity, a random variable with possibility of distribution is considered in order to measure the expected time for each activity through a certain formula.

Optimistic estimate is shown as an “*a*” which is the least time needed for each activity; when everything would have been done fully and on time, it would come true. This is the lower limit of the possibility distribution.

The most possible estimation is shown as “*m*”. It suggests the time needed for each activity under a normal condition and it is the top of possibility distribution.

Pessimistic estimate shown as “*b*” suggests the time needed for each activity under the most unfavorable condition and it is the highest limit of possibility distribution. Thus, the time needed or the time mathematical expectation (*t*) of a project assumes that the time needed for each activity is a random variable with a normal $\beta\beta$ distribution (Formulas 1 and 2).

$$t = \frac{a+4(m)+ba+4\,(m)+b}{6} \qquad (1)$$

Standard deviation:

$$SD = \frac{b-ab-a}{6\quad 6}\,\frac{b-ab-a}{6\quad 6} \qquad (2)$$

The project costs under the assumptions of normal and critical states were mentioned in Table 2. The needed triple time for PERT model is proposed, as well.

Table 2

Utilization project costs (in short)

Activity Code	Optimistic time (days)	The most Possible time (days)	Pessimistic time (days)	Normal cost (Dollar)	Prerequisite activity
A1	4	4	4	250	-
A2	1	1	1		-
A3	2	2	2		-
A4	10	15	20		A3
A5	8	15	20	300	-
A6	4	5	10		A4
A7	5	7	10		A6
A8	15	15	25		A7
A9	10	15	20	12.5	A8
A10	2	2	2		A9
A11	10	20	30	12.5	-
A12	1	2	3		A11
A0	20	20	30	237.5	A10
B1	5	5	7	10	A0
B2	3	3	3	50	B1
B3	30	50	70	2500	B2

3. Results

3.1. CPM Model Results

Results of this model include inputs of CPM model that have been analyzed in a normal time frame. The inputs of CPM model are shown in Table 1. Data analysis in terms of normal time is given in Table 3. As shown, finishing time and the number of critical paths have been estimated to 229 days and 3, respectively. There are 43 key activities in Table 3 which have their own analysis.

For instance, activity number 1 (A1) includes workers’ safety tools and provision of work tools. A1 is not considered as being a critical activity since it is the activity that triggers the following events and activities.

On the other hand, as it is a kind of activity which does not need any prerequisites, the earliest start time cannot be the same as the project start time. The earliest finish time of activity 1 has been considered to be of 4 days since it does not need any prerequisites. Therefore, the latest finish time of this activity has been considered to be 4 days before finishing the activity or the 225th working day. Accordingly, the latest finish time is the last day of the project *i.e.* the 229th working day. Hence, the time interspace of this activity is 225 days.

more concentration since if one of these is carried out with delay, it will affect the project. The path which the mentioned activities are placed on is the critical path and managers should give it special attention. In this procedure, the time required for activity A4 includes 15 days. As its prerequisite activity is activity A3 and also its earliest finish time is 2 days, the earliest start time for activity A4 is 17 days. Also, the earliest finish time and the latest finish time are 2 and 17 days, respectively. Finally, the interspace of this activity is considered 0 which is the result of the subtraction of the latest start time from the earliest start time. Analysis of activities A3, A4, A6, A7, A8, A9, A10, A0, C1, C3, C6, C0, D3, D0, E1 and E2 are interpreted in the same way. The critical path of finished activities is shown in Figure 1. In this study, three critical paths for the forest utilization operations were taken into software analysis (Table 4). The critical path No. 1 includes critical activities A3, A4, A6, A7, A8, A9, A10, A0, C1, C3, C6, C0, D3, D0, E1 and E2. The critical path No. 2 consists of critical activities A3, A4, A6, A7, A8, A9, A10, A0, C1, C3, D0, E1 and E2. The critical No. 3 includes critical activities A3, A4, A6, A7, A8, A9, A10, A0, C0, D3, D0, E1 and E2.

Table 3

Analysis of CPM model inputs (in short)

Analysis of Forest Utilization (using normal time)								
No.	Activity Code	Critical path	Average time	The first start	The first finish	The last finish	The last start	The first start - the last start
1	A1	No	4	0	4	229	225	225
2	A2„	No	1	0	1	229	228	228
3	A3	Yes	2	0	2	2	0	0
4	A4	Yes	15	2	17	17	2	0
5	A5	No	15	0	15	229	214	214
6	A6	Yes	5	17	22	22	17	0
7	A7	Yes	7	22	29	29	22	0
8	A8	Yes	15	229	44	44	29	0
9	A9	Yes	15	44	59	59	44	0
10	A10	Yes	2	59	61	61	59	0
11	A11	No	20	0	20	227	207	207
12	A12	No	2	20	22	229	227	207
13	A0	Yes	20	61	81	81	61	0
14	B1	No	5	81	86	220	215	134
15	B2	No	3	86	89	223	220	134
16	B3	No	3	89	92	226	223	134

Project finishing time: 229 days.
Total cost: 31827.5$ (cost of critical path: 1887.5$).
No. of critical paths: 3.

Activity A3 is the starting point of the critical path. Interpretation of activities 2, 5, 11, 12, 14, 15, 16, 17, 19, 21, 22, 25, 26, 28, 29, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42 and 43 are the same as activity 1 since these ones do not need a prerequisite activity, so they could be carried out while other activities are ongoing. Since A3 (Official request for sending out the tree marking team) is the start point of the critical path, it is essential to start and finish at the considered time, because any gaps in work could disturb the working procedures. Critical activities include A3, A4, A6, A7, A8, A9, A10, A0, C1, C3, C6, C0, D3, D0, E1 and E2. Their interspace is equal to 0 and they require

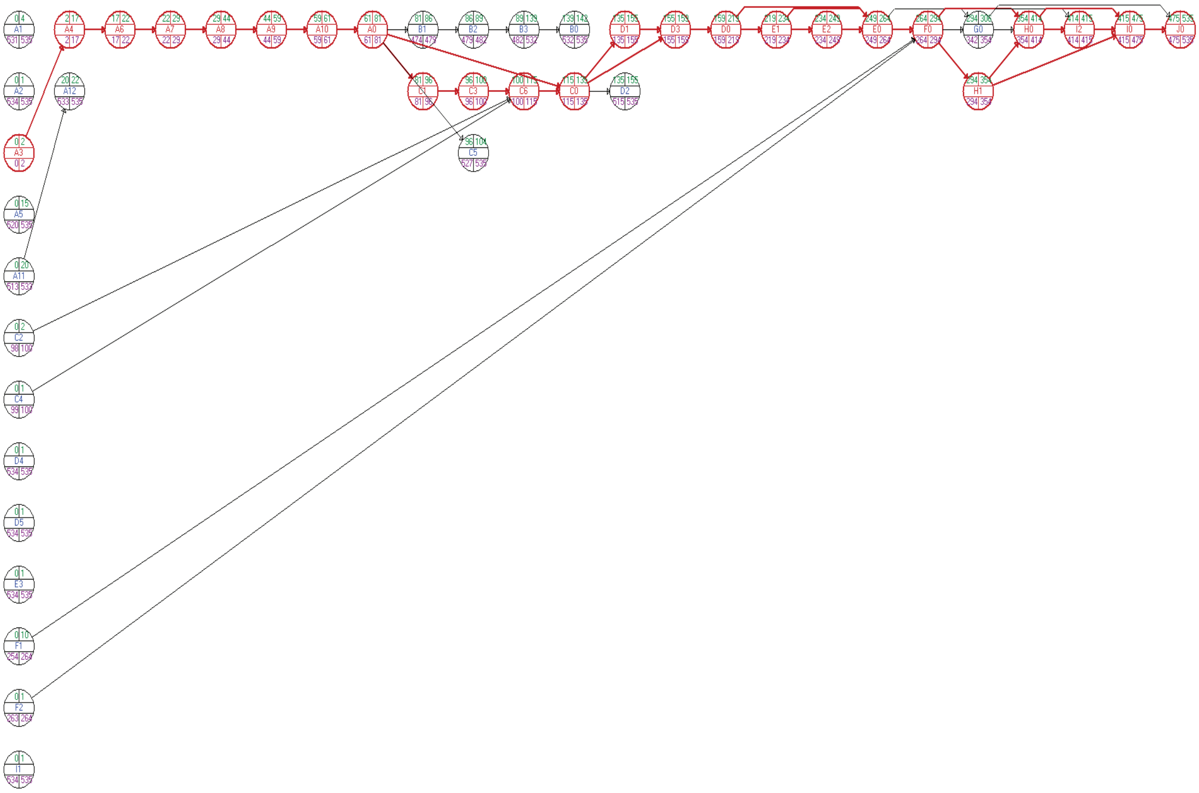

Fig. 1. Forest utilization project network with 43 activities.

Table 4

Critical paths of forest utilization in CPM (in short)

Critical Paths of Forest Utilization (using Normal Time)			
No.	Critical Path 1	Critical Path 2	Critical Path 3
1	A3	A3	A3
2	A4	A4	A4
3	A6	A6	A6
4	A7	A7	A7
5	A8	A8	A8
6	A9	A9	A9
7	A10	A10	A10
8	A0	A0	A0
9	C1	C1	C0
10	C3	D3	D3
11	C6	D0	D0
12	C0	E1	E1
Project finish time: 229 days	Project finish time: 229 days	Project finish time: 229 days	Project finish time: 229 days
Project total cost: 31827.5$ (cost of critical path: 1887.5$)			
No. of critical path: 3			

3.2. Results of PERT Model

Primary data include prerequisite activities, the most optimistic time of each activity, the most pessimistic time of each activity and the most probable time of each activity. These figures are shown in Table 5. The input data, activity time, the earliest start time, the latest finish time, the earliest start time, the latest start time and inter-space time were calculated using the critical path software while analyzing the data. The project finish time and the number of critical paths were estimated to 229 and 3 respectively, as shown in Table 6.

Regarding the available data, the critical path network for the PERT model was provided using the interest software (Figure 2). Critical activities and critical paths are presented in Table 7.

Table 5

Primary inputs of PERT model (in short)

No.	Activity Code	Pessimistic time (b)	The most possible time (m)	Optimistic time (a)	Immediate Predecessor
1	A1	5	4	4	
2	A2	1	1	1	
3	A3	2	2	2	
4	A4	15	15	15	A3
5	A5	15	15	15	
6	A6	5	5	5	A4
7	A7	7	7	7	A6
8	A8	15	15	15	A7
9	A9	15	15	15	A8
10	A10	2	2	2	A9
11	A11	20	20	20	
12	A12	2	2	2	A11
13	A0	20	20	20	A10
14	B1	5	5	5	A0
15	B2	3	3	3	B1
16	B3	3	3	3	B2

Table 6

Analysis of PERT model inputs (in short)

No.	Activity Code	On critical path	Average time	First start	First finish	Last start	Last finish	First start-last start	Time scattering	SD
1	A1	No	4	0	4	225	229	225	3-time estimate	0
2	A2	No	1	0	1	228	229	228	3-time estimate	0
3	A3	Yes	2	0	2	0	2	0	3-time estimate	0
4	A4	Yes	15	2	17	2	17	0	3-time estimate	0
5	A5	No	15	0	15	214	229	214	3-time estimate	0
6	A6	Yes	5	17	22	17	22	0	3-time estimate	0
7	A7	Yes	7	22	29	22	29	0	3-time estimate	0
8	A8	Yes	15	29	44	29	44	0	3-time estimate	0
9	A9	Yes	15	44	59	44	59	0	3-time estimate	0
10	A10	Yes	2	59	61	59	61	0	3-time estimate	0
11	A11	No	20	0	20	207	227	207	3-time estimate	0
12	A12	No	2	20	22	227	29	207	3-time estimate	0

Project finish time: 229 days

Number of critical path: 3

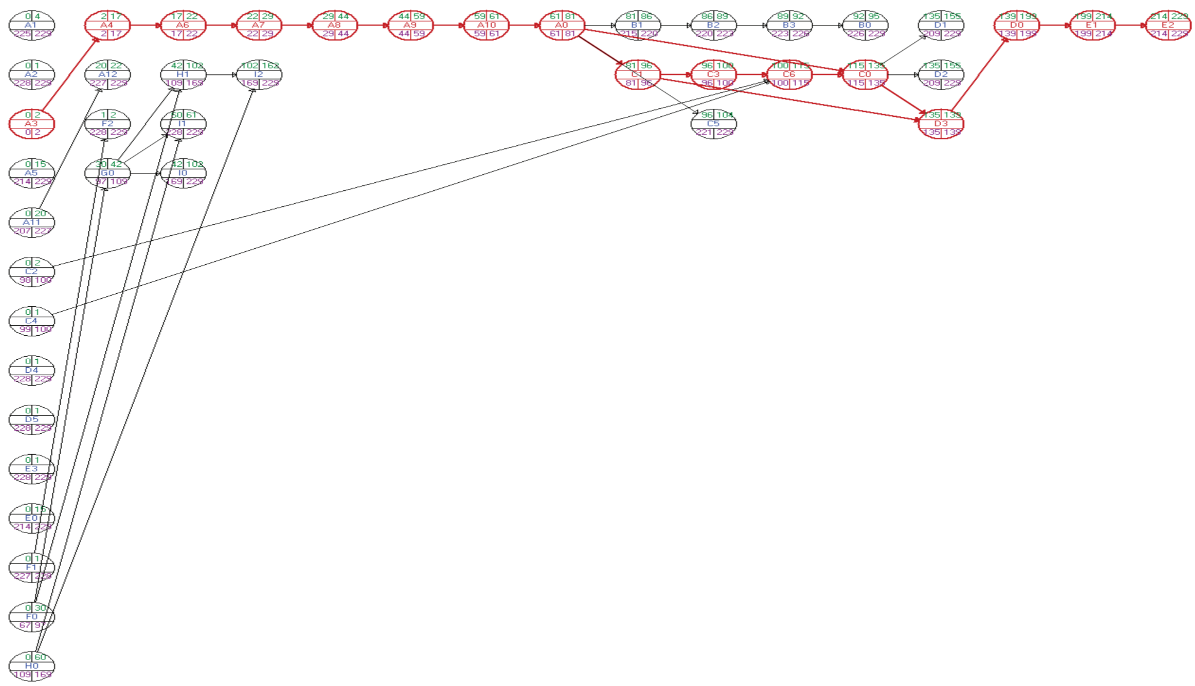

Fig. 2, PERT model network

Table 7

Forest utilization critical paths in PERT

Forest Utilization Critical Paths			
No.	Critical Path 1	Critical Path 2	Critical Path 3
1	A3	A3	A3
2	A4	A4	A4
3	A6	A6	A6
4	A7	A7	A7
5	A8	A8	A8
6	A9	A9	A9
7	A10	A10	A10
8	A0	A0	A0
9	C1	C1	C0
10	C3	D3	D3
11	C6	D0	D0
12	C0	E1	E1
13	D3	E2	E2
14	D0		
15	E1		
16	E2		
Finish time:	229	229	229
SD:	0	0	0

4.Discussion

According to the analysis of CPM, the calculated time and cost were 229 days and 31827.5$, respectively, out of which 1887.5$ were allocated to the critical path. The used software provides this capability enabling this way the development of various projects based on time allocation.

The favorable time for the project studied herein was considered to be 240 days. Based on input data and on those 240 days, the possibility percentage of activities was calculated as 100%, since the normal time in this case was of 229 days.

Using the methods presented herein, it is possible to save money and time. For instance, the time could be reduced by 29 days while the costs could be reduced by 90$. Also, the proposed time (200 days) of input data has been reduced to 198 days. Moreover, the project total cost in this case was of 31737.5$.

Using PERT, the project total time was set to 229 days which included three critical paths, and similar to the CPM, it used critical activities in terms of priority. According to this model, all of the critical activities will finish in 229 days. In the simulation part of PERT, when using the functionality "*use default random seed*", the project favorable time was considered to be 200 days. This simulation has been evaluated by considering 1000 activities.

This study revealed that the forest utilization operations in terms of cost and time could be managed using PERT and CPM approaches, eventually resulting in operational improvements by favorable effects associated with efficiency increments. In addition, by using these management methods, we could identify and avoid barriers during the work procedures.

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Majid LOTFALIAN
Associate Professor, Forestry Department, Sari University of Agricultural Sciences and Natural Resources,
mlotfalian@sanru.ac.ir

Mahboobe SABZI
M.Sc. graduated, Sari University of Agricultural Sciences and Natural Resources,
sabzi_mahbobeh@yahoo.com

Ali Hosseini YEKANI, * Corresponding author
Assistant Professor, Department of Agricultural Economics,
Sari University of Agricultural Sciences and Natural Resources,
s.a.hosseini@sanru.ac.ir

Saba PEIROV
PhD student, Forest engineering, Sari University of Agricultural Sciences and Natural Resources,
peyrovsaba@gmail.com

Application of PERT & CPM for Forest Utilization Planning

Abstract

This study was carried out in order to test the applicability of PERT and CPM in forest utilization planning of Darab-Kola forests. Firstly, the logging data of one cycle was collected and it was then processed and prioritized. Then, the software inputs were determined. In the next stage, we ran the inputs in QSB software to obtain simulation results. Data analysis showed that a duration of 229 days needed as a normal time to complete the project can be reduced to 171 days using an appropriate management so that the quality of work would remain the same. However, by using the traditional path of utilization, it takes much more time than that estimated. Accordingly, the project costs increase, an effect that can be properly managed by an accurate logging planning. This study suggests that the time and costs of forest utilization operations could be managed using PERT and CPM to obtain an appropriate outcome, by applying them in order to improve the work as well. Application of the above-mentioned methods could have a favorable effect on increasing the efficiency of production. Moreover, such management methods can identify and remove the bottlenecks on the pathway of forest utilization.

Keywords: QSB, forest utilization, critical activities, wood extraction

Utilizarea PERT și CPM în planificarea operațiilor forestiere

Rezumat

Studiul de față s-a realizat pentru a se testa aplicabilitatea tehnicilor PERT și CPM în planificarea operațiilor forestiere pentru un studiu de caz aplicat zonei forestiere Darab-Kola. În primul rând, s-au colectat date pentru un ciclu de recoltare, date care s-au utilizat pentru procesare și prioritizarea activităților. Apoi, s-au determinat intrările necesare pentru prelucrarea asistată de calculator a datelor în programul QSB în vederea obținerii rezultatelor simulării. Analiza datelor a pus în evidență o durată de 229 zile necesare ca durată normală de timp pentru completarea proiectului, durată ce poate fi redusă la 171 zile prin utilizarea unui management adecvat, astfel încât calitatea prestării muncii să rămână aceeași. Cu toate acestea, utilizarea căii tradiționale de implementare a operațiilor forestiere necesită mai mult timp comparativ cu cel estimat cu efecte în creșterea costurilor, efecte ce pot fi controlate printr-o planificare adecvată a operațiilor de recoltare a lemnului. Studiul de față sugerează că timpul și costurile asociate cu operațiile de recoltare ar putea fi gestionate utilizându-se tehnicile PERT și CPM pentru a obține rezultate adecvate, ca și prin aplicarea acestora pentru îmbunătățirea muncii. Aplicarea metodelor descrise ar putea să aibă un efect favorabil în creșterea eficienței producției. Mai mult, astfel de metode de management pot identifica și elimina problemele ce apar în astfel de procese.

Cuvinte cheie: QSB, operații forestiere, activități critice, exploatarea lemnului.

Map of Stone Quarries and Gravel Pits in Romania: Possibilities to Use the Materials in Forest Road Construction

Iulian Mihai NENU

1. Introduction

Natural aggregates can be divided in two major categories: above or near ground surface rock deposits that can be crushed, and deposits of sand and gravel respectively (Fodor, 2011). Although they are considered to be the most abundant natural resources and even if they are characterized as low-value resources, when opening an extraction site, whether it is a stone quarry or a gravel pit, several factors have to be considered as follows: the quality of the aggregates, the available quantity, the location relative to the recipient, the environmental impact and the existing legislation and regulations (Knepper *et al.*, 1995).

Natural aggregates, consisting of crushed stone, sand and gravel, are the most abundant natural resources on the planet (Bleischwith and Bahn-Walkowiak, 2006). Nevertheless, they cannot be considered as never-ending resources. Consumption of natural aggregates has increased significantly in the last century as it has been related to the industrial development all over the globe. Such resources are particularly used when building houses, industrial facilities and public spaces or to develop and maintain infrastructure (***, 2011), consisting of railways, public transportation and special use roads including here forest, agriculture and industrial roads.

Romania is located in Central East Europe and has a total surface of 237 500 km^2 being characterized by a highly complex geological structure. According to Fodor (2011) most of the territory is part of Alpine Orogen, covering all of the major landscape forms such as young mountains, hills, plateaus and plains. Such a geological structure offers, beside solid fuel (coal), iron ore and other minerals a great variety of useful rocks (Table 1). The available deposits can be divided in three large categories: magmatic rocks, sedimentary rocks and metamorphic rocks.

Requirements of natural aggregates in many industrial sectors have increased the number of extraction sites that can be divided into two major categories: quarries and gravel pits. In 2005-2006 there was a number of approximately 440 sites in Romania (Bohmer *et al.*, 2007), excavating a total of 23 million tons of natural raw aggregates. From these, gravel pits were used to extract approximately 15.5 million of tons while the rest of 6.5 million of tons were extracted from quarries. Currently there are registered almost 1000 extraction sites (***, 2017).

Table 1

Types of rock deposits available in Romania. Source: Fodor (2011)

Rock type	Mechanical Proprieties				
	ρ*104 [N/m3]	c [%]	σ_{rC}*10-1 [Mpa]	σ_{sm} [daNcm /cm^2]	σ_{uf} [g / cm^2]
Andesite	2.30 / 2.65	80/ 98	700 / 2500	3/100	0.02 / 0.4
Dacite	2.30 / 2.83	88/ 96	1300 / 2000	5.1/72	0.1 / 0.3
Granit	2.30 / 2.90	92/ 98	1200 / 2800	30/65	0.2
Granodiorite	2.30 / 2.90	92 / 95	1200 / 2800	25/65	0.01 / 0.3
Basalt	2.50 / 3.2	95 / 97	2500 / 3500	15/50	0.05 / 1.5
Diabase	2.50 / 3.7	95 / 97	2200 / 3000	15/50	0.05 / 1.5
Hone	1.90 / 3.70	88 / 98	400 / 2500	40/90	0.1 / 0.5
Limestone	1.4 / 2.8	80 / 97	500 / 1500	2.6/33	0.33 / 0.57

Note: ρ - density, c - compaction rate, σ_{rC} - breaking strength in dried state condition, σ_{sm} - strength to mechanical shock, σ_{uf} - wearing resistance during friction.

Paved forest roads are the most common option in forest transportation systems. At the same time, natural aggregates are commonly used as construction materials on the entire life span of the forest roads (Bereziuc, 1981). Although it is highly recommended to use the local materials to build forest roads as a way to lower the construction costs, the geological structure of a given construction site will not always allow such attempts. It is also more than likely for given construction sites not to find the necessary quantities or the required qualities of the need material. Furthermore, the local environmental impact generated by the extraction of the needed natural aggregates cannot be neglected, due to the fact that such activities may produce irreversible landscape changes.

In forest road design and construction, it is recommended to use quarry products when building the wearing and base course (Bereziuc *et al.*, 2009). More precisely, hard or medium-hard rocks such as the chopped stone (pavers, blocks, curbs) or crushed stone in different sizes or mixes of sizes (*e.g.* 40-63 mm) are to be used in the construction of mentioned layers. At the same time, the road design is often influenced by some parameters as being specific to a given area. Among them, are the climate as well as other geographic parameters including the available construction materials. Lack of given materials into a specific area, as well as the need to use adequate construction materials as a function of local climate, topography and transportation requirements often translates in the necessity to procure such materials from other places. Procurement costs depend to a great extent on the sourcing location, local market prices and the forecasted quantities and qualities. To manage and plan their production, logistics and costs, road-building practitioners need updated information including that related to the location of available resources. To this end, interactive maps showing the location, resource type and procurement costs are particularly helpful because they enable comparisons and best option analysis in the procurement of raw materials. For instance, the Romanian state forests are managed by the State Forest Administration - RNP Romsilva. At the end of 2014 they had in their administration a number of 7,752 forest roads developed on 26,055 km out of which about 9,068 km were not functional (Vișan, 2017) needing specific repairing and maintenance operations.

The goal of this paper was to develop a nation-wide interactive map showing the available resources such as the stone quarries and gravel pits and to enable route and cost calculation based on the routes taken into consideration in the procurement activities.

2. Materials and Methods

The aim of this study was to analyze and map all of the available sources of raw materials that could be used in road construction operations in a nation-wide attempt. A first step was that of developing a database containing the existing stone quarries and gravel pits in Romania. The developed database contains the name of the extraction source, type of rock, county and the name of company which owns the extraction license. Based on a satellite imagery analysis, the GPS coordinates of the extraction sources were obtained. Then, a map was developed using Google Maps ® - an open source platform - that enables the analysis as well as online publishing of maps. Different colors and layers were built and used to represent the stone quarries as a function of rock deposits identified in the previous step. For those users interested in a particular type of raw material, the application enables the activation and deactivation of layers. The developed map enables routing and distance calculation functions that can be used to determine the transportation distance between a given source and a forest road construction site. The map can be either used online or downloaded as a printable portable document format (*.PDF*) or as a *.KML* format that enables its use in more complex software for further analysis.

This paper concludes by a case study that demonstrates the functionality of the developed map. By choosing an existing location of a forest road, the distances from all nearby stone quarries were determined.

3. Results

Quarry products are obtained by dislocation and processing of massive rock located near or above the ground surface (Fodor, 2011). The products resulted after the processing operations have sharp edges and rough surfaces, generating internal friction between particles, making them suitable for the construction of a forest road. The locations of the stone quarries were related to the geo-morphological structure of Romania. Table 2 shows the number of stone quarries per county for each type of hard rock suitable for the development and maintenance of forest road infrastructure.

The most important stone quarries in Romania are located near the Carpathian Mountains as well as in the Dobrogea area (Southeastern Romania), where it can be found the oldest mountainous formation in the country. A sample of the map

Table 2

Number of quarry stone extraction licenses available in Romania. Source: NARM (2017)

County	A	D	G	GD	B	DB	H	L	T
Alba	3	1	-	-	-	-	1	-	5
Arad	1	-	-	-	1	3	-	1	6
Argeş	-	-	-	-	-	-	-	2	2
Bihor	-	-	-	1	-	-	4	4	9
Bistriţa-Năsăud	3	3	-	-	-	-	1	-	7
Braşov	-	-	-	-	2	-	1	-	3
Buzau	-	-	-	-	-	-	-	1	1
Caraş-Severin	1	1	2	-	-	-	-	2	6
Cluj	-	2	-	-	-	-	-	4	6
Constanţa	-	-	-	-	-	-	-	9	9
Covasna	2	-	-	-	-	-	-	-	2
Gorj	-	-	3	-	-	-	-	-	3
Harghita	11	-	-	-	-	-	-	-	11
Hunedoara	1	-	-	-	-	-	-	-	1
Maramureş	11	-	-	-	-	-	-	2	13
Mehedinţi	-	-	1	-	-	-	-	-	1
Mureş	1	-	-	-	-	-	-	-	1
Neamţ	-	-	-	-	-	-	2	-	2
Prahova	-	-	-	-	-	-	1	-	1
Sălaj	-	-	-	-	-	-	-	3	3
Satu-Mare	1	-	-	-	-	-	-	-	1
Suceava	2	-	-	-	-	-	5	3	10
Timiş	-	-	-	-	-	-	-	-	0
Tulcea	-	-	2	1	-	2	-	5	10
Total	37	7	8	2	3	5	15	36	113

Note: A - Andesite, D - Diorite, G - Granite, GD - Granodiorite, B - Basalt, DB - Diabase, H - Hone, L - Limestone, T - Total

developed in Google Maps is shown in Figure 1, giving an overview of the source locations. At the moment, there were mapped 75 from the total of 113 identified stone quarries.

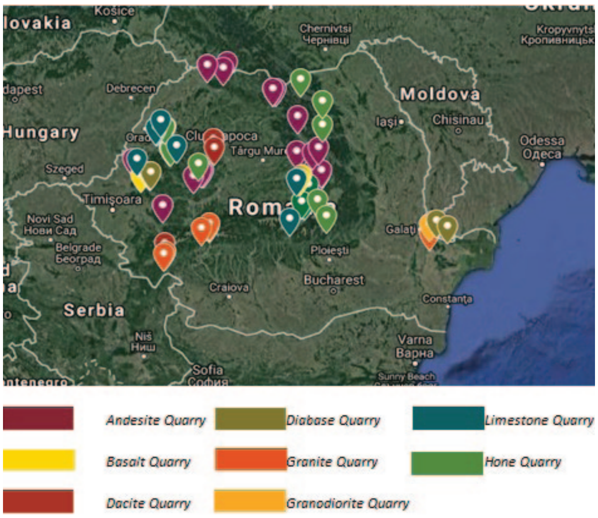

Fig. 1. Map of stone quarries

Gravel pits are large deposits of gravel and sand, usually located in riverbeds, near rivers or into lakes. The main characteristics of the gravel pit products are the round shapes, smooth surfaces and absence of sharper edges.

In relation to the construction and maintenance of forest road infrastructure, gravel pit products are used for concrete manufacturing, subgrade and in the case of low volume traffic roads and, in some cases, even for base course and wearing course if other materials are not available. Their rounded edges and smooth surfaces often result in a lack of friction and cohesion between the particles following the compaction process of the roads, which will subsequently lead to deformations of the road surface.

Due to the Romanian geological characteristics and to a rich hydrological network, gravel pits can be found all across the country in a higher number compared to stone quarries. Table 3 shows, for each county, the number of licenses released for gravel and sand extraction. Such resources are often located near the cities where there is a constant need of gravel or similar products. Another characteristic of such extraction sites is that they often change their location as the pits are depleted. From this point of view, keeping records on an interactive map becomes even more important.

In what concerns the utility of the developed interactive map, a case study was designed to demonstrate its capabilities and functionalities.

Table 3

Gravel Pits. Source: NARM (2017)

County	No of GP	County	No of GP
Alba	49	Harghita	12
Arad	17	Hunedoara	25
Argeș	27	Ialomița	2
Bacău	23	Iași	15
Bihor	25	Ilfov	2
Bistrița-Năsăud	13	Maramureș	45
Botoșani	14	Mehedinți	15
Brașov	20	Mureș	28
Buzău	21	Neamț	28
Călărași	1	Olt	24
Caraș-Severin	5	Prahova	37
Cluj	26	Sălaj	16
Constanța	7	Satu-Mare	16
Covasna	5	Sibiu	21
Dâmbovița	34	Suceava	38
Dolj	8	Teleorman	2
Galați	9	Timiș	19
Giurgiu	22	Vâlcea	23
Gorj	26	Vrancea	21
		Total	741

Figure 2 presents a simulation of distance calculation for a specific point, marked by the user on the map and considered as being a construction site. For convenience, a forest road located near Zărnești city (Brașov County) was taken into consideration. As potential supply sources, 3 of the closest raw material extraction sites were considered for routing analysis as follows: B - Vad 1 (gravel and sand - 28 km), C - Mateiaș Sud Quarry (limestone - 78 km) and D - Valea Stânii (basalt - 96 km).

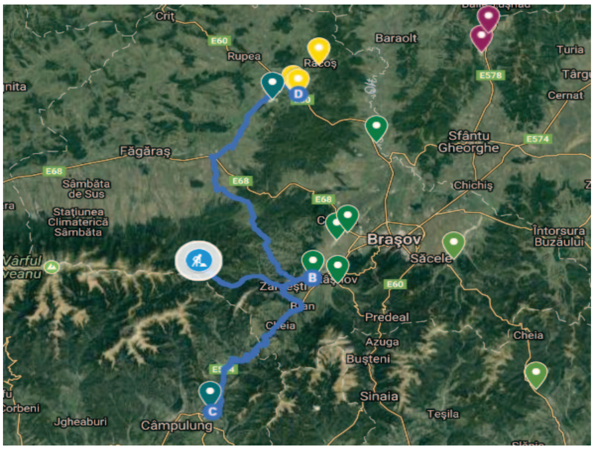

Fig. 3. A case study of sourcing and raw material transport routing

Distances were calculated using the public road network up to the center of Zărnești city. From there, all of the 3 supply routes merged into a common road segment (route) of 23 km up to the construction site. Although the closest source is the gravel pit (B), such materials were not considered as a viable solution for cover layers.

A comparison was carried out by considering the two closest quarries (Table 4), namely Mateiaș Sud Quarry (C) and Valea Stânii Quarry (D). The analysis was done to evaluate the number of loads needed to cover a given quantity of material, as well as the number of kilometers to be covered in the transportation between the source of origin and the construction site. To this end, the average rock density, a 24t truck and the volume of 1000 m^3 of crushed rock were considered as parameters.

Table 4: Analysis of scenarios. Sourcing of raw material

Location	Valea Stânii (B)	Mateiaș Sud (C)
Distance (km)	96	78
Rock type	Basalt	Limestone
Material Density (t/m3)	2.85	2.10
Required supply (m3)	1000	1000
Truck capacity (t)	24	
Truck load (m3)	8.42	11.43
No of required loads	119	88
Kilometers covered*	11400	6825

In order to enhance the functionalities given by the map, one can use the density for each type of rock as well as reference trucks used for transportation to derive and estimate the fuel consumption and the costs related to material procurement. Also, the fuel consumption may be further used to estimate the direct energy inputs and environmental burdens associated with raw material procurement for construction of forest roads. In order to be able to obtain accurate results, elevation data of each produced track should be analyzed also because it is influencing the fuel consumption, therefore the best provisioning routes.

In the analyzed scenarios, the number of covered kilometers was lower in the second option both, due to the material density and distance. On the other hand, this option needs transportation of material over the Carpathian Mountains a fact that could be negatively reflected into the costs as an effect of the route topography, even if the distance is shorter. However, this study was designed only to give a tool for material routing and distance calculation. As mentioned before, such data can be exported and the best options could be explored based on detailed analyses using external software.

4. Conclusions

Distance from the source of raw materials plays a key role in the procurement of materials needed into the forest road construction activities. Furthermore, the density of procured materials affects the procurement activities due to the fact that public transport limits the weight of trucks to 40t including here the transported load. As a large volume of natural aggregates are used for each forest road project, each technical detail could play an important role in establishing the best provisioning source.

An interactive map with the stone quarries and gravel pits as specific to Romania could help and guide practitioners in the procurement process of natural aggregates. Being an open source (and public) map, it could be updated to cope with the dynamics of some of the procurement sources, enabling this way a reliable support for practitioners.

The developed map was focused more on the existing stone quarries and less on the gravel pits. However, all of the existing gravel pits were identified and the contact information was included into the database.

Furthermore, the methodology proposed in this paper could be developed further by integration into a web portal. Such an attempt could result in the provision of more details on the sourcing and procurement of raw materials as well as a more detailed map including those routes able to provide significant savings in terms of time, fuel and money.

Acknowledgements

The author would like to thank the Romanian National Agency of Natural Resources for the support given and their guidance in the procurement of data needed to build the database and the map. Also, the author would like to thank Prof.dr.eng. Stelian Alexandru Borz for his advice and suggestions related to this paper, as well as to the Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, Faculty of Silviculture and Forest Engineering, Transilvania University of Brașov for support and logistics needed in the development of this study. This paper is also supported by the PhD School of the Transilvania University of Brașov.

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Eng. Iulian-Mihai NENU
Faculty of Silviculture and Forest Engineering, Department of Forest Engineering, Forest Management Planning and Terrestrial Measurements, *Transilvania* University of Brașov
iulian.nenu@yahoo.com

Map of Stone Quarries and Gravel Pits in Romania: Possibilities to Use the Materials in Forest Road Construction

Abstract

As products of stone quarries or gravel pits, natural aggregates such as the crushed stone and gravel are essential components in the construction of forest roads. Nevertheless, the road system choice is influenced by the types of local or nearby existing material. At the same time, both in terms of economics and labor the road systems have a significant share in the construction of a forest road and the choice of material sources should be done carefully. This study aimed to identify, classify and map all of the Romanian stone quarries and gravel pits to provide a spatial database containing the existing sources of supply for the development, maintenance and rehabilitation of the forest road infrastructure in Romania. The developed database allows the analysis, in a sustainable approach, of technical and economic, social and ecological drivers, by offering the possibility of running various scenarios to provide comparative results between the effects of extracting natural aggregates on site or to source them from quarries or gravel pits existing nearby.

Keywords: forest roads, spatial database, natural aggregates, quarry, gravel pit.

Hartă interactivă a carierelor de piatră și a balastierelor din România: Posibilități de utilizare a materialelor în construcția de drumuri forestiere

Rezumat

Agregatele naturale, cum ar fi piatra spartă și balastul, sunt materiale esențiale în construirea de drumuri forestiere. Cu toate acestea, în multe cazuri, alegerea sistemelor rutiere este influențată de tipurile de materiale existente la nivel local sau în apropiere. În același timp, sistemele rutiere au o pondere semnificativă în construcția unui drum forestier în ceea ce privește economia și forța de muncă, iar alegerea surselor de materiale ar trebui făcută cu atenție. Acest studiu a urmărit identificarea, clasificarea și cartografierea tuturor carierelor de piatră și a balastierelor din România pentru a furniza o bază de date spațiale care să conțină sursele de aprovizionare existente pentru dezvoltarea, întreținerea și reabilitarea infrastructurii rutiere forestiere din România. Baza de date dezvoltată permite analiza, într-o abordare sustenabilă, a factorilor tehnici și economici, sociali și ecologici, prin oferirea posibilității de a analiza diverse scenarii pentru a furniza rezultate comparative între efectele extragerii agregatelor naturale locale și cele specifice extragerii din cariere sau balastiere existente în apropiere.

Cuvinte cheie: drumuri forestiere, bază de date spațială, agregate naturale, carieră de piatră, balastieră