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Content

DYNAMIC SIMULATION OF BIOENERGY FACILITY LOCATIONS IN GIS ENVIRONMENT

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Abstract: *The targets of reducing fossil based energy sources and replacing them with renewables have increased the interest towards new bioenergy and biorefining facilities. Typically, new facilities have been installed in regions with sufficient availability of feedstock. There are several static analysis approaches that can be used for optimizing the location of the installation but, however, they usually exclude the dynamic elements of supply, demand, and logistics. An agent-based simulation model was developed to account for the dynamic features of feedstock logistics, including the large variation of supply and demand over time. The method enables studying the costs of feedstock procurement and the need for workforce, machinery, transport fleet and storage capacities. The model collects its feedstock data from a geographical information system (GIS), covering 36 countries in Europe. This data includes the annual availability and the estimated roadside storage price for the material. The results from the model are highly theoretical. As the model only uses pre-selected locations and does not include optimization, it is highly recommended to use some static GIS-analysis to create the population of alternative locations for the simulation runs. The model provides a cost-efficient method to study and compare the geographical properties of biomass logistics, and it can be utilized to get more information to support decision making.*

Keywords: forest biomass, agent-based modeling (ABM), logistics, optimization

IN-FOREST DEBARKING OF RADIATA PINE TO IMPROVE SUPPLY CHAIN EFFICIENCY IN AUSTRALIA AND NEW ZEALAND: EFFECT OF HARVESTING SEASON, SYSTEM AND EQUIPMENT

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Abstract: *Depending on the point of view of the participants in the forest-to-customer supply chain, the presence of bark can be considered as either a benefit or a cost. Understanding which factors affect bark removal should help with managing bark quantities, and the design of harvesting systems and equipment. Over 4000 stems and logs in 11 studies were measured in Australia and New Zealand using digital photos and a line intercept method to determine the amount of bark removed during normal operations. Among other things, we have been able to show that bark removal is greater in spring than winter, with tree-length systems than cut-to-length systems, and with mechanized processing rather than manual processing systems. We were also able to show that the greatest portion of bark removal occurs during felling and extraction with tree-length operations, with a small proportion occurring during delimbing and bucking. There was limited and weak evidence that bark removal may differ with location on pine stems. Finally, we were able to show that the number of knives on a processor head can affect bark removal, although we would recommend that further research be carried out on this topic, since the results ran counter to expectations.*

Keywords: in-forest debarking, radiata pine, forest supply chain, harvesting systems and equipment

DESIGN AND IMPLEMENTATION OF AN INTEGRATED TRANSPORT FRAMEWORK SYSTEM TO OPTIMIZE TIMBER AND BIOMASS SUPPLY LOGISTICS: A CASE STUDY IN ASTURIAS, SPAIN

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Abstract: *Transport accounts for up to 50% of the costs of supplying roundwood and biomass from the forests to consumption centers, which means several million of dollars annually for the forest industry worldwide. This level of expenditure makes it essential to apply optimization tools to plan and implement timber and biomass transport operations efficiently. In this study, we designed and implemented an integrated transport framework comprising two optimization tools. The first tool called MCPLAN implements a linear programming model, allowing optimal monthly harvest scheduling, transport flows from the forest to consumption centres, and drying time of logs and biomass in the forest. The second tool called FastTRUCK implements a Simulated Annealing algorithm, allowing daily optimal scheduling and routing of a fleet of trucks at a minimum cost. Our integrated transport framework was tested in a case study in Asturias, Spain under three scenarios, including a) the drying of logs and biomass before transport to the consumption center, b) transport without drying, and c) drying with volumetric (logs) and content of organic matter (biomass) losses. Our results indicate that the application of the integrated transport framework can potentially reduce fleet size by 15-20%, and transport costs by \$2-3 / m^3.*

Keywords: transport optimization, timber and biomass logistics, logs and biomass drying, linear programming, simulated annealing

AUTOMATED VOLUMETRIC MEASUREMENT OF TRUCKLOADS THROUGH MULTI-VIEW PHOTOGRAMMETRY AND 3D IMAGE PROCESSING SOFTWARE

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Abstract: *Given that wood represents on average about 1/3 of the delivered cost, it is key to adopt correct measurement procedures and technologies that provide better wood volume estimates. Poor measurements not only impact the revenue obtained by haulage contractors and forest companies but also might affect their contractual business relationship. Although laser scanning has become a mature and more affordable technology in the forestry domain, it remains expensive to adopt and implement in some real-life operations. In this study, multi-view photogrammetry and commercial 3D image processing software were tested as an innovative and alternative method for automated volumetric measurement of truckloads. Multi-view 3D reconstruction is an inexpensive, effective, flexible, and user-friendly photogrammetric technique for obtaining high-resolution datasets of complex topographies at different scales. According to the results obtained in the study, about 76% of the variation of the solid volume was explained by the frame volume calculated from Multiview 3D reconstruction. This preliminary test shows promising results for the future implementation of this approach in real life operations, and more tests will be conducted to validate the proposed approach.*

Keywords: volumetric measurements, multi-view photogrammetry, 3D image reconstruction, truckloads

MODELING A SKIDDING OPERATION CONSIDERING RUT DEPTH CAUSED BY A RUBBER-TIRED SKIDDER

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Abstract: *Highly mechanized ground-based logging operations are more productive, environmentally friendly, and safer comparing with traditional logging operations. However, if they are not planned and implemented properly, ground-based equipment potentially causes serious damages on forest ecosystem, especially on forest soil. The common indicator of the impact of the logging equipment on soils is the rut depth caused by logging machinery after each tire passage. Ruth depth may cause operational problems such as machine downtime, relocation of operations, extra stockpiling cost, and reduction in timber quality. In order to overcome these problems, potential rut depth generated by harvesting equipment must be carefully estimated prior to harvesting system planning. In this study, a model was developed to plan skidding operation by considering the rut depth resulted from a rubber-tired skidder. Optimum transportation plan was searched based on road spacing, skidding trail spacing, load capacity, and tire pressures. The capability of the model was examined in a sample skidding operation taken place in Brutian pine (Pinus brutia) stands in the city of Çanakkale in Turkey. In harvesting operation, trees were cut by a feller-buncher and then transported to landing area by a Tigercat skidder. The results indicated that the model can be effectively used to evaluate the alternative transportation plans and choose optimum choice based on specified decision variables.*

Keywords: mechanized harvesting, skidding, rut depth, vehicle mobility

DEVELOPING PRIMER TRANSPORTATION PLAN FOR FORESTED AREAS UNDER THE RISK OF WINTER STORM DAMAGE

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Abstract: *Abiotic and biotic factors cause biological and ecological damages on forest ecosystem which leads to long term impacts on sustainability of forest resources. The most detrimental abiotic factors include forest fires, winter storms, snow damages, avalanches, and drought. In last few years, winter storms have resulted in serious effects on forested areas in western regions of Turkey. The severity of storm damage generally depends on stand structures, topographical characteristics, climatic parameters, soil types, and soil depth. In order to minimize negative effects of winter storms on forest resources, the areas with high storm damage risk should be determined, necessary strategies should be developed and integrated into forest management plans. In this study, it was aimed to produce risk map of winter storm damage by using advanced GIS techniques and develop primer timber transportation plan for the risky areas. The study area was selected from Kutahya Forest Regional Directorate where serious winter storm damage was encountered in winter of 2015. In order to conduct spatial analysis, digital database was constructed by generating digital layers for specified factors such as stand structures, ground slope, aspect, soil type, soil depth, wind speed and direction. Then, optimum primer transportation plan was developed by considering risk level of storm, terrain properties, and operational factors. Alternative logging methods included tractor skidding, cable logging, chute system, tractor winching, and portable winching. The results indicated that GIS techniques can be effectively used to generate risk map of winter storm damage.*

Keywords: storm damage, risk map, logging plans, primer transportation

CAPABILITIES OF USING DRONES IN MONITORING AND ASSESSMENT OF MECHANIZED HARVESTING OPERATIONS

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Abstract: *In recent years, drones have been utilized in many disciplines including geological studies, assessment of natural disaster, managements of forest resources, and 3D terrain modeling. It is possible to collect high resolution data with low cost by using recently produced high-tech drones. In this study, it was aimed to investigate capabilities of using drones in monitoring and assessment of mechanized harvesting operations. Phantom 3 was used to capture videos during logging operations performed in Brutian pine (Pinus brutia) stands in the Çanakkale, Turkey. In the field, trees were cut and processed by a harvester, and logs were transported to landing area by a skidder. The operation was recorded by the drone from the average altitude of 100 meters. Then, time spent on designated work stages (moving inhaul, loading, skidding outhaul, unloading) was computed based on video records to assess the skidding productivity. The log volume was also computed based on the records by considering reference objects (skidder, trucks, etc.) with known dimensions. The results suggested that drone technology potentially provides far better views and time data for implementing time study approach, comparing with traditional methods using chronometers or video cameras in the field. Even in windy days, the camera integrated with gimbal technology ensures smooth footages by taking out unwanted vibration in-flight. The downside is the flight duration of the drones which is limited by battery life (about 30 min). Thus, to capture sufficient number of cycles, flights should be scheduled according to operation and extra batteries must be available.*

Keywords: drones, mechanized harvesting, skidding, time study, productivity

SEASONAL VARIATION OF FOREST ROAD PAVEMENT COMPACTION

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Abstract: *Forest roads serve many different forestry activities such as logging, transportation etc. Different heavy vehicles operate on forest road to manage forestry activities. Therefore, so as to fulfill these functions, the pavement is an important component. In this regard, compaction and degradation in forest road play a fundamental role in the continuity of forestry activities. The aim of this study is the monitoring of the seasonal forest road pavement compaction ratios depending on traffic characteristics and meteorological effects. Our study was carried out on B type of forest road. The forest road is 630 m long and has 11 curves. Compaction ratio was measured with five points which are Side zone (SZ-2points), Rut Zone (RZ-2points) Center Zone (CZ-1points), on the cross section of the road axis with 10 meter intervals along the road. The compaction measurements were performed seasonally by using Eijkelkamp digital cone penetrometer as MPa from October 2015 to July 2016. Climate data were obtained from the weather station at the Istanbul University Green Roof Research Area. All data evaluation process was performed in ArcGIS geographic information system software. For each period, data were spatially interpolated and surface compaction models were created. According to mean compaction results, for curve sections were found as (SZ:0.76 MPa; CZ:2,62 MPa; RZ:2,60 MPa), for alignment sections were found as (SZ:0.97 MPa; CZ:2,66 MPa; RZ:2,74 MPa). Conclusion, it was revealed that compaction ratios were showed to seasonal fluctuations along road depending on traffic characteristics and meteorological effects.*

Keywords: penetration resistance, forest road, pavement

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EVALUATION OF UTILIZING UNMANNED AERIAL VEHICLE ON FOREST ROAD PLANNING AND DESIGN

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Abstract: *In forest road planning, determination of cut and fill volume with high accuracy is very crucial in computing the cost of road construction. Basically, volume calculation is estimated from topographic maps, which can be derived from field survey or photogrammetric methods. The accuracy in volume calculation shows variation from one another depending on preferred tools and methods. The main concept of this study is to evaluate capabilities of topographic map based Digital Elevation Model (DEM) versus Unmanned Air Vehicle (UAV) based DEM in estimation of earthwork volume in forest road design. In the study, 850 meters of forest road with 4-meter platform was planned in Istanbul University Research and Application Forest. The results showed that UAV based DEM suggested more cut and less fill volume than that of 1/25000 scaled topographic map based DEM. Briefly, total cut volume difference between UAV based and map based DEM was calculated as 29700.92 m3 while total fill volume differences was -4621.61m3. Besides, UAV based generated near-infrared orthophoto was used for detection of individual trees which can be cut and/or effected within 20-meter buffer during road construction. Ecognition software, which can be used for object-based classification, was preferred for image analysis in order to perform individual tree detection. According to detection results, 167 trees were directly affected on the road route, and tree crown damages were detected on 343 trees in the area. The results suggested that UAV based data can be effectively used for road planning due to its' reliability and accuracy.*

Keywords: forest road, unmanned aerial vehicle, earthwork

SOCIAL ASSESSMENT OF THE AVAILABILITY OF LOGGING RESIDUES IN TURKISH PINE FORESTS

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Abstract: *Bioenergy has become one of the most important sectors of the global renewable energy market. Forest biomass is increasingly becoming important worldwide as a component of renewable energy source in both industrialized and developing countries. One of the most significant elements of forest biomass is logging residues. These residues that are composed of; thin branches, barks, needles and leaves and etc., components that are formed at the result of timber harvest operations. This paper investigates the views of some stakeholders concerning the utilization of logging residues. The findings illustrate that; (1) logging residues are either left in the forest floor or collected by forest villagers for the purpose of firewood because of rising costs based on factors such as; topographic structure of Turkey, actual timber harvesting system, work force abundance, and lack of technology. (2) Turkish forestry has a growth trend with respect to the increasing forestlands and forest resources. Therefore, Turkey has an important potential in terms of logging residues. (3) It is a widespread opinion of the stakeholder that production of bioenergy and using logging residues for this purpose is a subject that should be taken into consideration in Turkey. (4) Additionally, there are barriers using logging residues in this purpose. For example, current forestry and wood production system does not let to logging residues to be procured economically and this make the development of an ideal supply chain system to be difficult in Turkey.*

Keywords: bioenergy, biomass utilization, forestry biomass, logging residues, stakeholders, Turkey

DAMAGE OF THE REMAINING STANDS CAUSED BY LOGGING TECHNOLOGY WITH VARIOUS TYPES OF CHASSIS

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Abstract: *Forest harvesting causes various types of logging damages. Damage of the remaining stand belongs to this group. These damages have different character. Their origin, range, and type is affected by the type of machinery, harvesting technology and the machine operator. This paper was focused on the negative impact of three types of forest harvesting technologies to the remaining stand. We considered wheeled skidder technology, and CTL technology with wheeled and tracked chassis. The harvest in stands varied between 21 and 52%, with an average concentration of felling 13,7–95,4 m3 per one skid trail. We observed that the damage rate in stands processed by CTL technology was between 7,3 and 8,03%. Skidder technologies caused damage between 17,8% and 44,6%. The average size of wound caused by CTL technologies was between 167 and 322 cm^2. Skidder caused damages with area between 395 and 506 cm^2. We also observed differences between damages caused by various types of chassis. CTL technology with tracked chassis caused more damages of timber and tree root system. We used multivariate regression and correlation analyses to evaluate the effect of stand density and intensity of harvest on the intensity of damage. The analyses did not confirm significant influence of these two characteristics on intensity of damage, with coefficients of correlation of 0.22 (stand density) and 0.53 (intensity of harvest).*

Keywords: cut-to-length technology, skidder technology, type of chassis, damage of remain stand

Introduction

In terms of the protection of ecosystems or maintaining stand production capacity, the primary objective of forestry is to ensure a stable development of forest ecosystems and to preserve optimal productive and non-productive functions of forests. It is necessary to define the acceptable changes of key soil characteristics (Sommer, 1979). Soil compaction is affected by a large number of endogenous and exogenous factors (Horn, 1988). The extent of soil compaction depends on soil characteristics and the pressure and vibration applied to the soil surface by forestry machines (Ole-Meilude and Njau, 1989). The critical value of bulk density of soil ranges from 1,2 to 1,8 g.cm^{-3} (Lousier, 1990, Buchar et al., 2011, Arshad and Coen, 1992). Root growth in a majority of soil types is effectively stopped if these values are exceeded. Soil susceptibility to compaction is defined by the following factors: the magnitude of the contact pressure applied by the vehicle, the instantaneous soil moisture content, the share of soil skeleton and sand particles, soil structure, bulk density of soil, soil porosity, and the current thickness of the topsoil (Arnup, 1999).

The primary objective of this paper is to compare the extent of soil compaction caused by various types of forestry machines and to define the critical soil moisture content values, leading to maximum compaction resulting from the forestry machine traffic. Soil compaction is one of the most dangerous soil disturbance factors, particularly in highly productive stands, which can result in long-term reduction of tree growth.

Material and Methods

Measurements were conducted in eight forest stands located in Slovakia and the Czech Republic, where different types of machines were deployed. They were cut-to-length (CTL) machines, both tracked and wheeled, and wheeled skidders (Table 1). A GIS database provided by the National Forestry Centre was used to identify the soil types in the individual forest stands and their coordinates (Table 2). Thinning was carried out in two of the five stands, clear cut in two stands, and shelterwood cut was performed in the last stand; the total soil volume of harvest in the individual stands ranged from 90 to 411,3 m^3.

Table 1. Basic equipment parameters

Stands	Machine	Technology	Weight (kg)	Width of contact surface (mm)	Chassis type
2052, 2027	JD[a] 1070D + 810D	CTL[d]	14100 + 10970	600 - 620	wheeled
805J13	Ponsse ERGO + BUFFALO	CTL[d]	17200 + 17400	700 - 710	wheeled
2051	Zetor 7245 UWS[b]	Skidder	3985	280 - 420	wheeled
574B11, 588	HSM[c] 805 HD	Skidder	9200[e]	600	wheeled
187C2, 188	Neuson 132 HVT - Novotný LVS 5	CTL[d]	14400 + 4475	400 - 520	tracked/wheeled

[a]John Deere; [b]Universal wheeled skidder; [c]Hohenloher Spezial-Maschinenbau; [d]Cut-to-length technology; [e]Weight without hydraulic arm.

Table 2. Overview of the details of the individual stands

Stand	GPS	Type of harvest	Volume of harvest (m^3)	Soil type	Soil texture
2052	48°40'37.95"N 18° 5'41.25"E	thinning 50 +	265.9	luvisol	clay – 9%, silt – 11%, sand – 28%, gravel – 60%
2027	48°41'19.48"N 18° 5'38.19"E	thinning 50 +	232.6	40% luvisol 60% stagnosol	clay – 4%, silt – 33%, sand – 42%, gravel – 21%
805J13	49°49'59.69"N 14°46'25.71"E	clear cut	96.6	modal cambisol	clay – 2%, silt – 38%, sand – 37%, gravel – 23%
187C2	48°58’6.31”N 18°39’15.40”E	thinning < 50	90	20 % debris rendzina 80 % typical rendzina	clay – 1 %, silt – 46 %, sand – 31 %, gravel – 22 %
188	48°58’5.55”N 18°39’24.47”E	thinning < 50	190	10 % debris rendzina 90 % typical rendzina	clay – 4 %, silt – 46 %, sand – 48 %, gravel – 2 %
2051	48°41'9.31"N 18° 4'57.79"E	thinning 50 +	95.4	luvisol	clay – 1%, silt – 46%, sand – 31%, gravel – 22%
574B11	48°35'25.84"N 19° 2'41.66"E	clear cut	411.3	95% cambisol 5% luvisol	clay – 4%, silt – 46%, sand – 48%, gravel – 2%
588	48°34'59.62"N 19° 3'16.79"E	shelterwood cut	215.2	40% cambisol 60% luvisol	clay – 3%, silt – 28%, sand – 40%, gravel – 29%

Soil samples were collected to determine the extent of soil compaction and soil moisture content in the investigated stands. These samples were collected from sample plots established across the stand. In general, the area of the sample plots was 10 % of the total area of the stand in stands up to 5 ha. In stands larger than 5 ha, the area of the sample plots was 5 % of the total area of the stand (Lukáč, 2005). The sample plots were located

on skid trails disturbed by the machine traffic. The sides of the sample plots were 20 x 20 m or 20 x 40 m, depending on the type of machines employed in the individual stands. The sample plots were primarily selected because besides soil disturbance measurements, damage to the remaining stand was inspected too (not the subject of this paper). The measurement locations for soil disturbance were positioned on two opposing sides of each plot, and were located on the skid trail. The measurement locations were:

- in the ruts of the skid trail (one side),
- in the centre of the skid trail (between the individual ruts),
- in the undisturbed stand (control measurements).

This allowed collection of two sets of material on a one sample plot and a total of six samples. In stands where the soil disturbance was not studied through the sample plot method (clear cut stands 574B11 and 805J13), measurement sites positioned on the skid trails were established with spacing of 5 m (Schürger, 2012). The measurement locations were the same as for the sample plot method. Soil samples were collected from every measurement location in order to determine soil bulk density in its natural conditions. The samples were collected into 100 cm^3 Eijkelkamp cylinders. They were hermetically sealed in the cylinders to prevent any loss of moisture content. Samples were then weighed in laboratory conditions on calibrated laboratory scales with an accuracy of 0,1 g and dried at a temperature of 105ºC for 24 hours. Finally the mass of the samples in dried state and their moisture content were determined. Soil moisture content ($w_{\%}$) was calculated using the following equation (Hraško et al., 1962):

$$w_{\%} = \frac{m_w - m_s}{m_s} \quad \text{.....(1)}$$

Where: m_w – weight of the fresh sample, m_s – weight of the dry sample.

Soil disturbance was assessed from a total of 130 measurement locations. A total of 390 soil samples were collected from all measurement locations. The Proctor standard test (STN 72 1015), was used to determine the soil moisture content, at which the maximum compaction is achieved. Laboratory analyses were conducted to define the soil texture (the percentage share of clay, silt, sand, and gravel) in the individual stands using sieving method to determine the share of material larger than 2 mm and the Casagrande method for the finer granular fractions (< 2 mm). Moisture content, at which maximum soil compaction is achieved, is primarily influenced by soil texture and the share of clay, silt, and sand. Therefore, it was influenced by the conditions at the measurement location. A 2,5-kg cylinder was used for the Proctor standard test. It was used to strike a layer of soil stored in a special container with a known volume from a height of 30 cm. Dried soil was sieved through 16 mm sieves and compacted in three layers by 25 strikes from the cylinder to each layer. The test was repeated several times at increased soil moisture content, with the sample of compacted soil weighed at each moisture content level. The measurement results were then plotted on a diagram where optimum soil compaction corresponding to maximum bulk density of the soil sample was determined. Proctor empirically proved that soils compact to different bulk densities by the same compaction work at different moisture contents. Dry soil creates clumps that do not break down during compaction and large pockets are formed in the soil. At low moisture, great friction is exerted by the grains as they move, which leads to imperfect compaction, and hence low bulk density. Increasing soil moisture beyond the optimum moisture content levels results in over saturation of the soil with water and subsequent decrease in bulk density. Water moves into the soil's pores and prevents further compaction. The STATISTICA 10.0 software was used for statistical analyses of gathered data, namely multivariate analysis of variance (MANOVA) and Duncan's test.

Results

Soil compaction is one of the primary indicators of soil disturbance caused by machine traffic. On average the bulk density in ruts of the skid trails was 0,39 $g.cm^{-3}$ (32%) higher than the bulk density observed in the undisturbed stand. Wheeled CTL machines caused 34,7% compaction in ruts of the skid trails compared to the control measurements (bulk density increased by 0,42 $g.cm^{-3}$), while the tracked CTL machine caused 34,9% compaction compared to the control measurements (bulk density increased by 0.37 $g.cm^{-3}$). Skidders caused an increase in bulk density of 0,36 $g.cm^{-3}$ (29% compaction) in ruts of the skid trails compared to the control measurements, which in this case appears to be the lowest level of impact. Comprehensive data is shown in Table 3.

The level of compaction in the centre of the skid trails reached a lower value. Compared to the control samples from the undisturbed stand, wheeled CTL machines increased the bulk density by 0,13 $g.cm^{-3}$ (10,7% compaction), tracked CTL machine increased the bulk density by 0,21 $g.cm^{-3}$ (19,8% compaction), and skidders increased the bulk density by 0,24 $g.cm^{-3}$ (19% compaction). The highest level of compaction of soil in natural

conditions was reached by tracked CTL machine. This was probably due to differences in soil moisture content and texture. MANOVA analysis was used to determine if statistically significant differences were present between soil bulk densities in their natural arrangements in the individual stands and in the measurement locations. The results of this analysis showed that there were statistically significant differences in density between the individual stands (F = 36.23; p = 0.00) and measurement locations (F = 130.38; p = 0.00) in the individual stands, which can be attributed to the variability of soil conditions (Figure 1).

Table 3. Changes in soil density caused by various types of chassis

Stand	2052	2027	805J13	187C20	188	2051	574B11	588
chassis	wheeled	wheeled	wheeled	wheeled/ tracked	wheeled/ tracked	wheeled	wheeled	wheeled
machine	harv.	harv.	harv.	harv.	harv.	skidder	skidder	skidder
moisture for max. compaction (%)	16,87	15,93	12	28,08	34,06	15,34	21,9	27,95
moist stand ($g.cm^{-3}$)	1,21	1,10	1,32	1,05	1,07	1,14	1,43	1,16
moist rut ($g.cm^{-3}$)	1,64	1,71	1,54	1,34	1,52	1,46	1,79	1,56
moist centre ($g.cm^{-3}$)	1,31	1,37	1,46	1,18	1,22	1,31	1,72	1,42
dry stand ($g.cm^{-3}$)	0,96	0,90	1,12	0,82	0,83	0,95	1,05	0,97
dry rut ($g.cm^{-3}$)	1,31	1,36	1,35	1,02	1,06	1,24	1,35	1,29
dry centre ($g.cm^{-3}$)	1,05	1,12	1,27	0,91	0,90	1,09	1,28	1,18
stand moisture (%)	25,94	23,04	13,20	28,2	20,4	20,18	39,2	20,41
rut moisture (%)	25,48	26,36	11,17	31,5	32,4	18,60	33,6	20,92
centre moisture (%)	24,80	22,98	11,47	28,7	24,8	20,35	35,1	20,80

The variability of soil moisture content serves as a bias. Soil moisture content varied from 11,2% to 39,2% in the individual stands when the measurements took place. The differences in moisture content manifested in differences of bulk densities of moist samples. The moisture level, at which the maximum compaction is achieved, was exceeded in all stands and varied in a range of 12 – 35% based on the individual conditions and soil texture, therefore the maximum soil compaction occurred already after the first machine passage. MANOVA analysis was carried out to compare the soil moisture content between the measurement locations and the individual stands. The results of this analysis showed that statistically significant differences in soil moisture occurred between the individual stands (F = 53,65; p = 0,00), but did not occur between the measurement locations in the individual stands (F = 1,98; p = 0,14) (Figure 2). Average soil moisture content in the undisturbed stand was 23,8%, 25,0% in the ruts, and 23,6% in the centre of the skid trail. The dried soil samples were analysed in order to eliminate the moisture content of soil as a bias and to determine the extent to which surface soil compaction was the result of the different forestry machine types. The average bulk density of dried samples measured in the ruts of the skid trails was 0,30 $g.cm^{-3}$ (32%) higher than the bulk density measured in the undisturbed stand. Wheeled CTL machines caused 0,35 $g.cm^{-3}$ (35,4%) increase of bulk density, tracked CTL machine caused a 0,21 $g.cm^{-3}$ (25,3%) increase of bulk density, and skidders caused 0,30 $g.cm^{-3}$ (30,3%) increase of bulk density compared to the control measurements. The tracked chassis proved to have the least effect on soil once the bias factor of moisture content was removed. The increase of bulk density in the centre of the skid trail was 0,16 $g.cm^{-3}$ (16,2%) for wheeled CTL machines and 0,08 $g.cm^{-3}$ (9,6%) for tracked CTL machine; skidders compacted the soil to a higher level, which was primarily caused by skidding the load. They compacted the soil by 0,19 $g.cm^{-3}$ (19% compaction). The bulk densities of soil samples after drying fluctuated in range of 1,25 – 1,36 $g.cm^{-3}$ for wheeled machines and 1,02 – 1,06 $g.cm^{-3}$ for tracked machine. The results indicate that the wheeled chassis caused 25% higher soil compaction compared to the tracked chassis. MANOVA analysis was used to compare the samples.

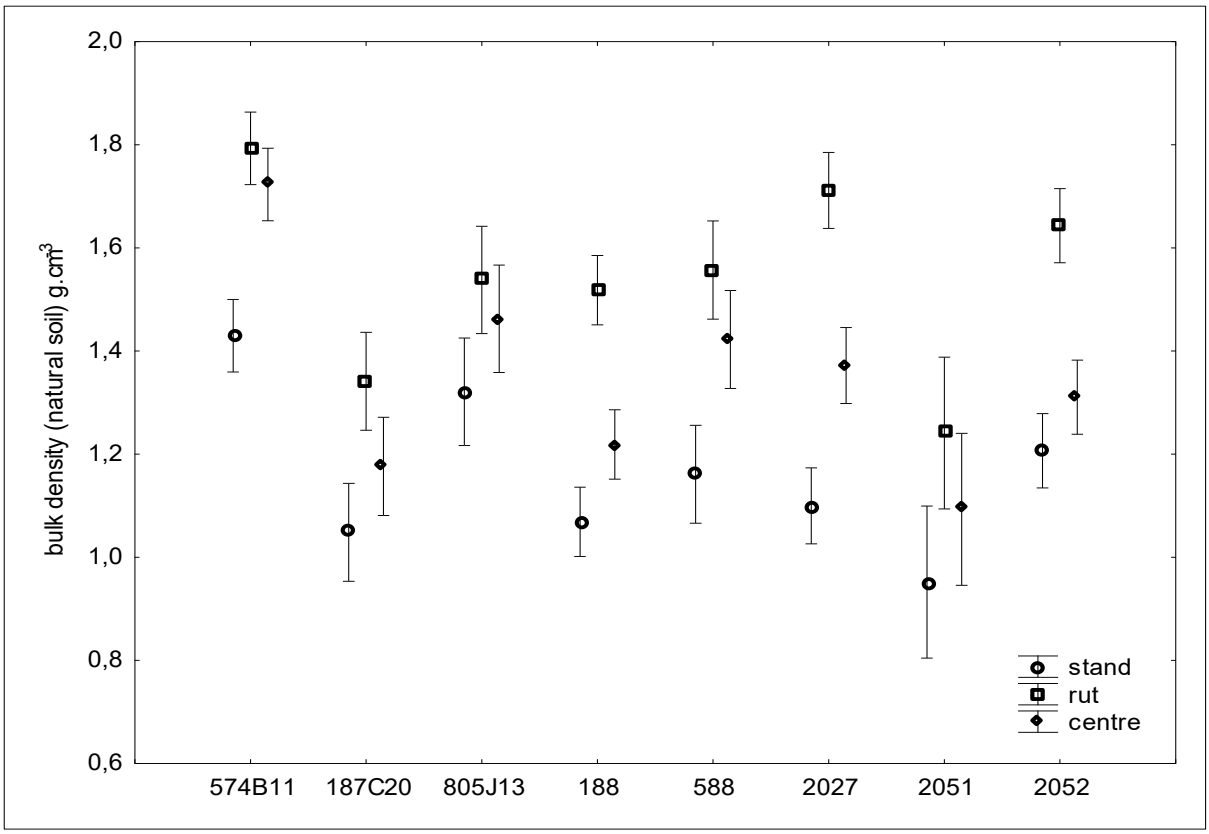

Figure 1. Average soil density values in natural conditions (moist) in the individual stands and measurement locations (vertical lines depicting 95 % confidence intervals)

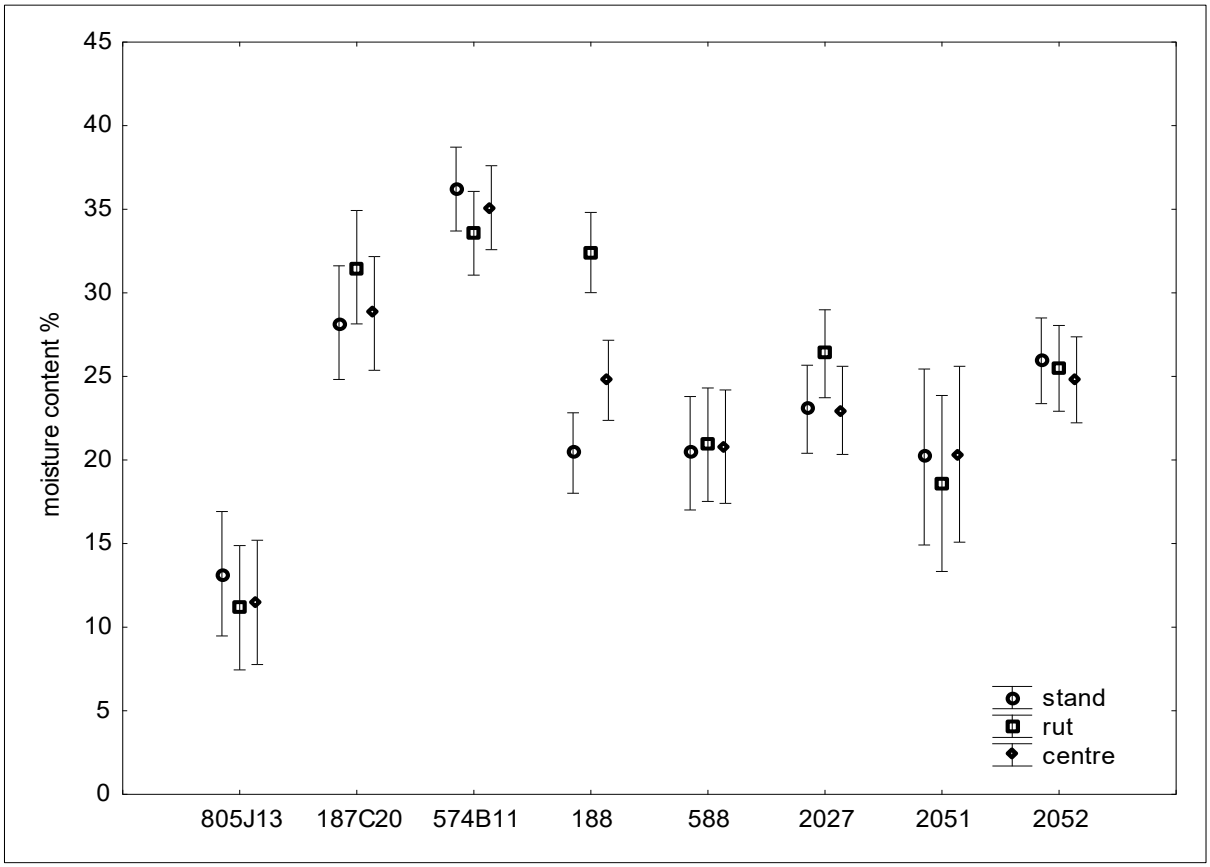

Figure 2. Average soil moisture values in stands and individual measurement locations (vertical lines depicting 95 % confidence intervals)

The results showed that there were statistically significant differences in level of soil compaction between the individual stands (F = 32,94; p = 0,00) and measurement locations (F = 97,54; p = 0,00) in the individual stands (Figure 3).

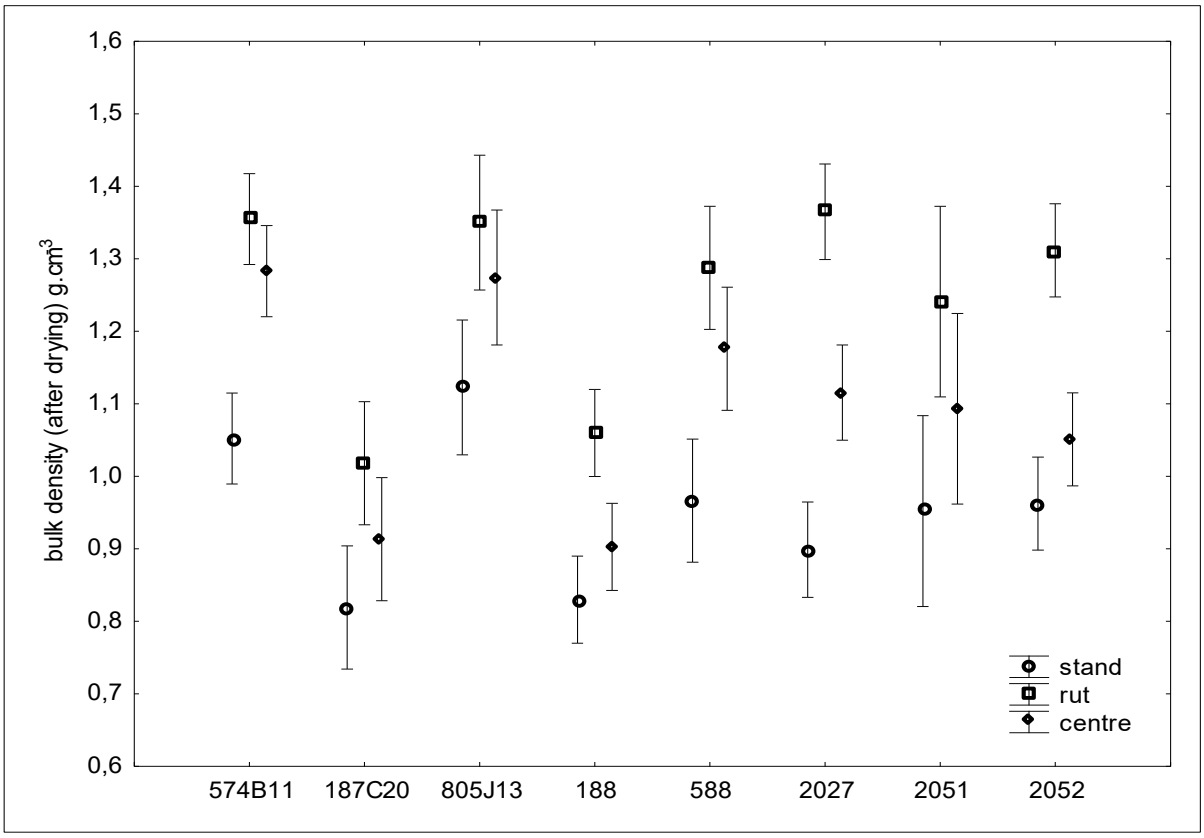

Figure 3. Average bulk density of dried samples in individual stands and measurement locations (vertical lines depicting 95% confidence intervals)

It is important to determine what variables contributed to refuting the hypothesis of the equality of the averages of bulk densities. The Duncan's test was used to analyse the dried soil samples from ruts. The test results show all combinations of changes in soil density between the samples from the ruts (Table 4).

Table 4. Duncan's test of bulk density of dried samples in ruts

Duncan test, average density in g.cm–3 (dry sample) Approximate likelihood of post hoc tests Error: between groups. PČ = 262.71, sv = 118.00								
stand	1 135,01	2 101,82	3 135,49	4 105,98	5 128,76	6 136,49	7 124,11	8 131,18
805J13		0,000028	0,941157	0,000074	0,373223	0,832586	0,132366	0,559490
187C20	0,000028		0,000023	0,525553	0,000173	0,000018	0,001331	0,000066
574B11	0,941157	0,000023		0,000068	0,356236	0,878481	0,125179	0,538930
188	0,000074	0,525553	0,000068		0,001051	0,000047	0,006585	0,000396
588	0,373223	0,000173	0,356236	0,001051		0,301393	0,478802	0,712963
2027	0,832586	0,000018	0,878481	0,000047	0,301393		0,100750	0,466744
2051	0,132366	0,001331	0,125179	0,006585	0,478802	0,100750		0,313442
2052	0,559490	0,000066	0,538930	0,000396	0,712963	0,466744	0,313442	

The Duncan test confirmed that in stands where wheeled machines were used (even with various types of machines used, different volumes of harvests, and different machine weight classes) the same level of soil compaction was reached (805J13, 574B11, 588, 2027, 2052, 2051). The bulk density varied in a range of 1,24 $g.cm^{-3}$ - 1,35 $g.cm^{-3}$. The tracked chassis enabled a better weight distribution and caused lower compaction in

stands 187C2 and 188 with the bulk densities ranging from 1,01 to 1,05 g.cm^{-3}. The results of this study indicate that maximum soil compaction occurred even at minimum surface soil loading and a minimum number of passages, even when wide and low-pressure tyres were used.

Discussion

Soil bulk densities in their natural arrangement fluctuate between the individual measurement locations and stands, which was confirmed by multivariate analysis of variance (MANOVA). A similar conclusion was reached by who studied the soil compaction in ruts of the skid trails at a depth of 10 cm caused by skidders. The results of study by Williamson and Neilson (2000), confirmed that soil bulk density increases by 62% compared to the control plots in the undisturbed stand after the first passage of forestry machines through the forest stands. Soil compaction and the formation of ruts in relation to the number of forwarder passages was the subject of a study by Proto et al. (2012), who determined that the first passage causes 20% compaction of the top layer of the soil. The issue of forest soil compaction was also the focus of a study by Leutz et al. (1980), who investigated machines traffic in loess - clay sites. Measurements showed the changes in soil properties are caused by the machines traffic. Makineci et al. (2008) investigated the impact of timber forwarding on soil at depths of 0 – 5 cm and 5 – 10 cm. The results of their study indicate that the bulk density of the dry soil samples from the ruts increases significantly compared to the samples from the control plots in the undisturbed stand. When looking at the compaction of soil in natural condition, it would seem that the tracked chassis had no positive effect on soil disturbance. However, the positive effect was found when dried samples were assessed. Machines with wheeled chassis caused 30,3 - 35,4% compaction (bulk density ranged from 1,24 to 1,36 g.cm^{-3}), whereas the compaction of soil in ruts formed by the tracked machine varied from 1,02 to 1,06 g.cm^{-3} and the level of compaction increased by 25,3%. The highest bulk densities for soil in the centre of the skid trails was reached in stands where skidders operated. This was due to the nature of skidding – semi-suspended loads caused increased compaction in this location in comparison with the compaction caused by CTL machines. An important note is that the critical value of compaction for tree root growth was exceeded in the skid trail ruts in all cases. The greatest compaction occurs in the top 30 cm of the soil, which contains the majority of the root biomass (Sands, Bowen, 1978; Kozlowski, 1999). Skidder passage results in 41 – 52% compaction of the top soil layer (0-8 cm) (Kozlowski, 1999). Lousier (1990) found that the top layer of soil (0 – 10 cm) compacts by 15 – 60% in skid trails. According to this author, the compaction in deeper soil layers decreases but he observed some levels of compaction in depths of 30 cm and more. The highest level of compaction occurs after the first machines passage. The critical level of moisture content, at which the soil reaches maximum compaction maximum soil compaction according to Rab (2005) is in range of 39 – 49,2%. The results of our study indicated that maximum compaction in the top layers of soil occurred at lower moisture contents, i.e. from 12 – 34%. Some authors investigated the relationship between bulk density and moisture content. Gerasimov et al. (2010) studied the effects of forwarder traffic on soil surface at various moisture contents and reached the conclusion that an indirect correlation exists between bulk density and moisture content, i.e. soil density decreases as moisture increases. Soil moisture content served as a bias factor in bulk density assessment, which showed in the fact that when samples were evaluated in moist state, machines with wheeled chassis caused the same level of compaction when compared to tracked machines. When moisture content was removed, tracked machine proved to have smaller effect on soil compaction. The fact that all wheeled machines caused roughly the same level of compaction can be attributed to the physical properties of soils and a similar mode of transmission of the vibrations from the wheeled chassis to soil, when machines move through forest stands. Moisture content necessary for maximum compaction was exceeded in all samples taken from the stands. Simultaneously it was confirmed that in these conditions machines with wheeled chassis were able to compact soil to the maximum possible extent in a relatively small number of passages, because they did not have sufficient contact surface that would effectively distribute their weight. This was confirmed by the results from stands where the tracked CTL machine operated, where it caused a lower level of compaction. Average soil moisture contents were different in the individual stands and the statistical significance of these differences was confirmed by statistical analyses. Conversely, the differences of moisture in the individual measurement locations within the individual stands were minimal and statistically insignificant.

Conclusions

Before any forestry machine is allowed to operate in forest stands, the soil should be tested for whether or not the Atterberg plasticity limits of soil are exceeded in the stands. The soil moisture content also should be

monitored throughout the whole forest harvesting process to ensure that the forest manager has enough information on the natural conditions and the susceptibility of soil to disturbance. These procedures along with classification of skid trails into trail types according to Lüscher et al. (2009) would give useful information to the forest managers during the decision-making process on whether or not to stop the harvesting process, to prevent excessive disturbance. The number of passages on the skid trails was not considered in this study and the measurements took place in stands with different natural conditions. This area of research requires a larger, more extensive research, which would consider more machine types and various volume of harvest as well as consideration of the effects of harvesting remains on the soil compaction levels. A drawback of the used gravimetric sampling method is that it is only informative, providing information on bulk density of soil. Despite this, the submitted paper provides valuable objective results of the compaction levels reached by the given machines and in given natural conditions, confirmed by statistical analyses.

Acknowledgements

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TWO YEARS STEEP SLOPE INITIATIVE - QUESTIONS, ANSWERS, AND PRACTICAL OUTCOMES

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Abstract: *One of the biggest recent transformations in harvesting practices in B.C., Canada is happening on some of the province's steepest slopes, and is driven in part by FPInnovations' Steep Slope Initiative. The program aims to facilitate international information sharing to ensure that any new safety measures and learnings are identified and communicated to BC stakeholders. The objective is to dramatically improve the safety of steep slope harvesting, and the solution is ground-based, winch-assisted felling machines which put workers under the protective cover of machine cabs. The technology is still evolving and the rapid introduction of new equipment presents several challenges; adaption to Western Canadian conditions is needed. Terrain is more broken and gullied with shallow soils, rock outcrops and large stumps compared to other areas. Winters are cold with deep snow and frozen soils, and locations are remote. Operator training is an ongoing concern. Layout and planning for this new system has a steep learning curve and it is challenging to keep a steady diet of suitable wood and ground in front of this expensive equipment. The Steep Slope Initiative, now in its third year, is intended to provide safe and cost-effective solutions to these challenges currently focusing research efforts on:*

- *Widely accepted best management practices and international standards.*
- *Terrain and soil conditions and impacts on traction and stability.*
- *Use of trees to change machine direction (rub trees).*
- *Anchor types and use of blocks.*
- *Cable tension behavior in relation to machine activity.*
- *Extreme temperatures and the effects of snow and ice.*

ASSESING THE FOSSIL ENERGY INPUTS IN CASE OF A LDH 45 DIESEL LOCOMOTIVE

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Abstract: *The use of modern harvesting and transportation equipment has increased in the last decade as a requirement for more precision, productivity and less environmental impact compared to older technology. However, in some cases older technology could still mean an efficient solution for the 21st century. Since its construction in 1933 the Vişeu narrow gauge railway (760mm) is the only operational timber railroad in Europe. In the use of such equipment, gravity is a key factor, enabling the downhill movement of loaded wagons while the braking is driven by a combination of manually and mechanically steered devices. While in the past the uphill movement was assured by steam-powered locomotives, nowadays they have been replaced by those equipped with diesel engines. With a total length of 46.3 km the line serves a forest area of approximately 5000 ha. This paper estimates the fossil energy inputs of a LDH-450 HP locomotive as a function of hauled timber mass and distance using the data gathered from the equipment's owner. The data was collected from the shift-level accounting system of the company and covers the fuel consumption, running hours and transported payload (tons).*

Keywords: forestry railway, hauled timber, energy expenditure, gravity

PERFORMANCE OF A MID-SIZED HARVESTER-FORWARDER SYSTEM IN INTEGRATED HARVESTING OF SAWMILL, PULPWOOD AND FUELWOOD

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Abstract: *Fully mechanized timber harvesting systems are generally characterized by a high operational performance being widespread and used across many regions. Such systems are adaptable to different levels of operational integration, enabling also the recovery of energy wood, but given integration configurations may affect their performance. A production study was carried out in a Norway spruce clear-cut aiming to estimate the performance of a mid-sized harvester-forwarder system in general, and the effect that fuelwood recovery from tree tops may have on its performance. Data was collected in the field during 11 days of observation using state-of-art equipment and software. Harvester's operations were monitored using a digital camera. Data refined from 27.5 filmed hours that accounted for 1045 felled and fully processed trees was used to model and compute its performance indicators. In addition, fuel consumption data was sampled in the field. The results indicated that a delay-free cycle time consumption was affected by variables characterizing the tree size. The net production rate was estimated to about 26.5 m3 × h^{-1}, being substantially affected by supplementary tree-top processing. Forwarding operations were monitored using a handheld computer and a Global Positioning System unit. The delay-free cycle time consumption was affected by forwarding distance and the amount of loaded wood, resulting in a net production rate of about 19.2 m3 × h^{-1}. Under these circumstances, the forwarding performance matched the harvester's outputs for an extraction distance of about 100 m, indicating that the supplementary processing of the tree-tops had no effect on the system's productive performance in the studied conditions. Most likely, it affected the harvester's fuel consumption given its proportion of 9% in the delay-free harvester's cycle time. The results also indicated a mean fuel consumption of about 1.7 l × m^{-3} for the studied harvesting system.*

Keywords: cut-to-length, fully mechanized, fuelwood recovery, integration, harvester-forwarder, operational performance

CURRENT SITUATION ON BIOENERGY FROM FOREST IN JAPAN

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Abstract: *In July 2011, the Feed-in Tariff (FIT) Scheme for Renewable Energy Use was introduced in Japan, in accordance with new legislation entitled the Act on the Purchase of Renewable Energy-Sourced Electricity by Electric Utilities. Under the FIT program, electricity generated from woody biomass must be procured at a fixed price (without tax) for over 20 years for (a) unused materials such as thinned wood and logging residue (at USD0.32/kWh), (b) general materials such as sawmill residue (at USD0.24/kWh), and (c) recycled materials such as construction waste wood (at USD0.13/kWh). Incentives have promoted the use of power generated from unused materials, and they are expected to increase the use of thinned wood and logging residue from 3 million m^3 in 2015 to 8 million m^3 in 2025. To promote the use of thinned wood and logging residue from small areas, the price of USD0.40/kWh for unused materials with less than 2 MW of direct combustion was set, starting from April 2015. The price of USD0.40/kWh was determined based on a model plant featuring 1.5 MW of direct combustion with initial cost USD6, 200.00/kW, annual operating cost USD640.00/kW, and Internal Rate of Return 8%. Annual consumption of fuel wood chips was 20,000 ton/year collected within 30 km with a price of USD 90.00/ton. Prices of chip logs were increased from USD 43.00/m^3 in 2013 to USD 53.00/m^3 in 2015.*

Keywords: unused material, general material, recycled material, chip price, log price;

APPLICATION OF ARTIFICIAL NEURAL NETWORKS IN DIFFERENT LOGGING SYSTEMS MODELLING

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Abstract: *Having accurate information about the effectiveness of forestry machinery to improve the economic situation of a project for forest managers and contractors is essential. Estimating of forest equipment production is an important part of cost management in forestry, which results in a reduction of operations expenses. The most important factor in the skidding time modeling is the consideration of all effective factors in an investigating framework which is able to consider all linear and non-linear relationships among input and output variables. The aim of this study was using ANNs to model the skidding time in different direction skidding in the forests of Mazandaran Wood and Paper Company. Simultaneously measuring the time winching, factors affecting winching time were measured. Two ANNs- Radial Basis Function and Multi- Layer Perceptron- were used to develop winching time model by ANNs. In addition, in order to compare the accuracy of ANN and mathematical model, the regression analysis, was developed. The results of regression analysis showed that this method for skidding data for TimberJack 450 C, HSM 904 and total data, has coefficient of determination accounted 61%, 66% and 76% respectively. The most important variables in this analysis, was skidding distance, the number of logs per turn and skidding slope. Results showed that RBF network provided more accurate results in skidding time estimation than to MLP neural network. This model has a coefficient of determination 91%, 63% and 72%, respectively, for TimberJack 450 C, HSM 904 and the total data.*

Keywords: forest management, logging, work study, artificial intelligence, skidder

ESTIMATING MARGINAL TREE(S) DAMAGED FOLLOWING FOREST HARVESTING BY ARTIFICIAL NEURAL NETWORKS

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Abstract: *Undoubtedly, high performance forest harvesting is key objectives of forest management system. Forest harvesting is an activity that causes adverse impact on residual stand. Few techniques such as regression, neural networks and etc. are utilized to estimate residual damages. They make a logical connection between the wound and independent effective parameters and could be used for future operations to predict wounds. In this study two neural networks subset, were used to predict the number of marginal trees damaged in the felling and winching operations in Neka Choob Co. For this purpose 84 trees of marked trees were selected, and then the number of damaged trees around the marked trees was recorded at winching. Results showed that, according to the area under ROC curves for both models of neural networks, MLP and RBF neural networks had predicted damaged trees in category 2 in winching stage were estimated 0.977 and 0.967, respectively. Wound trees categorized in class 1 in cutting stage were estimated by RBF neural network had more precision (0.655) compare to those obtained by MLP (0.543).*

Keywords: forest harvesting, artificial intelligence, estimation, skidding, logging

Introduction

The Hyrcanian (Caspian) forests of northern Iran are rich in both endemic and endangered species, and exist under a diverse range of economic and social conditions. Ground-based skidding of logs is the most prevalent harvesting system in the region, which is characterized by large trees with huge crowns growing on steep terrain. The extraction of logs with minimum injury to wood and with the least quantity loss is very important since forestry sector is an enterprise based on the cost of the last production and sale. Logging is known to severely affect the forest environment (Hamer *et al.*, 2003; Bayati and Najafi, 2013).

Damage to the residual stand in forest operations is most often caused during transport of timber (Vasiliauskas, 1993; Košir, 2008). Trees are wounded during log yarding (Siren, 1982; Grinchenko, 1984). The number of trees damaged and the severity of damage increases with the size of the felled trees and yarded logs, the number of trees harvested, skidding distances, ruggedness of the terrain, and understory vegetation density (Shea, 1960; Froese and Han, 2006).

The aim of this study was to compare data from a monitored logging operation with the outputs of models used to predict the number of trees injured during felling and ground-based log yarding operations. The methods tested are based on regression, fuzzy logic, and neural networks and all use independent variables that are easy to measure such as DBH (stem diameter at 1.4 m) and height to predict the number of trees damaged by logging. One of these methods is artificial neural networks (ANNs), which are often used to implement complex functions in other fields such as for identity recognition in image processing (Kia, 2010). ANNs are becoming popular at least partially because they do not require assumptions about the forms of underlying distributions (Gurney, 1997).

Artificial neural network has also begun to emerge as an alternative approach for modeling nonlinear and complex phenomena in forest science (Atkinson and Tatnall, 1997). Artificial neural networks are based on the assumptions (Fausett, 1994) that a) information processing occurs at many simple elements (neurons or nodes), b) signals are passed between elements over connection links, c) each link has an associate weight and d) each element applies an activation function to its net input to determine its output signal. One of the most commonly and useful neural networks in natural resource management, is the feed forward neural network with back propagation algorithm (MLP network) (Rumelhart *et al.*, 1986). Another one of the most important types of neural networks is radial basis function (RBF). This network considering to variety of applications, have become one of the most famous neural networks and is most important competitor a multi-layer perceptron.

A number of researchers have investigated the applicability of ANN models to such diverse natural resources and engineering modeling applications. For example, ANN models have been used to predict forest cover type from cartographic variables such as aspect, altitude and etc (Blackard and Dean, 1999), forest age using TM images (Jensen *et al.*, 1999), pine bark volume (Diamantopoulou, 2005), windthrow risks (Hanewinkel *et al.*, 2004), tree felling times (Karaman and Çalışkan, 2009), and landslide susceptibility (Lee *et al.*, 2006; Yilmaz and Akay, 2008). Comparisons between MLP and RBF neural networks and regression analysis were made of on the basis of precision of trunk volume estimates (Bayati and Najafi, 2013). In this study, we compare two neural network models, multi-layer perceptron (MLP) and radial basis function (RBF), on the basis of their predicted numbers of trees damaged during log skidding operation in NEKA CHOOB Co forests.

Material & Methods
Study Site

The study was conducted in a 29 ha of compartment 329 in NEKA CHOOB Co Forests (36º30'-36º31' N, 53º31'-53º32' E) in northern Iran on northwestern-facing slopes of 0-30% (average of 15%) at altitudes of 730-780 m.

Field Data Collection

We assessed damage to the residual trees due to the skidding of 84 trees. Trees damage due to timber yarding was recorded in the winching trail (alongside winching trail, upper and lower sides' of-slope, resp.). The kinds of damage considered included debarking of boles, root damage, and crown damage. Distance from stump to center of skidding trail, winching trail slope, bole volume at every cycle winching (release and pulling winch, hook and winching) and number of bole at every winching cycle, were variables that measured before and during extraction operation.

Designing Neural Network Model

Distance from center of bole to center of skidding trail (D); winching trail slope (SW), bole volume at every winching turn (V) and number of bole at every turn winching (NB), were network inputs in winching operation (Figure 1 & Figure 2) and variable the number of surrounding trees damaged was considered separately as the network output. SPSS 19 software was used in this study to design and implementation of neural networks.

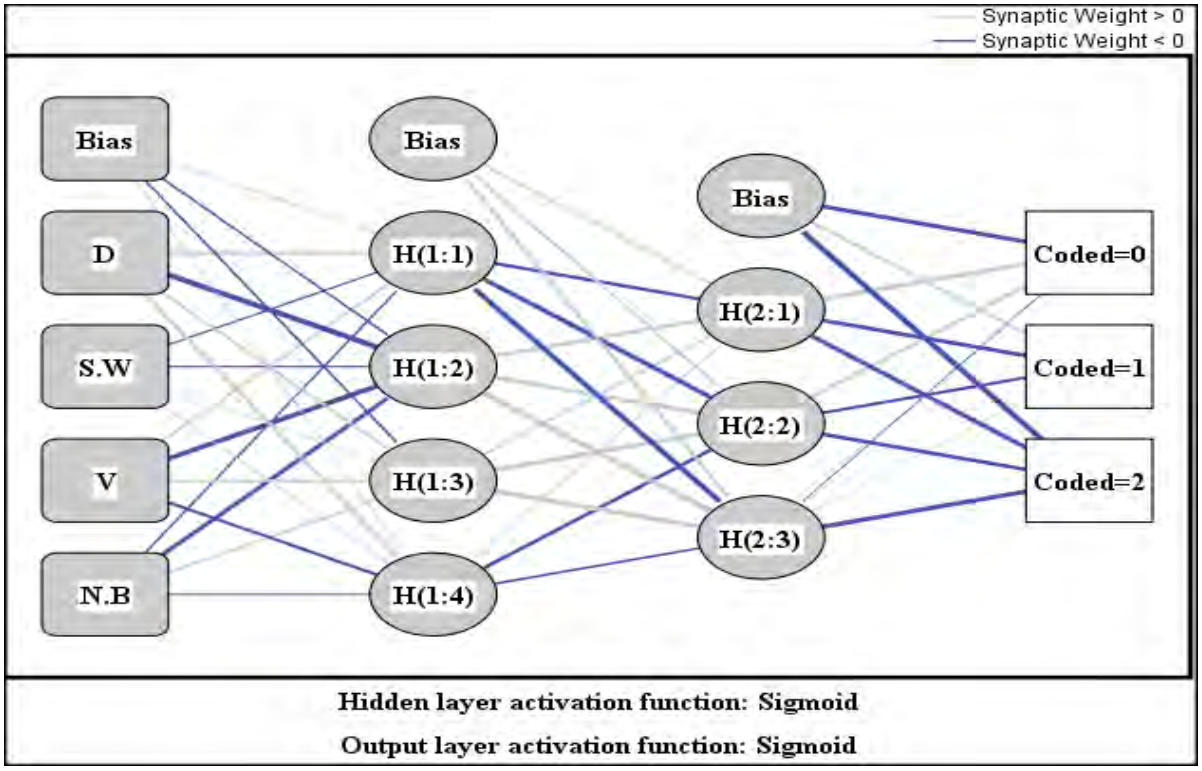

Figure 1. MLP Structure in Winching Operation

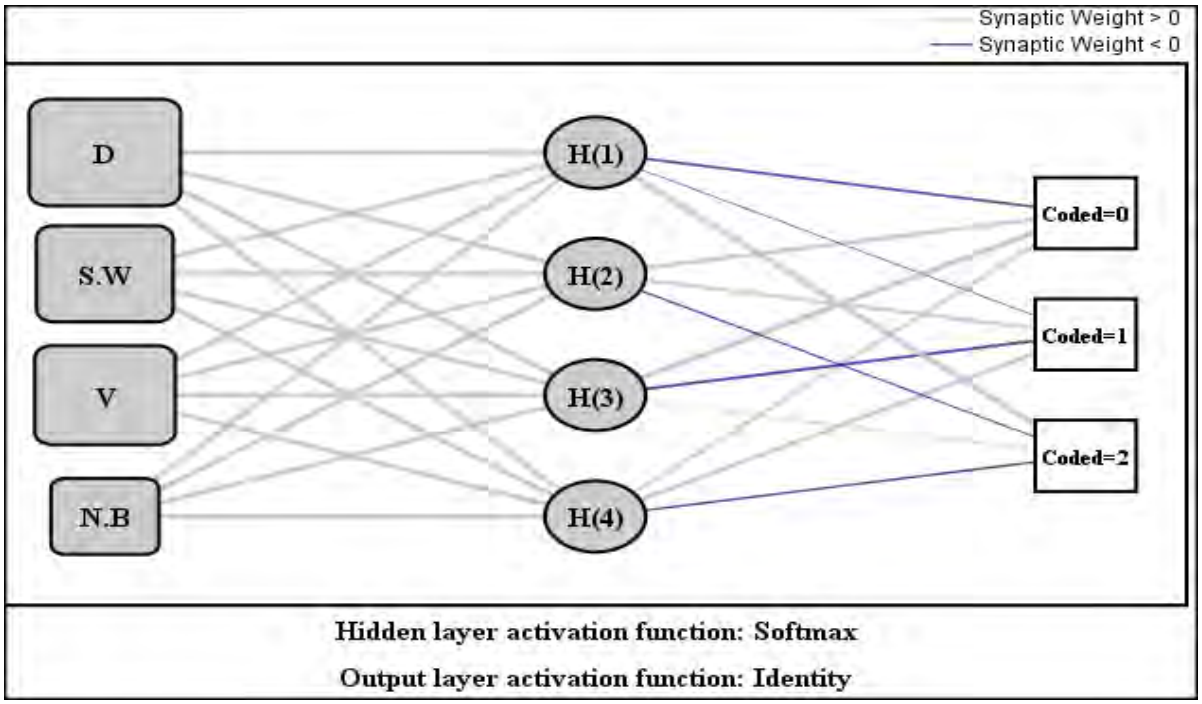

Figure 2. RBF Structure in Winching Operation

It must be noted that, in order to better predict the number of trees damaged using artificial neural network, the number of damaged trees in felling and extraction operations were grouped based on tables (Table 1).

Table 1. Grouping Number of Trees Damaged in Winching Operation

Number Trees Damaged	Code
0	0
1-2	1
2>	2

Results and Discussion

The comparison of precision two neural networks to predict damage to surrounding trees showed that the MLP neural network with two hidden layers and 4 neurons in the first layer and 3 neurons in the second hidden layer and activation function (Sigmoid) than RBF neural network with one hidden layer and 4 neurons in this layer and activation functions (Exponential and Identity), have more Precision and is less error (Figure 3 & Figure 4, Table 2, Table 3 & Table 4).

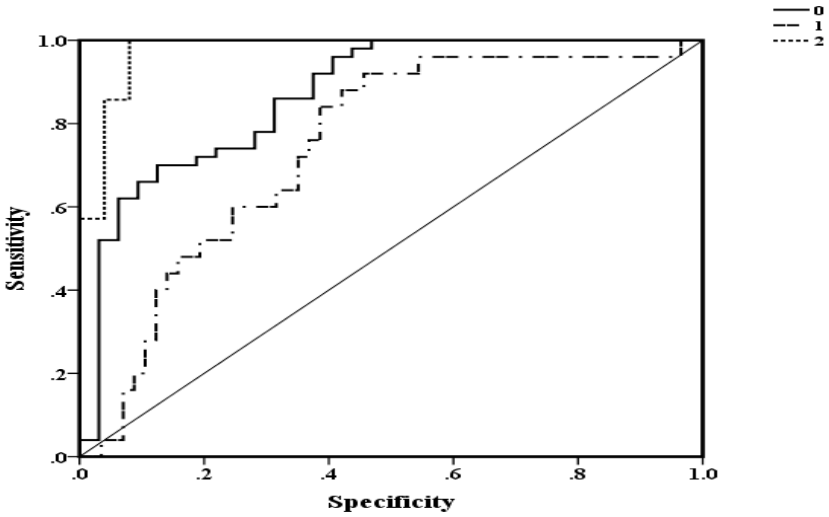

Figure 3. ROC Curve of MLP in Winching Operation

Table 2. Area under the MLP ROC Curve

		Area
Coded	0	.869
	1	.742
	2	.977

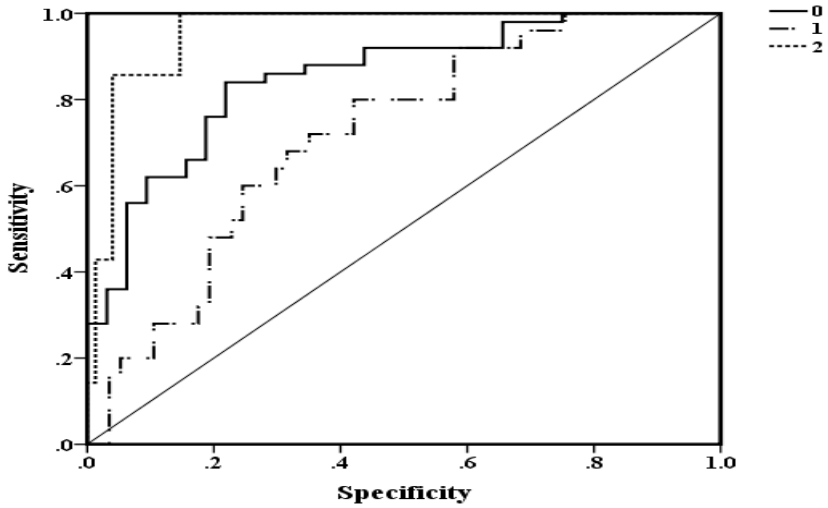

Figure 4. ROC Curve of RBF in Winching Operation

Table 3. Area under the RBF ROC Curve

		Area
Coded	0	.852
	1	.718
	2	.958

Table 4. Best Composition of Neural Networks in Number of Trees Damaged in Winching Operation

Network Type	Optimal Composition Network	Activation Function	
		Hidden Layer	Output Layer
MLP	4-4-3-3	Sigmoid	Sigmoid
RBF	4-4-3	Softmax	Identity

Sensitivity analysis showed that in neural network MLP, distance of bole from center of skidding route (D) (100%) and the winching slope (SW) (13.4%) and in neural network RBF, distance of bole from center of skidding route (D) (100%) and number of bole at every turn (NB) (61.9%), respectively, are respectively highest and lowest important (Table 5).

Table 5. Independent Variable Importance

Network	Variable	Importance	Normalized Importance
MLP	Distance	.535	100.0%
	S.W	.072	13.4%
	V	.291	54.3%
	N.B	.102	19.0%
RBF	Distance	.325	100.0%
	S.W	.236	72.8%
	V	.238	73.2%
	N.B	.201	61.9%

Conclusions

The prediction of the possible damage depending on land peculiarities will prevent economic loss and provide an opportunity to take precautions before felling and extraction. For this reason, damage prediction models were developed to predict the quantity loss occurring on the trees as a result of winching. The model is based on parameters such as distance from center of bole to center of skidding, winching trail slope, bole volume at every winching turn and number of bole at every turn winching. This enabled producers to predict the quantity loss before winching, and to take necessary precautions.

Results showed that, according to the area under ROC curves for both models of neural networks, MLP and RBF neural networks had predicted damaged trees in category 2 in winching stage were estimated 0.977 and 0.967, respectively. Wound trees categorized in class1 in cutting stage were estimated by RBF neural network had more precision (0.655) compare to those obtained by MLP (0.543).

Residual stem damage is also directly correlated with the skills and attitudes of the logging contractor and machine operator (Reisinger and Pope, 1991; Smith et al., 1994), the season of harvest (Aho et al., 1983; Lamson et al., 1984), road layout (Deitschman and Herrick, 1957), and site variables (Cline et al., 1991).
In uneven-aged mixed forests, special felling and skidding operations should be performed to minimize residual stand damage and to secure natural regeneration process (Nyland, 1994).

Several factors such as tree species, slope of skid trail, traffic intensity, log volume, stand density, as well as mechanical equipment affect severity of damages and late occlusion of wounds on stems of trees across the skid trails (Heitzman and Grell, 2002).

Prediction of number of trees damaged before skidding is important for decreasing the possible volume loss. Therefore, the producers were provided with the opportunity of predicting the quantity loss and taking necessary precautions before felling and skidding activities, e.g. directional felling, skidding road maintenance and use of wood cover.

The ANN technique introduced in this study has the ability to overcome problems in forest data, such as non-linear relationships, heteroskedasticity, multicollinearity, outliers and noise, and it appears promising as an alternative to the traditional regression models.

The choice of technology and performing operations under suitable terrain and weather condition are most important means of reducing harvesting disturbances on forest stand (Modrý and Hubený, 2003). Even though acceptable result has been obtained in this manner, but it is necessary to use other networks in modeling of physical objects, Such as Cascade Forward Back Propagation, and different learning algorithm like LM, BGF and CGF to derive the best model. The nature of the problem determines which neural network or learning algorithm can be used. Generally, in the modeling of physical object such as felling and skidding damage, for the reason that unknown factors may affect on the damage, and these mutual effects in the most cases would cause to creating of nonlinear space, its modeling will be very critical and with error.

The results of this research can be useful as environmental criteria for future researches to evaluate current logging systems in hilly terrains and to choose the best alternative and develop a decision support system for logging planning in this area. Finally, considering the fact that this study carried out in a small-scale in order to evaluate the performance of artificial neural networks in one of the most common activities in the forest, therefore it is recommended that further studies using this technique in the field to do more comparisons created with this technique.

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APPLICATION OF LASER RANGEFINDERS IN FORESTRY SURVEYS

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Abstract: *In the forestry practice of the 21th century, traditional surveying methods are needed to be replaced with faster and more effective ways. Remote sensing is a well proven solution and the field GNSS systems have made mapping easier as well. The GNSS-based survey can be erroneous by several meters if the conditions are far from ideal, e.g. closed canopy or complex relief. Therefore, there are such cases when traditional survey is the right solution. Traditional methods can be carried out with the use of contemporary equipment like laser rangefinders and rotary encoders whose accuracy can be enough for certain mapping tasks. The suitability and reliability for forestry use of these tools was tested. The basic survey instrument of the former forestry practice was the Wild T0 theodolite whose accuracy is sufficient for forestry purposes even nowadays. The aim of this research was to assess the accuracy of laser rangefinders - specifically the TruePulse 360B - by using traditional survey methodologies like traversing and polar point measuriement. Based on the results the suitability of these tools for road surveys and forest stand mapping was evaluated.*

Keywords: surveying, rangefinder, field measurements, mapping

ASSESSING OPERATIONAL PERFORMANCE OF FELLER-BUNCHER: A CASE STUDY OF DARDANELLES, TURKEY

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Abstract: *Logging operations are considered as one of the most costly stages in extraction of forest products. Besides, they are very difficult and time consuming activities especially in mountainous regions with steep slope. In order to overcome potential economic and operational problems related with logging operations, timber extraction methods should be well planned and implemented in the field. Therefore, operational productivity should be estimated by a scientific approach and the main factors that affect performance of logging operations should be carefully evaluated. This study aims to analyze logging operations performed in Brutian pine (Pinus brutia) stands in Dardanelles region in Turkey. In the field study, trees were cut by a feller-buncher and then rubber-tired skidder was used for skidding whole trees from stump to landing area. In this study, operational performance of the feller-buncher was assessed by estimating its productivity based on the time study method. The results indicated that the average productivity was 91.11 m^3/hr. Moving from stump to next tree was the most time consuming work stage (47.25%), followed by felling and bunching stages. To improve performance of the overall operation, trees should be felled uphill to enable downhill skidding. Compared to chainsaw felling, feller-buncher potentially provides a much safer environment for the operators. Besides, the skidder should travel on the same trails as the feller-buncher to reduce the impact on the forest soil.*

Keywords: timber logging, feller-buncher, productivity, time study

ASPECTS REGARDING THE USAGE OF GROUND AUGERS IN THE FORESTRY SECTOR

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Abstract: *This paper presents the results of our research regarding the usage of ground augers in the forestry sector for drilling holes in order to plant saplings. In order to carry out the research, we settled in two forest divisions in the plains of the West of Romania so that we could have four different types of soils which are representative for that specific area. The objectives of the research were to make a comparative determination, on different types of soil, of the qualitative parameters, among which the most important ones are: degree of loosening of the soil taken and left in the hole, resistance to penetration, resistance to shearing, timing of drilling holes, degree of scattering of the soil taken out from the hole, degree of evacuation of the soil from the hole, fuel consumption for the drilling of the hole, using the Stihl BT 121* auger *in order to establish its technical efficiency. In order to observe the influence which the drilling of holes has on its walls, we measured the resistance to penetration and resistance to shearing every 10 cm at a 30 cm depth, the proper depth for planting small-sized saplings, on two opposing sides, so that we could get the most probable values of these physical-mechanical properties of the soil. We started by measuring the particle size distribution and the main physical properties of the soil (moisture, bulk density and total porosity) and then, we determined the duration of drilling holes, split times (duration of movement from one hole to the other) and the fuel consumption when using a Stihl BT 121 auger equipped with a 200-mm diameter drill. The average values for the duration of digging and the fuel consumption for each type of soil was as follows: 1st type of soil - timing 11.7±3.09 sec. and average consumption 4.31±1.14 ml; 2nd type of soil - timing 12.0±3.76 sec. and average consumption 5.75±1.80 ml; 3rd type of soil - timing 12.06±1.99 sec. and average consumption 4.76±0.79 ml; 4th type of soil - timing 9.83±2.52 sec. and average consumption 3.49±0.89 ml (mean±SD). The usefulness of the present paper stays in the research data collected, processed, analyzed and valorized in order to offer a pertinent study material, which could indeed be used by specialists in designing the process for obtaining, through a mechanized means, the holes for planting small-sized saplings on a horizontal ground, using the Stihl BT 121 auger.*

Keywords: ground auger, physical properties, duration of drilling holles, fuel consumption

Introduction

The need to afforest greater and greater surfaces in Romania as a result of widely known causes, together with the development of forestry nurseries that are able to produce a certain quantity of saplings to cover the production needs, imply an enormous work volume in the afforestation sector which is difficult to carry out only by manual means.

In the future, the afforestation activity will become compulsory in even greater surfaces. For this reason, we consider that the optimal solution in this case is the mechanization of hole digging for planting saplings by using ground augers.

From this point of view, there is a wide range of ground augers able to mechanically dig holes for saplings, which are available on the market. In order to comparatively observe the performance rate, we used a Stihl ground auger. From the very many types of machinery available in Romania, we have chosen for the study regarding the auger performance in terms of fuel consumption: the Stihl BT 121 auger[1,2].

The research was carried out to observe the auger efficiency and to make measurements regarding the quantity and auger performance in a shift (8 hours)[3,4,5].

In order to encompass the ground diversity in forests, we chose to make our research on four different types of soil (1st soil, 2nd soil, 3rd soil, 4th soil).

The present research is carried out only on plains, and fuel consumption are linked to the nature of the ground in terms of particle size analysis.

The soil is the environment of the growth and development of the saplings, because in it and through it there are the nutritive elements and the activity of the micro-organisms in the context of a normal thermo-aero-hydro regime. It can be penetrated by the roots of the plants, it is stirred, it contains water, air and living matter (flora and fauna) and it represents the necessary support for the growth and development of the saplings[6].

The characteristic of the soil as a growth and development environment for the plans is given by a series of properties (texture, structure, porosity, compaction, reaction, humus content and nutritive elements), expressed globally through the notion of fertility[5,7,8].

In order to obtain pertinent results, the research was done according to a complex methodology, with a novelty character in this domain, which gave the possibility to study different technical aspects of usage of the motto-borer.

Because of the compaction, while digging holes for planting saplings, there are several phenomena of friction occurring which increase the resistance to penetration through the walls of the hole. For the same reason, the soil offers resistance to some mechanical, exterior forces, presenting resistance to compression, shearing and penetration[3].

Machinery that realize digging holes to plant seedlings are part of the large group of ground working machines whose active components have a moving rotation generated by a power source. The specific of these machinery is the fact that the soil is prepared by chipping, action from which the soil mobilization and aeration is carried out with or without putting out the soil from the hole.

The principle of this action is not exclusively reserved to machinery digging holes for seedlings. This principle exists in other machinery whose destination is to prepare the soil to be a germinating bed, to maintain crops along rows gap, a.s.o. The same principle has applicability on a large scale in the wood and metal industries[4,5].

Experimental

The experimental research was conducted in two forest divisions in the plains (fig. 1). For this purpose, we chose the soils which are most frequently spread in those areas. In this respect, we made measurements in order to determine the moisture, the bulk density, the total porosity and the particle size analysis of the soils. The particle size analysis of the soils was carried out in a specialized laboratory.

We determined the fuel consumption and digging duration for each hole, but also the split times (duration of movement from one hole to the other). The digging duration and the split times were determined by using a timer; for determining the fuel consumption, we placed inside the tank a precise quantity of fuel and after depleting it, we related it to the digging duration and we multiplied it with the digging time allotted for each hole, according to the relation (1):

$$Q_n = \frac{Q}{\Sigma T} \cdot t_n \quad \text{.....(1)}$$

where: Q_n is the fuel quantity needed for each hole,

Q – total quantity of fuel placed in the tank,

$\sum T$ – total sum of digging duration of the holes

t_n – duration of digging of a hole

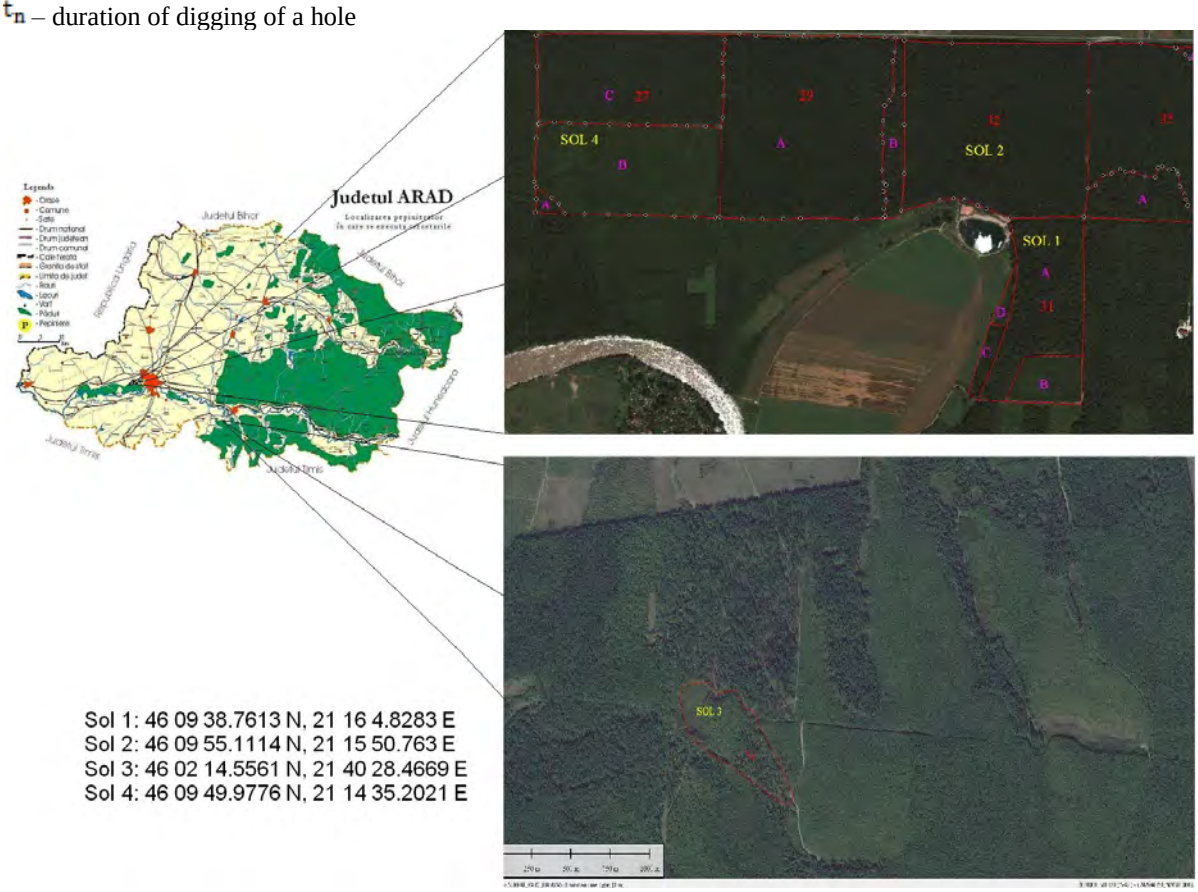

Figure 1. Experimental field map

The technical characteristics of the ground auger used in our research are given in Table 1, and its photography appears in Figure 2.

Figure 2. Ground auger Stihl BT 121[9]

The technical characteristics of the ground auger Stihl BT 121 are given in Table 1.

Table 1. Technical data of the ground auger Stihl BT 121[9]

Cylindrical capacity	30,8 cm³
Weight	9,4 kg
Power	1,3/1,8 kW/CP
Level of vibrations left/right	2,2/2,5 m/s²
Speed of rotation	190 1/min
Level of acoustic pressure	103,0 dB(A)
Level of acoustic pressure	109,0 dB(A)

In this paper, we presented the results gathered after digging the holes for planting saplings in the previously unprepared ground, taking into account: the durations implied by digging holes according to the physical-mechanical properties of the soil and the fuel consumption needed for digging a hole.

The physical properties were determined by using the method of the cylinders with a constant volume of 100 cm^3, carrying out five repetitions at different depth, from 10 to 10 cm until the depth of 30 cm. The methods of analysis and interpretation of the results as well as the work procedure for the determination of the physical - mechanical properties are those indicated in the specialized literature[10,11,12,13,14].

In order to reach our objectives, we have dug n holes for each type of soil chosen for the experiment, placed on a previously unprepared horizontal ground, using the Stihl BT 121 auger with a 150/200-mm drill, until exhausting the whole quantity of fuel placed in the tank (500 ml)[15,16,17,18].

In order to observe the influences which the digging of holes have on their walls, we measured the resistance to penetration and the resistance to shearing on the holes' walls from 10 to 10 cm until the depth of 30 cm, on two opposing sides, so as to get the most probable values for these physical-mechanical properties of the soil, depth sufficient enough for the planting of small-sized saplings. The placement of samples for the resistance to penetration and shearing on the walls of the holes is given in Figure 3.

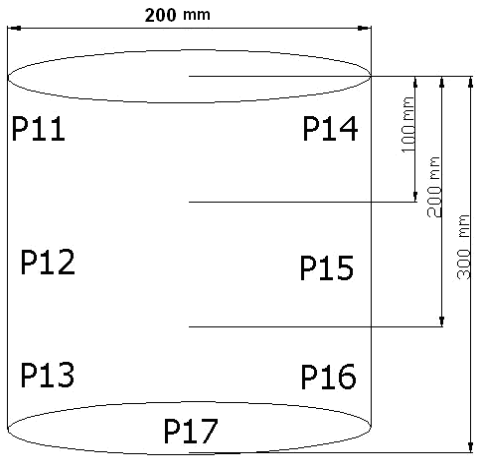

Figure 3. Placement of samples for the resistance to penetration and shearing on the walls of the holes

The degree of scattering of the evacuated soil from the hole was expressed by the ratio of the maximum diameter of scattering or of the diameter at which is deposited most of the quantity of soil, at the diameter of the hole. The degree of evacuation of the soil from the hole was expressed by the ratio between the volume of the soil evacuated from the hole and the volume of the soil left in the hole at a 30 cm - depth. The elements measured for the determination of these qualitative indexes are given in Figure 4.

In order to accomplish the objectives we have for each type of soil chosen for the experiment, placed on a horizontal ground, previously unprepared, using the Stihl BT 121 motto-borer with a 150/200 mm drill.

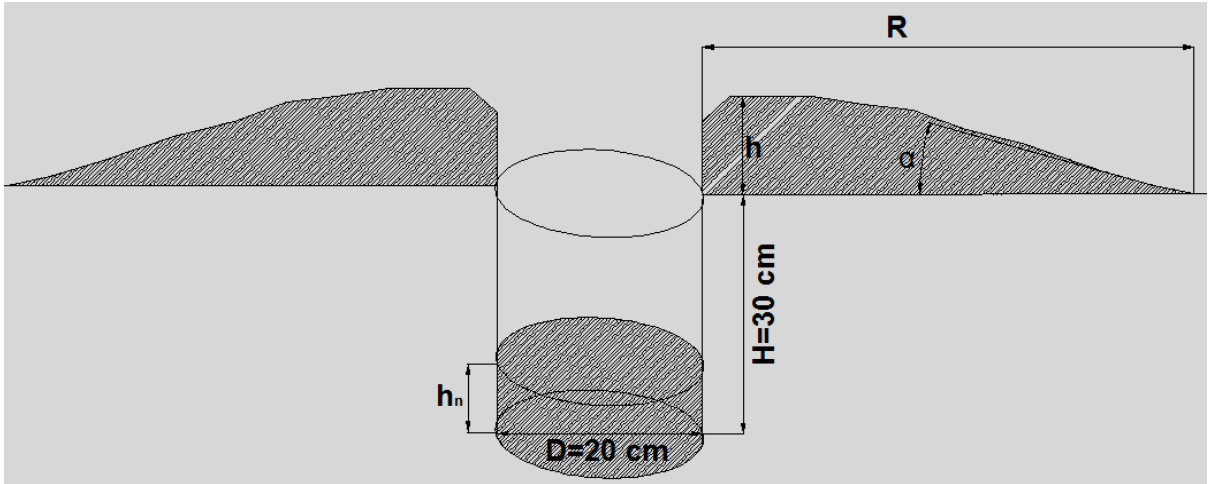

Figure 4. Determination of the degree of scattering and degree of evacuation of the soil in the hole

(H – depth of digging, hn – height of the un-evacuated soil, h – height of the soil bed evacuated, D – diameter of the hole, α - angle of setting of the evacuated soil, R – radius of scattering of the evacuated soil (meanR))

Statistical analysis. Data was subjected to two-way analysis of variance (ANOVA) (P = 0.05), and in order to determine the samples means statistical differences the Tukey test of pairwise comparisons was done (Minitab software, Minitab, Inc. Quality Plaz, 1829 Pine Hall Road, State College, PA 16801 USA). Multivariate analysis was done following the sequence: principal component analysis (PCA), and (P = 0.05), in order to determine the possible variables grouping and samples clustering [19].

Results and discussion
Physical properties

The state of aeration of the processed soil in the natural setting can be expressed through specific issues such as: bulk density and total porosity[20,21].

The types of soil on which the research was carried out are: gley-soil the muddy subtype (soil 1), alluvial soil the vertical-gleyed subtype (soil 2), brown typically luvic soil (soil 3) and a alluvial soil-typical (soil 4). The physical properties determined during the digging of the holes and the particle size distribution of the soil are presented with average values in Tables 2 and 3.

Table 2. The values of physical properties of the soils analyzed (mean±SD)

Type of soil	Physical properties	Depth 0-10 cm	10-20 cm	20-30 cm
SOIL 1 gleysoil – muddy	Soil moisture, %	24.11 ± 1.2	22.73 ± 1.0	20.09 ± 0.8
	Bulk density, g/cm^3	1.62 ± 0.23	1.69 ± 0.19	1.72 ± 0.06
	Total porosity, %	37.89 ± 2.51	37.43 ± 2.24	36.45 ± 1.15
SOIL 2 alluvial soil – vertical gleyed	Soil moisture, %	20.75 ± 0.9	19.46 ± 0.7	17.38 ± 0.5
	Bulk density, g/cm^3	1.70 ± 0.02	1.75 ± 0.01	1.73 ± 0.00
	Total porosity, %	36.97 ± 1.32	35.73 ± 1.11	35.19 ± 0.92
SOIL 3 brown typically luvic	Soil moisture, %	22.43 ± 0.8	21.10 ± 0.5	8.74 ± 0.3
	Bulk density, g/cm^3	1.69 ± 0.05	1.71 ± 0.03	1.73 ± 0.01
	Total porosity, %	37.43 ± 1.05	36.31 ± 0.96	36.09 ± 0.53
SOIL 4 alluvial soil – typical	Soil moisture, %	23.35 ± 0.5	21.68 ± 0.3	19.54 ± 0.1
	Bulk density, g/cm^3	1.64 ± 0.01	1.58 ± 0.01	1.51 ± 0.00
	Total porosity, %	35.54 ± 2.52	33.28 ± 2.01	31.25 ± 1.85

We could notice the fact that the holes were dug when the values of soil moisture were ranging from 20.75 to 24.11 % for the 0-10 cm depth, 19.46-22.73 % for 10-20 cm depth and 8.74-20.09 % for the 20-30 cm depth.
In order to show the influence of the soil type (particle size distribution) and of the physical properties of the soils included in the experiment on the digging duration and fuel consumption, all the holes were dug on a

previously unprepared ground, which can be noticeable in the values of total porosity that vary as follows: for 0-10 cm between 35.54-37.89%; for 10-20 cm between 33.28-37.43% and for 20-30 cm between 31.25-36.45%.

Table 3. Average values of the granulometric analysis at different depths of prelevation

Type of soil	Depth of prelevation	Values of the granulometric analysis		
		Sand (Coarse+Fine)	Dust (I+II)	Clay
SOIL 1	0-10	36.78	33.88	29.54
gleysoil –	10-20	47.78	25.08	27.34
muddy	20-30	41.18	30.38	28.64
SOIL 2	0-10	40.78	38.78	20.64
alluvial soil –	10-20	39.38	37.18	23.84
vertical gleyed	20-30	41.98	33.08	25.24
SOIL 3	0-10	38.78	36.33	25.09
brown	10-20	43.58	31.13	25.59
typically luvic	20-30	41.58	31.73	26.94
SOIL 4	0-10	40.36	38.36	21.28
alluvialsoil –	10-20	40.63	36.08	23.29
typical	20-30	41.2	33.95	24.85

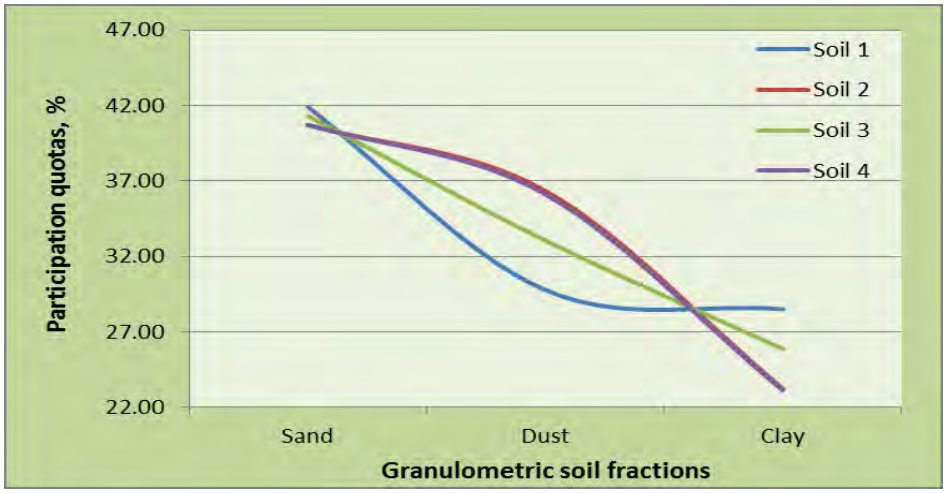

Figure 5. Granulometric curves analysis of the soils

When analysing the granulometric curves presented in Figure 5, one can notice the fact that there was a sandy-dusty-clay-like texture in all the soils encompassed in the experiment at a participation quota that scarcely varies, with the exception of the 1st soil where the particle size distribution is slightly different: sandy-clay-like-dusty texture.

Qualitative parameters

Significant differences between the borer type and between the four types of soils studied in relation to the physical and mechanical properties of the soil were assessed using two-way ANOVA (Figures 6-13), principal component analysis (PCA) (Table 4, Figure 14), linear discriminant analysis (LDA) (Figure 15) and multivariate analysis of variance (MANOVA)

The highest value for the duration of digging was registered for the 2nd type of soil (17,708 s), while the lowest value appeared in the case of the 1st type of soil (8,553 s). Taking into account the diameter of the drill and the type of soil, the maximum digging duration was noted with the 15-cm diameter drill on the 2nd type of soil (D15*Soil02=23,420 s), while the minimum one was found with the 15-cm diameter drill on the 1st type of soil (D15*Soil01=5,407 s).

Analysed only from the perspective of the type of soil, the fuel consumption reached maximum values on the 2nd type of soil (5,649 ml) and minimum ones on the 1st type of soil (4,513 ml). Analysed both from the perspective of the type of soil and the type of drill, the fuel consumption reached maximum values with the 15-cm diameter drill on the 4th type of soil (D15*Soil04=6,863 s) and minimum ones with the 20-cm diameter drill on the 4th

type of soil (D20*Soil01=3,486 s). In the present case, the amplitude of variance of fuel consumption can reach values of ±3,377 ml in the same pedological conditions.

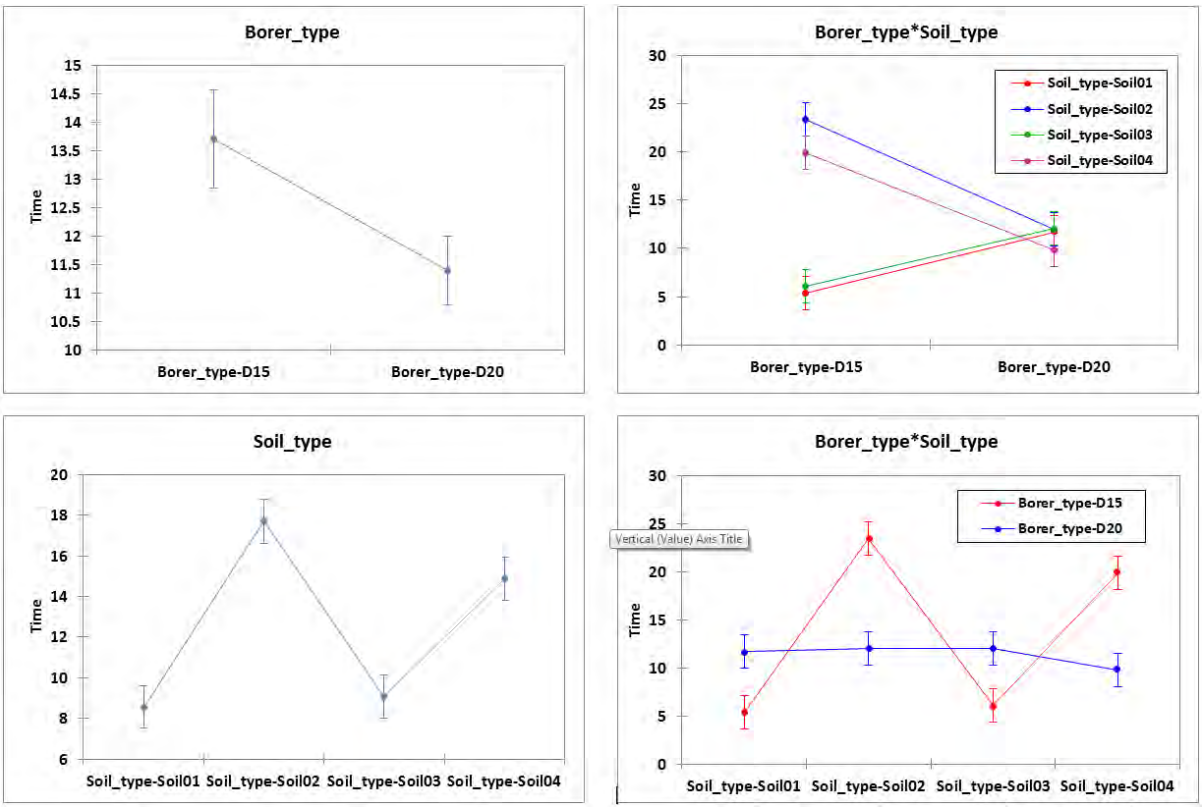

Figure 6. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated timing of drilling holes (Time)

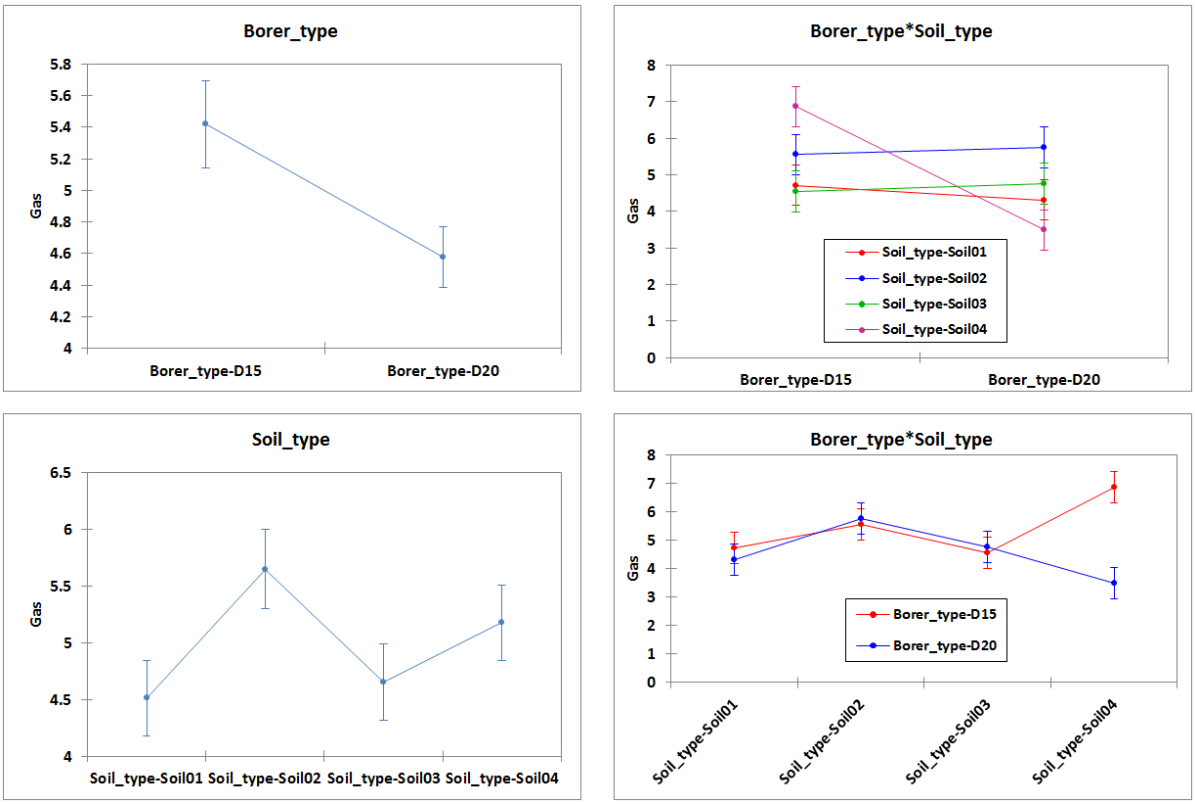

Figure 7. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated fuel consumption (Gas)

The volume of the earth removed reached maximum values in case of the 4th type of soil (0,180 m^3) and minimum ones with the 1st type of soil (0,005 m^3). The same values also apply when we take into account both the type of soil and drill: a maximum value was acquired in the case of the 15-cm diameter drill on the 4th type of soil (D15*Soil04=0,352 m^3) and a minimum one with the 15-cm diameter drill on the 1st type of soil (D15*Soil01=0,003 m^3).

The removal ratio acquires maximum values for the holes dug in the 3rd type of soil and minimum ones for the 2nd type. However, when we analyse both the type of soil and drill, maximum values appear with the 20-cm diameter drill on the 4th type of soil (D20*Soil04=6,012) and minimum ones with 15-cm diameter drill on the 4th type of soil (D15*Soil04=2,903).

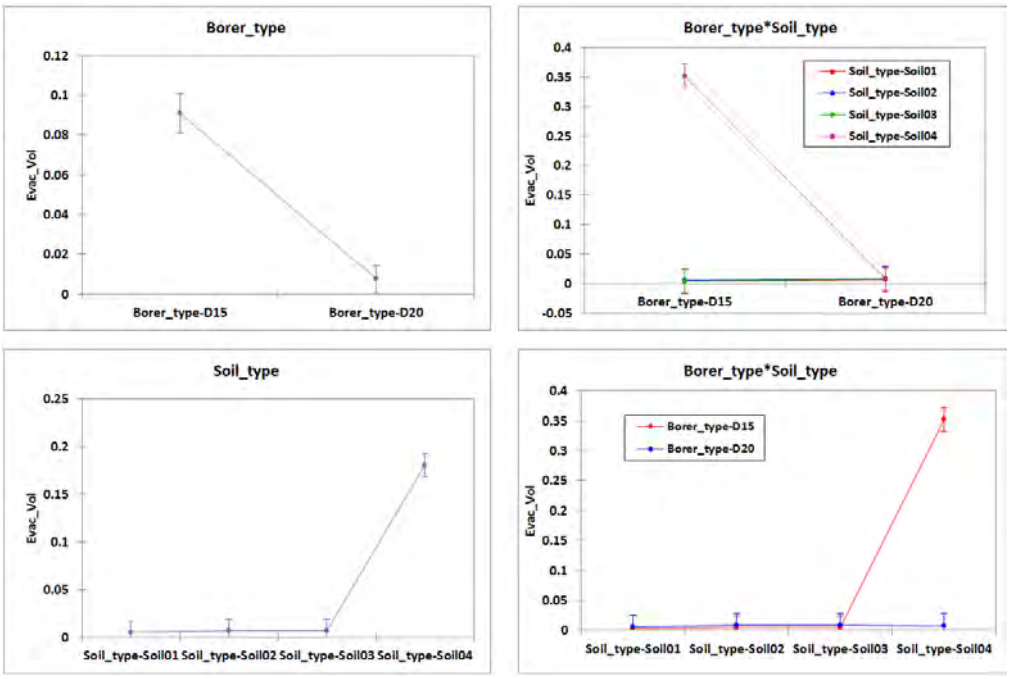

Figure 8. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated degree of evacuation (Evac_Vol)

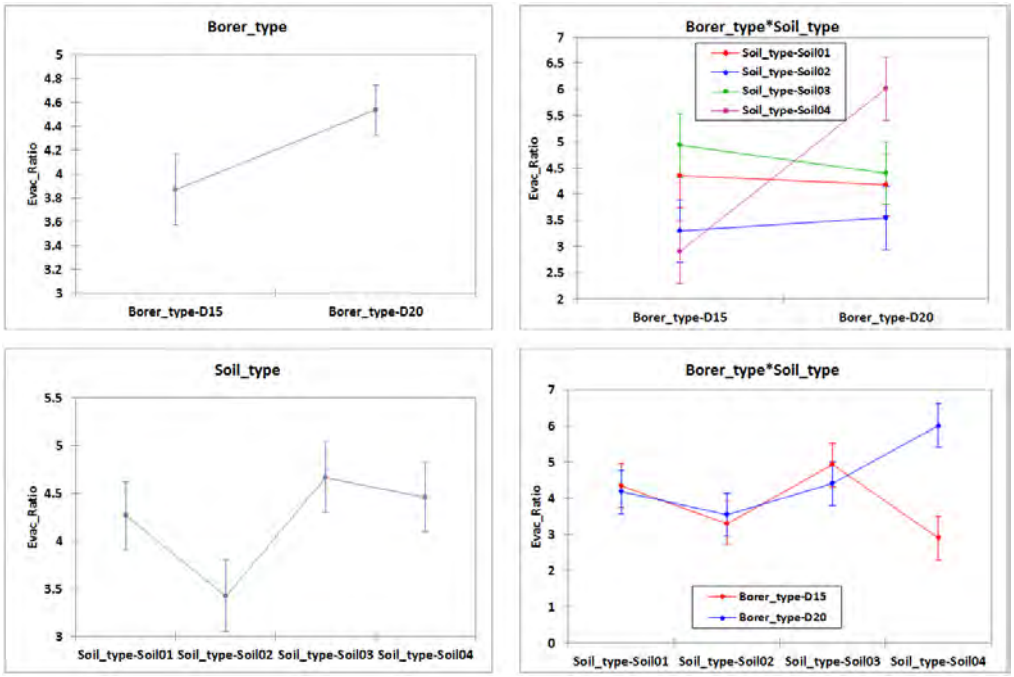

Figure 9. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated evacuate ratio (Evac_Ratio)

The average radius of scattering of the earth removed had maximum values in the case of the 4th type of soil (34,355 cm), and miminum ones with the 2nd type of soil (13,495 cm). The same situation occurs when we analyse both the type of soil and drill: a maximum value is reached with the 15-cm diameter drill on the 4th type of soil (D15*Soil04=36,125 cm) and a minimum one with the 20-cm diameter drill on the 2nd type of soil (D20*Soil02=12,899 cm).

The angle of placement of the earth removed reaches maximum values in the case of the 3rd type of soil (22,578°), and minimum ones in the 1st type of soil (11,213°). By analysing this qualitative index both from the point of view of the type of soil and drill, a maximum value is reached with the 20-cm diameter drill on the 2nd type of soil (D20*Soil02=32,399° and a minimum one with the 15-cm diameter drill on the 1st type of soil (D15*Soil01=9,597°).

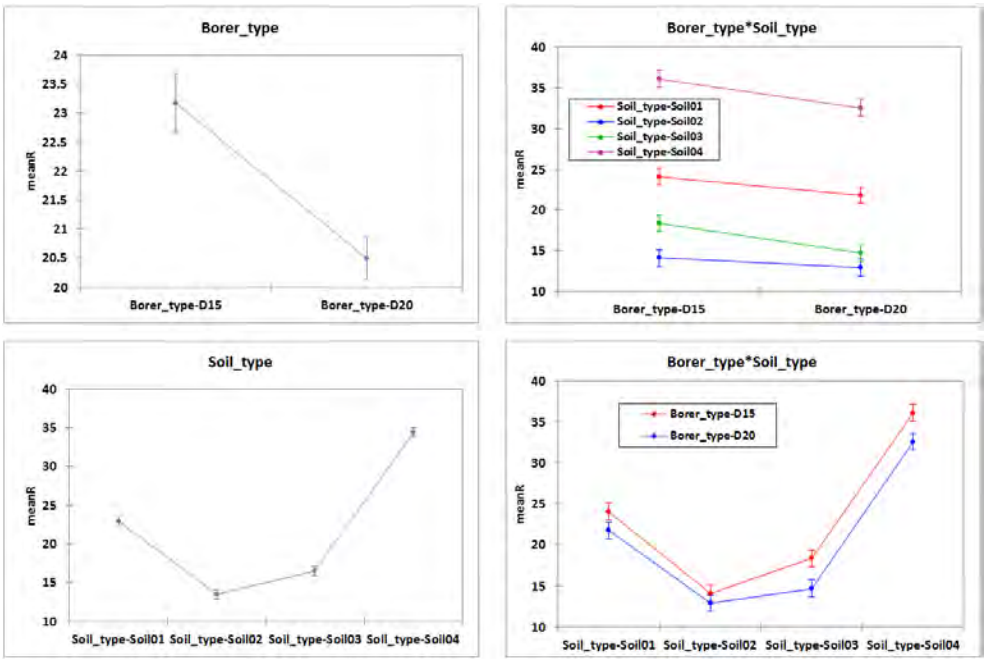

Figure 10. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated medium range scattering (meanR)

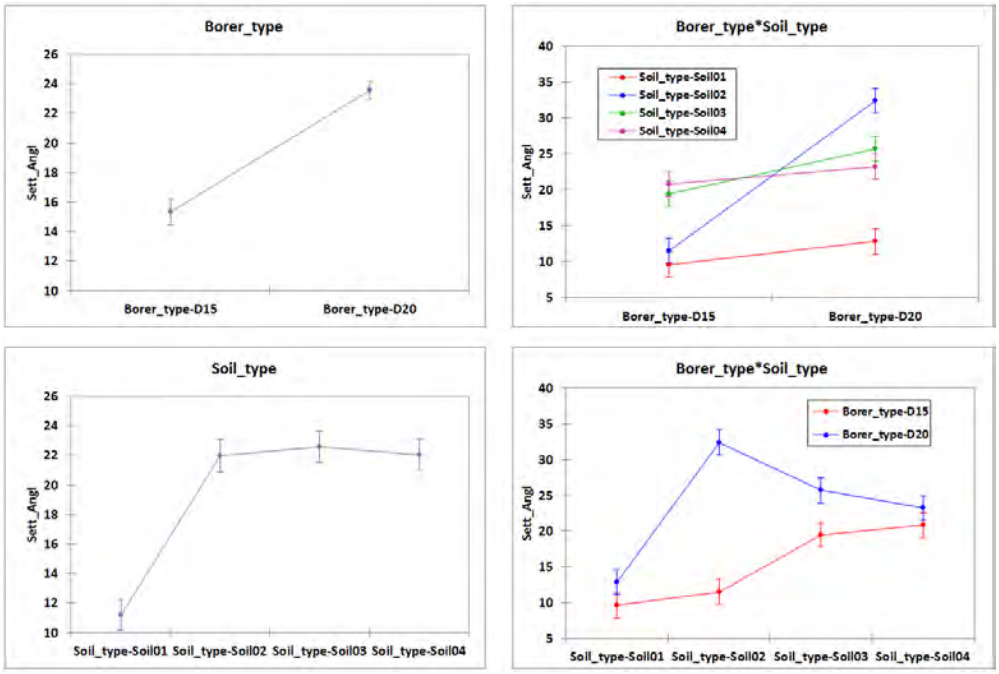

Figure 11. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated settlement angle (Sett_Angl)

By analysing the values of the penetration resistance, only from the point of view of the soil, the highest value is met in the case if the 4th type of soil (2,557 daN/cm^2) and the lowest one in the 3rd type (1,734 daN/cm^2). Thus, there is a very low risk that saplings could experience a physiological unbalance due to the fact that their roots cannot penetrate the sides of the holes (as a result of the fact that they were pressed during execution). The same situation also occurs in the case of the analysis based on both the type of soil and drill, as we run a very low risk of pressing the sides of the holes: a maximum value appears with a 20-cm diameter drill on the 4th type of soil (D20*Soil04=2,822 daN/cm^2) and a minimum one with the 15-cm diameter drill on the 3rd type of soil (D15*Soil03=1,232 daN/cm^2).

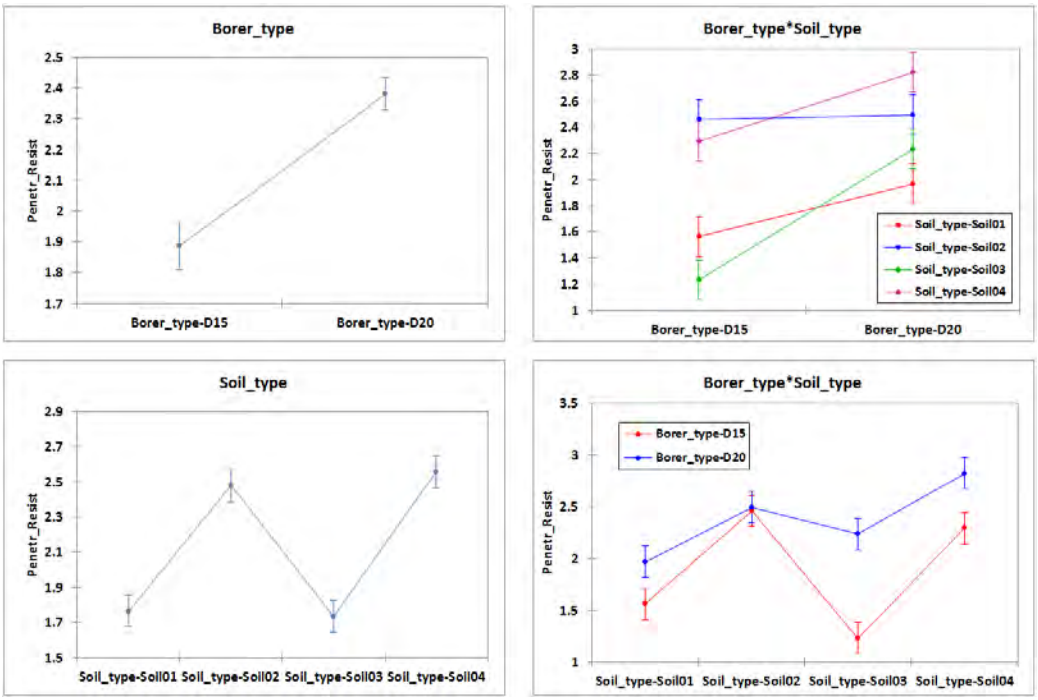

Figure 12. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated resistance to penetration (Penetr_Resist)

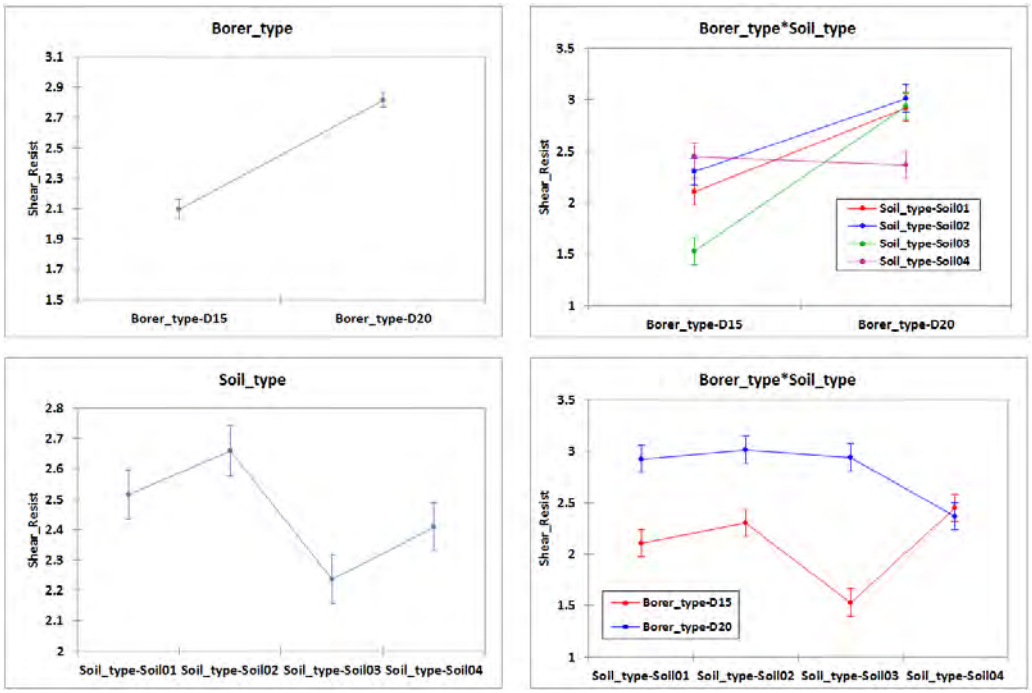

Figure 13. Interaction plots (two-way ANOVA) for the factors soils type and borer type for the investigated resistance to shearing (Shear_Resist)

A similar situation also occurred in the case of the shear resistance measured in the holes: the highest value was acquired in the 2nd type of soil (2,658 daN/cm^2) and a minimum one in the 3rd type (2,236 daN/cm^2). The quotas are maintained for the values involving both the type of soil and drill, as the maximum value was reached with a 20-cm diameter drill on the 2nd type of soil (D20*Soil02=3,016 daN/cm^2 and a minimum one with the 15-cm diameter drill on the 3rd type of soil (D15*Soil03=1,530 daN/cm^2).

PCA analysis was calculated using the correlation matrix of the variables and the between group algorithm. First two principal components explain 65,24% from the total variance of the data. The first three principal components explain 81,89% from the total variance of the data (Table 3 and Figure 14).

Table 3. Principal components statistical results

Principal Component	Eigenvalue	Variance (%)
1	2.84974	40.711
2	1.71729	24.533
3	1.16566	16.652
4	0.736855	10.527
5	0.456835	6.5262
6	0.0718962	1.0271
7	0.0017237	0.024624

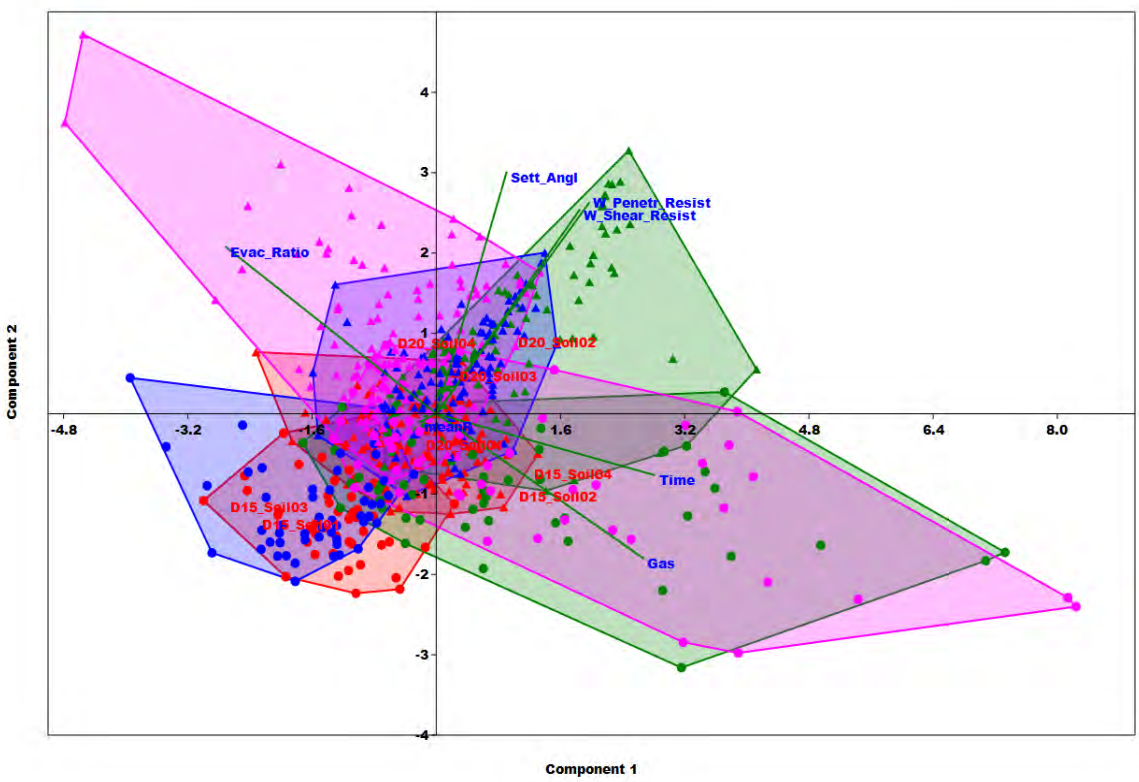

Figure 14. Principal component analysis (PCA) biplot

To alleviate the samples groups overlapping in PCA biplot, there was used the linear discriminant analysis (LDA) which uses canonical projections similar with the PCA method but aims to increase the linear distance between the samples groups (i.e. to get a better discrimination).

Figure 15 presents the 3D representation of the samples groups using the first three canonical axes of LDA. The MANOVA statistical results (P = 0.05) are presented in Table 3 where can be noticed that all eight sample groups are validate (with 95% accuracy) as sample clusters.

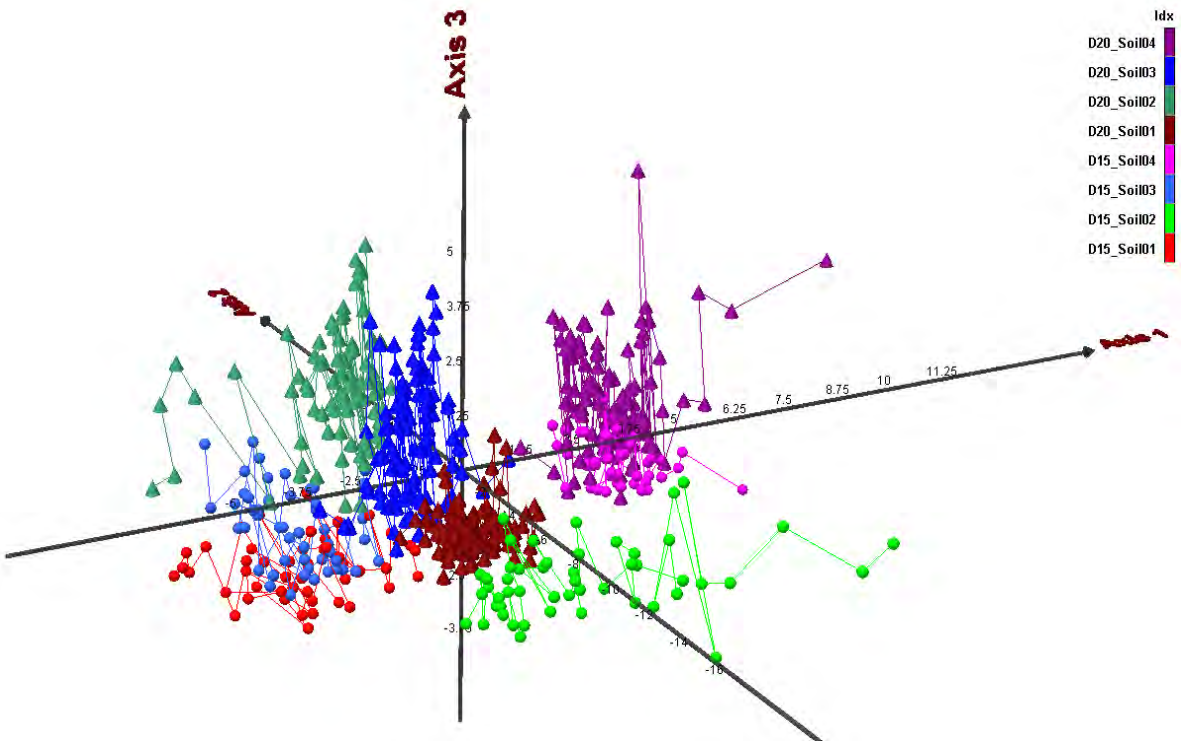

Figure 15. 3D reprezentation of LDA grouping

Table 5. MANOVA pairwise comparisons statistical significances (P=0.05)

p-value	D15_Soil01	D20_Soil01	D15_Soil02	D20_Soil02	D15_Soil03	D20_Soil03	D15_Soil04	D20_Soil04
D15_Soil01		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
D20_Soil01	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
D15_Soil02	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
D20_Soil02	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001
D15_Soil03	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001
D20_Soil03	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001
D15_Soil04	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001
D20_Soil04	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	

Conclusions

From all of the above, we can infer the following conclusions regarding the behaviour of the Stihl BT 121 auger with a 150/200 mm drill in the forestry sector and on a previously unprepared horizontal ground:

- The holes were dug when the values of soil moisture were ranging from 20.75 to 24.11% for the 0-10 cm depth, 19.46-22.73% for 10-20 cm depth and 8.74-20.09% for the 20-30 cm depth.

- The values of total porosity that vary as follows: for 0-10 cm between 35.54-37.89%; for 10-20 cm between 33.28-37.43% and for 20-30 cm between 31.25-36.45%.

- The average values of duration needed to dig holes (starting from the moment when the drill penetrated the soil, bored until reaching the 30 cm depth and was pulled out of the hole) vary between 9.83±2.52 and 12.06±1.99 seconds (mean±SD).

- The amplitude of average variation (the mean between the difference of maximum and minimum values) for the duration of digging holes is 13.36 sec., which is a high value. However, in terms of particle size distribution, the soil texture is similar. These differences occur as a result of physical properties of the different soils while digging.

- The average value of split times derived from hole digging (time lapse of the auger put on, from one hole to the other, according to the planting layout: 1, 2, 3 or 4 metres), is at a 1m-distance, 2.71±1.41 sec.; at 2 m, 5.42±2.83sec.; at 3 m, 8.14±4.24 sec. And at 4 m, 10.85±5.66 sec. (mean±SD).

- The average values of fuel consumption for the four types of soil are: 3.49±0.89 for the 4th type of soil, 4.31±1.14 ml for the 1st type of soil, 4.76±0.79 ml for the 3rd type of soil and 5.75±1.80 ml for the 2nd type of soil (mean±SD).

- The average quantity of fuel needed for digging a hole up to 30 cm: 4.31 ml for the 1st type of soil, 5.75 ml for the 2nd type of soil, 4.76 ml for the 3rd type of soil and 3.49 for the 4th type of soil.

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A NEW SPATIALLY EXPLICIT METHOD TO ASSESS THE QUALITY OF A FOREST NETWORK IN TERMS OF TERRAIN ACCESS FOR HARVESTING OPERATIONS

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Abstract: *Although the road density in Switzerland is rather high, a high percentage of the forest road network does not fulfill the requirements of the state of the art. Before upgrading or rebuilding the road network, there is a need to identify areas with an insufficient access. Classical methods just deliver specific values, such as the road density [m/ha]. However, such values do not identify parcels or areas with an insufficient access. We present a method that is based on spatial modelling of the harvesting systems and road network analysis to identify for each parcel in the forest the quality of the access (optimal harvesting system, weight limit for trucks and cost estimation). The method is particularly designed for steep terrain and was applied in the canton of Graubünden in Switzerland.*

Keywords: road network access, steep terrain harvesting, forest operations, spatially explicit

THE PROFITABILITY OF BIOMASS HARVESTING IN SPRUCE STANDS WHEN CONSIDERING NUTRIENT CYCLING

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Abstract: *More and more tree tops are chipped and used for energy supply in Bavaria. Tree crowns are richer in nutrients than the stemwood. If the loss of nutrients by biomass harvesting and seepage water exceeds the input into the ecosystem by deposition and weathering the soil will leach out. This can reduce the forest soil productivity. In this case fertilizing is necessary to compensate the losses. Which intensity of harvesting is economical when considering the costs of compensation? The revenues from harvesting during a whole rotation period are calculated for a spruce stand on a poor site and one on a rich site. In the calculation the harvesting intensity is raised stepwise from the thick to the thin stemwood and is finally extended to the limbs, twigs and needles. Also the rising extraction of nutrients is calculated as well as the costs of fertilizing for compensating the losses. All costs and revenues are prolonged to the end of the rotation period. The increase of the revenues and costs depending on the harvesting intensity is shown in a chart. The harvesting intensity is optimal at the point where the marginal revenues equal the marginal costs. The results show that the fertilizing costs are low in comparison to the revenues. However, whole-tree harvesting isn't profitable on the poor site. It is necessary to draw up a nutrient mass-balance for determining critical nutrients. Then a nutrient management system for forestry can be developed.*

Keywords: whole-tree harvesting, nutrient balance

CHALLENGES IN FOREST ROAD NETWORK DEVELOPMENT IN EASTERN EUROPE

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Abstract: *Forest roads provide access to a wide range of forest services and products while they are contributing also to other human activities. This study investigates the challenges related to the forest road network development in countries of Eastern Europe based on factual data and expert views. First, a description of the current forest road network is provided for each participating country, along with information on regulations, involved stakeholders at strategic and operational level, available expertise, assessments on the need to develop new forest roads, financial mechanisms supporting the development of new forest roads and costs for forest road construction and maintenance. Then a SWOT analysis is implemented to assess the internal strengths and weaknesses as well as external factors that may affect the forest road development such as opportunities and threats. The information collected as weaknesses, opportunities and threats is then aggregated into meaningful sentences describing challenges to be addressed in the future. Six groups of possible challenges were identified describing issues such as: (i) environment protection, public perception, and human activity in relation with forest road network, (ii) road maintenance of existing and newly developed roads, (iii) the need of developing intelligent information systems, (iv) the need to find financial resources for developing new roads, (v) the need to increase the forest accessibility and (vi) the need to develop strategies, policies, regulations, expertise and training. The results of this study may be helpful in understanding that points which need further attention in the future.*

Keywords: forest roads, factual data, expertise, SWOT, challenges, development

MEASURING GEOMETRICAL CHARACTERISTICS OF THE FOREST ROAD - PUBLIC ROAD JUNCTIONS USING DRONES

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Abstract: *The junctions between forest and public roads are a common space designed to fulfill connection functions. Field research was carried out on forest road - public road intersections from Braşov County. During the field study, the geometrical characteristics (roadway width, sight distance, angle of junction, maximum gradient, etc.) of the the forest road - public road junctions were measured. For the first stage, the geometry of each intersection was surveyed using a TCR 407 total station manufactured by Leica Geosystems. For the second stage, geometrical characteristics of the same forest road-public road junctions were measured using formation drone aircraft. In the finaly, these two results were compared to observe the accuracy of the measurments with drone. Thus, it is found the method of measuring geometrical characterisitics of the forest road - public road junctions using drone is viable from scientific viewpoint.*

Keywords: sight distance, forest road, road junction, drone

APPLICABILITY OF CT SCANNING FOR LOG SAWING OPTIMIZATION

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Abstract: *Sawn timber is one of the most important products from forests in terms of traded volumes. For almost any of its uses, the intrinsic wood properties such as density and knottiness or other features decide on the quality and thus value of the product. Controlling the large natural variability of the raw material in the sawing process to obtain the highest value possible from every log is challenging with the high demand on production in modern sawmills. X-ray computed tomography (CT), widely recognized as the most feasible internal log scanning technique, is currently gaining ground in industrial practice. In this context, different application cases relating to product type - such as appearance- or strength-graded lumber - or raw material are reviewed based on the findings of recent studies. While these findings suggest that there is good potential to improve value yield by using CT log scanning in different production scenarios, the observed sensitivity of such an optimization system to the accuracy of the feature mapping indicates the importance of reliable feature detection in the CT image. The latter is a more intricate task in the case of hardwoods than in the case of softwoods due to the differences in wood anatomy, especially the higher wood density combined with lower density contrast between stem wood and knots of most hardwood species. Combining CT scanning with other techniques for non-destructive testing and external scanning might enable more detailed individual log characterization and thus improve material allocation already at pre-harvest or harvest stage.*

Keywords: internal log scanning, sawing optimization

INNOVATIVE AND ADAPTED WOOD SUPPLY CHAINS AS A PREREQUISITE FOR SUSTAINABLE MANAGEMENT OF THE BRAZILIAN ATLANTIC FOREST

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Abstract: *One of the largest rainforests in the Americas, the Atlantic Forest, originally covered around 150 million hectares in highly heterogeneous environmental conditions. Nevertheless, in the past century, the expansion of agriculture and urbanization rapidly shrunk the forest land base to approximately 12% of its original size. Conservation and management of the ecosystems are currently largely conflicting goals in the Brazilian Atlantic forest region. All fragments of the Atlantic Forest are protected and any timber harvesting is banned at the moment. However, environmental regulations for protecting remaining forests proved to be ineffective as landowners were not compensated and law enforcement was insufficient. A policy to promote the sustainable utilization of native species from secondary forests seems to be more promising with respect to protection and creation of income opportunities for the land owners, but scientific data to support effective policy-making are rare, in this respect. This research project aims to fill this gap by providing harvesting data from secondary forests exempted from the logging ban for research purpose and analyzing different wood supply chains of relevance. The goal of the study was to investigate economic feasibility and environmental impacts of timber harvesting operations including assessment of related species drifts. According to species composition, two different harvesting techniques were tested in a single tree selection approach. Time studies for the analysis of harvesting methods were performed and direct environmental impacts of timber harvesting operations were assessed. Based on the results recommendations for best management practices for sustainable utilization of secondary forests in the Atlantic Forest region are given.*

Keywords: cable winch, time study, environmental impact, RIL, secondary forest management.

EFFECTS OF SOIL PENETRATION RESISTANCE ON EARLY RESPONSE OF Q. ROBUR SEEDLINGS SINCE GERMINATION

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Abstract: *Negative consequences of compaction may cause changes in soil characteristics and such conditions can influence negatively seedlings development. Plantlets may delay both germination and penetration of the soil surface by the radicle and the alterations in compacted soil may also affect plants rooting through variations in structural arrangement in attempt to avoid the mechanical obstacle. This work aimed to assess the early response to the soil compaction of Quercus robur seedlings during the first month and half after germination. The experiment was carried out in a nursery and the compaction was obtained by direct compression of the soil surface on the top of containers using a compression machine in laboratory. Three compaction levels were considered (low:<0.5 MPa, medium: 1 MPa, and high: 2MPa). We investigated the effect of soil compaction on morphological attributes of seedlings grown in plastic containers on above and below ground traits during the first month after germination. In particular, morphological traits of seedlings' shoot and root system were analysed comparing the various degrees of compaction. Results showed significant differences in seedlings traits among treatments and a constraint effect of increasing levels of compaction on early seedlings growth. The effect was particularly detrimental on root system development, particularly on the development in depth (root system depth, main root length). This represents a critical factor for regeneration establishment. Our results suggest that compaction affects seedling root system growth since the first growth stages after germination, thus, it represents an additional critical factor for seedlings establishment, particularly in Mediterranean environments where the early growth is critical to overcome the dry season.*

Keywords: forest operations, seedlings growth, seedling root-system

USE OF HIGH MULTI-TEMPORAL GROUND RESOLUTION MODEL BY PORTABLE LASER SCANNER AND PHYSICAL PARAMETERS SAMPLING TO ASSESS SOILS DISTURBANCE CAUSED BY LOGGING OPERATION

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Abstract: *Forest operations may lead to negative consequences in terms of compaction and rutting, which may result in soil degradation processes such as erosion, mudflow and landslides. The damage depends on type of vehicle, number of passes, ground morphology, soil properties and slope. The aim of this research was to investigate the impact on soil caused by logging operations through ground survey and terrestrial portable laser scanner (PLS). Samplings were carried out in two trails that differed for the numbers of machine passes and slope. The data collection where performed before and after logging to analyze the impact on soil of forest operations. The specific objectives were: (i) to analyze how forest operations have influenced soil compaction and rutting; (ii) to assess soil compaction with traditional techniques; iii) to determine logging caused rutting with high-resolution ground surface models generated by PLS scans; iv) to assess the differences in the soil disturbances in two different trials. Significant impacts were detected with both investigation methods, i.e. physical parameters and multi-temporal analysis of high resolution ground surface models derived by PLS. Therefore, in order to limit the damage to the soil, it is important to apply extraction methods and machines in relation with the specific site conditions, especially when a high mechanization level is used. We demonstrated that PLS technology can produce a fast, precise and accurate measurement of the impact of forest operations on soil.*

Keywords: forest logging, soil disturbance, precision forestry, PLS, terrestrial laser scanner

COUPLING MOTION DETECTION AND SOUND PRESSURE SENSORS TO AUTOMATE DATA COLLECTION IN MOTOR-MANUAL PRODUCTION STUDIES

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Abstract: *Motor-manual tree felling and processing is a common option in harvesting operations. In addition, equipment such as brush-cutters is used to manage the willow short rotation cultures in operations such as cut-back and shoot felling. Nevertheless, collecting production data in such operations can be particularly demanding and resource intensive. This paper explores the possibility to substitute the human capabilities in activities related to the collection of production data by coupling motion detection and sound pressure sensors to automate such tasks in a simulated approach. To this end, motion detection and sound pressure sensors were tested on a chainsaw and a brush-cutter in a comparative test. Typical engine functioning regimes, as well as the typical motions in tree-felling, processing and willow shoot felling operations were simulated by an experienced worker in several replications. A digital camera was used to collect the real succession of simulated events and the collected files were used for comparison purposes. Data gathered by sensors was paired into a MS Excel sheet and synchronized with data collected by video camera. Our results indicate promising ways of automating the data collection activities. In particular, the engine functioning regimes can be easily inferred from vibration and sound pressure data. Also, the motion detection data indicates real possibilities to infer the type of cuts carried out motor-manually, therefore to detect specific work elements without actually observing the operations in the field. More research would be needed to test and validate the applicability of such techniques in real operations.*

Keywords: motor-manual, motion detection, sound pressure, sensor, production data, automation.

USING SOUND PRESSURE SENSORS TO MONITOR THE PERFORMANCE OF MANUALLY OPERATED CIRCULAR SAWS: WHAT PARAMETERS CAN BE INFERRED?

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Abstract: *Sawmilling operations are implemented in order to transform the logs into various wood products required by manufacturing industries. While large-scale sawmills integrate the latest wood processing technology including those systems enabling the production monitoring, the small-scale facilities use simpler equipment to process the wood and often lack monitoring systems. However, production monitoring data is crucial in maintaining an optimized operational layout. This study explores the possibility to monitor the operational behavior of small-capacity manually-driven circular saws using external sound pressure sensors. To this end, a sound pressure sensor was used to gather operational data in order to compare it with video recorded events specific to such equipment. Observations were carried out in real operational conditions. Data gathered by sensors was synchronized with data extracted from video files. The results were promising from several points of view. First of all, such approaches may automate the data collection activities for that kind of equipment integrating low or no production monitoring functions, enabling the implementation of informed decision-making processes on the operational optimization in small-scale sawmilling facilities. Engine functioning time in both, no sawing and sawing tasks may be extracted from data gathered by sensors supporting an accurate separation in both regimes. In addition, the time consumption in no engine running regime as well as the number of crosscuts can be accurately inferred from the data. However, different kind of delays overlapping with the engine running during no sawing tasks cannot be extracted from the automatically collected data*.

Keywords: sawmilling, production monitoring, sound pressure sensor, automation

CONDITIONS OF FOREST ROAD NETWORK IN TERMS OF SUSTAINABILITY IN GERAKA - KIMMERIA - XANTHI FOREST COMPLEX

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Abstract: *The present study of the forest road opening-up works of the forest complex Geraka - Kimmeria - Xanthi, aims to improve the existing forest road network and the wood skidding conditions, in order to satisfy all the modern demands of the sustainable management. Another purpose of the paper is the improvement of the forest recreation conditions, the utilization of the natural beauty of the pre-mentioned area and the increase of tourism which has a fundamental role in the local economy. The paper deals with the collection and the analysis of the field data and also data concerning the geographic position and the land area of the forest complex. Moreover, information for the geological, climatic, demographic and economic conditions of the region is included. Finally, there are data for the existing vegetation, the recreation and the mountainous tourism conditions and transportation conditions. Furthermore, the optimum road density is calculated and it is compared with the existing road density. Then, the quality of the road network is examined, as a result of the optimum road density that was achieved. Thus, improvements are proposed and specifically the improvement of forest road category C to forest roads category B. It has been also studied the construction of technical projects in terms of sustainability which should be in harmony with the natural environment, without causing damages but aiming to protect the environment. Also, the relation between the forest road network and forest recreation in the forest complex of Geraka - Kimmeria - Xanthi is examined. Improvements to the existing recreational areas are proposed and it is also studied the optimum way of the design and the construction of forest roads for recreational purposes. In the last but not least part of the paper the improvement of the wood-skidding conditions is studied. Specifically, the most appropriate means of the wood-skidding are proposed according to the local, economic-technical and ecological data of the area.*

Keywords: Geographic Information Systems (GIS), managment, recreational activities

ECONOMIC ANALYSIS OF LONG-TERM OPERATION OF A HARVESTER AND FORWARDER UNDER FOREST OWNER MANAGEMENT

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Abstract: *Acquisition of a harvester technological line (harvester, forwarder and other operating machinery) represents considerable investment which requires a detailed economic analysis of the return on investment. The paper presents a complex cost analysis of a harvester technological line consisting of a John Deere 770D harvester, small forwarder LVS 5 by Novotný and two technological transport operating vehicles over a 10-year period from 2007 to 2016. The cost analysis will include the description of work organization within the given harvester technological line, system of worker remuneration and a performance evaluation of the entire period. Conclusions will discuss the advantages and disadvantages of running an independent harvester technological line from the perspective of a forest owner.*

Keywords: harvester, forwarder, acquisition costs, operating costs

Supported by National Agency for Agricultural Research Czech Republic under the project no. QJ1520005: "*Optimization of cut-to-length logging and grading of harvester-processed timber and proposed control procedures of timber volume measurements accuracy with the objective to enhance the production function of forests and maintain stand stability with respect to harmful agents*."

A REPLACEMENT COST APPROACH ON ASSESSING THE HYDROLOGICAL ECOSYSTEM SERVICES PROVIDED BY FORESTS IN TORRENTIAL CATCHMENT AREAS

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Abstract: *The study aims to estimate the hydrological services brought about by forests in torrential watershed located in mountainous or hilly areas where other methods like contingent valuation, opportunity cost or avoidance costs cannot be used for insufficient or difficult to collect data. We have assumed as proxy of the runoff control and flood prevention ecosystem services the value of the two types of alternative projects frequently put in place mountainous areas prone to torrents: dams and channels. Having whatever statistical function that gauges the relationship between a given set of independent variables (including the forest percentage) that describe a series of catchment area where dams and channels have been installed in order to prevent floods downstream it is possible to derive the expected additional volumes of dams and lengths of channels needed to offset a theoretical loss of one percent of forest in the catchment area. Based on this hypothesis and having the average costs for one cubic meter of dam and one meter of channel respectively and a series of data describing more than 100 watersheds where dams and channels had been constructed in the last fifty years in Suceava county (North-East Romania) we have appraised the marginal cost of reducing the forest area with one, five and ten percent.*

Keywords: forest hydrological services, social costs

A CHARACTERISATION OF THE ASH CONTENT OF CONIFER STUMP WOOD HOGFUEL

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Abstract: *A study was carried out in the south-east of Ireland in which stumps were harvested from two sites: a peat soil site and a peaty gley site. The stumps were harvested by excavator machines with a stump harvesting head which split and shook as much soil off the stumps as possible. The stumps were stored on the site for a period to further reduce soil contamination by weathering. The stumps were forwarded to the roadside and comminuted into hogfuel with a shredder. Samples were collected and prepared in three ways: hogfuel as received, clean stumpwood, and sieved hogfuel. The hogfuel as received was collected from the shredder. The clean stumpwood was collected from stumps with a chainsaw prior to shredding. The sieved hogfuel was prepared using a oscillating sieve using apertures of 63 mm, 45 mm, 31.5 mm, 16 mm, 8 mm, 3.15 mm, and the collection of fines below 3.15 mm. The samples were analysed for ash content using a muffle furnace, and gross calorific values using an oxygen bomb calorimeter. Results have allowed for the comparison of clean stumpwood and hogfuel as received, which identifies the proportion of ash content associated with soil contamination, and that which is inherent to stumpwood. Results also describe the ash content along the particle size distribution, and describe which particles, and thus the proportion of the fuel, need to be sieved out in order to increase the fuel quality to an acceptable condition, and the effect of this on the energy content.*

Keywords: stump harvesting, fuel quality, ash content, calorific value.

IRISH WOOD FUEL DATABASE (A WEB BASED DATABASE OF WOOD FUEL PARAMETERS)

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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, 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.*

Keywords: wood fuel characteristics, database

EXTRACTION FOREST ROAD LINES FROM HIGH SPATIAL RESOLUTION SATELLITE DATA

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Abstract: *To understand the importance of the forest road network, it is necessary to know that the roads are an integral part of forestry activities such as harvesting, transport, forest protection, fire prevention, recreational actions etc. Road network plans (maps) required to plan, organize, implement and supervise forestry operations are already developed through the road network inventory taken by terrestrial methods (GPS-assisted). Data regarding the spatial structure and some physical features of a road network are collected by means of remote sensing data and methods instead of labour-intensive and time-consuming conventional terrestrial methods, which has resulted in the emergence of innovative approaches. The progress and developments in remote sensing technology have yielded satellite images with high spatial resolution. It is possible to identify the roads and distinguish the other objects on these high-resolution satellite images. The purpose of this study is to identify the roads in forest areas with the help of satellite images with high spatial resolution. During the study, an attempt was undertaken to detect the road network using object-based classification method in addition to pixel-based classification methods. The road network detected by using WorldView-2 satellite image was compared with the existing road maps to verify their accuracy. In this way, a methodology was developed to map the forest roads automatically.*

Keywords: forest roads, semi-automatic road detection, object-based classification, pixel-based classification, WorldView-2

UTILIZATION OF PHONE APPLICATION TECHNOLOGY TO RECORD LOG TRUCK MOVEMENT IN THE SOUTHEASTERN UNITED STATES

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Abstract: *In order to accurately gather information concerning delay times at the mill, the landing, and during travel to and from each location, a phone app was created that recorded driver location using GPS. This app also allowed the driver to input the reason for their delays, record their fuel stops, delivery scale tickets, load sheet numbers, starting mileage and ending mileage. Initial research was conducted in three states to ensure its ability to work in various environments. Results indicated that turnaround times for all drivers from all states averaged approximately 36 minutes both in the mill and on the landing. Maximum turn times ranged from 1:16 to 2:29 at landings and 1:18 to 3:39 at mills. Average turn times were determined to be reasonable, however, the maximum turn times caused issues of concern with driver time, haul costs, and overall costs which need to be addressed.*

Keywords: delays, turn times, android phones, google technology, GPS

Introduction

Delays incurred by loggers hauling wood from the landing to the mill affect profitability and have the potential to make harvesting some areas unfeasible. Studies have been conducted to determine single direction turn times for logging trucks from the landing to the mill, however, these studies failed to portray real life situations such as the traffic accidents, road conditions, lunch breaks, admin delays and when the driver is forced to wait in order to load his truck. These previously mentioned reasons can potentially cause delays and influence overall harvest cost negatively if they occur too often or for an extended duration of time (Deckard, Newbold, and Vidrine 2003, Holzleitner et al. 2011, Barrett 2001, Sankaran & Wood 2007).

Past studies collected delay response data by using fleet management equipment that connected to the drivers' tractor but, unless there was someone monitoring the computer screen observing all of these delays for the duration of the driver's work day, delay reasons were not recorded. Logging companies are looking for ways to reduce their haul costs in addition to their overall costs. If a company is forced to hire an additional person to observe truck locations and inquire about delays, they will not be reducing their costs significantly enough and could, in fact, increase their overall expenditures. By directly asking the driver the reason for the delay at the exact moment it occurred from a piece of equipment he has on him, accurate information in real time can be recorded.

Potential harvest sites are often times discarded after an economic analysis is conducted because of the haul costs associated with the sale. Mathews 1942 originally found that haul costs produce one of the biggest expenses to the logger a majority of the time due to increased fuel prices and frequent maintenance costs required to maintain the equipment that travels in a wide variety of road conditions. While this research may have been conducted decades ago, it is still found to be true and applicable today. Even the best drivers and

businesses inevitably incur delays, and although trucks that are idling due to a delay use less fuel than those that are driving on the road, they are losing production time and therefore losing money (Fluck 2012). Delays are considered to be maintenance on the machine, breakdowns on either the tractor trailer or another piece of equipment which inadvertently pauses the entire logging system process, waiting in line at the mill to unload because of a mill regulated quota, lunch breaks, administrative delays, or even dealing with traffic during travel (Baumgras 1978). Although it is understood that delays will occur, the types of delay, the duration of the delay and where the delay is occurring represent information that if communicated quickly could be used to diminish delay times or at least analyze them more accurately when determining haul costs.

Objectives for the Study

1) Create a phone app that collects drivers start and ending time, location, duration at each location, the number of stops made, and allows the driver to input a reason for being delayed.
2) Provide drivers the option of inputting starting and ending mileage, fuel stops made, gallons of fuel consumed, delivery and scale ticket numbers.
3) Analyze delay locations, driver durations at each location, and reasons for being delayed.
4) Provide results for both industry and loggers to view and utilize to reduce delays.
5) Provide turnaround times for various mills grouped by type, state, and/or region.
6) Provide cycle times for participating loggers.
7) Compare set-out trucking versus hot-loading.
8) Compare the tradeoff of in-woods utilization versus truck utilization.
9) Provide a productivity analysis during quota versus non-quota times.
10) Provide a haul cost analysis guideline for truckers.

Justification

The study was conducted using a cell phone app because cell phones now play such an immense part of everyone's lives regardless of age or gender. A recent survey indicated that 92% of adults in the United States own a cell phone and that 68% of these adults own a smartphone (Monica Anderson 2015). This number has increased 33% from 2011. Due to this fact, our belief was that more accurate results could be collected in real time from loggers using their cell phone as the medium rather than if you would try and inquire at the end of the week or even the end of every day on paper. Initially, there was a thought to have loggers record delays manually in a delay record book since truck drivers are required by law to keep log books recording their drive miles and hours, however, these books are not always kept up to date, therefore, it was assumed without significant incentive, ours may not be kept properly either. Bird et al. (2003) found that delays are not significant to the truck driver because they occur so frequently, therefore, the individuals incur a mentality of why should they remember exact details.

The study chose to record round trip delays from the landing to the mill rather than one-way delays for two reasons. First, one-way trips have already been covered in previous studies (Holzleitner et al. 2011, Barrett 2001, Sankaran & Wood 2007). These studies did a good job of portraying delays as they occurred one way, but in order to be able to truly fix the delay issue, it needs to be understood exactly where, when, and why the delays are occurring. This project intended to inquire about delays throughout the entire day and therefore every segment of the trip the driver covers to determine why the delay is occurring. The second reason for the round trip study was based on the fact that if the phone app was downloaded onto the drivers' phone, it was not able to differentiate between the drivers' routes to the mill or to the landing. Rather than create more confusion and potential errors by having the driver turn the app on and off for each trip, it was better to simply leave the app running and gather data the entire day.

Approach

Development of the phone application was initiated in the spring of 2015. The app was a Google-based application which only ran through Android-based phones; I-phones were not programmable for this project due to their high clearance security settings. The trucking app was programmed using Java. The phone application was shared to designated participants through a Gmail/Google Drive account that was created specifically for

each driver for this project. All collected data was received and stored in the drivers google drive account and was then shared through Google drive to a designated website that was created specifically so that it could analyze the data. This website provided the viewer with information concerning the driving date, the time the driver began and ended their day, the number of stops made, the total stopped time, mileage, the state they traveled in, the latitude and longitude of the stops made, the exact time the stop was made, the duration of each stops, user-defined stops (delays), the reason for the delay, and time associated with the delay. The website also provided a KML download of the file so the viewer could view the day in google earth.

Initial data collection began in the spring of 2016 and has intentions of continuing through the fall of 2017. Logging companies from the states of Alabama, Ohio and South Carolina were used for the initial research. These states were chosen based on accessibility of companies and their willingness to participate in research studies. Further state inclusion will depend on initial analysis findings but has the potential to expand throughout the eastern half of the United States.

Data collection for each participant officially began once the phone application was downloaded onto the driver's phone. A GPS (global positioning system) recorded location for the duration the driver ran the app. The app possessed a menu button with four tab options for the driver to choose from. The About tab, Stop Location Service tab, Archive Data tab and Set Driver Number tab. These tabs provided the user with licensing information, allowed the driver to close the program at the end of the day, send data to Google drive, and ensure their identity was kept confidential. The main page for the app provided the driver with four additional tabs to choose from, an Add Fuel Stop tab, Add Delivery, Add Delay, and Add Load Stop. The Add Fuel Stop allowed the driver to indicate when they had a fuel stop. The Add Delivery and Add Load Stop gave the driver the option of including ticket numbers for each load. The Add Delay tab gave the driver the option of recording when they had been delayed by choosing from one of nine reasons for the delay in movement. The nine reasons provided were: in woods loading, in-woods delay, waiting at the mill, maintenance/repair, traffic, DOT stop, fueling, personal/meal time, and other.

Stops would accumulate on the main page throughout the day until the driver archived the data at the end of their working shift. Once the data had been collected from the server, they were viewed in google earth for verification purposes. The routes the drivers took were compared with their delay responses. Polygons/geofences were established around the mill and landing areas and all turn times which fell within the polygon zone were recorded from the time the driver entered the geofence until the time they departed. All data were recorded in Microsoft Excel where initial description statistics were calculated. T-tests and linear regression models will be determined after all data has been collected.

Results

Initial results from the data collected were broken down by state as well as the location the event occurred at focusing on either the mill or at the landing (See figure 1 & 2). All turn time data was collected from the time the driver entered the geofence (polygon) until he left the geofence area. These geofences were determined based on property boundaries and entrances. Mill event data showed that Alabama had the highest average turn time at 42 minutes. The average turn time at the mill for South Carolina was 36 minutes and 30 minutes for Ohio. Average landing turn time data for the three states were as follows: Alabama at approximately 28 minutes, South Carolina was 44 minutes, and Ohio was 38 minutes.

Minimum turn times were recorded for all states at each location. These turns were designated as the shortest amount of time a driver spent at the particular location. Minimum mill turn times indicated that Alabama was the highest at 21 minutes for their minimum turn time, South Carolina was next at 17 minutes, and Ohio had the shortest mill turn time at 10 minutes. Minimum landing turn times found South Carolina to have the highest minimum at 22 minutes, Ohio followed at 11 minutes, and Alabama has the lowest minimum at 10 minutes.

Maximum turn times for each state at each location were designated as the longest time period a driver was stationed or delayed within the polygon boundary. Maximum mill turn time depicted Alabama to be the highest at 3 hours and 39 minutes, Ohio to follow at 2 hours and 10 minutes, finishing with South Carolina at 1 hour and 18 minutes. Maximum landing turn time once again indicated that Alabama had the highest turn time at 2 hours and 29 minutes, South Carolina was next at 1 hour and 39 minutes, and Ohio had the lowest at 1 hour and 16 minutes.

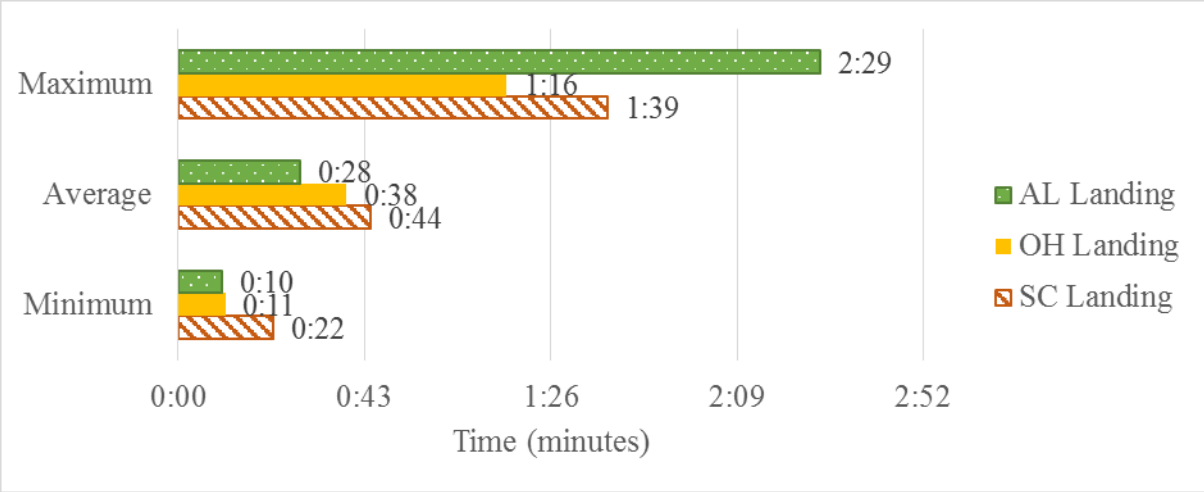

Figure 1. A state comparison of landing turn times

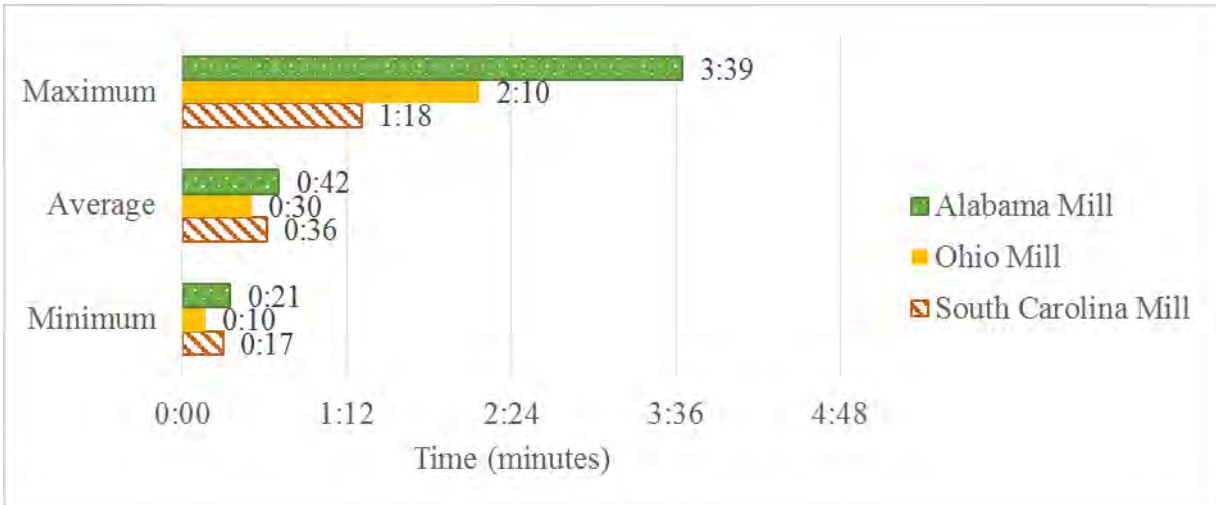

Figure 2. A state comparison of mill-turn times

Discussion

One of the first points to be noted is that this study chose to record turn times from the property line boundaries. Many mills record turn times from the time the truck enter the scale to the moment he leaves the scale, however, we felt this provided a biased representation of the driver's actual wait time. We used the same method for recorded turn times at the landing to eliminate potential bias that could be created otherwise.

It is important to recognize the difference in loading methods at the landing when comparing the differences in the average turn time at the landing between the states. All Alabama drivers who participated in the study worked for loggers who utilized set-out trucking solely. The South Carolina drivers all worked for loggers who hot-loaded and the Ohio drivers all used a cold-decking method for loading their trailers. Set-out trucking requires loggers to have multiple trailers and an area where they can set the loaded trailer off the main highway. Often times the truck driver is able to hook up to the loaded trailer without ever having to go to the landing site saving them drive time as well as wait time on the loader if they were hot-loading. Hot loading requires the driver to back their truck next to the loader and wait while the truck is being loaded. If there is not enough wood on the landing, the driver must wait until the wood has been skidded to the landing and processed before it can be loaded onto his truck. Cold decking occurs in the areas where the wood can be harvested and skidded to the side of the road or landing in the winter when the ground is frozen and then hauled in the spring after the roads have cleared out again. Although the driver still has to load the wood onto their trailer with the cold-deck method, they are not required to wait on wood, which in some cases can speed up turn times.

Minimum, average, and maximum loading times correspond to the duration of time a driver will have to wait, either at the landing or the mill before they can get loaded or unloaded. Minimum times depict a situation where the driver's wait time is zero. Average wait times correlate to a driver having a few trucks ahead in line if at the mill or waiting for a short duration at the landing for various reasons. Maximum turn times are significant in both locations because they affect the drivers time allotted as well as haul costs and overall costs. New federal regulations mandate that a driver is only allowed to drive for 11 hours a day if they are spending over an hour of that time waiting in line to unload or load they are drastically reducing the number of loads they can haul in the day. Fewer loads equal less money but with the same costs incurred which inadvertently creates a higher hauling and overall cost.

Conclusion

Our study chose to calculate turn times based on pre-determined geofences to ensure each truck was measured accurately. In general, this explains the difference in our findings from mill produced data or other studies conducted. Our findings indicated that on average, for all three states, turn times were approximately 36 minutes for both the landing and the mills. Differences between states turn times ranged 12 minutes at the mill for the average turn time and 16 minutes at the landing for the average turn times. A majority of the differences in the landing turn time averages can be explained by the loading system choice.

Although they happen less frequently, the maximum turn times pose the greatest concern to both loggers and mill owners. These extended turn times pose the highest risk for delays that will decrease productivity, increase costs, and increase the amount of time required to haul wood to the mills.

Overall accurate truck turn time information at the mill as well as the landing may allow the owner to minimize delays seen by their drivers by choosing alternate routes or mills, repairing any tractors which are causing them significant delays due to breakdowns or DOT (Department of Transportation) stops, providing more accurate haul cost analysis for determining if a tract is economically feasible or even alter their trucking operation more drastically.

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EFFICIENCY OF WORK IN SOFT AND HARD BROADLEAF STUMP CHIPPING USING A TRACTOR

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Abstract: *Stump removal in the establishment of poplar plantations is a common measure of ground preparation aimed at a more efficient implementation of regular silvicultural measures and comprehensive timber utilization. Stump removal in the plantation production of poplar is performed using different equipment. The aim of this study was to estimate work efficiency of the tractor Same Laser 150 with a Rotor "S" chipper in soft and hard broadleaf stump chipping under different operating conditions. The research was carried out in several sample plots in Public Enterprise "Vojvodinašume". The differentiation of operating conditions was carried out based on several criteria (distance between the stumps, forest order level, carrying capacity of the ground, etc.). The effects of work in stump chipping were determined by the time and work study. Chipping time varied from 0.82 min/stump to 2.29 min/stump. The analysis served as the basis for factor ranking according to their impact on the effects of work using the investigated equipment. In addition, it was concluded that greater effects can be achieved if controls allow the aggregate to move back and forth without pressing the clutch pedal and pulling the gear lever by installing a lever to change the number of revolutions of the output shaft in the driver's cabin. Currently, this lever is located on the differential housing next to the left wheel, so that the operator has to come out of the cabin to change the number of revolutions. Better operating conditions and results would probably be achieved with more space and a better position of the specified controls.*

Keywords: stump, chipper, effects of work, state of ground, work study

TECHNOLOGICAL CHALLENGES FOR INTENSIVE CULTIVATION OF POPLAR IN SHORT ROTATION CYCLES FOR BIOENERGY IN THE HILLY REGION OF NE ROMANIA

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Abstract: *The interest for rapidly obtaining woody biomass for energy purposes has increased in recent years in Romania, to this effect, since 2010, only in the hilly region of Suceava County (Rădăuți Depression) where over 600 ha of short-rotation hybrid poplar forestry have been installed. Thus, for the development of such crops, the investor (FE AGRAR Rădăuți) selected a cultivation technology successfully used in Italy's hilly region (at that moment Romania lacking an intensive poplar cultivation technology in the conditions requested by the customer), which guaranteed that after a 5-year cycle, a minimum 10 t/ha/year of dry biomass are to be obtained. Unfortunately, preliminary results obtained in the Rădăuți region didn't confirm the predicaments, the production being reduced with approx. 25-35%. In this situation it took a series of research in order to identify the main factors that directly affected the biomass production, so that considering them, technological adjustments are made which then will result in a significant biomass increase. The research results clearly showed that in this region a significant biomass increase can be obtained compared to present cultures if the plant material used (rods) will be planted mechanically at a depth greater than 60 cm (this way reducing the rods loosed by drying) and at a higher density (2000-2600 rods per ha), thus, using more efficiently the production potential of the lands holding the crops. Also, the higher density of the crops will contribute to the earlier closing of the coppice's canopy, leading to fewer interventions regarding soil maintenance and weed removal.*

Keywords: poplar energy plantations, short rotation crops, biomass yield, effects of disc harrowing, weed control

DAMAGES INFLICTED TO THE RESIDUAL TREES, PRE-EXISTING SEEDLINGS AND SOIL IN MIXED STANDS IN WHICH WERE APPLIED LOW EXTRACTION SELECTION CUTS

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Abstract: *Researches were conducted in mixed stands (spruce, fir and beech) with relative uneven structure, in which were applied low extractive selection cuts with 10-16% intensity. In these stands were made measurements on the remaining trees, pre-existing seedlings and soil. The results highlight that by taking into account the harvesting systems, stands density and the terrain slope, different situations could occur in term of impact. We conclude that even for low extraction sylvicultural systems, manual sliding and bunching is a technical procedure that produces damages with higher negative effects on the elements that were took into study.*

Keywords: manual sliding, bunching, impact, residual trees, seedling, soil

THE IMPLEMENTATION AND APPLICATION OF THE EIA DIRECTIVE IN THE GREEK FOREST TECHNICAL WORKS IN THE 21th CENTURY

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Abstract: *To paraphrase the famous saying of Wilson Churchill could be argued that "never before in human history has been said so much by so many in so little time" as the last time for the environment and the need for its protection. However, especially amid the economic crisis, many may think that protecting the environment is economically unattractive and does no good for our pocket and even more it is already costly. Environmental Impact Assessment (EIA) is a policy and management tool for both planning and decision making. It assists to identify, predict and evaluate the foreseeable environmental consequences of proposed development projects, plans and policies. EIA is a detailed and documented scientific work and research aimed at assessing the effects of certain public and private projects on the environment, as in the balanced development of the national territory to become easy and effective effort to prevent pollution and degradation of the environment assessing direct and indirect impacts of projects and activities. The paper also aims to investigate how well the EIA Directive has been implemented and applied in the Greek forest technical works. EC Directive 85/337/EEC or the EIA Directive was agreed on in 1985 and required Member States of the European Community to achieve formal compliance by July 1988. The Directive sought to ensure that, before a development consent decision is taken, a minimum level of information describing the potential significant effects on the environment of certain development projects is supplied both to the relevant competent authority and to the public.*

Keywords: decision making, management tool, development works

IS LIFE CYCLE ASSESSMENT IN FORESTRY STILL AT A STARTING POSITION?

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Abstract: *Life cycle assessment (LCA) is one of the most used tools for environmental management, but its application in forestry is still slow. Forestry and wood technology together produce vast amount of different wood products, but the production of timber as raw material is still not included often enough in the LCA process. Production steps have a significant influence on the environmental impact of wood products depending on machinery used, building and maintaining forest roads, management type (clear-cut, even-aged management or selective cut) etc. This paper will show past and present of LCA studies in forestry and its sections: 1) harvesting operations, 2) biomass and 3) forest infrastructure network construction and maintenance.*

Keywords: life cycle assessment, energy consumption, environmental management, wood products, environmental impact

COMPARISON OF DIFFERENT SCALING METHODS OF HARVESTER-PROCESSED TIMBER

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Abstract: *Annually, harvester technology in the Czech Republic processes 38% of annual wood yield, which represents 6.1 mil m^3. The open issue is the possibility of electronic scaling and grading of timber from harvesters. The quality of grading must be supported by correct methods of timber scaling in forest stands. The primary aim of this paper is to define a methodology for compaing the differences in timber scaling by harvester production-recording software and manually within the stands. The results are expected to range from 1.5 - 5% in electronic calculations of timber volume as compared with "Recommended Rules for the Measurement and Grading of Timber in the Czech Republic".*

Keywords: harvester technology, scaling, assortment

TRACTOR MOUNTED WINCHING SYSTEMS FOR SMALL SCALE HARVESTING

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Abstract: *Wood harvest operations are usually carried out by forest villagers with labor-intensive methods using the basic or intermediate technologies in Turkey. Annual allowable cut in a harvest block is prorated to villagers and then they perform the operations by a family workmanship with own capacity in a limited time and place. At the local scale; the problem about lack of skilled labor force and low working productivity cause to prolongation of harvesting time and increasing of total costs. As a solution, they fronted to more commonly use agricultural tractors in logging depending on the improvement on purchasing power of the villagers. So, agricultural tractors belonging to the villagers have acted a base machine in wood extraction from stump to roadside. In this study, different types of short-distanced and tractor 3 point skidding winch apparatus were considered during the cable logging of long logs from stump to roadside. The aim of the study is to give information on technical characteristics, working principles, average productivity and costs of the tractor mounted winch systems. As result, it was found that two types winch systems was used in logging; one of which was powered by the tractor's tail shaft and the other one was powered differential gear. Both two system could operate effectively on gentle and moderate terrain slope and shorter than 100 meters skidding distances, from top to bottom of Mediterranean pine forest in Turkey.*

Keywords: cable logging, tractor winches, harvesting, log skidding, tractors

IMPACT OF SPLITTING ON THE DRYING PERFORMANCE OF POPLAR (POPULUS SPP. L.) LOGS STORED IN PILES FOR ENERGY PURPOSES

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Abstract: *Natural drying is an efficient and low-cost method to decrease the raw material moisture content in fuel wood supply. Moisture content is the key parameter in fuel wood supply, with strong influence on the net calorific value and transport economics. With the rise of bioenergy in the last two decades, large and low-quality logs have become a significant source of wood energy as well. These type of material is challenging in terms of drying. In wood in bark, moisture is transported primarily in longitudinal direction and expelled at the cutting surfaces. Radial movement of moisture is somewhat slower and additionally hampered by the presence of bark. Through splitting, a larger drying surface-to-mass-ratio is achieved. By this, the average distance to the drying surface is reduced and this should result in a significantly increased drying rate compared to intact logs. Despite the technology for splitting large logs has already been on the market for years, it has not been studied thoroughly in the past. The question if splitting of large logs is a feasible practice, both in terms of drying performance and economics, has not been answered satisfyingly yet. Therefore, the aims of the present study were to determine the impact of splitting on the drying performance of large poplar (Populus spp. L.) logs by employing the continuous weighing approach and to investigate the respective break-even point of splitting in terms of system type, productivity and cost.*

Keywords: splitting, log wood, fuel wood, natural drying, drying modelling, meteorological models

SUSTAINABLE DEVELOPMENT OF A MULTIFUNCTIONAL SEMI MOUNTAINOUS AREA IN GREECE

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Abstract: *Sustainable development of semi mountainous regions has as objective to increase the economic investments to profit of residents of region, without however it influences drastic the natural environment. The respect to the natural environment and the goods that to us offers, gives the possibility of its sustained use. The refuting opinions for the effect of anthropogenic action of economic nature come in contrary with the interdependent of the coexistence of men and nature, as the men is piece of nature. The manner of coexistence of development and natural environment is the sustainable development, which was used soft rhythms, without the intense intervention in the more-wide space in which it is practiced. Green Infrastructure (GI) can be broadly defined as a strategically planned network of high quality natural and semi-natural areas with other environmental features, which is designed and managed to deliver a wide range of ecosystem services and protect biodiversity. More specifically GI, being a spatial structure providing benefits from nature to people, aims to enhance nature's ability to deliver multiple valuable ecosystem goods and services in perpetuity, such as timber, clean air or water. Above all, GI offers us a smart, integrated way of managing our natural capital. Aim of the paper is to indicate manners of sustainable development with direct priority the maintenance of natural environment. The potential of social and ecological factors is examined as it concerns the promotion of the protected area within sustainable rural development.*

Keywords: green infrastructure, forestry, recreational activities

SUSTAINABLE PLANNING AND DEVELOPMENT OF THE OPENING-UP OF GREEK FORESTS

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Abstract: *From initial logging planning until implementation, it is obvious that there will always be problems. However, there are techniques and analytic systems available to ease the design and contribute to improved timber harvest activities. The logging engineer must clearly understand the objectives of the forest management plan. In case of multiple resource planning with conflicting objectives and constraints, limits of acceptable performance must be established for forest values. The planner must then maximize the forest values within these constraints. To achieve this, the planner needs to acquire as much information as possible about the forest, the topography, and the operating characteristics and costs of the machines and systems he is contemplating using. Planning should cover enough area and enough time that it is not disjointed and does not sacrifice long-term gain for short-term advantage. The desktop computer will not eliminate the need for competent field examination but will permit better use of the data and will provide a means to quickly compare a variety of plans. Minimal environmental damage and minimal loggings costs are not necessarily incompatible objectives. In many cases both can be achieved with the same design. Road costs and environmental damage can be minimized by timber harvest designs that call for reduced road and landing density, and minimal earthwork. Lower skidding costs can be achieved by using mechanically efficient systems that have minimal impact on the environment. The net result of good planning is achievement of desired land management objectives and minimization of total logging costs.*

Keywords: logging costs, road costs, environmental damage, timber harvest design

DESIGN AND CONSTRUCTION OF A FOREST VILLAGE IN SOUTHERN GREECE

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Abstract: *The aim of this paper is the study for the construction of a forest village in the area of Souvardo in Kalavrita in the prefecture of Achaia. In this paper presents the history and purpose of forest villages, as well as the laws that govern them and information regarding the delimitation of the zones of the Chelmos Mountain. The methodology of the paper is analyzed and the particular characteristics of the study area are examined with the accompaniment of the design goals and principles and the general characteristics related to the formation of the space. Further, aerial photographs are listed with the help of Google Earth program, giving emphasis to the general plan of the study area. Also, there is an analysis of the stone and wood as materials and to the construction plan that was followed. In addition, reference is made to the key preparation stages of the project which are the excavations, the foundation, the stonework, the plumbing installation, electrical installation and the construction of roof with wooden trusses. The reception building and the host installation of the forest village are described, as well as the building and topographic plans are designed with the use of AutoCAD and Photoshop programs. Furthermore, the cost of the development project is analyzed. Finally, the conclusions of the study and recommendations to the visitor of the area about sights, natural landscapes and archaeological sites are given. Criteria for intervention and promotion of tourism and proposals for tourism development in the area, such as ideas for the development of cultural tourism and ecotourism in the region, are suggested.*

Keywords: stonework, AutoCAD, Photoshop, recreational activities, cultural tourism, ecotourism

FUTURE SCENARIO ANALYSIS FOR PREDICTING FOREST WOODY BIOMASS AVAILABILITY FOR ENERGY USE AND ITS ECONOMIC IMPACT FOR THE MEXICAN BIOECONOMY

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Abstract: *In order to meet climate change targets, actions for reducing fossil based products must be performed. A transition towards an economy less fossil dependent and supported by biomass sources has leaded the path to conduct analyses on wood resources access, harvesting operations, silvicultural practices and business models. Worldwide, data regarding forest operations and management considering environmental, social and economic indicators starts to be fundamental, and for Mexico this is not the exception. This research presents results regarding forest woody biomass availability and its economic impact comparing different scenarios for year 2030 in Mexico. Based on numerical modelling using sustainability constraints as limits for biomass production, a conservative increment on the mechanization level amounts to 38.37 million USD (731.78 million MXN) of GDP for 2030 from forest woody biomass for energy use, compared to 1.99 million USD (38.05 million MXN) observed in 2014. Under the assumption of applying advanced techniques of forest operations, the sustainable supply of energy from woody biomass could be increased by 12% to 44.55 PJ by year 2030 compared to 44.32 PJ for a status quo scenario. The developed methodology, which includes Monte Carlo simulations, Holt-winters exponential smoothing and sensitivity analysis among others, gives insights for decision making process regarding forestry and energy generation.*

Keywords: bioenergy, forest woody biomass, Mexico, modeling

A M.S. EXCEL - V.B.A. TOOL FOR POSTURAL DATA PROCESSING AND ANALYSIS IN FOREST OPERATIONS

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Abstract: *As stated 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. An important field of ergonomics is that related to the postural assessment of jobs. The ergonomic assessment of work postures may require a great amount of data to be collected, processed and analyzed, requiring lots of resources. To ease such tasks, IT applications may be developed and used to process and analyze data in less time and to increased accuracy. 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 was developed containing specific parameters and variables, related to forestry work 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. This paper presents the design of the developed application, then it demonstrates its efficiency for a number of tasks and jobs specific to forest operations.*

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

HARVESTING CONDITIONS, MARKET PARTICULARITIES OR JUST ECONOMIC COMPETITION: A ROMANIAN CASE STUDY REGARDING THE EVOLUTION OF STANDING TIMBER CONTRACTING RATES

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Abstract: *A survey of timber harvesting operations and tendering prices was conducted in a representative forest region of Romania aiming to see to what extent the technical parameters of the sold harvesting lots affect the tendering prices. Based on a sample of 1192 contracts, accounting for more than 20,000 harvested hectares and for more than 600,000 harvested cubic meters, descriptive statistics of harvesting conditions and tendering prices were computed and prediction models of tendering prices as a function of harvesting conditions were estimated. Technical factors such as the felling type, lot size, removal intensity, tree size and pruning condition, slope and extraction distance had rather a low effect on the initial (adj. R^2 = 0.20) and final tendering prices (adj. R^2 = 0.17) showing that the remaining variability could be related to other factors. No obvious relations were found between the variation of technical factors and the variation of the difference in price paid by the contractors to buy the wood. As a consequence, a more detailed price analysis was conducted to see to what extent prices can be explained by the demand and supply evolution. Although the evolution of the prices and negotiated quantities may be considered confusing in the context of a normal market supply and demand, the analysis revealed that the stumpage market demand increase during analyzed years and there was a bigger demand for resinous species. The results of this study could be of help for both, the forest management and harvesting contractors in shaping and conducting their businesses. In addition, the study gives detailed statistics on the forest operations practices and conditions under the Romanian forestry, being of help for comparisons with other regions.*

Keywords: survey, harvesting conditions, model, auction price, selling price, demand

OPERATORS IN STEEP SLOPE LOGGING AND SAFETY MEASUREMENT

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Abstract: *Logging workers felling trees and cable yarding on steep slopes suffer accident rates greater than mechanized logging workers. Worldwide efforts to use tethered logging machines to fell, pile and transport trees have shown potential for feasible, safer and more productive operations. A team of researchers at Oregon State University are studying systems to improve safety on steep slopes under a project funded by the National Institutes of Occupational Safety and Health (NIOSH). Systems within the study include: Conventional Manual Timber Falling, Choker Setting and Yarding; Feller-Buncher with Choker Setting and Yarding; Feller-Buncher with Shovel Logging; Feller-Buncher with Mechanized Grapple Yarding; Feller-Buncher with Grapple Skidder; and Harvester with Forwarder. Operators are studied without the tether and on steep slopes using a tether. Safety assessments among the systems are compared along with the effects on the physiology of the operators. Current Forest Activities Code in Oregon permit tethered steep slope operations in excess of 50% slopes only using a research variance that provides information to regulators with the basis for drafting permanent safety regulations. A number of other important questions are considered in the research effort over the three-year span of the research. The research is described and some results to date are described.*

Keywords: steep slopes, logging, safety measurement, operator effects

FORWARDER 2020: SMART FORWARDER FOR SUSTAINABLE AND EFFICIENT FOREST OPERATION AND MANAGEMENT

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Abstract: *Forwarders are an essential part in fully mechanised timber harvesting chains. In a cut-to-length logging system, forwarders pick up felled logs and transport them from the harvesting site to logging roads. Within the project 'Forwarder2020' at the Karlsruher Institute of Technology (KIT), embedded in and sponsored by the European program 'Horizon 2020, a forwarder will be optimized to increase its sustainability and environmental compatibility. Especially, implement hydraulics holds a huge potential for efficiency improvement. In order to exploit this potential, the hydraulic circuit will be revolutionized by an innovative conjunction of existing and new components. With this concept, fuel savings up to 30 %, compared to series machines, can be achieved by using energy recuperation and regeneration in the crane system. Particularly during thinning a substantial effect can be obtained, because in this case a high number of loading cycles with potential for energy recuperation and regeneration appear. Hence, this procedure becomes more competitive compared to clear cutting whereby a sustainable forest management is easily feasible. Due to the energy savings during loading processes of forwarders, forest management can be conducted in a more economical and ecological way, thus a major contribution to emission reduction during the production of renewable raw material is made.*

Keywords: smart forwarder, crane, fuel savings, energy recuperation & regeneration, efficiency

THE POSSIBILITY TO IMPROVE THE QUALITY OF FOREST CHIPS DURING TRANSPORT

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Abstract: *The most important parameter of chips supplied for heating plants is heating value strictly related to their humidity. Moisture in turn depends on the species composition of wood chips and the content of the green, weather conditions and time of year in which they were harvested. The calorific value is the most important parameter of chips, on the basis of which the recipient of biomass (heating plant) determines their price. The investigations undertaken aims to verify the possibility of reducing the moisture content of biomass during transport to the power company. In Poland distance transport of wood chips from forest areas to energy plants reaches 300 km. Traveling this section, depending on the type of road which the vehicle moves, it may take 5-7 hours. This time can be used to reduce the moisture content of wood chips by blowing a layer of wood chips with air at ambient temperature or heated, by heat received from the engine and / or exhaust system of the truck. In order to carry out laboratory tests, was designed measuring stand - model of truck trailer. The stand has been equipped with a system of supply of drying agent - air. The position allows to adjust the temperature and flow rate of drying agent. Preliminary results show that moisture content of wood chips in the trailer can be reduced by means of the appropriate selection of drying parameters (temperature and air flow rate) and thus raise their calorific value. It was observed here that as a result of the drying process does not result in a uniform chip moisture content in the whole volume of the bed. In the lower layers of biomass (closer to the air supplying manifold) occurs greater decrease of chips humidity. The conducted observations also show that significant importance for the drying process has a density of chips in the container. Higher density (decrease the porosity of the bed), results in a reduction of the drying air flow (increase in resistance of the bed) and thus slowing the drying process. Taking into account that during transportation, due to vibration and shocks, and the density of the bed increases, thus the drying process of wood chips need to be further studied.*

Keywords: forest biomass, moisture content, wood chip, chip transport

REVIEW OF EFFICIENT AND COST EFFECTIVE BIOMASS RECOVERY TECHNOLOGIES AND SUPPLY CHAINS IN FOREST OPERATIONS

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Abstract: *This study provides an overview of most efficient biomass harvesting technologies and supply chains applied in North America, Europe and Southern Hemisphere. The productivity and cost of selected efficient technologies have been presented for each country with a brief description about source of the biomass and working method. Expert's opinions on the most successful biomass operations have been also stated briefly for each country. The main conclusions from various intentional studies have been provided in addition to future requirements for research and development in biomass harvesting operations. Provided information in this report can be useful guide to the forest industry and academic users.*

Keywords: biomass harvesting, supply chain, felling, extraction, chipping, productivity, cost

Introduction

The generation of energy from biomass has a key role in current international strategies to mitigate climate change and enhance energy security. The European Union (EU) committed to produce 20% of their energy from renewable sources, including bioenergy, by 2020 (Routa et al. 2012) and 27% by 2030 (COM/2014/015). Australia's target for 2030 is 20% while USA has recently announced the same target for 2030. One of the main renewable energy source options to help countries meet their long term renewable energy targets is forest biomass. Biomass can contribute in reducing carbon dioxide concentrations in the atmosphere in two ways, through: (1) biomass production for fossil fuel substitution and (2) carbon dioxide storage in vegetation and soil (Ericson and Nilsson 2006). In conventional harvesting, the stem of tree is mostly used which covers only 67.7% of the tree volume (Pine). However, the share of tops/branches is 19.7% of tree volume which can be a major

source for forest biomass. The remaining share of tree volume is 8% for the roots and one fifth of this share (1.6%) is also harvestable (Karjalainen et al. 2004). Dedicated energy crops, small diameter trees and failed plantations are another sources of woody biomass for energy (Ghaffariyan 2010). Harvesting usually occurs in winter (and sometimes in summer) and the harvested stems are often converted to chips on the site and then transported to the conversion plant (IEA Bioenergy 2002).

Study objectives

Considering the large volume of forest biomass resources, the different types of available woody biomass, and the often difficult terrain and relatively long transport distance between forest areas and mill/energy plants the biomass producers require efficient harvesting machines and proper supply chain management to deliver their biomass products. The overall goal would be the most cost-effective option, delivering the highest quality with the lowest practicable site impacts. To provide a general road map and guideline on efficient biomass harvesting systems this project aimed to:

Identify the most productive and cost-effective biomass harvesting machines and supply chains based on local research and development experience in various biomass leading countries.
Provide the summary of machine productivity and operating cost of most efficient biomass harvesting technologies in each country.
Provide concluding remarks and guidelines on efficient biomass harvesting technologies.
Identify future research and development requirements to gain sustainable biomass harvesting operations.

Methodology

Sustainable forest management as a dynamic and evolving concept aims to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations (UN 2008). Considering the large scope of the study covering most of the forestry regions**,** it was decided to focus on the economic aspect of sustainability (productivity and costs of most efficient supply chains and harvesting machines). Detailed or consistent information on product quality, environmental and social impacts were not available from international studies and hence these factors, while also very important, are outside of the scope of this study.

The supply chains were mainly classified as harvesting residues from clear cuts, stump collection, energy wood (or fuel wood referring to plantations established for bioenergy usage) harvested by cut-to-length method or whole tree harvesting method and integrated biomass harvesting (combined biomass and sawlog/pulpwood recovery). To collect the information, a questionnaire was designed and sent to different international forest biomass harvesting researchers. The main question was to identify what is the most sustainable and efficient biomass harvesting supply chain in each country/region. The second question was to know what harvesting technologies are most suitable ones to operate within the supply chain. Due to the large number of available studies, harvesting technologies and supply chains in biomass producing countries, expert's knowledge in each region was used to identify the most appropriate biomass harvesting machines/systems. The answers of each participant have been analysed and concluding remarks on most useful supply chains/technologies in each region/country have been provided. The machine productivity data has been listed based on the provided information and local reports/publications sent by participants. The productivity (and cost) of best technologies have been reported mostly as Bone Dry Metric tonnes (BDMt) per Productive Machine Hours (PMH) to keep consistency in this report. However, in some case studies, that BDMt has not been reported by the participants or has not been available in the literature, the units of solid m^3 or GMt (Green Metric tonnes) have been used. The costs have been presented based on the US Dollar ($) to give same economic base for comparison.

Efficient biomass harvesting technologies/supply chains
North America
Canada

The main sources of woody biomass in Canada are sawmill residues and harvesting residues from clear cut operations. The residues are used to produce pellet for domestic use (e.g. for power production in Ontario) and

mostly for export to Europe and Asia (Thiffault et al. 2015). In Eastern Canada, harvesting residues at road side and in cut-over area, unmerchantable trees and round woods from thinnings are main sources of biomass. Because of small trees (average tree size less than 0.2 m^3) and flat terrain in Eastern Canada, most of the trees are cut by feller-buncher and extracted by skidder to be processed at the landings which yields significant amount of residues at road side. Chippers (disc or drum chippers) and grinders are applied to process the road side residues into wood chips. Ralevic (2013) developed Biomass Opportunity Supply Model (BiOS-Map) in northeastern Ontario to analyse the cost of different types of biomass comminution. His model suggested that due to technical and operational limits, between 55%-59% and 16%-24% of aboveground biomass was not recovered under roadside residue and whole-tree harvesting respectively. The cost of delivering roadside residues was estimated at 39.24-43.09 $/BDMt, and for whole trees 69.47-73.08 $/BDMt. In Western Canada trees are mostly processed at the stump using cut-to-length method so harvesting residues are scattered in cut-over area and too expensive to be collected (Stokes 1992). Thus, application of terrain chippers collecting scattered residues following cut-to-length operations has not been very much applied due to high cost of collection and chipping. Mobile chippers are mostly used for operating at road sides or landings. There are also some operations to harvest small trees where trees are felled by feller-buncher and extracted to landing by grapple skidder in bunches to the chipper (MacDonald 2006). In this case full-tree chipping occurs at the road side using a loader feeding the mobile chipper which blow the chips directly into chipvans.

MacDonald (2006) has modelled the cost of road side chipping operation. Road side chipping can allow skidding and chipping operation to be operated separately. This might increase the utilisation rate of both skidder and chippers however the trees need to be stacked into piles at road side to ensure chipper works properly. MacDonald (2006) indicated that this system had the lowest operating cost in comparison with other harvesting systems where the stands had less than 50% of fuelwood (suitable for bioenergy usage). In another study by FPInnovations in Vancouver Island (in British Columbia) the costs of harvesting residues at road side were modelled (MacDonald 2009). The harvesting system included a grinder and loader to comminute the residues and semi-trailer chipvans were used to transport the chips. The estimated productivity of grinding, as an efficient way to process biomass, was 25.0 BDMt/PHM_0 which costed 18.01 $/BDMt. Grinder and loader require additional cost to be mobilised between harvesting blocks which depends on the volume of residues and actual moving cost. Difficult and steep terrains slowed the movement of grinder. Also, high maintenance and delays occurred by trucks reduced the grinder utilisation to 65%. Some areas allowed using water transport. The barging cost for biomass transport from remote locations costed about CAN$10 ($7.5) per m^3 per 100 km. Table 1 presents the summary of machine productivity and cost for two biomass supply chains in Canada.

Table 1. Summary of the selected efficient biomass harvesting technologies in Canada (*1 CAN$=0.75 US$*)

Supply chain	Machine	Model	Productivity (BDMt/PMH_0)	MC (%)	Cost ($/BDMt)	Reference
Residue from clear cut (road side piles chipping)	Track-mounted integrated with grapple Truck	Morbark 50/48 Mountain Goat Semi-trailer	20-30 -	- -	16.2-10.8 17.5-29.7 **Total:** 33.7-40.5	MacDonald (2006)
Residue from clear cut (road side pile grinding)	Grinder and loader Truck	- Semi-trailer	25 -	-	18.0 Mobilisation cost: 1.1-4.5 20.6 **Total**: 39.7-43.1	MacDonald (2009)

Northwest USA

After timber harvesting, most of the forest residues are piled and burned to clean the areas for replanting, and to reduce fuel loadings, and potential insect and rodent problems (Zamora-Cristales et al. 2013). It is estimated that a total of 127.4 million m^3 of logging residues were produced in the United States in 2006 (Smith et al. 2009). There are different systems for processing and transport in the United States. Comminution options include stationary horizontal grinders (electric or diesel), tub grinders, and forwarder-mounted mobile chippers. Short

distance in-forest transportation options for unprocessed residues use a truck with container such as a hook-lift truck or a bin truck, and others use a converted off highway end-dump truck. Long distance transportation options include chip vans with different types of tractor-trailer configurations. Trailers vary in length from 9.75 to 16.15 m. They usually contain an extension in the bottom centre of the trailer (drop-centre or possum-belly) to increase the trailer capacity. Different processing and transportation systems include: (1) stationary grinder at centralized landing with bin, dump, or hook-lift truck; (2) stationary grinder processing at each pile location; (3) mobile chipper processing at each pile and loading set-out trailers; (4) stationary grinder at centralized processing yard with direct discharge into piles; and (5) bundling in forest and grinding or chipping at the bioenergy plant (Zamora-Cristales et al. 2015). Based on the study results, the most cost-effective processing option was the medium-size horizontal grinder (522 kW). A total cost of $53.73/BDMt including transportation was expected using this grinder. The mobile chipper total cost was $67.97/BDMt. The slash-bundler was the most expensive option (total cost of $69.46/BDMt) due to high cost of bundling.

The use of a mobile chipper for processing forest residues for energy purposes represents an alternative to the use of stationary grinding machines currently used in the U.S. Pacific Northwest. The advantages of mobile chippers are the mobility to reach different locations within the forest where the forest residue piles remain following harvesting, flexibility to unload the material into different types of containers and a self-feeding system. Also, the use of independent containers partially disconnects processing from trucking, reducing truck dependence. However, productivity is highly sensitive to the size, cleanness and type of harvest residue material, and the number of stages involved in the chipping process (chipping, moving, and dumping into trailers) gives more complexity to this process compared with stationary equipment (Zamora-Cristales et al. 2013). In Pacific Northwest, on steep terrain, whole tree systems that bring biomass to roadside with the sawtimber has the highest economic and lowest environmental impact for recovery of biomass. On flatter terrain, whole tree shovel logging is the most common method when yarding distance is less than 150 m. Many branches break off and a following operation by excavator-base loader to directly forward biomass to roadside for distances less than 50 m or the use of an excavator-base loader to load forwarder(s) for longer distances. An excavator-base loader can load a forwarder much more quickly and much higher volume than the forwarder can load itself. The point of comminution and trailer transport depend upon a number of factors, but in general grinding occurs at the landing and transporting biomass is done by chipvan (standard, stinger-steered, or self-steered) directly to the mill.

Southeast USA

Most of the timber harvesting activity in Southern USA forests uses ground-based skidding to deliver material from forest to the landing and this method has been used in whole-tree chipping operations. Chipper processes whole trees into uniform chips, which are then hauled to the mills by the chipvans (Johnson et al. 2012). Greene (2013) mentioned that if the green trees are chipped the moisture content can be about 50% and if trees are allowed to be dried in the field after felling the moisture content can drop from 53% to 43% and 39% in 4 and 8 weeks, respectively. This significantly reduced the cost of operations. When the moisture content decreased from 55% to 30% the delivered cost of the biomass decreased by over 50% (Greene 2013). Whole tree chipping provided the lowest cost option ($14.98 per MWh) at ash content levels less than 1%, and unscreened grinding of clean chip residue produced the least expensive option ($9.79 per MWh) at 5% ash. Clean chipping and round wood systems were considerably more expensive than whole-tree chipping operations on all tract sizes. Costs declined significantly as truck payload increased and/or haul distance decreased (Greene, 2013). O'Neal and Gallagher (2008) studied a biomass harvesting system including small tracked feller-buncher, mini-grapple skidder and a small Morbark chipper to supply woody feedstock from small size trees for bioenergy usage. This system could be adopted for Southern Pine and Appalachian hardwood thinning as well. The total system cost was 122.37 $/SMH and average production rate was 10 GMt/ha which was a cost-effective system (unit cost of 12.2 $/GMt) due to application of less expensive machines. For larger tree sizes, in whole tree chipping operations, Johnson et al. (2012) tested similar system but with large feller-buncher, large skidder and medium size chipper. This was most efficient system with the harvesting costs (from stump to road side) of 19.40 $/BDMt and hauling cost of 28.50 $/BDMt. Total system cost averaged at 47.90 $/BDMt.

There are three main sources of biomass in South-East USA. The first main source of forest biomass is mill residues - very much in use and has been for a long time. Second source is harvesting residues including the tops, limbs and small diameter trees from a harvesting operation. Some operations keep a small chipper on the site and process this material for a market. The last one is small diameter tree harvesting.

Some of the most efficient biomass harvesting machines operating in USA have been selected and presented in Table 2. From this table, cost of whole tree chipping in small tree sizes was lower than for collecting residues by mobile chipper. Grinder's productivity (in Northwest USA) was much higher than mobile chipper although its cost was about $2 cheaper per BDMt.

Table 2. Summary of the selected efficient biomass harvesting technologies in USA

Supply chain	Machine	Model	Productivity (GMt/PMH$_0$)	MC (%)	Cost ($/BDMt)	Reference
Residue from clear cut **NW USA**	Mobile chipper Truck	Bruks 805.2 mounted on forwarder Single trailer-15.5t	12 -	30 30	37.9 18.1 **Total:** 56.0	Zamora-Cristales et al. 2013
Residue from clear cut **NW USA**	Grinder	Peterson 5710C	54.4	30	35.7	Zamora-Cristales et al. 2015
Whole tree chipping (large trees) **NW USA**	Large feller-buncher Large skidder Medium chipper Chip van	- - - 120 yd^3 with medium chipper	56 13.2 76.2 6.4	50 50 50 50	3.50 10.60 5.30 28.50 **Total:** 47.90	Johnson et al. 2012
Whole tree chipping including tops and limbs **SE USA**	Feller-buncher Grapple skidder Loader Chipper	Tigercat 718 John Deere 640D Prentice 280 Conehead 565	- - - 26.0	- - - 50	- - - **Total: 21.00-40.00**	Westbrook et al. 2006
Chipping residues from whole tree processing at road side **SE USA**	Bell-logger (as loader to feed chipper) Small chipper	- Dynamic Conehead	- 20	- 50	4.34 6.98 **Total: 11.32**	Jernigan et al. 2013; Aulakh 2008

Europe
Austria

There are various biomass harvesting systems applied in Austria in flat terrains or mountainous area. Stampfer and Kanzian (2006) described the development of the Austrian wood chips supply chains as following: "Potential woody material sources include thinning and coppice stands as well as harvesting residues. Additional

materials can also come from short rotation forests. Chipping in the forest stands is seldom used in mountainous conditions of Austria. In mountainous conditions working space at the road sides is the limited. Loading the truck directly with the chipper requires the machines to be positioned so that enough space is available. One solution is separating the work process, whereby the machines become independent from the other. However, additional costs occur in loading trucks. Another solution is the pre-concentration of material to be chipped at a central landing area. Provision of centralized processing areas close to the forest that can be provided with minimum infrastructure changes makes good sense. Central landings near to the public road infrastructure enable the use of non-specialized means of transportation (e.g. semi-trailer configurations with containers) for the transportation of woody biomass. The additional cost of preparing the centralized processing/storage area can be covered by these positive effects". There are several biomass harvesting technologies in Austria where each technology has its own strengths depending on terrain, forest type and operating conditions (Table 3 presents three selected systems)." Thus Kühmaier and Stampfer (2012) have developed a multiple-criteria decision support tool for energy wood supply chain management in Austria to consider technical limits as well various criteria such as economic, environmental and ergonomic factors. Extraction cost by cable yarders are higher than ground-based harvesting equipment (such as forwarders, etc.) mainly due to lower productivity, higher machine cost and considerable cost for installation and take-down. The most important bottlenecks in fuel wood supply are cost-ineffective transport, truck delay at the chipper and the limited availability of well trained personnel and machine operators. Other transport-oriented issues are the low load capacity of trucks and long transport distances. Accessibility is limited by steep terrain and fragmented forest ownership. Lack of landings and landing space, equipment reliability issues and log soil contamination make working difficult (Erber et al. 2014).

Table 3. Summary of some selected efficient biomass harvesting technologies in Austria (*1€=1.13$*)

Supply chain	Machine	Model	Productivity (m^3/PMH_0)	Cost ($/$m^3$)	Reference
Energy-wood harvesting as by-product in steep terrain	Chain saw Tower yarder & processor Chipper	Turmfalke & Steyr KP 40 MUS MAX Wood Terminator 10	5.90 20.30	0 (by-product) 14.01	Affenzeller and Stampfer (2007a)
Energy-wood harvesting in flat terrain	Forwarder & Feller-buncher Chipper	HSM208 & Moipu 300ES Eschlböck Biber 80	4.90 33.90	25.60 8.10 **Total:** 34.70	Elmer et al. 2011
Energy-wood harvesting in flat terrain	Tractor & guillotine blade aggregate & forest trailer Chipper	Valtra 8050 & Naarve Grip 1500-25 & PATU MD Jenz HM 35D	25.40	31.80 12.60 **Total:** 44.40	Affenzeller and Stampfer (2007b)

Denmark

Suadicani (2015) indicated that "*Chipping of whole trees that have been dried during summer period is very well established in Denmark. This operation has low cost especially if the stands are large with large tree sizes. This operation works efficiently on flat terrain and sandy soils with sufficient bearing capacity. This harvesting system consists of a feller-buncher and front-feed chipper mounted on a container attached to a forwarder. If strip roads have been well established/prepared this system can be very productive." W*ood chips are transported to the plant with truck containers where chipping productivity gets as high as 25 to 30 m^3 (loose)/PMH_0 (Kofman and Kent 2009; Suadicani 2004). Table 4 presents the summary of cost and productivity of whole tree system.

Table 4. Summary of some selected efficient biomass harvesting technologies in Denmark (*1€=1.13$*)

Supply chain	Machine	Model	Productivity (m^3/PMH_0)	Cost ($/$m^3$)	Reference
Whole tree chipping at road side	Feller-buncher Chipper	Silvatec 656 TH Fendt Favorit 614 LSA/TP-960	14-50 25-30	2.26-7.91 11.19-13.45 **Total**: 13.45-21.36	Suadicani 2004; Kofman and Kent 2009

Finland

Finland has a target produce 38% of its energy from renewable sources by 2020. Processing residues from the forest industry (e.g. black liquor, bark and sawdust) are the most important source of wood-based fuels, but these by-products can be considered to be fully utilised at the present time Additional raw materials for energy production include logging residues, stump and root wood, small diameter wood, and other wood not in demand by the traditional forest industries. Biomass supply chains in Finland may be characterized based on the location of comminution into roadside comminution, terminal comminution, or comminution at a plant (Routa et al. 2013). The most efficient Finnish biomass supply chains are summarised as following*;*

a) Multi-tree cutting of thinning wood: Whole tree harvesting is applied when DBH of the harvested trees is less than 10 cm. Trees are harvested as delimbed, when DBH of the harvested trees is more than 10 cm. Whole trees are chipped at roadside landings and delimbed stems at the terminals or at the plant. The proper technologies for this supply chains includes medium size harvester-processor (to cut and delimb), medium size forwarder (to extract the cut trees), conventional timber truck (to transport the trees to plant) and a chipper at the plant or terminal. The average moisture content of thinning wood chips is about 40%.

b) Logging residues from clear-cuts: The residues can be collected and chipped at landings located at the roadside. The most efficient method is to pile the tops and branches by harvesters along the forwarding trails integrated with the mechanised cutting of round wood. The residues can then be collected and extracted using large or medium size forwarder. Chipping of logging residues will occur at the roadside with truck mounted drum chipper to be transported by a truck-trailer unit to the plant. The average moisture content of logging residue chips is about 50%.

c) Stumps: The stumps are excavated in the field and stumps will be grinded at the plant or at the terminal. Pre-grinding and integrated screening is a feasible way to guarantee the fuel quality expressed as ash content already at roadside landings, but the procurement costs are higher compared to grinding stumps at the plant, when the ash content of ground stumps is 6% or less. The most efficient working method for this supply chain is to uproot and split the stumps by a tracked excavator (weight about 20 tonnes). Large or medium size forwarder can then extract the stumps to the roadside. Next phase would be transporting harvested stump with a biomass truck for comminution at the plant or pre-grinding and sieving at the landing and final comminution at the end-use facility. The average moisture content of ground stumps is about 30%.

Table 5 presents the productivity of some of the selected efficient biomass utilisation technologies applied in Finland. From costing point of view, Routa et al. (2013) indicated that recovering logging residues requires lower costs than whole tree chipping or stump utilisation in Finland and Sweden. The difference in the production costs is caused by the cost of cutting of small trees and uprooting of stumps, whereas in off- and on-road transportation as well as in chipping or grinding the cost differences between logging residues, stumps and energy wood from thinnings are rather small (Laitila 2012, Routa et al. 2013).

Table 5. Summary of some selected efficient biomass harvesting technologies in Finland (*1€=1.13$*)

Supply chain	Machine	Model	Productivity (m^3/PMH_0)	Cost, $/m^3	Reference
Multi-tree cutting of thinning wood	Harvester	Naarva EF 28 harvester head equipped with multi-tree handling devices	8.7-19.9	23.73	Laitila and Väätäinen (2013), Laitila et al. 2015
Energy wood from thinning	Forwarder	Timberjack 810B	11.90 (after mechanized felling) 7.1 (after manual felling)	7.46	Laitila et al. 2007, Laitila et al. 2015
Stump utilisation	Crawler excavator (to excavate) Forwarder (to extract)	JCB JS 160 L excavator equipped with a extraction-splitting device Valmet 860	9.2 12.9	9.72 7.34 **Total:** 17.06	Laitila et al. 2008, Laitila 2010, Laitila et al. 2015

Germany

Cremer and Velazquez-Marti (2007) described two harvesting systems to produce biomass chips. In the first system harvesting residues were directly processed in the stand using a mobile chipper mounted on a forwarder. For the second one harvesting residues were concentrated with a forwarder in piles along the forest road and then chipped using a chipper mounted on a truck. Productivity of chipper working at road side was nearly 50% higher in comparison to a chipper working in stand. The higher productivity resulted from the fact that material was very well concentrated. The other reason for higher productivity was that the assortment that could have been utilised for pulpwood was also chipped by road side chipping system which increased the productivity. The other reason was due to larger machine power of road side chipper (442 kW) than chipper working in stands (272 kW). The chipping costs of both systems are comparable: 2.14 $/m^3 in first system and 2.54 $/m^3 for second system (Cremer and Velazquez-Marti 2007). There are also other available biomass harvesting systems in Germany. One system is combination of feller-buncher, forwarder and chipper. In this system, trees are cut by a feller-buncher, and then extracted to the road side by a forwarder to be chipped. Another harvesting system includes tree cutting and extraction to road side using a forwarder equipped by felling head. Trees would then be chipped into trucks at the road side (Cremer 2008). Grosse (2008) reported that short rotation plantations are another source of biomass to produce range of products such as log, bundle and wood chip. The techniques with agricultural reaper-chipper are able to harvest trees up to 12 cm cutting diameter. If cutting diameter is larger, one could use feller-buncher or harvester-chipper. KWF (2012) summarised some efficient energy wood harvesting systems using in-field chipping operation (Table 6) where the system including a harwarder and a chipper was less costly alternative.

Table 6. Summary of some selected efficient biomass harvesting technologies in Germany (*1€=1.13$*)

Supply chain	Machine	Model	Productivity (m^3/PMH_0)	Cost ($/m^3)	Reference
Energy wood from thinning (spruce)	Harwarder Chipper	- Jenz HEM 420 DL	3.29 22.05	31.59 3.07 **Total:** 34.67	KWF (2012)
Energy wood from thinning (spruce)	Harvester Forwarder Chipper	- HSM 208 F Jenz HEM 420 DL	4.86 8.10 22.05	27.20 10.75 3.07 **Total:** 41.02	KWF (2012)

Ireland

In 2012, more than 8% of total harvesting volume in Ireland has been used in the biomass sector which indicates the importance of biomass harvesting in this country. The most efficient biomass operations in Ireland as following:

Utilisation of standard thinning materials:
The supply chain includes a harvester to fell and process the trees into standard short logs (3 m length with minimum top diameter of 7 cm). The logs are extracted by forwarder to road side. The logs are chipped into trucks by a tractor-based or truck-based chipper. Woodchips are then transported to power plants using walking floor trucks (Kent et al. 2011, Sosa et al. 2015a, Devlin and Talbot 2014). Most effective machines includes Silvatec C 856 harvester, Valmet 840 forwarder and MusMax T8 drum chipper based on Valtra tractor.

Integrated energy wood from thinning:
Very similar operations to standard thinning operation except the shortwood (3m) now all becomes energy wood. The woodchip does obviously not require a minimum diameter. Any material that is not processed for stake or sawlog becomes energy wood (Kent et al. 2011, Sosa et al. 2015a).

Woodchip supply from whole tree thinning:
This operation produces a range of wood products: sawlogs with a minimum diameter of 20 cm, palletwood obtained from the mid-section of the log and has a small end diameter of 14 cm, and pulpwood with a diameter between 14 and 7 cm. In addition to branches, stem material of less than 7 cm in diameter is left on the forest area. Chipping is carried out at the forest roadside by tractor or truck-drawn machines (Kent et al. 2011, Devlin and Talbot, 2014).

Forest residues after clear cuts (bundling):
This supply chain is relatively new to Irish operations and still only carried out on specific sites. It was originally trialled in Coillte in 2009 with over 18661 bundles baled by slash bundler over 14 sites. Each was 2.5m long and 60cm diameter (Kent et al. 2011, Sosa et al. 2015b). The bundles were then transported to mill to be chipped there. Table 7 summarises the productivity and cost of most efficient harvesting systems in Irish conditions.

Table 7. Summary of some selected efficient biomass harvesting technologies in Ireland (*1€=1.13$*)

Supply chain	Machine	Model	Productivity (m^3/PMH_0)	Cost (€/m^3)	Reference
Energy wood from thinning	Harvester Forwarder Chipper	Silvatec C 856 Valmet 840 MusMax T8 drum chipper	2.57-5.22 3.41-10.25 11-17	**Total:** 42.96-62.66	Kent et al. 2011
Integrated energy wood from thinning	Harvester Forwarder Chipper	- - MusMax T8 drum chipper	- 3.63-7.3 7-60	**Total:** 37.78-59.53	Kent et al. 2011
Whole tree thinning	Feller-buncher Chipper	- Silvatec Terrain Chipper 878	3-8 12-23	**Total:** 19.04-33.64	Kent et al. 2011

Italy

Many Italian forest companies produce substantial amounts of wood chips. In most cases, chip is a collateral product obtained from less valuable trees and tree portions. Chipping is one of the most effective way to dispose of the harvesting residue (Spinelli and Hartsough 2001). Chip production is associated with the type of silviculture regimes. Clearcuts provide the highest contribution. Thinning operations also play an important role in providing substantial amounts of chip. When terrain conditions allow machine access to the cutover, energy wood is chipper there (in-field chipping). That is especially the case of poplar plantations. When terrain

conditions are less favourable, one could use a bulldozer to pull the truck or resort to tractor and trailer units. Chipping at the landing site is also common. It is performed when terrain conditions prevent in-stand truck traffic and when the logger believes that chip shuttling would not be viable option. At the landing, chips can be blown into a truck, a trailer, a container or directly on the ground forming a large heap. In the case of heaps, chips will be reloaded on the trucks. Some loggers prefer to reload the chip from a heap, in an effort to reduce truck waiting time. A loader can fill up a standard truck faster than the average professional chipper (Spinelli and Hartsough 2001). Harvesting the roots of popular plantations is another source of biomass (Spinelli et al. 2005). Complete tree harvesting is occasionally performed in pine plantations (Spinelli et al. 2009). Three efficient and common Italian supply chains are described briefly below:

a) Harvesting residues from clear cuts in steep terrains:
Whole trees are extracted with cable yarders to road side to be processed into logs. After the cable yarder is removed, a truck-mounted chipper drives up to the landing and chip the harvesting residues (tops and branches) into chip vans for transportation to the CHP plant (Spinelli et al. 2007).

b) Harvesting residues from poplar plantations:
Poplar plantations are clear cut at age of 12 years (DBH of 35 cm) to produce peeler logs and saw logs. After industrial wood recovery, the harvesting residues including tops and branches are piled. A self-propelled chipper accesses the field, chips the residues and blows the chips into trailers towed by farm tractors, which dump the chips on a pad for later reloading and transportation to the CHP plant (Spinelli and Magagnotti 2011).

c) Energy wood from second thinning:
Pine trees from second thinning operations are harvested at age of 20 years using a combination of feller-buncher, skidder, self-propelled chipper and truck. Whole trees are extracted to road side using skidders. The whole trees are then chipped into trucks (Marchi et al. 2011, Spinelli et al. 2014). This system is only viable in flat terrain, and on relatively large lots. When these conditions are fulfilled, then the system is extremely effective and allows producing energy wood at a very low cost.
The productivity and costs of efficient systems in Italy is summarised in Table 8.

Table 8. Summary of some selected efficient biomass harvesting technologies in Italy (*1€=1.13$, MC not available*)

Supply chain	Machine	Model	Productivity (GMt/PMH$_0$)	Cost ($/GMt)	Reference
Residues from clear cut in steep terrain (spruce)	Chipper Truck/trailer	Truck-mounted -	15 4	15.0 16.9 **Total:** 31.9	Spinelli et al. 2007
Residues from poplar plantations	Loader Chipper Loader Truck/trailer	- Self-propelled - -	25 20 30 6	2.7 22.6 2.3 11.3 **Total:** 38.9	Spinelli and Magagnotti, 2011
Energy wood from thinning (pine)	Feller-buncher Skidder chipper Truck/tailer	- - Self-propelled -	32 24 20 6	3.5 3.3 11.3 11.3 **Total:** 29.4	Spinelli et al. 2014

Spain

Spanish roundwood production reached 16.2 million m^3 in 2014. Forest logging operations are mainly located in central and north of Spain. After 2008 a deep construction activity crisis took place, and currently the most demanding industries are pulpwood and board, that represent the destination of 75% of fellings. Furthermore, these industries have increase recently the production, and on stand price of trees has increase significantly. That means there are a strong competition over small and medium-size. The wood energy market has kept positive. Heat use demand has compensated the lower consumption for electricity that was negatively affected by drastic reduction of subsidies for electricity production approved in 2012 and the new energy tax established in 2013.

Currently 3.8 million of m^3 are consumed by this sector (Gonzalez 2015). The efficient Spanish biomass supply chains includes (Garcia 2015);

a) Whole tree chipping operations (first thinning): This is applied for commercial pine, oak or beech thinning in moderate to flat terrains (slope less than 30%). This operation includes felling and bunching with a feller-buncher (e.g. John Deere 1270), extraction of full tree with forwarder (e.g. Timberjack 1410D) chipping at landing with a mobile chipper (e.g. Willibald ESU 4800) and stacked in piles along the roadside, loading in the truck with a telescopic crane (Laina et al. 2013).

b) Energy wood from second thinning (mechanized harvesting by-product). Minimum diameter for panel industry demand is the key factor affecting the amount of biomass per ha, for reaching high productivity and low cost for biomass extraction (top and branches). In Pinus radiata plantation in steep terrain (North Spain), a system based on manual felling, skidding from forest road with a 80 m cable skidder and processing and classification performed by harvester at forest road is well-working.

c) Residues from clear cut: This system is applied for commercial poplar, eucalyptus or pine timber harvesting. Felling and processing are carried out by a harvester (e.g. Ponsee Scorpion). The harvest residues (crown and branches) are left and separated on the site by harvester or just only left in case of poplar felling performed by chainsawers (Tolosana et al. 2011). Round woods are extracted by a forwarder or grapple front loader in poplar sites and the harvest residues are left on the site for a drying period of 3 to 6 months. Extraction of residues will then be carried out by a chipper mounted on a forwarder (e. g Timberjack 1210A with chipper package Erjo 7/65) or chipper attacked and propelled by farm tractor. In large forest areas the most productive system is chipping at the roadside. In eucalyptus plantations, slash-bundlers (e.g. Timberjack 1490D, *Monra ENFO 2000 etc.*) are also applied to collect the residues. Table 9 presents the productivity-cost of some of the selected efficient biomass utilisation technologies applied in Spain.

Table 9. Summary of some selected efficient biomass harvesting technologies in Spain (*1€=1.13$, MC not available*)

Supply chain	Machine	Model	Productivity ($BDMt/PMH_0$)	Cost ($/BDMt)	Reference
Whole tree chipping (pine plantations)	Harvester Forwarder Chipper	Valmet 911 Valmet 910 Willibald ESU 4800	6.30 6.50 31.64	12.87 9.43 3.73 **Total:** 26.03	Garcia (2015)
Energy wood second thinning	Fowarder (after mechanized harvesting) Grinding	John Deere 1270 D Hammel VB 950	4 18	7.0 9.0 **Total:**16.0	Tolosana et al. 2014
Residues from clear cut (Eucalypt plantations)	Forwarder (to extract bundles) Chipping	Timberjack 1410D Erjo 7/65	12.5 13.5	4.90 8.74 **Total:** 13.64	Garcia (2015)
Residues from clear cut (poplar plantations for plywood production)	Mobile chipper and forwarder	Erjo self-propelled John Deere 1410D	5	26	Tolosana et al. 2011

Sweden

The share of bioenergy in the energy use in Sweden is one of the largest in Europe. Its target, according to the Renewable Energy Directive, is that 49% of the consumed energy should be based on renewable sources by 2020. The consumption of forest chips was 20.8 TWh (8.7 million m^3) in 2013, whereof 10.6 TWh (8.7 million m^3) from harvesting residues and 6.9 TWh (8.7 million m^3) from defect round wood. The delivered amounts of biomass from small diameter wood was 2.3 TWh or 1.0 million m^3, while stump and root wood contributed to 0.28 TWh (0.12 million m^3) (Swedish Energy Agency 2015). In the same year the average supply costs per m^3 were $52 for harvesting residues, $49 for round wood, $54 for small trees and $58 for stumps (Brunberg 2016). Of the supply cost, payment to the landowner makes up $9 for harvesting residues, $14 for round wood, $2 for small trees, and $0 for stumps. The supply chains for defect round wood is very much the same as for saw logs and pulpwood, the only difference is the destination of the loads. When the defect round wood arrives to either a terminal or a CHP plant it is comminuited by a large chipper or grinder (700+ kW) (Eliasson and von Hofsten 2016).

Harvesting residue chains are different from the round wood chains as the residues in many cases are left in small piles on the cut area to dry over the summer. After drying the residues are forwarded to a road-side landing there they are stacked and covered. The stack must be placed in such a way that it is close to a place on the roadside where there is sufficient room to place containers or pile the chips if they are to be transported in a self-loading chip truck. Harvesting residues and small trees are usually comminuted on the landing, because it is difficult to attain acceptable payloads on residue and roundwood trucks while, in most cases, payload is fully utilised when chips are transported. On landings, drum chippers are mainly used. When a chipper is needed outside the road network, it is usually mounted on a forwarder. Where the chipper can stay on the road, chipper trucks (chip trucks with an integrated drum chipper, enabling both chipping and transport) are also used (Eliasson 2016).

The potential in multi-tree handling is greatest in stands with a low mean stem volume (0.02-0.05 m^3) that can increase machine productivity by 15-50 percent. Whole tree harvesting is not that common in Sweden at the moment, but sometimes applied when DBH is less than 7-8 cm and trees shorter 6-7 meters height. Wholes trees are stored at the landing before chipping and transport to the plant. Trees with a DBH over 8-9 cm are harvested as delimbed energy wood with medium or large size harvesters with multi-tree equipment, forwarded with a medium size forwarder and normally chipped at a terminal or plant. In the case of stump utilization because of low forest fuel demand and FSC regulations no stumps are being harvested in Sweden nowadays. Stumps are otherwise excavated in the field, forwarded to landing for storage and then either pre-grinded before transport or transported to the plant for grinding. Comminution at the landing is preferable if the transport distance is more than 70 km.

Table 10 summarised the productivity of some of the most efficient forwarding and chipping technologies tested by Skogforsk (the Forestry Research Institute of Sweden). It seems that the most effective method is applying chippers at road-side to chip the residue piles directly into containers or to a pile on the ground.

Skogforsk has also studied three alternatives for collecting and transporting harvesting residues including; harvesting residues comminution at the cutover area, comminution at the landing by chipper/grinder and systems with no moving costs between sites, i.e. direct transport of loose harvesting residue or chips comminuted by chipper truck. Comminution at the cutover is expensive from economic point of view. The system with landing-based chippers can compete over longer extraction distances (>100-120 km). On medium-sized to large harvesting sites, large chippers or crushers are preferable. The systems with no moving cost are superior for most of the raw material, particularly on small harvesting sites and short-medium hauls (Björheden 2011).

Table 10. Summary of some selected efficient biomass harvesting technologies in Sweden (*1€=1.13$*)

Supply chain	Machine	Model	Productivity (BDMt/PMH$_0$)	MC (%)	Cost (€/BDMt)	Reference
Residues from clear cut (pine and spruce)	Forwarder	John Deere 1110D with modified bin load	7.90	40	-	Eliasson et al. 2011
Residues from clear cut (pine and spruce)	Trucked based chipper at road side	Container handling chipper truck (CCT)	10.10	-	-	Eliasson (2011)
Residues from clear cut (spruce)	Truck based chipper at road side	Chipper link (Bruks-Kloeckner 805 CT)	25.84	-	-	Eliasson (2011)
Whole tree harvest	Harvester	Valmet 911, Bracke C16	2.80-5.50	-	-	Iwarsson Wide and Belbo (2009)
Multi-tree cutting of energy wood	Harvester	Eco Log 560C with LogMax 4000B	6.90	-	-	Iwarsson Wide and Fogdestam (2011)
Energy wood	Forwarder	Ponsse Elk	10.45	-	-	Iwarsson Wide and Fogdestam (2011)
Stump utilisation	Excavator	20-25 t	3.80-4.50	-	18.0	von Hofsten (2011)
	Forwarder	15t	5.70	-	-	Lazdins et al. (2009)

Southern hemisphere
Australia

Australia is at an early stage of exploring the use of forest biomass to produce energy. Woody biomass utilisation programs include power stations that co-fire wood waste with coal in New South Wales and Queensland. An energy-pelletising plant in Albany (Western Australia) has been recently commissioned to use forest biomass (Ghaffariyan et al. 2011(a)). There are three main sources for biomass including harvesting residues, dedicated plantations and mill residues. The estimated harvesting residues is Australia is more than 3 million tonnes (Ryan et al. 2012). Harvesting technology and working method can significantly impact the level of recovered and retained biomass (Ghaffariyan 2013). One of the technologies tested to recover harvesting residue from Eucalypt clear cuts was Pinox slash bundler. This slash bundler recovered 65% of the harvesting residues. It was applied under two treatments. Firstly it collected residues from cut over area (average productivity of 4.9 GMt/PMH$_0$) which costed 45.5-49 $/GMt to deliver the bundles at road side. Secondly the residues were raked by an excavator then collected by slash-bundler which resulted in higher bundling productivity (10.5 GMt/PMH$_0$) of 24.5-28 $/GMt at road side (Ghaffariyan at al. 2011 (b)). The chipping cost needs to be added to the bundling and forwarding cost which will increase the total cost. Given the price of delivered biomass chips at the mill gate around 21-28 $/GMt in Australia the slash-bundling system does not seems to be economically viable option. The other technology for harvesting residue collection is Bruks chipper mounted on a forwarder which was tested in Victoria to recover residues from a pine clear felled plantation (Ghaffariyan et al. 2012). The Bruks chipper in this study was more productive to chip road side residue log piles into trucks rather than collecting residues scattered in cut over area when operating as terrain chipper (Ghaffariyan et al. 2014). The biomass recovery rate ranged from 15% to 50%.

Integrated biomass harvesting was found as an efficient way to harvest residue logs during the sawlog and pulpwood recovery by conventional forwarders in pine plantations (Ghaffariyan et al. 2015). Residue logs (called Fibre plus) that do not meet the minimum length and diameter of a sawlog or pulpwood can be collected and extracted by forwarders during the operations with reasonable operating cost. The recovery rate of this type of operation is about 20% to 25%.

Whole tree chipping has been applied to harvest a low quality and failed Eucalypt plantations in Western Australia. The trees were cut by a tracked feller-buncher, then extracted by a grapple skidder to road side. A Husky Precision chipper was applied to chip whole tree into truck at road side and the wood chips were transported in Albany pelletizing plant. The biomass recovery was very high (90%-95%) due to whole tree extraction which may result in high nutrient removal. Table 11 presents the summary of productivity and cost of efficient biomass harvesting systems in Australia.

Table 11. Summary of efficient biomass harvesting technologies in Australia (*1 AUD=0.70 USD*)

Supply chain	Machine	Model	Productivity (GMt/PMH$_0$)	MC (%)	Cost ($/GMt)	Reference
Residues from clear cut (pine)	Mobile chipper	Bruks 805.2 STC mounted on an Ecolog 594C forwarder	43.88 (19.40 BDMt/PMH$_0$)	55.8	16.96 (=38.36 $/BDMt)	Ghaffariyan et al. 2012
Integrated biomass operations (pine)	Harvester Forwarder	Cat 541 with a Rosin RD977 processing head Valmet 890.3	88.30 71.20	- -	$2.24 1.89 **Total:** $4.13	Ghaffariyan et al. 2015
Whole tree biomass (Eucalypt)	Feller-buncher Grapple skidder Chipper	Tigercat 845C Tigercat 730C Husky Precision 2366	50.10 44.60 50.70	- -	2.10 1.88 5.32 **Total**: 9.30	Ghaffariyan et al. 2011(a)

New Zealand

The main source of woody biomass in New Zealand is harvesting and sawmilling residues (Hall, 2008). Sawmilling residues are either directly used at the mill as boiler fuel, but in one region where geothermal energy is available for drying the mill residues is also ground and pressed into pellets. The estimated harvesting residues produced at the landings is about 1 million m^3 per year (ranging from about 3 to 12% of total harvesting volume). In many regions there is also a diminishing market for lower quality wood for pulp manufacture that could also significantly increase the volume of woody biomass available (Visser 2010). Visser et al. 2010 published a Best Practice Guide for biomass harvesting operations in New Zealand. While many supply chain options are available, two economically viable systems were studies in more detail:

"**a) Processing biomass with a tub grinder, transport in a chip truck**: Large scale plantation clearcutting operations, where the stems are processed into logs on the landing, can produce a large volume of biomass that is left in piles around the landing. In this system, an excavator with a root rake is used to feed the tub grinder to produce hog fuel. A front-end loader is then used to pile and load the materials into a chip truck. Because of the considerable set-up and grinder operating cost, the success of this system depends on the volume of the residues available. It was estimated that at least 2000 ton should be available to ensure a successful operation.

b) Picking up 'short logs' residues (>2m) with self-loading truck and taking to commercial mill for chipping / grinding: The majority of biomass residues at a landing is branches / small off-cuts, and if this material has not been stacked carefully remains in contact with the ground so retains a high moisture content, decays quickly and is readily contaminated with soil scraped off the landing during operations. By targeting residues that are at least 2m in length and 15cm in diameter, a self-loading truck can quickly and effectively recover enough biomass by moving between landings to make the operation economically viable. In this recovery operation the contractor recognises that "more than 50% of the volume is in 10% of the pieces".
Table 12 presents the productivity and cost of the applied harvesting technologies in New Zealand.

Table 12. Summary of efficient biomass harvesting technologies in Australia (*1 NZD=0.63 USD*)

Supply chain	Machine	Model	Productivity (GMt/PMH_0)	MC (%)	Costs ($/GMt)	Reference
Harvesting residues at landing	Excavator Grinder Loader Truck	20 T tracked Diamond Z tub-grinder Hitachi LX200 Chip truck	15-30	55	**Total cost:** 23.94-28.98 (= 53.20-64.40 $/BDMt)	Visser 2010
Recovering residue logs from landings	Transport	Self-loading Log truck	12	25	**Total cost:** 20.16 (=26.88 $/BDMt)	Visser 2010

Studies have also been carried out to show that drying biomass logs in summer can quickly reduce moisture content to increase the product value (Visser et al. 2014). However, the cost of extra handling and storage, and the low volume demand, means that this is not common.

Chile

In Chile, biomass accounts for 43% of the non-conventional renewable energy sources and constitutes one of the major contributors of energy to the national grid. Biomass is mainly generated from residues after harvesting operations in *Pinus radiata* and *Eucalyptus globulus* short rotation plantations. These residues are recovered to obtain vapour, thermal or electric energy, which are used for cellulose and pulp production.

In 2015, the three major Chilean forest companies produced over 9,000 GWh of energy from about 6.7 million dry tonnes of forest residues, with an average surplus of 20% being sold to the National grid. Companies are developing plans to continue increasing the installed capacity in the next 5 years, with the goal to get total energy independence in their production processes.

In regard to the biomass harvesting, the most common system consists of a combination of forwarders, skidders, and excavators for piling, grinder and chippers for comminution, and chip van trucks for transports. Table 13 shows a summary of the productivity and cost for this harvesting systems in Radiata pine plantations.

Like in other countries of the Southern Hemisphere, residues are generated after large scale plantation clearcutting operations, where processing of the logs can occur at the stump, landing, or roadside. If processing occurs at the stump, residues are extracted to roadside by forwarders or skidders, and stacked at a distance of about 15 metres from roads (about 3-5 truckloads per pile). Then, the excavator with a root rake feeds the tub grinder, which discharge the hug fuel onto chip van trucks. Several systems and brands of grinder equipment have been implemented including Peterson 4710B, Bandit 2680, and CBI 58000T, with capital costs ranging between 1-4 M$ dollars depending on the scale of the operation where they are allocated. In small areas and thinning operations, continuous work of the grinder requires the use of about 7 chip van trucks, whereas about 10-12 chip van trucks are required in big harvesting operations. Given the cost of the operations and the capital cost involved, it has been determined that at least 120 m^3/ha of residues need to be produced for the operation to be cost-effective.

Table 13. Summary of the productivity and cost for a biomass harvesting system in Radiata pine plantations in Chile

Supply chain	Machine	Model	Productivity (m^3/PMH_0)	MC (%)	Costs ($/$m^3$)	Reference
Harvesting residues at landing	Grapple Skidder	John Deere 648L	-	-	-	Carrasco 2013
	Excavator	Komatsu PC200	120-190	50-52	15-25	
	Grinder	CBI 58000T	-	-	-	
	Truck	Chip van truck	-	-	-	

Discussions and Conclusions

The main source of biomass is different in various parts of the world. European countries seem to be utilising the woods from thinning operations as well as harvesting residues (Routa et al. 2013). Recovering biomass from thinning operations is more costly than recovering residues because biomass recovery in thinning operations needs to carry all the cost of the operation, while harvesting residues only needs to carry the cost of chipping and secondary transportation – and eventually extraction – but not the cost of felling and processing. In Oceania or Southern USA the main source for bioenergy is clearcut residues although in southern parts of USA logs and stems are also used for bioenergy purposes. (Ghaffariyan 2013, Gallagher 2015). This may be mainly due to different bioenergy policies applied in different regions as in some parts of Europe growers are subsidized for biomass production while in Australia there is lack of such a federal support resulting in focusing on recovering residues from cut-over or landings. Low price of biomass in most countries has led to application of integrated biomass and conventional wood recovery to reduce the cost (Ghaffariyan et al. 2015, Spinelli and Magagnotti 2011), while in European countries separate biomass recovery still sounds as an economically viable option. Moisture content of the biomass materials has an impact the cost of harvesting and in particular transportation. In some countries the harvesting residues or round woods are dried in the forest (in the cut-over area or at road side) which seems to be effective way to decrease the cost of operations (Visser 2010, Erber et al. 2012, Garcia 2015). However, harvesting and transporting the green materials are still being applied especially in the areas such as Australia, where payment is based on green metric tonnes rather than dry tonnes or calorific values per tonne.

From technological point of view, terrain and availability of the biomass make significant impact on the type of technology to apply and operating costs. Mountainous forests in Central Europe or North-West of USA would require cable yarding systems to extract the woods from steep terrain which may result in higher costs however less impacts on forest soils compared to ground-based harvesting systems like forwarders (Affenzeller and Stampfer 2007a). Most of the cable yarding operations are applied as integrated harvesting to extract biomass and sawlogs. From New Zealanders' perspective the higher the volume of woody residues available at the landings the more the chance to operate successfully (Visser 2010). This fact was also proved in Sweden that higher yield per ha will result in lower operating cost as a key factor on biomass supply chain management (Björheden 2011).

One of the lessons learned in residue collection by terrain chippers in Sweden, Canada, Australia and Germany is that applying a terrain chipper to roadside chipping is a sub-optimum strategy. The decision is always between terrain chipping with a terrain chipper or roadside chipping with a roadside (mobile) chipper. For the same power and capacity, a terrain chipper is much more expensive than a roadside chipper, and it is worth using only if terrain access is required. If that is not required, a roadside chipper is a more rational decision. Roadside chipping is more efficient than terrain chipping, regardless of chipper type. The harvesting residues can be collected or concentrated into larger piles (using forwarders or any other suitable type of forestry machines) then chipped directly into trucks to reduce operating costs (Desrochers et al. 1993, Björheden 2011, Ghaffariyan et al. 2012, Ghaffariyan et al. 2014). However, terrain chipping is still a competitive option under specific circumstances, such as the Danish spruce plantations and the Italian poplar plantations.

Other lesson learned internationally from European, North American and Australian research experience is that using slash-bundlers to collect harvesting residues is one of the most expensive options. This is mainly due to high hourly machine cost and relatively low productivity (Spinelli and Magagnotti 2009). The other fact is that bundles will need to be chipped either in forest or at mill which add another cost element to total operating costs (Spinelli et al. 2010). Bundles are sometimes difficult for small chipper to feed in. In such a case, it may require de-bundling as an additional cost.

Size of machine is the other factor influencing the productivity and costs to be considered managing supply chains. Larger machines have larger power which can result in higher productivity however the cost of operation per tonne needs to be taken into consideration as a key decision factor as larger equipment usually have hourly cost. Whole tree chipping of small tree sizes with small feller-buncher, mini skidder and small chipper in Southern USA resulted in productivity of 10 GMt/PMH_0 (total cost of 12.10 $/GMt) (O'Neal and Gallagher 2008) while the same operation in Western Australia (similar tree size to Southern USA case study) was operated by a large feller-buncher, a skidder and a large chipper that yielded lower total costs (9.30 $/GMt), mainly due to higher productivity (50.7 GMt/PMH_0). For larger machines, it will be important to maintain high utilization which requires proper planning and adequate (available) tract size.

Future research and development (R&D) requirements

This current review gives the overview of the most efficient biomass supply chains, however, there are still some needs for future R&D projects to move towards more sustainable operations listed as following:

Application of whole tree extraction (Stokes 1992) or recovering extra volume of the wood using integrated biomass harvesting after cut-to-length operations may endanger the site sustainability in next rotations due to nutrient removals (Ghaffariyan 2013). Considerable R&D is required to examine the sustainability aspects (nutrient loss, ash recycling, etc.) (Björheden 2011, Spinelli et al. 2014) and to define the thresholds of maximum allowable biomass recovery in different soils and stands considering the economic and environmental benefits. In short, forest biomass growers will require a practical guideline/tool on how to manage/recover/retain their harvesting residues. The contributions of different parts of the biomass to forest sustainability need to be recognized. For example, the needles or leaves contribute different mineral concentrations than the bark or stem wood. Moisture management plays an important role in needle retention, transport and energy yield.

Several countries have agreed on a new framework for climate and energy, including targets and policy objectives to achieve a more competitive, secure and sustainable energy system. EU countries have agreed for the year 2030 to cut greenhouse gas emissions compared to 1990 levels by 40% and to have at least a 27% share of renewable energy consumption (COM/2014/015). This means that also in future there will be a need for energy wood supply systems, but their performance has to be more efficient from both from an economical and an ecological perspective.

Cost-productivity is a very important factor in supply chain management which gives key information to the industry users. However, a more comprehensive information will be required to include environmental and social impacts of the biomass technologies.

The information received from international participants of this project will need to be enriched by collecting more detailed data on environmental, ergonomics and social aspects of supply chains. This may even require carrying out some research projects in different parts of the world where sufficient information is not currently available. Then the completed data base could be used by future research project to develop a decision support tool for international users to identify most sustainable biomass supply chains/technologies.

To estimate the amount of harvesting residues and potential for bioenergy usage in each stand there has been several inventory trials carried out in post-harvest phase however a future study could look at the feasibility to use the harvester's processing head data in planning (e.g. equipped with optimisers) to predict and control the level of harvesting residues prior to tree cut (Brunberg and Eliasson 2011). More sophisticated study can merge the pre-harvesting inventory data with log scanners identifying the quality of the wood for different products to predict the potential volume for biomass production in addition to sawlog or pulpwood.

From operation management perspective, the FPinnovations experienced a low utilisation rate for grinders in Canada (MacDonald 2009) as a result of delays caused by transportation (e.g. trucks not available to be loaded). The same problem has been diagnosed in road side chipping operations in Australia and seems to be occurring in most of the biomass operations in other regions (Spinelli and Visser 2009). Equipment balancing requires appropriate costing methods. Research is needed to examine if traditional average machine rates are appropriate for equipment balancing analysis and decision-making. To solve such operational problem of chipping/grinding (and indeed any in-stand biomass operations) the operation needs to be optimised considering fleet design and trucks productivity and availability. Zamora-Cristales et al. (2013) have developed a model to optimise mobile chipping and transportation in USA and Acuna et al. (2012a) constructed a tool to optimise the wood transportation (called Fast-truck) and another tool for biomass harvesting (called BIOPLAN) in Australia (Acuna et al. 2012b, Ghaffariyan et al. 2013a) however the knowledge can be transferred to other biomass producer regions using Task43 networking mechanism while comprehensive modification to the current optimising tools will be required to each specific operation conditions in different countries through future research projects.

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SCENARIO PLANNING FOR SKID TRAIL IMPLEMENTATION AND LONG TERM TRAFFICABILITY

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Abstract: *It's now widely acknowledged by French forest managers that all forest machineries (harvester, forwarder, skidder…) must drive on permanent corridors to preserve soils from compaction and rutting. Implementation of such infrastructure requires in-depth analysis at stand level and needs to be done before starting a logging operation. A geo-based comparison of skid trail implementation scenarios and their consequences on haulage activity has been carried out. Cumulated weights and numbers of times forest machines will drive on the skid trails are simulated on a typical rectangular hardwood stand of oak high forest with hornbeam coppice on sensitive soil. Haulage efficiency is proposed at first as a performance indicator for decision support. Depending on the longitudinal or transversal orientation, on the number of possible landing area (1 or 2) and on the possibility to drive as a loop, seven scenarios for haulage organization are compared in terms of driving distance and driving time. For a single operation, significant distance gains up to 19% and time gains up to 25% are observed. As an additional criterion for the early planning of skid trail implementation, cumulated tonnages transported on each skid trail over the 150-year forest rotation are also simulated in the study. Major differences (from 805 to 3 663 cumulated tons at the beginning of a skid trail) highlighted in this typical case help to provide practitioners with recommendations on how the preservation of long term trafficability of their skid trail infrastructure can be taken into account.*

Keywords: trafficability, permanent skid trails, haulage efficiency, soil preservation

Introduction

It's now widely acknowledged by French forest managers and logging operators that all forest machineries (harvester, forwarder, skidder…) must drive on permanent corridors to preserve soils from compaction and rutting. Implementation of such infrastructure requires in-depth analysis and planning at stand level and if possible on a larger area. Moreover, consequences over the whole forest rotation need to be taken into account. Thus, when there is no pre-existing extraction tracks network and skid trails need to be opened, thinking needs to be done upstream instead of under the pressure of a starting logging operation.

This article presents results of a study carried out in European project SIMWOOD[1] for a regional pilot project. Through the latter, regional forest cooperative Forêts et Bois de l'Est (F&BE) and FCBA aimed at increasing professional know-how for enhanced environmental friendly logging operations on sensitive soils (Pupin & Ruch 2017). The scenario planning approach is motivated by the fact that 25% of the area where the cooperative operates is identified as sensitive and F&BE has only recently started advocating for the installation of permanent skid trail to its private forest owners clients.

[1] SIMWOOD project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 613762

A geo-based comparison of skid trail implementation scenarios and their consequences on haulage activity is hence carried out. Cumulated weights and numbers of times forest machines will drive on the skid trails are simulated on a typical rectangular hardwood stand of oak high forest with hornbeam coppice on sensitive soil.

National recommendations for skid trail implementation in France

Skid trails are meant as a network of permanent corridors. Traffic is hence banned from the rest of the stand surface in order to preserve productive area. Indeed, soil compaction due unregulated traffic when bearing capacity are poor (high moisture content, soil type…) hinders soil biological action and consequently stand productivity, regeneration, health conditions and biodiversity (Pischedda 2009).

Without skid trail implementation, driven surface (based on machine wheelbase) in a plot can ranges from 30 to 60% of the total area during just one operation (Lewin et al. 2004). Thereby, the surface driven after several operations over a whole sylvicultural rotation can exceed 60%. Furthermore, when moisture content increases soil sensitivity, most of the damages (from 60 to 80% compaction impact) happen during the first pass (Pischedda 2009).

Given forest machine sizes in France, the optimal skid trail implementation has the following characteristics: 4 m wide (a machine width is between 2,5 and 3 m), 18 m interspace (twice the average outreach length of a crane), as straight as possible, following the slope (even gentle slopes in plain), obliquely to exits to make maneuvering easier and to avoid damage on border trees (Figure 1). For better visibility, oblique orientation at the end of skid trails are not represented on figures of this paper. However, some parameters are to be adapted as necessary on field conditions depending on presence of wetland or stream or slope break or existing trails. In addition, skid trail implementation is conditioned by forest road access and landing area location (Fiche technique ONF – Sol n°7, Mourey et al., 2012).

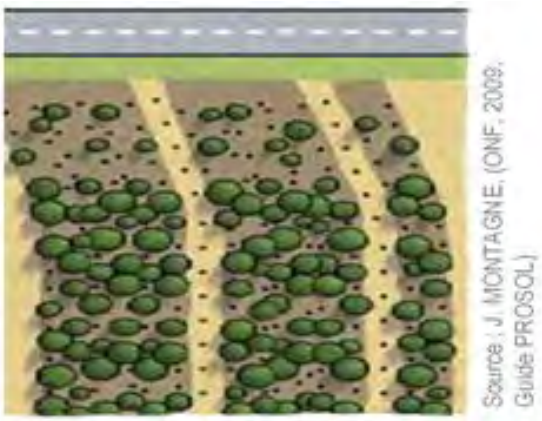


Figure 1. Oblique orientation at the end of a skid trail

Material and Methods

In the study, three aspects are investigated by using a GIS simulation of haulage activity in a typical rectangular stand of 8.7 ha.
At first the impact of skid trail orientation on productive area (or forest area without compaction by machine) is quantified. Three skid trail orientations are compared: longitudinal, transversal and oblique. And in each configuration, the following indicators are calculated: number of skid trails, average length, cumulated length and proportion of skid trail area and wooded area.

The second step means to identify the most efficient skid trail implementation for haulage operation. A geo-based comparison of skid trail implementation scenarios and their consequences on haulage activity is carried out. Focus is still on a single logging operation, namely the forwarding of crowns (80 m^3/ha) after the final felling and haulage of the log at the end of the 150-year rotation. Skid trails are 18 m apart and 4 m wide. To simplify modeling, products are unloaded at the center of the landing area. Seven scenarios were compared (Figure 3, scenarios ① to ⑦) in terms of driving distance and productive time, depending on the combination of four conditions:

1. Number of landing areas: one or two;
2. Skid trail orientation: longitudinal or transversal;
3. Driving direction: one-way drive (drive backwards first and return forwards with load) or loop drive;
4. Forwarder speed: same speed on every skid trails or variable speed depending on skid trail status (main skid trail or not). Speed scenarios are given in Table 1.

In regard to productive time, only empty displacement time from the landing area and load displacement time to the landing are taken into account (loading time, unloading time and other times are not calculated because there is no link with driving distance).

Table 1. Forwarder speed parameters used

		Speed (km/h) by scenario		
Skid trail status	**Load status**	**V 1**	**V 2**	**V 3**
First main skid trail (to east border with other stand)	Empty	9	9	6
	Loaded	8	8	5
Second main skid trail (inside stand, near west border)	Empty	9	6	6
	Loaded	8	5	5
Other skid trails	Empty	6	6	6
	Loaded	5	5	5

Finally, cumulated tonnages on skid trails are quantified over the 150-year forest rotation. Two types of forest machines are used for haulage: a skidder for long logs (11 tons plus 7 tons load); a forwarder for energy products (18 tons plus 8 tons load).

By way of simplification, it is considered that only energy products are forwarded over the 150-year forest rotation although pulp and industry woods could be extracted instead depending on market demand.
Also in order to simplify the calculation, it is also considered that one cubic meter equals one ton.

Moreover, a load which is not full at the end of a skid trail is taken into account according the following rules:

- if load is less than 20% full it is added to the previous load;
- if load is 20% to 60%, full it is completed in the next skid trail;
- if load is more than 60% full it is not completed and the machine drives to the landing area.

Over the 150-year forest rotation, the 14 forest operations carried out within the stand are described in Table 2.

Table 2. Operations program in the private forest of hardwood stand of high oak forest with hornbeam coppice for a 150-year rotation

Stand age	Operation	Storey	Product	Haulage machine	Harvested volume (m^3/ha)
25	Skid trail implementation		Wood energy	Forwarder	55
30	1st thinning		Wood energy	Forwarder	30
50	2nd thinning		Wood energy	Forwarder	30
60, 70, 80, 90, 100, 110, 120, 130	8 increment fellings	High forest	Logs	Skidder	25 / operation
			Wood energy	Forwarder	20 / operation
		Coppice	Wood energy	Forwarder	20 / operation
140	Regeneration felling	Coppice	Wood energy	Forwarder	10
		High forest	Logs	Skidder	120
			Wood energy	Forwarder	85
145	Regeneration felling	High forest	Logs	Skidder	120
			Wood energy	Forwarder	80
150	Final felling	High forest	Logs	Skidder	120
			Wood energy	Forwarder	80
14 operations in total					1 250

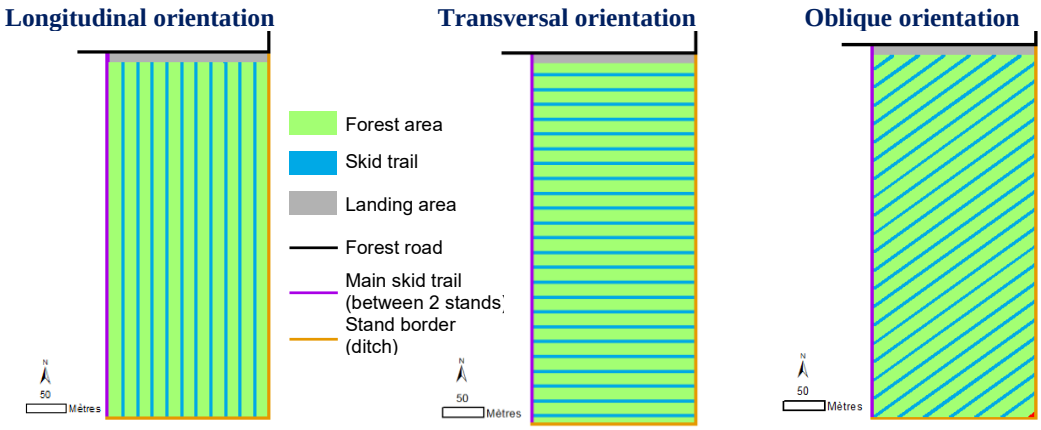
Results and Discussions
Is there an impact of skid trail orientation on the productive area?

All things being equal, Figure 2 shows for our studied stand the theoretical impact of skid trail orientation on the driving area and consequently on the forest area which will be preserved from potential damages (compaction and rutting).

It appears from the comparison of three scenarios (longitudinal, transversal, oblique orientation) that there is no significant difference in terms of skid trail area (about 20% of total area).

However, there is obviously a clear difference on skid trail average length: 437 m for longitudinal orientation against 195 m for transversal orientation and 189 m for oblique orientation. Concerning skid trail cumulative length, the lowest length is obtained with longitudinal orientation (4,365 m) and a 7% and 8% increase of the length only with transversal and oblique orientation respectively.

These results can be generalized to any rectangular plot.



Stand area	87 178 m^2	87 178 m^2	87 178 m^2
Skid trail spacing	18 m	18 m	18 m
Skid trail width	4 m	4 m	4 m
Landing area	2 %	2 %	2 %
Number of skid trails	10	24	25
Average length	**437 m**	**195 m**	**189 m**
Cumulated length	4 365 m (0%)	4 680 m (+7%)	4 720 m (+8%)
Skid trail area %	**20 %**	**22 %**	**22 %**
Productive area %	**78 %**	**76 %**	**76 %**
Inaccessible area	0 %	0 %	0 %

Figure 2. Impact of skid trail orientation on productive forest area, example of a typical rectangular stand

What is the most efficient skid trail implementation for haulage operation?
With one landing area

Under the scenarios with one landing area, the shortest driving distance (41 km) is obtained with longitudinal orientation of skid trails. In this case, empty and loaded displacements are carried out in the same skid trail: backwards from landing area and forwards when load are brought to the landing area. This scenario (Figure 3 scenario ①) is used as a reference. In addition, transversal orientation increases the driving distance by 56% in the case of backwards and forwards displacements (Figure 3 scenario ②). However, when instructions are given to drive as a loop, the driving distance increases by 46% or 10% depending if the driver returns to landing area with the last load of a skid trail only partially filled (Figure 3 scenario ③) or if the load is completed in the neighboring skid trail (Figure 3 scenario ④).

Under the scenario with one landing area, longitudinal orientation (Figure 3 scenario ①) is still very effective and used as a reference. Indeed, transversal orientation increases the driving time by 30% in the case of backwards and forwards displacements (Figure 3 scenario ②) while the possibility to drive as a loop (by using a second main skid trail) is 6% higher if the driver completes its load in the neighboring skid trail (Figure 3 scenario ④). Otherwise, if the driver returns to landing area with the last load of a skid trail partially filled, the driving time increases by 21% (Figure 3 scenario ③).

Moreover, in scenarios ③ and ④, when the same speed is used for all skid trails (no higher speed in the 2 main trails), driving time increases respectively by 49% and 14% compared to the baseline scenario. In addition, when forwarder speed in the second main skid trail are the same as speed in skid trails inside the plot (V2 case), driving time increases respectively by 37% and 4%.

Looking at cumulated weights, in scenario with longitudinal orientation and backwards/forwards drives (Figure 3 scenario ①), 265 tons add-up at the entrance of each skid trail against 130 tons in the scenario with transversal orientation (Figure 3 scenario ②), hence a difference of -51%. For scenarios with transversal orientation and haulage as a loop, in case where last load of a skid trail is partially filled (Figure 3 scenario ③), the cumulative weight at the exit of a skid trail amounts to 75 tons against 62 to 80 tons in case where last load of a skid trail is fulfilled (Figure 3 scenario ④). In comparison with reference scenario, weight reduction is 72% and 70% to 77% respectively.

With two landing areas

When two landing areas are available, transversal orientation with full last loads is always the most efficient organization (Figure 3 scenario ⑥). Indeed, total driving distance decreases by 19% and productive time by 15% (V3) or by 25% (V1) depending on speed scenarios. In case of incomplete last loads, benefit on productive time (-8%) is only possible with higher speed on the two main skid trails (Figure 3 scenario ⑤ V1). Longitudinal implementation allows 16% saving on driving distance and 15% on productive time (Figure 3 scenario ⑦).

Moreover, for within-stand skid trails, cumulated weight in scenarios ⑤ and ⑥ are the same than in scenarios ③ and ④. But working with a second landing area decreases cumulated weight on main skid trails. Indeed, with longitudinal orientation (Figure 3 scenario ⑦), cumulated weight at the entry of a skid trail is 116 tons and is 156 tons at the exit, which represents a respective reduction of 41% and 56% compared to the reference scenario (Figure 3 scenario ①).

Discussion

As a first conclusion, it appears that the best scenario is the one relying on two landing areas (one at each opposite side of the stand), transversal orientation of skid trails and loop-drive instructions (Figure 3 scenario ⑥). However, this presupposes that it is possible to drive with a higher speed on the two main skid trails and that the latter can really support high cumulated weight. Indeed, since traffic is mostly distributed on the periphery of the stand so are compaction and rutting risks. Considering that transversal orientation is easier to implement in practice, the little extra time is not considered as significant compared to profitability of haulage operations and soil protection.

If only one landing area is possible, then longitudinal orientation of skid trails is better than a transversal one, but the traffic is high at the entrance of each skid trail. Nevertheless, transversal orientation is to be preferred despite its impact on productivity when considering the need to maintain the long term trafficability of the infrastructure and risk mitigation against compaction.

Figure 3. Cumulated weight (forwarder and load) depending on haulage scenario and number of landing areas when forwarding tree crown (for energy products) at final felling stage (Table 2)

Results on cumulated tonnages along skid trails over the 150-year forest rotation

Beyond traffic intensity on skid trail during one logging operation (as quantified in 3.2 for tree crowns haulage after final felling) and how transversal orientation can report traffic on the periphery of the stand, a longer time span is here down considered. As an additional criterion for the early planning of skid trail implementation,

cumulated tonnages transported on each skid trail (machine weight and load) over the 150-year forest rotation are also simulated.

Longitudinal orientation

In a longitudinal orientation scenario relying on one landing area, 200 passes adding-up to 3,663 tons (Figure 4) would happen at the end of each skid trail over 150 years, for an average of 14 drives and 262 tons per operation and skid trail. Cumulated weights are equally distributed from one skid trail to the next but not along a skid trail. Indeed, the longer the distance from landing area, the lower cumulated weight. Moreover, the skid trail at the edge of the stand (grassy path limit with adjacent stand) is lightly used.

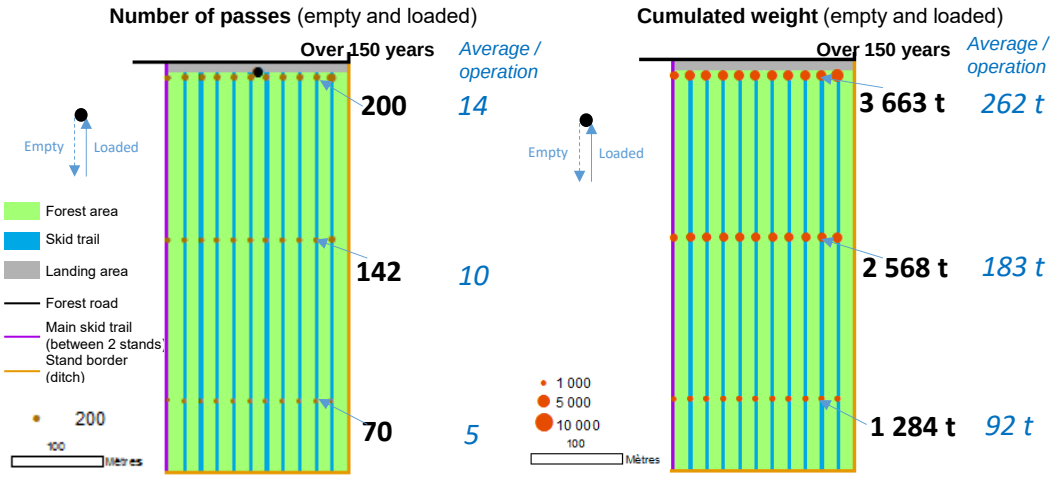


Figure 4. Number of passes and cumulated weight for haulage operations over the 150-year revolution for longitudinal skid trail orientation and one landed area scenario

Transversal orientation

Over 150 years, we observe (Figure 5) at the end of a skid trail 104 drives cumulating 1,887 tons, for an average of 7 drives and 135 tons per operation and per skid trail. However, at the end of the main skid trail, we note 2,256 drives cumulating 40,810 tons, or on average 161 drives and 2,915 tons. Under modeling of transversal orientation and one landing area, cumulated weights and numbers of times forest machines will drive are focused on the main skid trail (in edge of the stand) as illustrated in Figure 5.

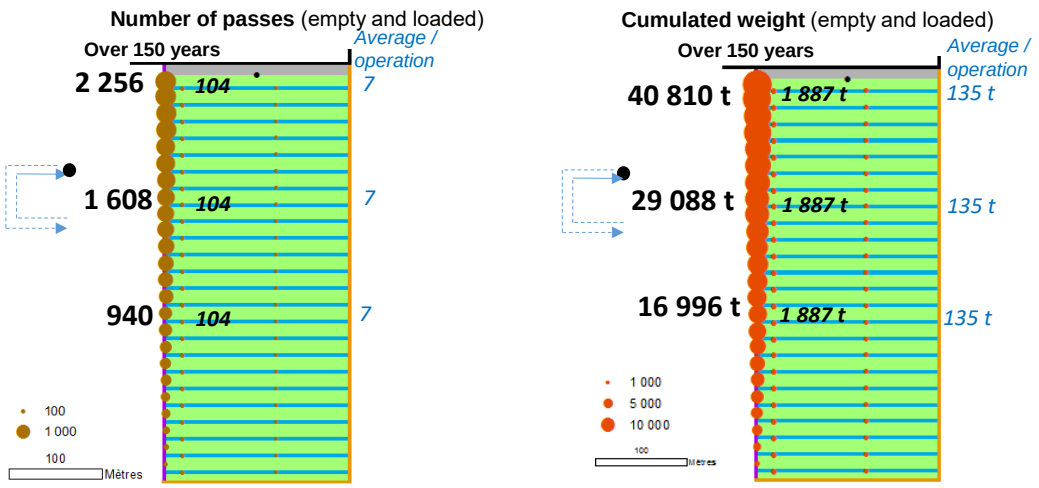


Figure 5. Number of passes and cumulated weight for haulage operations over the 150-year revolution for transversal skid trail orientation, one landed area and one main skid trail scenario (forwards and backwards drive)

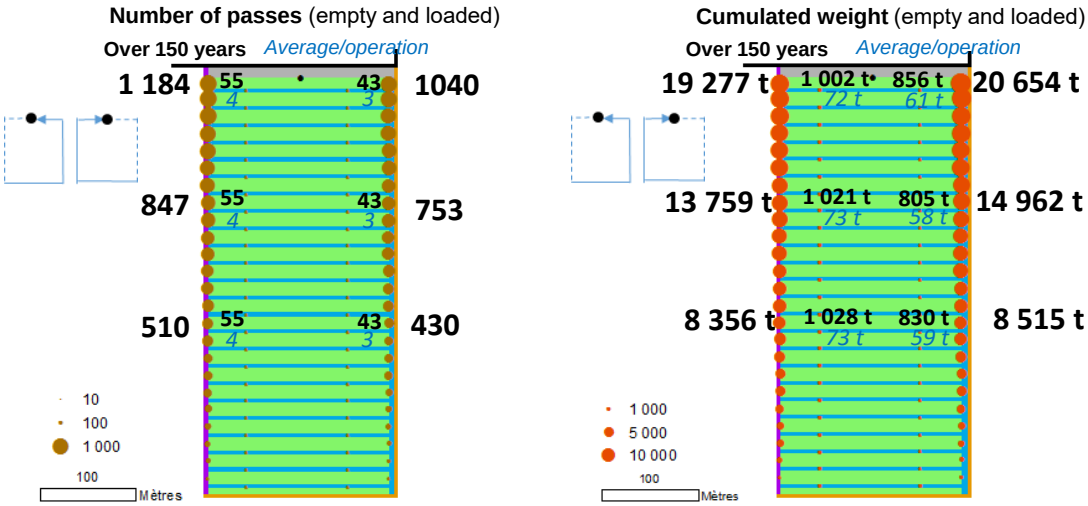


Figure 6. Number of passes and cumulated weight for haulage operations over the 150-year revolution for transversal skid trail orientation, one landed area and two main skid trails (drive as a loop)

Over 150 years, we observe (Figure 6) at the end of a skid trail 55 drives cumulating from 1,002 to 1,028 tons, for an average of 4 drives and approximately 72 tons per operation and per skid trail. However, at the end of main skid trails we note on left main skid trail 1,184 drives cumulating 19,277 tons (or on average 85 drives and 1,377 ton) and on right skid trail 1,040 drives cumulating 20,654 tons (or on average 74 drives and 1,475 tons). If a second main skid trail at the opposite side of the stand is added, haulage is as a loop for forwarding but not for skidding because logs and tree crowns blocking skid trails. In this configuration, in average (Figure 6), cumulated weight on the ends of skid trails is divided by 2. Main skid trails must be capable to support heavy loads.

From the foregoing, it appears that to reduce impact on “normal” skid trails, it is possible to increase the number of landing areas. Of course, this assumes that road accesses are adapted to trucks and that main skid trails are strengthen.

Conclusions and Recommendations

All forest machineries (harvester, forwarder, skidder…) must drive on permanent corridors to preserve soils from compaction and rutting. Implementation of such infrastructure requires in-depth analysis and planning at stand level and if possible on a larger area. Moreover, consequences over the whole forest rotation need to be taken into account. Thus, when there is no pre-existing network and skid trails need to be opened, thinking needs to be done upstream instead of under the pressure of a starting logging operation.

With a typical rectangular hardwood stand of oak high forest with hornbeam coppice on sensitive soil, it appears that the best implementation is to use two landing areas, one at both side of the stand and also to use transversal orientation of skid trails and to haulage as a loop. However, this presupposes that it’s possible to drive with a higher speed on the two main skid trails and that these skid trails are allowed to support high cumulated weight. Indeed, traffic is mostly on the periphery of the stand as well as compaction effect and rutting risk. In addition, skid trail transversal orientation is easier to implement in practice. So, even if it takes a little more time this is insignificant compared with profitability of haulage operations and soil protection.

However, if only one landing area is possible, then longitudinal orientation of skid trails is better than transversal orientation, but there is a high traffic at the entry of each skid trail. Nevertheless, from sustainable trafficability point of view transversal orientation is to be preferred but there is an impact on productivity.

Finally, the smaller the forwarder is (which may not always mean a low ground pressure), the higher the number of time it will drive. Or this number has also an impact on haulage efficiency and so on the financial balance.

Traffic simulation is now used as a part of training session to increase professional know-how for enhanced environmental friendly logging operations on sensitive soils. It's well received by participants and it's sometimes an eye opener. It helps adding scenario planning in the decision process of designing new skid trail infrastructures and it contributes to getting agreement of forest owner.

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FULLY MECHANIZED FOREST HARVEST IN WITHERED PINE PLANTATION

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Abstract: *The operation of the Valmet 911 harvester together with the Valmet 835 forwarder in harvesting of dead pine plantations in Bulgaria has been investigated. A comparative analysis of motor-manual logging (chainsaw+horses) vs. full mechanization (harvester+forwarder) has been made, incl. time studies. The results have been compared to performance data from Finland.*

Keywords: felling, harvester, forwarder, performance

HARVESTING AND USE OF URBAN WOODY BIOMASS

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Abstract: *Harvesting and chopping of urban woody biomass (by arborists, elevating platforms, and three types of small chippers) were studied. The objects of the study were dangerous trees (standing dry trees and rotting live trees) in the parks and green areas of the Bulgarian capital Sofia which were cut down and chipped. As an alternative to energy use of the chips produced, the proposal is made to compost and use the chips directly on the spot. This way the costs and the further disadvantages of transportation of urban biomass are avoided.*

Keywords: urban area, branches, steams, small chippers, compost

INVESTIGATIONS ON THE SOIL PREPARATION WITH RT 400

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Abstract: *The preparation of the soil of harvested poplar plantations by using the mulching system RT 400 has been investigated. The shredding of poplar branches and trunks has been examined. The performance of the machine and the evenness of depth and width of shredding have been determined. The wear of the shredding teeth in dependence on their location on the mulching head and on the working time have been investigated, also the sizes of wood chips and wood fibre which are important for their decay in the soil layer, the soil structure and composition before and after treatment and the degree of decay of wood particles 1 and 2 years after treatment.*

Keywords: mulcher, waste wood shredding, soil cultivation, performance

MULTI-CRITERIA DECISION-MAKING METHODS IN THE MANAGEMENT OF FOREST ROAD MAINTENANCE

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Abstract: *Today, in order to better management of existing forest roads maintenance in the country beside to economic indicators, it is essential to contribute other effective factors such as improvements in road pavement, road effects on economic conditions of forestry plans, cost of forest operation, users and natural conditions. Due to economic issues and road conditions as well as their impact on the prioritization options, requires a multi-criteria decision which has been investigated in this study. For this purpose, the maintenance factors determined by expert's opinions. Then 50 km of forest road under management of Mazandaran wood and paper company was selected. Concerning to the extent of quantitative and qualitative factors and the huge number of alternatives, Analytical Hierarchical Process (AHP) was developed to prioritize the repair and maintenance of forest roads. The result showed that decision makers are able to prioritize forest roads from different spatial and temporal point of view using the generated model according to expert knowledge and effectiveness of these factors.*

Keywords: temporal and spatial planning, maintenance, forest roads, AHP rating, prioritizing road maintenance

SOIL DISTURBANCE OF A CABLE ASSISTED CTL HARVESTER FORWARDER THINNING IN NORTHWEST US

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Abstract: *Soil disturbance is a primary concern for privately- and federally-owned lands across the United States (US). The Pacific Northwest region of the U.S. is known for its timber production capability and social concerns around forestry and timber harvesting. Legacy logging practices have made way for strict environmental regulations that currently bars ground-based systems from operating on steep slopes on federally-owned land, while these systems can be applied to some steep slopes on private land as long as safety is not compromised. Soil productivity, soil quality, and site hydrologic functions are specifically important regardless of the landowner. However, harvesting systems proven to have minimal soil impacts (i.e., below threshold disturbance values) can be exempted from current regulations and allowed to operate on federal lands. The purpose of this study is to quantify the soil disturbance of a harvester-forwarder system operating with and without cable-assistance while operating on a slash mat on wet soils. Our hypothesis is that cable-assistance will help reduce the negative impacts on soil from harvester-forwarder operations. Corridors in the thinning unit will be paired: one will use cable-assistance and the other will not. Measurements of rut depth, soil compaction through bulk density and penetrometer samples, slash mat volume, cable tension, and number of machine passes are collected to link soil disturbance with specific trackable variables of the operation. This is part of a larger study examining the productivity and cost, as well as soil disturbance, of various cable-assisted harvesting systems common to the Pacific Northwest of the U.S.*

Keywords: soil disturbance, harvester forwarder, cable-assistance, Pacific Northwest

THE ASSESSMENT OF MUSCULOSKELETAL WORKLOAD OF THE HARVESTER OPERATOR DEPENDING ON THE CONTROL UNIT TYPE

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Abstract: *In the paper a musculoskeletal workload of harvester operators was assessed. Four types of control units were studied: joystick, mini-joystick, sphere with mini-joystick, and harwarder control unit. The Rapid Upper Limb Assessment method (RULA) was used for the assessment of upper body load (upper limbs, trunk, neck). The analysis was conducted on the basis of videos of two continuous hours of operation/work for each type of control unit in the RULA software (NextGen Ergonomics, Canada). The analysis of RULA showed that a type of control unit has an influence on a degree of musculoskeletal load of upper body part of harvester operators. The tested constructions had the medium or high risk of musculoskeletal disorders development. The highest level of MSDs risk was noticed in case of harwarder which is a combination of two types of machines: a harvester and a forwarder. A wider range of application (harvesting and forwarding) required an elaborated control unit forcing a higher number and range of hand movements. In all types of studied control units a higher MSDs load of the left hand was noticed.*

Keywords: harvester, control unit, operator, musculoskeletal load, RULA method

ASSESSMENT OF STUMP HEIGHT RELATION WITH TERRAIN SLOPE: THE CASE OF KAHRAMANMARAS FOREST ENTERPRISE CHIEF, TURKEY

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Abstract: *Timber production of Turkish forests perform with forest workers (generally villagers) according to stumpage sale (standing timber sales). Chainsaw, which is commonly preferred for tree cutting and felling, is main tool for the most part of forest lands in Turkey due to limited budget and harsh mountainous terrain. There are partial wood volume waste reveal as the result of cutting method or tool use. Thus, this study is considered slope, species, stump diameter, chainsaw specifications and worker experience as factors were analyzed to understand the success in chainsaw oriented timber production. Field measurements were performed in Brutian pine (Pinus brutia Ten.) clear-cut stand within Cinarpinar Forest Enterprise Chief located in Kahramanmaras Forest Regional Directorate in Turkey. During the field studies, the slope of terrain, geographic coordinates, diameters and the lengths of the stumps were measured. Chainsaw specifications and worker experiences are also noted. Consequently, this study carried out that stump heights of felled trees show differences up to terrain slope and worker experiences.*

Keywords: timber harvesting, tree felling, stump site, chainsaw assessment

PRODUCTIVITY ANALYSIS OF SKIDDING OPERATIONS WITH FARM TRACTOR ON SKID ROADS: THE CASE OF OSMANIYE FOREST ENTERPRISE CHIEF, TURKEY

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Abstract: *Timber extraction is usually done by implementing cut-to-length logging method in Turkey. In recent years, whole-tree method has been preferred in timber extraction especially in thinning operations. Skidding of whole trees require mechanized logging since traditional methods using animal power cannot handle whole trees and may not be appropriate for productive and safe operations. In Turkey, modified farm tractors are generally used for extraction of timber where terrain conditions and stand types are suitable. In this study, the productivity of skidding operation employing a farm tractor was analyzed during a thinning operation. The field studies were conducted in Brutian pine (Pinus brutia Ten.) stands within Osmaniye Forest Enterprise Chief located in Adana Forest Regional Directorate in Turkey. Time study method was performed to evaluate work stages of skidding operation by using chronometer. The operation productivity was computed as 13.50 m^3/hour with the average volume of 0.91 m^3. It was found that operation productivity increases as log volume increases. Hence, there was a close correlation between skidding distance and the total cycle time.*

Keywords: logging operation, skidding, productivity, farm tractors

Introduction

In small scale forest operations, timber extraction activities are mostly carried out by chainsaw, felling the trees, and skidders that transport the log from stump to landing areas (Akay and Yenilmez, 2008). Skidders can skid the timbers using a skidding chain or a grapple (Kellogg et. al., 1992). In Turkey, mechanized logging operations are mostly done by farm tractors. After some mechanical modification and attachments, farm tractor is used as skidder, loader, forwarder and cableway (Ozturk and Akay, 2007).

In areas, where ground slopes are lower than 30% or within 0-33% along skidding road, products could be extracted by skidding using farm tractors (Erdas, 2008; Turk, 2011). In mountainous terrains where slope is higher than 30%, tractor is located on an appropriate site of the forest road or the skidding road, as the motion ability is limited, so it carries out the logging operation by using cableway method. Generally, cableway method is used during extraction of the products from valleys or valley floors to the skidding roads or landing areas. In this system, one end of the cable is fixed to the drum and the other end is fixed to the product to be pulled with the help of a hook (Acar, 2004).

In order to determine suitable logging method and select right equipment, productivity of the equipment should be carefully evaluated. The productivity of the logging equipment or harvesting methods used in the timber extraction operations are generally determined based on the production time. The most widely used work measurement technique for calculating the production time is time and motion study method (Gulci, 2014). The aim of this study is to perform the productivity analysis by using time and motion study of the skidding operations carried out with farm tractors on the skidding roads.

Material and Method

The study field was selected from a sample stand within the borders of Osmaniye Forest Enterprise Chief located in Adana Forest Regional Directorate, Osmaniye Forest Enterprise Directorate (Figure 1). Dominant tree species in the stand of about 161 hectares was Brutian pine (*Pinus brutia* Ten). Average ground slope and altitude were 30% and 980 meters, respectively.

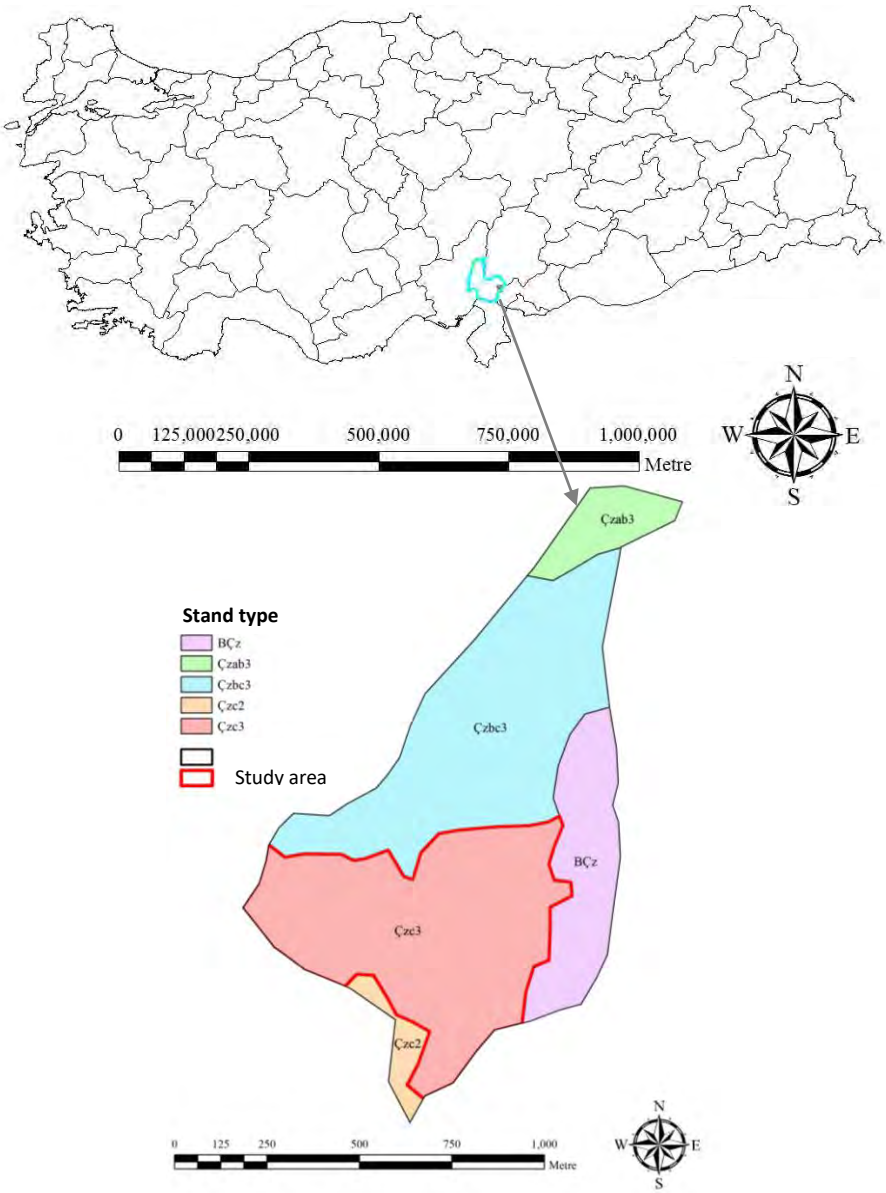

Figure 1. Study area

Skidding operations were performed by using 73 – 75 D Turbo 2009 model farm tractor with 75 hp power. The skidding distance was an average of 73 meters with 20% skidding road slope (Figure 2). The work stages evaluated were move-out unloaded, loading in the stump, move-in loaded and unloading at the landing. Time measurement of the work stages were performed for total of 30 trips by using reset method (repetitive time measurement) with the help of chronometers.

Figure 2. Skidding operations with farm tractor

Statistical analyzes of the time measurement were performed using One-Way ANOVA at 0.05 significance level. Pearson correlation was used to investigate the relation among length, diameter, volume, and skidding distance. In order to evaluate the effect of timber volume on productivity, timber volumes were divided into three classes: 1- low (<0.68m^3), 2- medium (0.68-1.04 m^3), 3- high (>1.04 m^3) according to their volumes. Timber volume (*V* in m^3) was computed by medium surface approach (Huber Formula), which is widely preferred in technical forestry applications:

$$V_i = \frac{\pi}{40000} d_i^{\,2} L_i \qquad (1)$$

d_i = *i* medium diameter of the timber (cm)
L_i = *i* length of the timber (m)

Then, using the data that were obtained by the field measurements, hourly productivity (*P* in m^3/hour) was computed. Following formula was used for productivity calculations:

$$P = (V / T) \qquad (2)$$

V = Timber volume in a cycle (m^3)
T = Total time in a cycle (hour)
60 = Coefficient used for converting minute to hour

Results and Discussion

The time measurements and main statistical information of variants are given in Table 1. While average extracted log diameter was 30.83 cm, minimum and maximum diameters were determined as 23 cm and 40 cm, respectively. Average log length was found to be 11.63 m, where minimum and maximum lengths were 10 m and 13 m, respectively. Main statistical information of work stages at time measurements are given in Table 2. According to the results, average skidding time and average total cycle time were determined as 2.10 min and 3.92 min, respectively.

Table 1. Statistical results of productivity variables

Variables	Min.	Max.	Mean	Std. Deviation
Log diameter (cm)	23.00	40.00	30.83	5.09
Log length	10.00	13.00	11.63	1.00
Log volume (m^3)	0.42	1.63	0.91	0.35
Skidding Distance (m)	72.00	84.00	79.03	2.76

Table 2. Statistical results of work stages

Work stages	Min.	Max.	Mean	Std. Deviation
Move-out unloaded	1.28	1.35	1.32	0.02
Loading	0.30	0.48	0.38	0.04
Move-in loaded	1.30	3.15	2.10	0.51
Unloading	0.08	0.15	0.11	0.02

Table 3 shows the average percentages of the work stages in terms of total time. Move-out unloaded time was the most time-consuming work stage (53.57%). The move-in loaded was found to be the second time-consuming work stage (33.67%), followed by unloading as the least time-consuming work stage (3.07%).

The results of One-Way ANOVA analysis are given in Table 4. The results showed that volume classes of the timber had a significant statistical effect ($p<0.05$) on the productivity. The average productivity for the high volume class was found to be greater (17.66 m^3/hour) than the medium (13.05 m^3/hour) and low (9.78 m^3/hour) volume classes.

Table 3. Percentage of time spent on each work stage

Work stages	Time (%)
Move-out unloaded	33.67
Loading	9.69
Move-in loaded	53.57
Unloading	3.07

Table 4. One-Way ANOVA analysis results

Volume Classes	Number of Sample	Average Productivity	Std. Deviation	Std. Error	95% C.I. For Mean		Min.	Max.
					Lower Bound	Upper Bound		
Low	10	9.78	1.25	0.39	8.88	10.67	8.06	11.54
Medium	10	13.05	1.88	0.59	11.70	14.40	10.50	15.30
High	10	17.66	0.97	0.30	16.96	18.36	16.33	19.28
Total	30	13.50	3.56	0.65	12.16	14.82	8.06	19.28

Pearson correlation was performed in order to reveal the relation among independent variables (length, diameter, volume, and skidding distance), which effect the total cycle time of the skidding operations (dependent variant). The correlation test results were given in Table 5. According to these results, there was a significant relation between length (x_1), diameter (x_2), volume (x_3), and distance (x_4) and total cycle time (y) at a 99% of confidence level. It was found that the total time increases as length, diameter, volume and distance values increase (Figure 3). Similar results were reported by Akay et al. (2016) who conducted time and motion study during skidding operation in a Brutian pine stands.

Table 5. Results of correlation tests

Variable		Total time (y)
Length (x_2)	Correlation coefficient	0.78**
	P	0.00
	N	30
Diameter (x_1)	Correlation coefficient	0.95**
	P	0.00
	N	30
Volume (x_3)	Correlation coefficient	0.94**
	P	0.00
	N	30
Distance (x_4)	Correlation coefficient	0.83
	P	0.00
	N	30

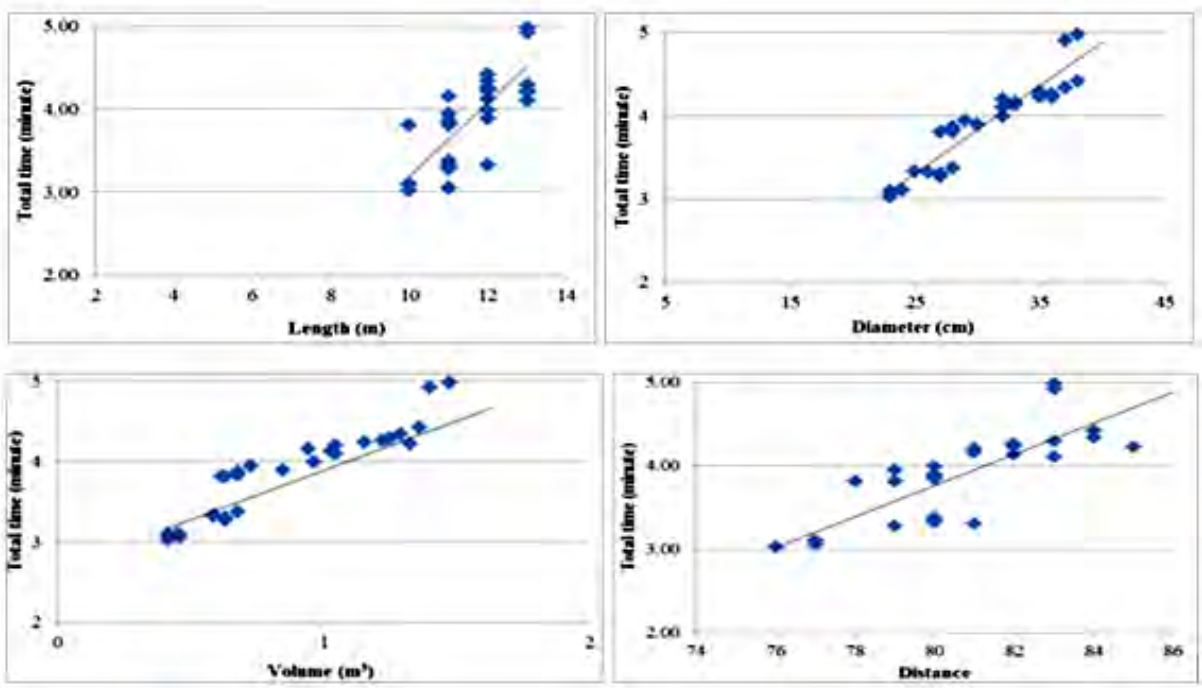

Figure 3. The relation between total time and length, diameter, volume and distance

Conclusions and Suggestions

In this study, skidding operations on skidding roads with farm tractors were evaluated in terms of productivity. Average productivity of the skidding operations with farm tractor was determined as 13.50 m^3/hour. Statistical analysis suggested that production rate is closely related with timber volume. In many regions of Turkey, logging operations are still performed by manual methods relying on animal-human power due to economic and socioeconomic factors. However, these methods require excessive operation time which minimizes the production rate and adversely affect the quality of harvested timber. Besides, it is difficult and sometimes impossible to perform manual logging operations in mountainous fields. Therefore, small scale logging techniques using farm tractors should be used as an efficient method in timber extraction operations. In current conditions, modified farm tractors can be equipped with necessary logging attachments with reasonable investment which can be afforded by the small size enterprises and even by individual contractors.

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INSPECTING WIRE ROPES AND END CONNECTORS ON WINCH-ASSIST MACHINES

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Abstract: *Cable-assist operations, where a timber harvesting machine is lowered down steep slopes supported by a winch on an anchor machine, are becoming commonplace to address issues of safety and productivity on steep terrain in New Zealand. Such systems remove the need for motor-manual felling and facilitates the use of grapple yarder extraction for a fully mechanised harvesting system. A critical safety aspect of managing these systems is ensuring the integrity of the rope and choosing the correct type of end-connectors to attach the rope to the machine. We will present the findings on two studies. The first is the use of non-destructive testing equipment to inspect six ropes with a range of operating hours. Important findings include that about half of wire breaks occurred in the inside of the rope, and that most damage occurs through mechanical damage. Overall a well maintained rope can last more than 1,500 operating hours. The second study is an expert survey that highlighted the advantages and disadvantages of 6 different end connector types. Important findings include that split wedge ferrules are susceptible to bending failure. Eye splices, while not as strong as other options, are a preferred connector that can be readily installed in the field.*

Keywords: traction-assist, cable-assist, tethered, wire rope inspection, end connectors, logging

Introduction

Tree falling is one of the most dangerous tasks within the New Zealand forest industry; with faller deaths accounting for around 41% of fatalities in the industry (McMahon 2006). The last few years have seen the introduction of winch-assisted (also called cable-assisted or tethered) harvesting systems challenge the status quo and influence the industry in new directions. Winch-assist systems developed in New Zealand primarily use a wire rope to connect an anchoring machine (that typically houses the winch) to a felling and or shovelling machine that is working on the slope (Figure 1). Conversely, those developed in Europe primarily integrate the winch onto the machine working on the slope. Regardless of type, these systems significantly extend the operating range of ground-based equipment, improving safety and productivity (Visser and Stampfer 2015). With the introduction of any new technology in forest operations there are often challenges in understanding their limitations and how to implement them safely and cost effectively.

One of the most important components of winch-assist systems is the wire rope or ropes that are used to connect the felling machine to the winch machine. In New Zealand the types of wire ropes used are currently the same ropes used on cable yarders as skylines or mainlines. The issue with their use in winch-assist operations is that very little is known about the deterioration of the ropes being used and therefore their expected lifespan. Ropes in winch-assist applications are being used in conditions they were not directly designed for. For example, commonly ropes are being dragged along the ground, through mud and dirt, pulled around trees and rocks and spend most of their time outdoors exposed to the weather (Figure 2). Trees and rocks are far from being ideal sheaves for a rope to be worked over, and there are no rope lifespan models in literature for anything other than a running sheave in ideal conditions.

Figure 1. Tethered system where felling machine is winch-assisted by bull dozer at upper road.

Figure 2. Operating conditions wire ropes are commonly subject to, in winch-assisted harvesting applications.

In New Zealand there are requirements for inspection of wire ropes used in winch-assist applications (HFMNZ 2016) set by industry, but mainly they are aligned with the ISO 4309 standard for ropes on cranes. Visual inspection of wire ropes is at times considered an unreliable way of determining wire rope condition as visual inspections do not easily pick up internal wear and damage, especially for ropes being worn through bending fatigue as compared to external abrassion. However, visual inspection is still the most common method used in forest operations.

Modern electromagnetic testing equipment can assess wire ropes in a non-destructive manner and are commonly used in other industries. The testing equipment can pick up broken wires (local fractures, LF) within a rope, the continuous change in cross sectional metallic area (loss of metallic area, LMA), and the aggregate surface roughness (wire rope roughness, WRR) of the wires within the rope (Ramsey, 1989). The location and number of fractures is only indicative of rope condition, but is good for locating discrete flaws within the rope. The LMA is also a good basis for discard criteria of wire ropes as it gives the area of available steel for strength within the rope and how much the rope has worn mechanically. The WRR is used for determining if there has been any corrosion or pitting within the rope.

Another important component of winch-assist systems are the end connectors required to secure the wire rope(s) to the machines and many options are available. The importance is the fact that an end connector is not as strong as the rope itself, and many rope failures occur at or near the connector. Considerable focus is given to the strength of the wire rope. In New Zealand there is a rule for the required load rating; “The tension on the wire rope shall be restricted to 33 percent of its breaking load at all times (MBIE, 2012).” Guidance on wire rope

inspection and discard criteria are provided in best practice guides (e.g. CompeteNZ 2005, WorkSafeBC 2006) or as standards (e.g. ISO 4309). However, few rules or guidance is provided to aid end-connector selection or inspection procedures.

While recent research on winch-assisted machines has helped to quantify the loads imposed on the ropes (Schaare et al. 2016), the extent of maximum operating slope for these machines (Visser and Stampfer 2015), and their effect on productivity for harvesting operations (Evanson et al. 2013); there has been no direct investigation into the deterioration of wire ropes used in this context by means of non-destructive testing (NDT) or an investigation into the suitability of various end connectors. With more knowledge about the types and extent of deterioration of wire ropes still in service, it would be possible to better direct future inspection schemes and further research in this area. In addition better guidance on inspection and maintenance of end connectors will aid practitioners in planning for safe and cost effective operations.

This paper summarises the findings of two recent studies: The first study, Byron (2016) used NDT on six different machines to describe how wire ropes are wearing in winch-assist applications. Considering the reasons wire ropes were failing NDT inspections and determining where the main wear on the ropes was occurring. The second study, Harrill & Visser (2017) surveyed eight accepted cable logging and wire rope experts regarding end connectors, specifically for use in winch-assisted harvesting systems. The survey consisted of two parts: evaluating the suitability of different types of end connectors; followed by discussing current inspection and maintenance procedures.

Wire Rope Wear

Non-destructive electromagnetic tests were carried out on the ropes of the 6 systems, to assess them for further use in this application. Allowed wire breakage rates were three adjacent wires in a single strand, six breaks in six wire rope diameters and 14 breaks in 30 rope diameters. The NDT gives information on the location and prominence of broken wires in the wire rope, and an indication of the actual wear of the rope by giving a percentage of the loss in metallic area from the most worn section relative to that of the best section.

The non-destructive testing is a very simple procedure. The NDT equipment is taken to site for the inspection, and consists of three parts; the magnet which is used to magnetise the rope and contains the sensors that pick up the electromagnetic signals, a signal converter, and a computer that is used to collect and process all the NDT data. Figure 3 shows the NDT electromagnet prior to one of the tests.

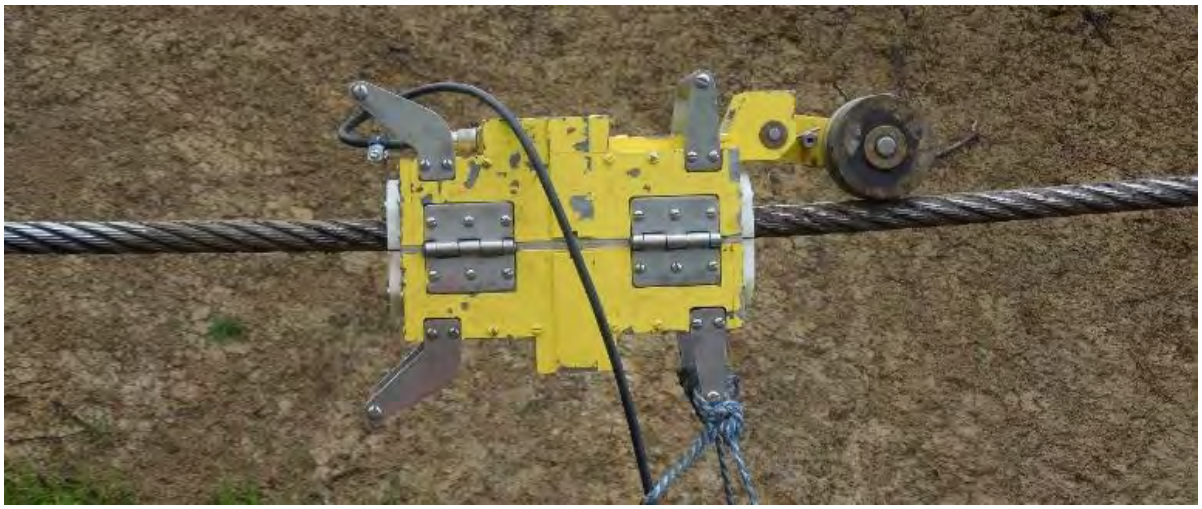

Figure 3. The NDT electromagnet prior to one of the tests

Before the test, the rope was magnetised, a procedure that only had to be conducted once per rope. For each system in this study, this was the first inspection and so the magnetisation was performed before each test. The NDT machine was placed around the rope at the winch machine end, and the full length of the rope is paid out though the NDT tester by walking the felling machine away from the winch machine. The test itself is then performed as the rope is drawn back on to the winch.

Results

On the whole, the ropes were considered to be wearing well in this application. Broken wires in and of themselves were not cause for concern. Due to the large radial stresses in a loaded rope, stresses from a broken wire are passed on to adjacent wires through the length of contact before the breakage. Valley breaks can be serious as they are as sign of internal wear in the rope and an indication that there might be a large number of internal wire breakages, as well as a significant point weakness; hence their being a cause for immediate discard. All the ropes that failed inspection failed from mechanical damage or damage in the valleys between the strands. This is damage that should be able to be picked up in a visual inspection if the ropes were not coated in soil and debris. Although visual inspections can be carried out, the entire length of the rope would need to be cleaned for a thorough inspection. All ropes tested had corroded, which occurs when the ropes are sitting unused or exposed to the elements for extended periods of time. In all cases the corrosion was only minor.

Bending around trees does not seem to be detrimental to rope life as there was no discernible difference in condition between the ropes that had been bent around stumps and those that had not. There was also no evidence of discoloration due to heat from friction. Bending around trees does pose other operational risks which were not considered in this study.

Control over working rope tension appears to affect wear to some extent. The operators that work the ropes at the minimum tension required to assist the felling machine up slope tended to have ropes in better condition.

Tight radius bending does not appear to be affecting rope life in this application. The ropes only go through a small number of bending cycles per day as they are not running as much or as fast as a crane rope for instance.

Rope length loss from mechanical damage and end connector replacement is a more common reason for replacement than that of simply wearing a rope out as indicated by the NDT testing. Rope damage in valley breaks was the only cause for rope failure in a certificate, not excessive wear of the rope (Figure 4). No rope failed solely due to a significant loss of metallic area, or development of wire breakages. The greatest loss of metallic area on any rope was 2%, which although not insignificant is still only minor.

Figure 4 The mechanical damage resulting in failure of the LH rope in System 6.

Winches that hold a large amount of rope on the winch drum have shown some signs of drum crushing on the innermost wraps. This can be mediated by end for ending the rope before the winch crushing and rope distortion gets excessive.

Longer term deteriorations seen in other industries have not been detected to a significant extent in this test set (Table 1, Table 2). There is little to no evidence of bending fatigue and only slight corrosion was picked up on four of the six systems but was not developed enough to be considered a risk to accelerating abrasive wear or compromising rope strength. Very little abrasive wear was spotted on any of the ropes tested, however only one rope was close to the end of its life. External wear is minimal, all ropes appeared to be in good condition externally, and only diameter measurements taken throughout the rope life can quantify this properly.

Table 1. Summary of main recorded variables for tests 1, 2, and 3.

	System 1	System 2		System 3	
Anchor machine	Sumitomo SH330, 39 tonne est.	Cat 329 35 tonne		Terex 82-40 40 tonne approx.	
Make of winch	DC Repairs, single drum	EMS Twin drum		Custom made twin drum	
Tethered machine	Tigercat LS855C, 39 tonne	Cat 552, 38 tonne		John Deere 909H 37 tonne	
Rope type	Single 1 1/8" Swaged	2x 7/8" Power Swaged		2x 1" Swaged	
Initial length (m)	440	300		400	
Length at test (m)	260	260		380	
Hours on rope	1500	580		400	
Operator experience	3 years felling	2 years felling		10 years' steep slope harvesting	
No of operators on machine	1	2		2	
Operators learnt on this rope	1	2		0	
Is tethered machine ever caught by winch	Initially frequent, not anymore	Initially while learning		No	
Maximum distance of rope fed out	240m	150 - 200m		100-200m	
Bending around stumps	All the time	Most of the time		Minimal	
		Front Winch	**Back Winch**	**RH Winch**	**LH Winch**
Rope diameter	28.6mm	22.2mm	22.2mm	25.42mm	25.45mm
Rope length (m)	241	263	263	380	380
Rope condition	Used	Well Used	Well Used	Used	Used
Type of end connector	Spliced eye	Spliced eye	Spliced eye	Wedged socket	Wedged socket
Wear	Normal/Medium	Medium to Heavy	Medium to Heavy	Medium	Medium to Heavy
No. broken wires	3	10	6	5	4
Locations (m)	48, 142, 146	7, 14, 64, 114, 134, 264	9, 20, 70, 98	116, 176, 245, 256, 291	150, 197, 211
Result	PASS	FAIL	FAIL	PASS	PASS
Reason		Valley Breaks cause for failure			
Notes				Dry at front end	40m flattening at back end

Table 2. Summary of main recorded variables for tests 4, 5, and 6

	System 4	System 5		System 6	
Anchor machine	Hitachi Zaxis 330	Hitachi Zaxis 240, 34 tonne		Liebherr 734, 27 tonne	
Make of winch	DC Repairs, 470 hours	EMS twin drum		ROB Twin drum	
Tethered machine	Hitachi Zaxis 290, 34 tonne	Tigercat LS855C, 39 tonne		John Deere 909K, 40 tonne	
Rope type	Single 1 1/8" Swaged	2x 7/8" Power Swaged		2x 7/8" Power Swaged	
Initial length (m)	500	400		500	
Length at test (m)	450	260		500	
Hours on rope	470	480		190	
Operator experience	4 years falling	15 years' machine operation, 1 year on tether		1-year felling, 3 years tethered felling	
No of operators on machine	2	2		1	
Operators learnt on this rope	0	0		0	
Is tethered machine ever caught by winch	no, never	never occurred on this rope		never	
Maximum distance of rope fed out	200-300m	300m		200m in this block	
Bending around stumps	All the time	trying to avoid		all the time	
		Back Winch	**Front Winch**	**LH Winch**	**LH Winch**
Rope diameter	29.04mm	22.81mm	22.69mm	22.49mm	22.21mm
Rope length	453	260	260	350	348
Rope Condition	Good	Good, Used	Good, Used	Good	New with mechanical damage
Type of end connector	Splice	Spliced eye	Spliced eye	Wedged socket	Wedged socket
Wear	Normal/Medium	Medium	Medium	Medium	Nil
No. Broken wires	2	0	1	0	3
Locations	365, 418		247.5		54
Result	PASS	PASS	PASS	PASS	FAIL
Reason					Mechanical damage at 54m

End Connector Suitability

In the first part of the survey for each end connector type (Figure 5), participants were asked to: (1) State whether or not the end connector type presented was suitable (i.e. yes, unsure or no) for winch-assisted harvesting operations; (2) Rate the existing advantages and disadvantages associated with each end connector (i.e. strongly agree, somewhat agree, somewhat disagree, strongly disagree); and (3) Add any comments they deemed pertinent. Survey participants chose not to respond to some questions.

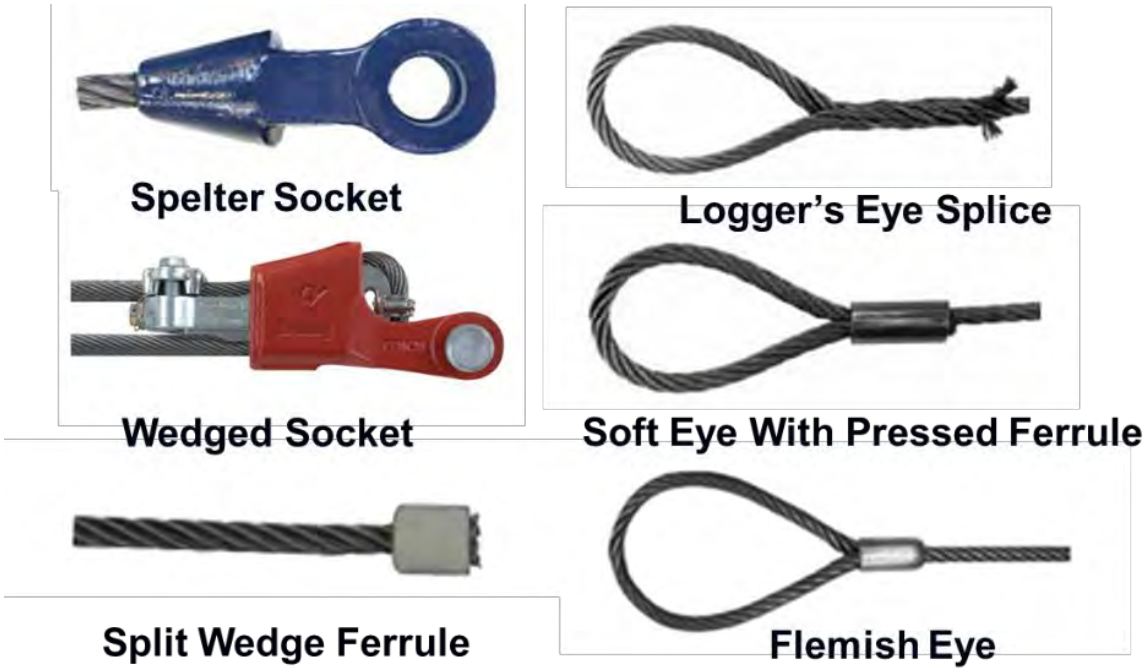

Figure 5. Types of end connectors used for winch-assisted machines that were discussed by survey participants.

In the second part of the survey, participants were asked which type of connector they preferred/recommended, the inspection interval for the type selected and what was their replacement strategy.

A logger's eye splice was the only end connector all participants agreed was suitable for winch-assist applications (Table 3). While the loggers' eye is versatile and common to loggers, there is still some preference towards other types of end connectors as noted by the varying responses; which could be due to machine type, past experience and cost or availability of various connectors, to name a few reasons. For the full list of advantages and disadvantages for each end connector see Harrill and Visser (2017).

Table 3. Summary of survey participant responses of end connector suitability for winch-assist applications.

End Connector	Yes	No	Unsure	NR[a]
Spelter sockets	5	1	2	0
Split wedge ferrules	4	3	0	1
Loggers' eye splice	8	0	0	0
Soft eye with pressed ferrule	3	2	1	2
Flemish eye	4	0	3	1
Wedged sockets	4	1	1	2

[a] No Response (NR)

Participants in the survey were asked to state a recommended inspection interval for the end connector. Every participant agreed that regardless of the end connector type used, a daily visual inspection should be undertaken. Additionally some said that the end connector should be inspected any time the operator had put it in a situation where it could have been damaged. In addition to the daily visual inspection, some suggest that a more thorough inspection should be conducted weekly or monthly and perhaps a third party inspection on an annual basis; but this varied depending on the type of connector used.

The final question to participants asked if, in addition to any damage criteria, they recommended a replacement strategy (i.e. hours or weeks of use) for the type of end connector they prefer. Due to the changing conditions and environment where winch-assisted machines are used and their non-cyclic nature, it was stated that some

users prefer to apply damage criteria as their replacement strategy rather than a measure of time. One participant said that they took a conservative approach of refitting their wedged sockets monthly, to account for any unseen damage.

There was also some discussion about replacement strategy for the rope and whether this is separate from the end connectors used. One participant said the potential damage to the rope from such practices as bending around stumps/trees was more of a concern than wearing out the end connectors. Some companies and contractors are mandating a replacement of ropes after a specified hours of operation, whether the rope appears in good condition or not. However, this could be wasteful if the rope is still in good condition both externally and internally. Internal inspection of wire ropes is difficult and time consuming but non-destructive testing (NDT) is an option.

Conclusion

NDT examination of 6 wire rope systems shows that wire ropes are wearing well considering the conditions they are subjected to. Most ropes are getting damaged mechanically or running out of usefulness by gradual loss of length with damage at the free end and replacement of the end connectors. Longer term deterioration patterns are not being observed: abrasive wear is minimal, corrosion is minimal both externally and internally, and internal wear and bending fatigue are not observed to any significant extent. Instances of drum crushing have been observed and could possibly become an issue in future as new rope lengths are increasing.

There are a variety of end connectors used in New Zealand winch-assisted harvesting operations. Each have their own advantages and disadvantages, based on the type of machine used and operator preference. While there are varying levels of consensus on the suitability of each type, it is clear that all participants agreed that the loggers' eye splice is a good option considering its advantages and disadvantages; both as an initial connector and as a replacement.

In terms of inspecting end connectors all participants agreed that regardless of end connector type, it should be visually inspected daily. Many suggested a more thorough inspection on a weekly or monthly basis, depending on type and perhaps a third party inspections annually if still in service. Most participants also agreed that a wire rope inspection standard (e.g. number of broken wires visible at the end connector) from the BPG for Cable Logging should be applicable to winch-assisted machines; but should be used for "hard" end connectors and not spliced eyes.

Due to the variable operating conditions encountered and various machine designs used in winch-assisted operations, a replacement strategy based on damage criteria rather than a specified number of hours of operation, may be preferable. There were also responses about the replacement strategy of the wire rope. Currently it appears that replacement strategies in place for both end connectors and wire rope are conservative due to uncertainty regarding end connector and wire rope life given the relatively new application of winch-assisted machines in New Zealand. A conservative approach is certainly prudent and not unwarranted, and it is recommended that more research be undertaken to add to the growing body of experience with these systems over time to determine what is most appropriate.

Acknowledgements

We would like to thank Keith Raymond and the support of the Forest Growers Research funding group for their support of the end connector research, Rowan Struthers and Hancock NZ Ltd. for their support of the NDT testing, and all the contractors that have taken part in the studies.

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FORECASTING PAVEMENT DETERIORATION OF FOREST ROADS USING ARTIFICIAL NEURAL NETWORKS

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Abstract: *The most important part of building the road is pavement. Road pavement reconstruction projects, especially in areas where pedestrians forest machines are done every day, often creates cost, difficulties and limited access to the road users, therefore, it is necessary to plan for the adoption of appropriate practices in order to minimize the damage of investment in forest roads and it is necessary according to this situation. This study aimed to investigate the forest road pavement and maintenance in a timely manner for reduce the costs of environmental damage of road construction projects and done in the Sari wood and paper industries forests in Amol. In order to collect the required data, 50 kilometers of roads in accordance with the conditions such as slope, aspect, canals, traffic and the height above sea level, segmented, and data were collected in five site that different from each other. The research of pavement deterioration used with the Artificial Neural Networks (ANNs). The values of pavement deterioration due these factors were predicted. The results showed that artificial neural networks have outperformed (R 0.94). Artificial neural networks because of the ability to use more variables in the model making and better results had better efficiency in forest roads. Although Detour model also showed good results, but because those models need to be calibrated, more research is needed in the future.*

Keywords: pavement system, transportation, forest roads maintenance, forest management

PRESSURE ALLOCATION UNDER FOREST TIRES - STATIC AND DYNAMIC EXAMINATION AND RUTTING PROCESS IN FIELD TESTS

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Abstract: *The usage of bogie tracks on forest machines, especially on harvester and forwarder, has been increased clearly for the last years. There are different reasons which favor the usage of tracks on wheel based forest machines. Firstly there is a possibility to increase the traction and reduce the slip by using tractive tracks. One the other hand it is also possible to improve the floatation and decrease ground disturbance with wide and long chain links for higher amount of contact area between vehicle and underground. Various manufactures offer different types of bogie tracks for manifold tasks in the forest sector. For these types of tracks steal is the mostly used material. In the project "Soil protecting use of forest machines" the advantages and disadvantages of synthetic tracks (Felastec™ from Felasto Pur GmbH) in comparison with steal tracks and tires will be reviewed with focus on static and dynamic pressure allocation and also the rutting process on skidding trails in field tests will be compared. Since the start of the project in 2015 there have been a lot of measurements in the test fields east of Göttingen (rutting on skidding trails) and in the test stand at the campus (PrAllCon – static/dynamic) with a modified forwarder Rottne F14 Solid. Main results of measurements and first trends in recommendation of track usage will be given at the 50th International Symposium on Forestry Mechanization.*

Keywords: rutting, soil disturbance, tracks, pressure allocation, synthetic tracks

COMPARISON OF HARVESTING MEASURING SYSTEM TO THE REAL TRUNK VOLUME AND THEIR PRACTICAL APPLICABILITY FOR FOREST INDUSTRY

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Abstract: *The research project "Fairlog2020" is dedicated to implement the results given by harvester as a reliable measured value. Until now, the appropriation of harvester measured values for sale are prohibited by law, in Germany. On the forest side, manual-methods with calliper and automated measurement systems by harvester are used. At forest roads, photo-optical measurement systems are available. In the sector of softwood processing industries, opto-electronic measurement devices are used at the infeed of sawmills. In Germany, the manual method, photo-optical method and opto-electronic systems allow the determination of log volume and log dimensions for sales purposes according to legal requirements. In timber industry, the results given by harvester are causing for distrust. The results given by harvester are serving as checking measurement, but not for calculation of a bill. The upcoming work is to analyse possibilities of measuring systems and define requirements according to the German guidelines (like guidelines of The National Metrology Institute of Germany). In order to achieve this purpose, one aim of this investigation is to determine reference parameters. Before discussing a law-based harvester measured value, the accuracy of harvester measurement systems, as well as manual-method with calliper and essentially the "real trunk volume" must be determined. In this investigation, the manual measurement and harvester measurement system are compared with the real trunk volume. The main feature is that the real trunk volume has been determined as a reference by using the principle of Archimedes (water displacement technique). Up to now, comparative measurements were carried out and a relative difference between the methods is indicated. In this investigation, independent measure as a reference is used and absolute volume deviations are shown. Thus provides a criterion, which the usual volume measuring methods can be assessed in their quality.*

Keywords: harvesting measuring systems, manual method, water displacement technique, principle of Archimedes, trunk volume, PTB-The National Metrology Insitute of Germany,

PERFORMANCE OF A MOBILE STAR SCREEN TO IMPROVE WOODCHIP QUALITY OF FOREST RESIDUES

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Abstract: *Low harvesting costs and increasing demand for forest-derived biomass led to an increased use of whole-tree harvesting (WTH) in steep terrain areas in Austria. Logging residues, as a by-product of WTH, present an easily accessible bioenergy resource, but contaminants and high portions of fine particles make them a complex and difficult fuel. The present research focuses on the productivity and performance of a star screen, which was used to remove fine and oversize particles from previously chipped, fresh Norway spruce (Picea abies) logging residue woodchips. Three different screen settings were analyzed. Time studies of the star screen were carried out to estimate screening productivity and costs. Furthermore, 115 samples were collected from all material streams, which were run for particle size distribution, calorific value, ash content, compartment and elemental composition. Average productivity was 20.6 tons (t) per productive system hour (PSH15), corresponding to screening costs of 9.02 €/t. The results indicate that the screening of chipped logging residues with a star screen positively influences material characteristics like ash content, particle size distribution, compartment and nutrient composition. The different screen settings had a big influence on the quality characteristics of the screening products. An increase of the rotation speed of the fine stars reduced screening costs per unit of screened material in the medium fraction, but also lowered screening quality.*

TRANSPOSITION OF FOREST ROADS IN GIS BASED ON DTM DERIVED FROM AIRBORNE LIDAR DATA AND AERIAL ORTOFOTO IMAGES

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Abstract: *Analysis of LiDAR terrain data presents an opportunity to map forest roads with unprecedented completeness and accuracy. Traditional remote sensing data such as satellite imagery and aerial photography are often insufficient for identifying forest roads because passive sensors are unable to penetrate dense canopy. The purpose of this study was the extraction of 1 km long forest road three-dimensional, efficiently and accurately featured from Airborn LiDAR data and aerial OrtoFoto images and to determine the suitability for mapping forest roads in areas of dense forest canopy and steep terrain. The test site is 37,5ha wide and is located in Romania, Vâlcea county, in the area of Voineasa Forest District, within the Lotru river valley. Previously processed and classified LiDAR data and ortorectified aerial images were used. Then, in order to obtain the spectral data the classified LiDAR data were fused with aerial imagery spectrum attribute into groups by kinds of feature, such as ground, vegetation etc. Finally, the 3D models of interested regions are quickly constructed, based on the classified points and the aerial-image. The position, gradient and total length of a forest haul road were accurately extracted using a 1 m DEM. In comparison to a field-surveyed centerline, the LiDAR-derived road exhibited a positional accuracy of 1.5 m and total road length within 0.3% of the field-surveyed length.*

Keywords: forest roads, airborne LiDAR, OrtoFoto Images

THE COMMINUTION COST OF WOOD RAW MATERIAL FOR FUEL IN ESTONIAN CONDITIONS - A CASE STUDY

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Abstract: *In Estonia up to now the producers of wood fuels have not yet adequately analysed the production and transport costs although it is known that the share of these costs form up to half of the final price of wood chips or hog fuel. With this in mind the goal of the case-study was defined - to analyse the price formation of comminuted wood fuels in Estonian conditions. Within one year of the survey the initial data from SLG Energy company was collected. Different types of machines (7 in total) were observed - wood chippers Jenz HEM 561, Jenz HEM 582, Jenz HEM 700, Heinola 910ES, Bruks 805CT, Doppstadt DH 910, Doppstadt DH 608. All machines were equipped with a GPS tracking device which records the route and the fuel consumption and during the observation period all costs and revenues related to the concerned machines were accounted. It was determined that due to frequent repairing the maintenance costs of older machines were higher and productivity lower compared with new machines. The biggest item of expenditure turned out to be the fuel consumption. The second was the cost of repairs in the case of older machines and salary in the case of new machines. Also, the type of chipper had the impact on the production cost. Under the cumulative effect of various factors the production cost turned out to vary widely 1.03-2.38 €/m3l. On the basis of the results of the study suitable technologies for Estonian conditions were specified.*

Keywords: wood chippers, productivity, forestry, costs

USE OF TIMBER HARVESTING DATA FROM SINGLE GRIP HARVESTERS - A SURVEY OF CONTRACTORS IN CENTRAL GERMANY

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Abstract: *In Germany roughly 50 % of the annual cut volume of about 55 million m³ are harvested by single grip harvesters. While calibrated harvester heads are able to accurately measure log diameter and length German law does not allow for basing purchase and sale agreements on these data. Our study surveyed about 120 contractors operating in the province of North-Rhine Westphalia about potential uses of harvester data. The questionnaire focused on five main issues: company characteristics, current use of harvester data, evaluation of data accuracy, calibration efforts, challenges and opportunities for successful use of data. Most of the surveyed contractors operate two to four single grip harvesters and two to four forwarders. More than 80 % of the contractors, irrespective of the cut volume, make use of harvester data, already, but mostly for internal administrative uses. Surprisingly, most harvester data is used as print outs; only a third of all surveyed contractors process harvester data electronically. Almost half of the contractors are skeptical with respect to the quality of harvester data especially of low dimensional hardwood logs. One explanation may be the use of electronic calipers necessary for calibration of harvesters' measuring devices which is used by less than half of the surveyed contractors. Practical experience of the operator in using measuring and control devices is seen, by far, as the most important requirement for high data quality. Most important advantages of harvester data are instant data availability, fair accuracy and base for value optimization. Future potential of harvester data processing and use is seen in electronical processing of data, use of province wide data set for value optimized bucking, quality control and sustainability assessment and digital mapping.*

Keywords: single grip harvester, harvester data

COMPARISON OF VIDEO-BASED AND CONVENTIONAL TIME AND MOTION STUDIES OF MECHANIZED FOREST OPERATIONS

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Abstract: *Assessing harvesting productivity in forest operations remains of high importance. Different work cycle elements are commonly identified with the use of handheld (HH) computers. For several years now, video technology has also been used for forestry related time and motion studies. The goal of the study was to identify and assess possible differences between video-based (VB) and HH time and motion studies of fully mechanized forest operations using a cut-to-length harvesting system, while focussing on the accuracy of data collection. A pine stand was chosen as research site where 16 plots each measuring 30 m in width and 100 m in length were erected. Every tree selected for removal within the plots was inventoried. Live cut-to-length forest operations, using a Königstiger excavator-based harvester with a Ponsse H6 harvesting head, were then assessed with both test methods. During this time, individual work cycles (N = 465) were recorded and differentiated in common work elements directly in the field with the HH method. VB analysis of video footage recorded from the harvester cabin during harvesting of these same 16 plots was also performed using the software TimeStudy T1. Preliminary results indicate a low time variation for most work elements between VB and HH methods, with the highest difference for the boom-out element. Time required to collect and process (field and office tasks combined) time and motion data was considerably higher for VB compared to HH. Only 20 of 465 work cycles needed to be removed from further analysis of the HH data set due to incomplete or illogical information. Thus, the possibility to re-examine implausible data in VB studies did not have a high impact on the overall number of analyzable work cycles.*

Keywords: harvester, productivity, work cycles

FOREST WORKMANSHIP IN ISTANBUL DIRECTORATE OF FORESTRY: SITUATION, ASSESSMENT AND SUGGESTIONS

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Abstract: *Within the scope of this study, Istanbul Forest District Directorate was chosen as the study area. Istanbul Forest District Directorate's works covered Istanbul, Edirne, Kırklareli and Tekirdag cities. The total forest area of the study area is 602357 hectares. There are 8 main directorates (Bahcekoy, Çatalca, Demirköy, Istanbul, Kırklareli, Vize, Kanlıca, Şile) and 63 sub-directorates and 2 nursery directorates in Istanbul Forest District Directorate. A questionnaire has 35 questions and it was applied to the 275 forestry workers and in this questionnaire was collected about general information, working conditions, used equipment, health information and habits. In the study area, one of the significant effects of the study is to provide the possibility of determining the availability of forestry workers. With this study, a suggestion can be made about the problems encountered in the forest works in the study area and to evaluate pos-sible measures to be taken. The current situation of forestry work will be tried to be revealed by the numerical and statistical evaluations in the study area. It is observed that there are significant differences in the working conditions, health conditions and working conditions among the forest workers in the main directorates. It is thought that the with these important findings of the study is likely to carry an important original value that emerges from numerical and statistical data.*

Keywords: forestry worker's health, occupational safety, workplace safety, logging

DEPTH OF DAMAGE ON PINE LOGS FROM FEED ROLLER SPIKES AT VARIOUS ENGINE RPM IN 4 SEASONS

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Abstract: *Mechanised harvesting causes damage to the surface of logs due to feed roller spikes. This damage is done when tree trunks are processed in the harvester head. In conifers, damage not only causes a mechanical wood defect, but it can also influence grey fungi development. The aim of the study was to investigate damage to assortments of mature pine (Pinus sylvestris L.) caused by the spikes of a H-6 head on a Ponsse Beaver harvester in four different seasons and at a different feed roller speeds. The scope of the research included an analysis of the depth of wood damage in three sections of the trunk (butt, middle and top logs). Additionally, wood penetration resistance tests were performed with a pilodyn in the zone adjacent to the measured damage. The depth of wood damage was examined in 4 seasons on a total of 110 trees (330 logs). The average depth of wood damage was 4.15 mm, while the maximum value was 5.34 mm. The deepest damage occurred in summer. Significantly deeper damage to the wood was confirmed at a lower speed of feed rollers. The axial differentiation of the depth of damage was also observed: the shallowest on the butt logs, the deepest on the top logs. The wood resistance to pilodyn penetration did not correlate with the depth of damage. Finally, it can be concluded, that damage caused by feed roller spikes had a small negative impact and would be acceptable to manufacturers apart from in the plywood industry.*

Keywords: wood quality, Scots pine, pilodyn, harvester

FORECAST OF FOREST BIOMASS SUPPLY CHAIN CAPACITY AND EFFICIENCY AT THE REGIONAL, LOCAL AND INDIVIDUAL LEVEL IN FINLAND

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Abstract: *The forecast of needed forest biomass supply chains has been estimated at the national and regional level in Finland according to future supply and demand potential by now. Local and individual entrepreneurs´ investment possibilities should be estimated in order to provide more practical information. Large industrial and energy wood investments will increase the need for the capacity of supply chains and job opportunities also in harvesting and transportation companies. Especially, increasing forest energy supply could generate growth potential after the new investments, alongside the existing forestry sector. The aim of the study was to measure the increasing need for biomass supply chain capacity and efficiency at the regional, local and individual level by using corresponding forest management supply data and demand scenarios combined with supply chain simulations. Regional area was South Savo, which is one of the most important forest biomass supply area in eastern Finland. The study material included permanent regional plots from the latest data of National Forest Inventory (NFI11), which has been simulated to provide forecast supply information. Several future demand scenarios were also selected by focusing on the potential regional investments. The individual entrepreneur information was achieved by using statistical information with additional interviews. The agent-based simulation was used to analyse forest biomass supply systems in alternative scenarios. The study included three levels, where regional level was the whole South Savo area, local level was the procurement area of supply chain systems and individual level represented as an entrepreneur. Theory of Pareto optimality was used to allocate the competition between the needed machines, vehicles and supply systems in alternative scenarios. The study showed the increasing future need for machines, vehicles and chipping systems of forest biomass supply chains but the number is greatly dependent on the efficiency potential of individual factors. The highest increase would be for energy wood supply chains. The study produced new information to help local entrepreneurs´ decision making in future investments. The study also presented a novel method by using the detailed forest management growth simulation data combined with the supply chain simulation at the regional, local and individual level.*

Keywords: forest biomass, supply, simulation, forecast, entrepreneur

GOOD PRACTICES IN SAFETY AND HEALTH IN FOREST ENTERPRISES

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Abstract: *Interviews in German forest enterprises show that many good practices in accident prevention and health protection are applied. But prevention measures are rarely integrated in integrative concepts which would focus equally on technique, organisation and personal behaviour. Further, many measures are not integrated in a systematic health organisation in enterprises. Due to the high heterogeneousness of the sector it is of utmost importance to connect prevention activities to enterprise-specific strengths and weaknesses and current problems.*

Keywords: safety and health, forest enterprises, small and micro enterprises, heath promotion

Introduction

Research and development in forest operations have provided a rather comprehensive understanding of good practices in safety and health. A basic framework is e.g. provided with the ILO Code of Practice - Safety and Health in Forestry Work (ILO, 1998), and numerous handbooks and guidelines (SVLFG, 2016) provide guidance and instructions to good practice. And of course, continuous research and development activities must be carried out to adapt performance and safety and health standards to the ongoing technical and process development.

It can be presumed that in many forest operations good practices are applied. After all, the actual forest workforce is permanently proving its capability to carry out the various tasks in the forest production chains. This would not be possible without using good practice in many areas of work organisation, technology, and performance. This deserves the reference that many forest workers and entrepreneurs apply a high standard of performance, achieve a high productivity, and manage to work rather safe.

Undoubtedly, safety and health in forestry has considerably improved over the last decades. But it is obvious and continuously reported, that the situation is by far not satisfactory. This is evidenced by national and international accident statistics (Forest Europe et al., 2015). Compared to other professions, forestry still shows an outstandingly high record of accidents.

This of course is foremost determined by the nature of forest work itself. Based on a wide range of research and development activities a rather deep knowledge exists about the most common health and accident risks in forest operations. Motor-manual work is a task with outstanding high accident risks and continues to be physically straining. And forest machine operators are exposed to high mental stress and one-sided strain which frequently results in musculoskeletal disorders and repetitive strain injuries.

Subsequently, good practices for accident prevention and health protection were developed to cope with the various risks in forest operations.

- Guidelines for safety and health which offer instructions for safe and health-conscious performance are available.

- Ergonomic development and design of tools and machines proves to be effective to reduce health risks, particularly in modern forest machines.

- Work organisation which reduces risk exposure, particularly job rotation and job enrichment of forest machine operators can considerably reduce one-sided stress and strain.

- There is also an extensive range of knowledge about health and safety management principles and guidance to health-conscious work organisation.

- Health care initiatives on enterprise level have been taken in many industrial sectors.

Conditions in forestry are very heterogeneous

Naturally, these good practices are not commonly applied in the whole forest sector. Many cases can be found where safety and health standards are really good, but others, where the situation is very poor. The situation in forestry is very heterogeneous, not only when the situation between different countries or regions is compared [1]. Even within regions, yes even within individual enterprises there is a side by side of highly mechanised work systems with motor-manual labour, of highly skilled professionals with untrained workers, of excellent and poor performance. Particularly forest enterprises which offer forest operation services for forest owners and the forest based industries form an extremely heterogeneous sector. In German forestry there is a side by side of self employed contractors with micro companies with a workforce in operations of three to four people and only rarely enterprises with a workforce of more than twenty people [7]. There are also enormous differences in the range of tasks and activities, competence levels, and of course in owners´ and employees´ attitudes.

Focus on small and micro enterprises

The challenge for applying good practice in safety and health is particularly high for small and micro enterprises, not only in forestry [5]. Small and micro enterprises very often have limited professional management capacities and frequently employ workers who are not formally trained and educated. Further, these enterprises are generally under continuous economic pressure due to low profit margins of their business. They are hard to reach and control by labour inspectorates and accident insurers and they have little access to consulting and support for prevention measures [3]. They can actually be considered to be the most critical and most vulnerable target group with regard to safety and health in forestry. Therefore it seems to be advised to focus research and development on small and micro enterprises in forest operations to improve safety and health in forestry.

Objectives

The overall objective of the ongoing three year research project which is funded by the German Ministry of Science, is to develop integrated concepts for safety and health in forest enterprises [4]. These prevention concepts shall integrate approaches for preventing accidents, to protect workers´ health, and furthermore to promote health by a variety of measures. It was anticipated that prevention concepts need to be flexible and must fit to the specific conditions in individual enterprises. The objective of the work package which is subject of this paper was to analyse the actual situation in forest enterprises and to analyse how individual entrepreneurs and workers handle safety and health on organisational and performance level, or in other words, if and to what extend good practice in safety and health is already applied in forest enterprises.

Based on the results of this work package it will be possible to determine strengths and weaknesses of individual enterprises regarding organisation, technique, competences, attitudes, and the economic and situative context of their operations. This will allow to identify the connecting factors for effective prevention measures, building on existing strengths and to overcome threads and weaknesses.

Methods

To assess the actual situation in forest enterprises extensive interviews were carried out in twelve German enterprises, incorporating the entrepreneurs and some employees. The interview partners were selected based on their willingness to participate in a three year project process, which consists of a comprehensive analysis phase leading into a phase of testing and evaluating prevention measures together with the research team. Therefore, the sample does not aim at being representative. It rather represents a group of entrepreneurs who already have a considerably high awareness for safety and health, and who are already motivated to improve their situation.

The interview guidelines were based on literature research about safety and health in forestry, field observations of forestry work, elements of pre-existing structured assessments of safety and health management, e.g. used in German safety and health campaigns. Thus, the interviews were design to investigate risk awareness in specific forest operations, knowledge and motivation concerning prevention measures, the actually applied safety and health management and activities.

The interview data were transcribed and are subject to continuing content analysis. The core objective of the data analysis is to derive the most appropriate measures to facilitate enterprises in their efforts towards improved safety and health.

Results

Like the forest service enterprise sector as a whole also the group of participating enterprises is very heterogeneous. It includes self-employed contractors, micro businesses and a company with about 30 employees. Some companies have their task areas mainly in motor-manual harvesting and forwarding with forest tractors, and some undertake mechanised harvesting operations. Thereby, the study covers a wide range of task areas without claiming to be comprehensive.

In the following the research findings will not be presented for individual enterprises and no enterprise-specific data are uses. Since the analysis approach here is to assess the general occurrence of good practice in exemplary cases, the approach is to focus on dimensions which are relevant for safety and health. It will be illustrated in a summarising way, where good practices are readily applied and on the other hand, on which dimensions enterprises show considerable weaknesses and urgent need for prevention activities.

Risk awareness

Without exception the interviewed entrepreneurs and workers are well aware of the accident and health risks of their activities. almost all have a good understanding of safety regulations and safe working practices. This does of course not imply that regulations and safety standards are followed consequently.

What could be found in the interviews is that safety regulations are interpreted in a way whether they are conductive to achieve the work results. While from a very formal point of view the observed attitudes – that safety regulations can be negotiable – must be judged as a clear offence, it can also be considered as an indicator for individual risk awareness.

Some interview partners explained that in specific cases, e.g. handling a hung up tree, they engage with the question how to take the tree down. They were open-heartedly describing the decision process that they assess the situation, analyse the potential risk, and if the result is, that the risk might be controllable, and the award in terms of time saved is high enough, well, they throw another tree over the hanging one.

This example shall illustrate, that forest workers in many cases know risks and prevention measures, particularly when motor-manual work is concerned. And it can be presumed that the actual performance is based on balancing the perceived risk with the expected award. The level of risk which will be taken is based on the individual risk acceptation.

Motivation

In short, in the partner enterprises the motivation to work safe and health- consciously is high. As has been said, the enterprises have joined the project activities because they are interested to improve safety and health. But one can dare to assume that all entrepreneurs and workers generally have a high motivation to return back home from work safely.

Organisation of safety and health

Organisation of safety and health is a weakness in all partner enterprises. Some enterprises use safety advisory services or alternatively conduct a self-assessment of safety and health. This, matter of fact, is a legal requirement in Germany. But in no enterprise it could be found, that safety and health assessments are incorporated in a management system, which would provide a structure to systematically implement targeted measures. If at all, safety and health organisation is implemented to fulfil the legal requirements and it is seen as an imposition rather than a beneficial support.

A real blankness can be found when it comes to health promotion. Of course, when asked directly, all entrepreneurs underline that a promotion of their own and their workers´ health would be beneficial. Some also mention that they already thought about encouraging their workers to do sports to cope with the one-sided strain of their work, but so far no entrepreneur in this study has taken any action. Also, encouraging healthy nutrition of workers has not been a subject for action.

Competences

Technical skills - The education and training standard of entrepreneurs and workers can be described as good. It could be found that in most cases the workers provide appropriate skills for the tasks they carry out. Most workers have been formally educated as forest workers. Workers who have not been educated in an apprenticeship do at least hold a European Chainsaw Certificate, which in Germany is more and more seen as the basic requirement to prove that the basic skills for operating a chainsaw safely are available.

Of course, the technical competence level differs considerably between the enterprises. Individuals could be identified who clearly have deficits in felling and cutting techniques. Consequently, it will be advised to provide training to those workers who show deficits.

Formal training of harvesting operators is rather an exception in this sample, and this matches the situation in Germany in general, where only a small percentage of the actual machine operators hold a further education certificate. But it was clearly stated that the operators in the analysed enterprises are highly professional workers.

Managerial skills – Like in most forest enterprises, the interviewed entrepreneurs have no specific management skills. Structured management concepts are rarely visible. The focus is on acquisition of contracts and managing to deliver the contractual results. This of course reflects on safety and health management. A systematic management approach to prevent accidents and to protect health could not be identified in any of the twelve partner enterprises.

Technique

Technical equipment really is a strength in most forest enterprises which have partaken in this study. Protective equipment, tools and machines are, with regards to safety standards and ergonomic design, state of the arts. All interviewed entrepreneurs accentuate that they strive for using the best equipment they can achieve. In some cases it was mentioned that tractors with winch and cable are nearly always close to a harvesting site. Particularly when harvesting large dimensioned broad leaf trees, cable support was mentioned by one contractor as a “life insurance”. Additional technical means like helmets equipped with radio are used quite frequently, and this easy but effective safety tool will definitely be further promoted in the forest service sector.

Communication

Communication within the enterprise and with the contracting party is a rather critical issue in most enterprises. Safety and health related communication between entrepreneur and their workers is very different between companies. It ranges from a patriarchal stile of order and obey to a collegial stile of cooperation. An often heard statement is: "I tell them always to take care". A considerable lack of systematic and regular communication about risks and preventive actions can rather generally be observed. The improvement of communication in enterprises is definitely a goal for forthcoming activities in all enterprises.

Improving communication with the contracting forest owner, respectively their representatives is a really important challenge. One of the most common interview results was, that the entrepreneurs are not satisfied with the ways, how foresters communicate risks in forthcoming harvesting operations. Further, the contractors complain that the effort for measures, that are necessary for safe performance, is not covered in the contract and the negotiated prices.

Conclusions

The recent study confirms the presumption that in many forest enterprises good practices in safety and health are effectively applied. Of course, due to the enormous heterogeneousness of the service sector, the occurrence of good practices is very different, e.g. in some enterprises one can observe a priority on excellent technology, in others training and education is in the focus of the entrepreneur. Therefore, it is impossible to generalise the findings presented in this paper for forest enterprises in general.

In the actual study no outstanding case of good practice could be identified. Where good practice occurs, enterprises carry out their operations according to state of the arts standards.
Generally, it was found that entrepreneurs and workers offer an appropriate level of competence which provides the basis for safe and health-conscious performance. Where deficits were detected they will be resolved by targeted training in the course of the forthcoming project activities.

Technical standards are in most cases good. Again, ergonomic improvements of machines are feasible, and additional features like radio communication should be introduced where it is not available so far. But the project results so far indicate that technical improvement is not the most crucial factor towards improving safety and health.

The factor which was detected in all enterprises is that entrepreneurs and workers are highly committed to their profession and their tasks. A high level of job satisfaction was found, which is, in a nutshell, entailed by a feeling of independence and control, a feeling of freedom, and last but not least by an understanding that the work and its results are meaningful. This positive perception of forest work as satisfying and meaningful work is one of the outstanding resources in forest enterprises.

The most critical dimension and hence the most important connecting factor for improving safety and health is communication and cooperation. This accounts both for communication within enterprises and between entrepreneurs and the contracting forest owners.

One of the major deficiencies in enterprises, but also in safety and health research and prevention activities in general, still is that the focus tends to be narrowed to accidents and accident prevention. Health protection and furthermore health promotion still lacks attention and action.

Outlook

Based on the recent findings it is of utmost importance to use an individualised approach to improve safety and health and to promote workers´. Each enterprise has different problems, weaknesses and resources and – even more important – its actors have different attitudes and levels of risk acceptance.

It is auspicious that prevention measures which are directly focussed on actual problems will be effective, sustainable and accepted in enterprises.

This requires a methodology to identify strengths and weaknesses in enterprises as a connecting point for activities; it requires a method to deduce the most appropriate set of measures for an individual enterprise. In one enterprise it will be necessary to start with training activities, in other enterprises with raising awareness.

In the whole sector it will be necessary to find ways to reduce the level of risk acception of individual workers, mainly by continuous communication and ongoing raise of risk awareness.

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STUMP TREATMENT WITH CHEMICAL AND BIOLOGICAL CONTROLS AGAINST *HETEROBASIDION* SPP. ROOT ROT IN CONIFEROUS FORESTS OF FINLAND

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Abstract: *In this study, it was investigated the consumption of stump treatment materials and the quality of stump treatment work. The results indicated that the consumption of stump treatment material depends significantly on the average stem size of softwood removal. The consumption of stump treatment material was, on average, 1.09 dm^3/m^3 in first-thinning stands, 0.72 dm^3/m^3 in later thinnings and 0.39 dm^3/m^3 in clear cuttings. The average hectare-based consumption of stump treatment material was 51 dm^3/ha in first thinnings, 45 dm^3/ha in later thinnings and 81 dm^3/ha in clear cuttings. The results showed also that the quality of stump treatment work was good in the study: 72.2% of the coverage inventories reported that the work quality was good. Correspondingly, 26.4% of the impression of stump treatment work was satisfactory. Only 1.4% of the total stump treatment work inventories were ineligible. The best coverage rate was achieved with the stumps of 20-39 cm.*

Keywords: Root rot disease, stump protection, urea, *Phlebiopsis gigantea*, coverage

Introduction

The root and butt rot fungus *Heterobasidion annosum* sensu lato (Fr.) Bref. is widely distributed in coniferous forests of the Northern Hemisphere, especially in Europe, North America, Russia, China and Japan (Garbeletto and Gonthier, 2013). There are three native *Heterobasidion annosum* species in Europe: 1) *Heterobasidion annosum sensu stricto* (*s.s.*) has a wide range of hosts and causes mortality to pines (*Pinus* spp.), especially Scots pine (*Pinus sylvestris* L.), and root and butt rot to Norway spruce (*Picea abies* (L.) Karst.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.). 2) *Heterobasidion parviporum* Niemelä & Korhonen causes root and butt rot to Norway spruce and 3) *Heterobasidion abietinum* Niemelä & Korhonen causes disease to several Abies species in southern Europe (Korhonen et al., 1998; Garbeletto and Gonthier, 2013).

Heterobasidion spp. root rot causes severe damage to forests throughout the northern temperate zone: In the European Union, annual losses attributed to growth reduction and degradation of wood are estimated approximately at €800 million, of which about €120 million are accounted for Sweden and Finland (cf. Asiegbu et al., 2005; Thor, 2005; Oliva et al., 2010). In Finland, the damage caused by *Heterobasidion* spp. root rot for Norway spruce has been estimated to be approximately €40 million per year and some €5 million per year for Scots pine (Müller et al., 2012; Juurikäävän torjunta, 2016). Climate change is thought to favor the living conditions and spread of *Heterobasidion* spp. root rot (e.g. La Porta et al., 2008; Müller et al., 2014). In addition, shortening of winter lengthens the infection time of the spores of *Heterobasidion* spp. root rot and increases the proportion of summertime cuttings. Consequently, the prevention of *Heterobasidion* spp. root rot,

as well as the obstruction of spread of *Heterobasidion* spp. root rot can be considered to be one of the most significant challenges facing the modern forestry sector.

The pathogen of *Heterobasidion* spp. root rot infects fresh stumps after thinnings or clear cuttings and spreads to neighboring trees via root-to-root contacts. In order to prevent *Heterobasidion* spp. root rot infection in summertime cuttings, stumps can be treated with urea that increases the pH of the stump surface, making it unsuitable for spore germination and thus preventing *Heterobasidion* spp. root rot getting deeper into coniferous wood (Johansson et al., 2002; Vasiliauskas et al., 2004; Oliva et al., 2008). Alternatively, the stump surface can be covered with large amounts of inoculum of the antagonistic fungus *Phlebiopsis gigantea* (Fr.) Julich, to prevent any pathogen spores that subsequently land on the stump surface to germinate (Pratt et al., 2000; Nicolotti and Gonthier, 2005; Rönnberg et al., 2006; Oliva et al., 2010).

According to the Plant Protection Product Register (Kasvinsuojeluainerekisteri, 2016), four urea products are used in Finland: Moto-urea (license number: 3069), PS-kantosuoja-2 (1949), Teknokem Kantosuoja (3124) and Urea-kantokate (2928). Currently, the trademarks of biological control agents are Rotstop (1648) and Rotstop SC (2939) on market in Finland (Kasvinsuojeluainerekisteri, 2016). The stump treatment areas have been annually 45,000–117,000 hectares in 2010's in Finland (Metsänhoito- ja…, 2017).

The stump treatment material is applied on the stump surface of coniferous trees using the harvester equipped with stump treatment facilities. Nowadays, the volumes of storage tanks in harvesters for the stump treatment material are typically around 90–150 dm^3. The stump treatment material is pumped from a storage tank to the harvester head whence it is discharged onto the stump surface of conifer tree via holes spaced along the underside of the guide bar. By means of the number and location of holes in a guide bar and adjustments for the treatment equipment of a harvester, the harvester operator can control spraying of treatment material. Due to the variation in the stem size of removal in the forest stand, with smaller trees, some of treatment materials often passes through the stump surface because the number of holes in the guide bar has to be usually dimensioned according to the larger-diameter trees at harvesting site.

The stump treatment with both urea and Rotstop reduce the basidiospore infection of *Heterobasidion* spp. root rot by an average of over 90% (cf. Thor, 2005; Thor and Stenlid, 2005; Oliva et al., 2008; Oliva et al., 2011). Achieving good pesticide efficacy requires careful treatment in order to get the surface of the whole stump wet by reading (Johansson et al., 2002; Berglund and Rönnberg, 2004; Rönnberg et al., 2006). The effectiveness of prevention is reduced in relation to the uncovered area on the surface of the stump. Thus, the good coverage of stumps is an absolute prerequisite for high-quality stump treatment work.

According to the Government decree on the prevention of damage by *Heterobasidion* spp. root rot (Valtioneuvoston asetus…, 2016), *Heterobasidion* spp. root rot has to be prevented in mineral soils when the share of Norway spruce and Scots pine of the total initial stand volume is more than 50% before wood harvesting operation and in peatland forests if the share of Norway spruce of the total initial stand volume is more than 50% before logging operation. Accordingly, the Forest damages prevention act (Laki metsätuhojen…, 2013), the prevention of *Heterobasidion* spp. root rot must be carried out in thinnings and regeneration fellings in the risk zone of *Heterobasidion* spp. root rot between the beginning of May and the end of November in southern and central Finland (see Figure 1). Furthermore, the stump treatment has to be done for all conifer tree stumps of more than 10 cm at the stump diameter (d_0) and the stump treatment material must cover at least 85% of the surface of each stump being treated (Valtioneuvoston asetus…, 2016).

There is only one report in which the consumption of stump treatment materials has been presented in Finland (Mäkelä, 2011). Mäkelä (2011) has estimated that the consumption of stump treatment material is around 40–60 dm^3/ha in thinnings and approximately 50–90 dm^3/ha in final cuttings. Mäkelä has forecasted the consumption of treatment product on the basis of the number of stems cut and the total area of stump ends treated. Nevertheless, there is no information about what is the consumption of stump treatment material with different treatment materials (i.e. urea and Rotstop) and in diverse stand types, for instance when the stem size of removal is 100, 300 or 600 dm^3 in the stand.

Therefore, Stora Enso Wood Supply Finland (WSF) and the University of Eastern Finland carried out the study on stump treatment against *Heterobasidion* spp. root rot in Finland and clarified:

- the consumption of stump treatment materials and
- the quality of stump treatment work (i.e. the coverage of stumps treated).

Material and methods

Data on the consumption of stump treatment materials

For the study, the consumption of stump treatment materials in 46 harvesters was collected in May–November 2016 in Finland at the harvesting sites of Stora Enso WSF. There were 25 Ponsse (Beaver, Ergo, Fox, Scorpion and Scorpion King), 14 John Deere (1070D, 1070E, 1170E, 1270D, 1270E and 1270G), 5 Komatsu/Valmet (901, 901TX, 901TX.1, 911.4 and 911.5), 1 Logset (8H GTE) and 1 ProSilva (801) harvesters in the study. The data for the consumption of stump treatment material was collected by the accounting of harvester operators with recording forms. The cutting area-specific prd files were found from the enterprise resource planning (ERP) system of Stora Enso WSF. The prd files included the volume, number and average stem size of removal by tree species, as well as a harvesting method. Moreover, the hectare-based consumption figures for cutting areas were calculated using the maps of the harvesting instruction of cutting areas. If there was some indication of the abnormality planning of the cutting area harvested in the prd file, the hectare-based consumption was not calculated for such cutting areas.

Since the harvesters of the study did not have the technology for automatic measuring of the consumption of stump treatment material, the consumption of treatment materials was manually measured by the harvester operators. The measurement methods used by the operators differed between the harvesters of the study: Some operators measured the consumption of treatment materials when filling the storage tank of a harvester by measuring the amount of substance added by a flowmeter or by the signs in the storage tank, and some operators used a dipstick. All methods aimed at a minimum accuracy of five dm^3 per measurement.

There were 40 harvesters which used only urea as a stump treatment product in the study, and only Rotstop SC (later only: Rotstop) suspension was used in four harvesters. Furthermore, both urea and Rotstop were used in two harvesters. In total, the stump treatment materials were measured to spread 309,427 dm^3 during the study period. Of this volume, three urea products (i.e. Moto-urea, PS-kantosuoja-2 and Teknokem Kantosuoja) accounted for 272,754 dm^3 (88.1%), and the share of Rotstop was 36,673 dm^3 (11.9%). The stand information from the ERP system of Stora Enso WSF was received a total of 1,831 cutting areas. The distribution of cutting areas in the study is illustrated in Figure 1.

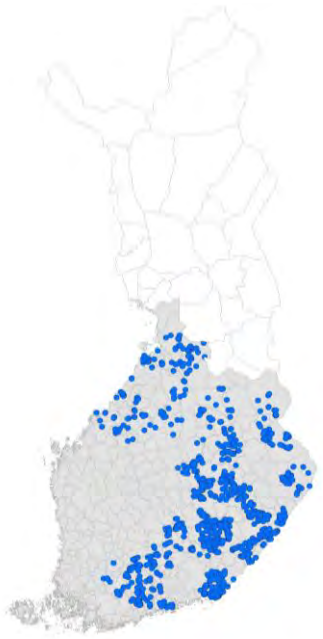

Figure 1. The distribution of cutting areas (n=1,831) in the study. The gray color in the map displays the risk zone of spread of *Heterobasidion* spp. root rot in Finland

The total volume of softwood trees in the cutting areas of the study was 587,120 m³ solid over the bark (m^3). The share of Norway spruce was 320,257 m³ (54.5%) and the share of Scots pine was 266,863 m³ (45.5%), and totally 2,413,256 softwood trees were cut. Most of the softwood volume was cut from clear cuttings (59.3%) and later thinnings (27.9%). From first thinnings, softwood was felled 5.8% of the total softwood volume, 4.5% from seeding fellings and 2.3% from other cuttings (i.e. cuttings of hold-overs, shelterwood fellings and special cuttings).

The study also detected the effect of the number of holes in a stump treatment guide bar on the consumption of stump treatment material. In total, the harvester operators recorded the number of holes in the guide bar for 1,808 cutting areas on the data collection forms. The volumes of softwood cut with the different numbers of holes are described in Figure 2.

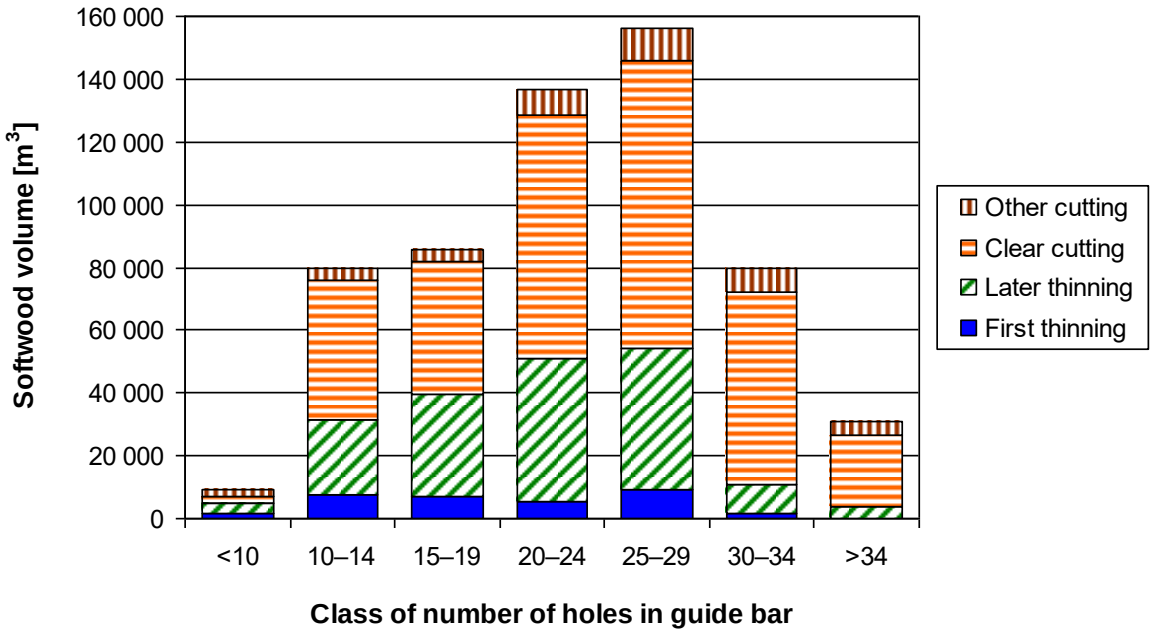

Figure 2. The distribution of the number of holes in harvesters' stump treatment guide bars by harvesting method

Furthermore, the influence of the adjustment habits by harvester operators on the consumption of stump treatment material was investigated. The changes of guide bars were not taken into account, but only the adjustments for the controlling systems of stump treatment equipment in a harvester (i.e. timing and duration in spraying and spreading pressures). The options for adjusting the stump treatment equipment in the interviews of harvester operators were:

- By harvesting site,
- By harvesting method,
- After detecting weak stump coverage in spraying or
- Never.

If the adjustment habits of the operators at the same harvester differed from each other, the harvester was grouped into the group based on the operator's response to most adjustments. The number of harvesters and cutting areas in different adjustment classes are given in Table 1.

Table 1. The number of harvesters and cutting areas in the different adjustment classes of the study

Class of adjustment habits	Number of harvesters [n]	Number of cutting areas [n]
By harvesting site	0	0
By harvesting method	12	490
After detecting weak stump coverage in spraying	19	726
Never	15	615
Total	46	1,831

The study hypotheses were that when there are lots of holes in the treatment guide bar and the harvester operator does not adjust the controlling system of stump treatment in a harvester, the consumption of stump treatment material is larger than when there is only few holes in the treatment guide bar and the operator sets actively the treatment system of the harvester.

Coverage data

The quality of stump treatment work was evaluated with all harvesters in the study by inventoring the coverage of stump treatment on the stump surfaces of conifer trees cut after the stump treatment work. The goal was to make three coverage inventories for each harvester during the study period. Moreover, the aim was to conduct one coverage inventory for each main harvesting method (i.e. first thinning, later thinning and clear cutting) with each study harvester. The inventory of different harvesting methods was done to ensure that the coverage of stump treatment would be valid on the stumps of different diameter with all harvesters involved in the consumption study.

The coverage of stump treatment material on the stump surface can be detected by the dye of treatment material (cf. Figure 3). The uncovered area of the entire stump surface by treatment material was estimated using a measuring plate (Figure 3). By changing the distance of the transparent measuring plate above the stump, the focal length is selected with combining the edges of the stump and the ring of the measuring plate. Based on the relative proportions of the plate, it is possible to determine the relative proportion of the uncovered area of stump surface.

Figure 3. A control plate (left) which was used to estimate the relative proportion of coniferous stumps uncovered by the stump treatment material. Photo: Uittokalusto Oy. On right the stump with the uncoverage rate of around 12-14 percent (not the blue area). Photo: Kalle Kärhä

In each coverage inventory, the target was to measure 50 stumps. In accordance with the Manual for inventoring of the coverage of stump treatment prepared for the study, the stumps were measured as cluster sampling on the longest line of each cutting area. From the line, the five closest conifer tree stumps were measured at the distance of ten meters from ten places, with a total sample size of 50 stumps. The stump diameter (d_0) and coverage percentage (i.e. coverage rate) of each stump selected for the inventory were recorded on the Inventoring form of

the coverage of stump treatment. The quality of stump treatment work was evaluated on the basis of the criteria of Finland Forest Center (Maastotarkastusohje, 2016), i.e. 85% or more of the stump surface of the approved stump should have been covered. Contrary to the consumption data, the quality inventories of stump treatment were carried out at a harvesting site-specific level (i.e. harvesting site may consist of one or several cutting areas) instead of the cutting area-specific measurements of consumption.

After inventoring the coverage of stumps, the percentages below 85% covered stumps were calculated on the form. When the sample was 50 stumps in the inventories, the deduction percentage was calculated by multiplying the number of uncovered stumps by two. The verbal estimate based on the deduction percentage was given to the quality of stump treatment work as follows:

- The deduction percentages of 0–9% marked a good level of coverage,
- 10–29% a satisfactory level, and
- 30–100% marked an ineligible level of coverage (cf. Maastotarkastusohje, 2016).

The quality inventories of stump treatment were performed by a responsibility wood harvesting officer at Stora Enso WSF for each study harvester. The quality inventories made by the harvester operators themselves were not used in the study. All harvesters did not cut in the stands of all of three main harvesting methods (i.e. first thinning, later thinning and clear cutting), thus several inventories for the same harvesting method were conducted with some harvesters. In total, 144 quality inventories (27 in first-thinning stands, 65 in later thinnings and 52 in clear cuttings) were carried out in the study. Each stump measured with its diameter (d_0) and coverage rate, as well as identification data was recorded. When analyzing the data, some stumps of less than 10 cm at diameter and unclear stumps marked on the form were removed from the final coverage data which was 7,042 stumps (Figure 4).

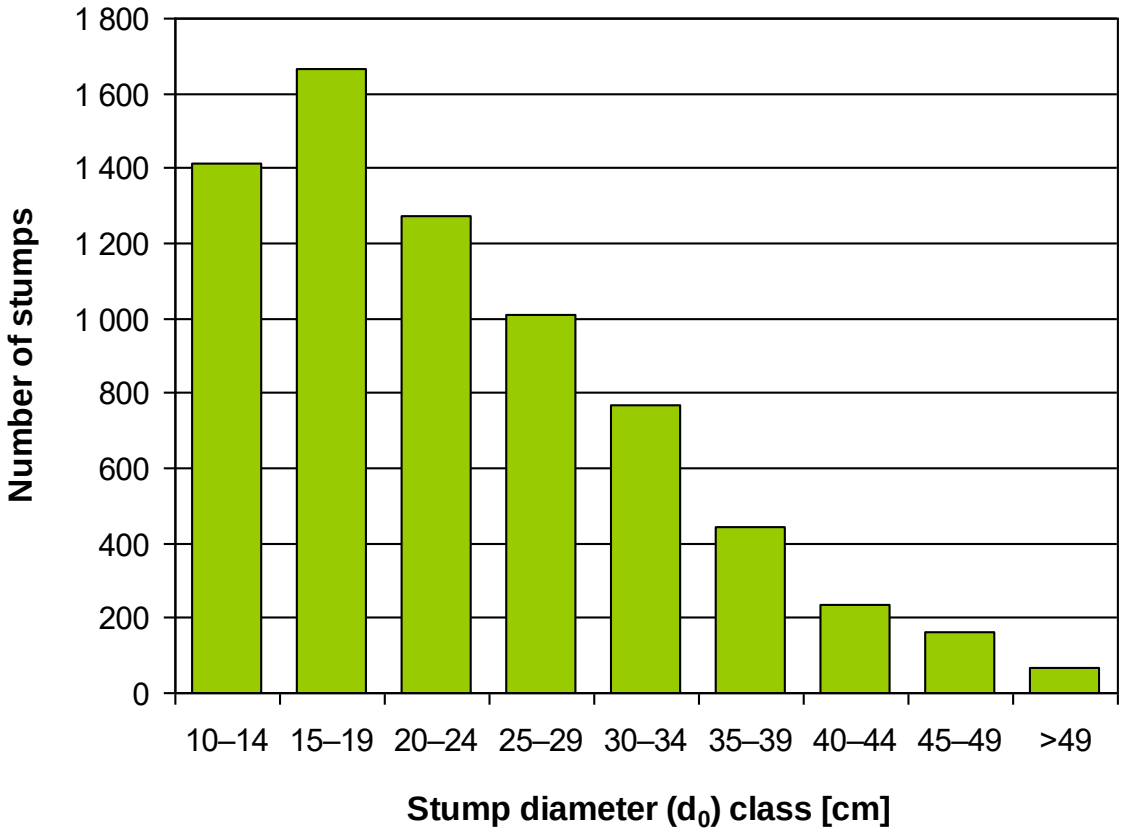

Figure 4. The number of stumps (n=7,042) inventoried for the final coverage data of the study

Analyzing of study materials

The cutting area-specific data on the consumption of stump treatment products, as well as the coverage data of the stumps inventoried were initially tested for normal distribution assumption by a Kolmogorv-Smirnov test. Based on the results of the test, the consumption and coverage data did not comply with normal distribution. Since the material was not distributed normally, the non-parametric methods were applied in the statistical analysis of the study: For comparison of multiple populations in the study a Kruskal-Wallis one-way ANOVA test was used and for comparison of two populations a Mann-Whitney U test. A regression model for the consumption of stump treatment material was created as a function of the average stem size of softwood removal in the stand.

Results
Consumption of stump treatment materials

The study results indicated that the consumption of stump treatment material depends significantly on the average stem size of softwood removal in the cutting area (Figure 5). The consumption of stump treatment material was, on average, 1.09 dm^3/softwood m^3 cut in first-thinning stands (the average stem size of softwood removal in the stand: 83 dm^3), 0.72 dm^3/softwood m^3 cut in later thinnings (154 dm^3), 0.39 dm^3/softwood m^3 cut in clear-cutting stands (423 dm^3) and 0.43 dm^3/softwood m^3 cut in other cuttings (i.e. seeding fellings, cuttings of hold-overs, shelterwood fellings and special cuttings) (355 dm^3).

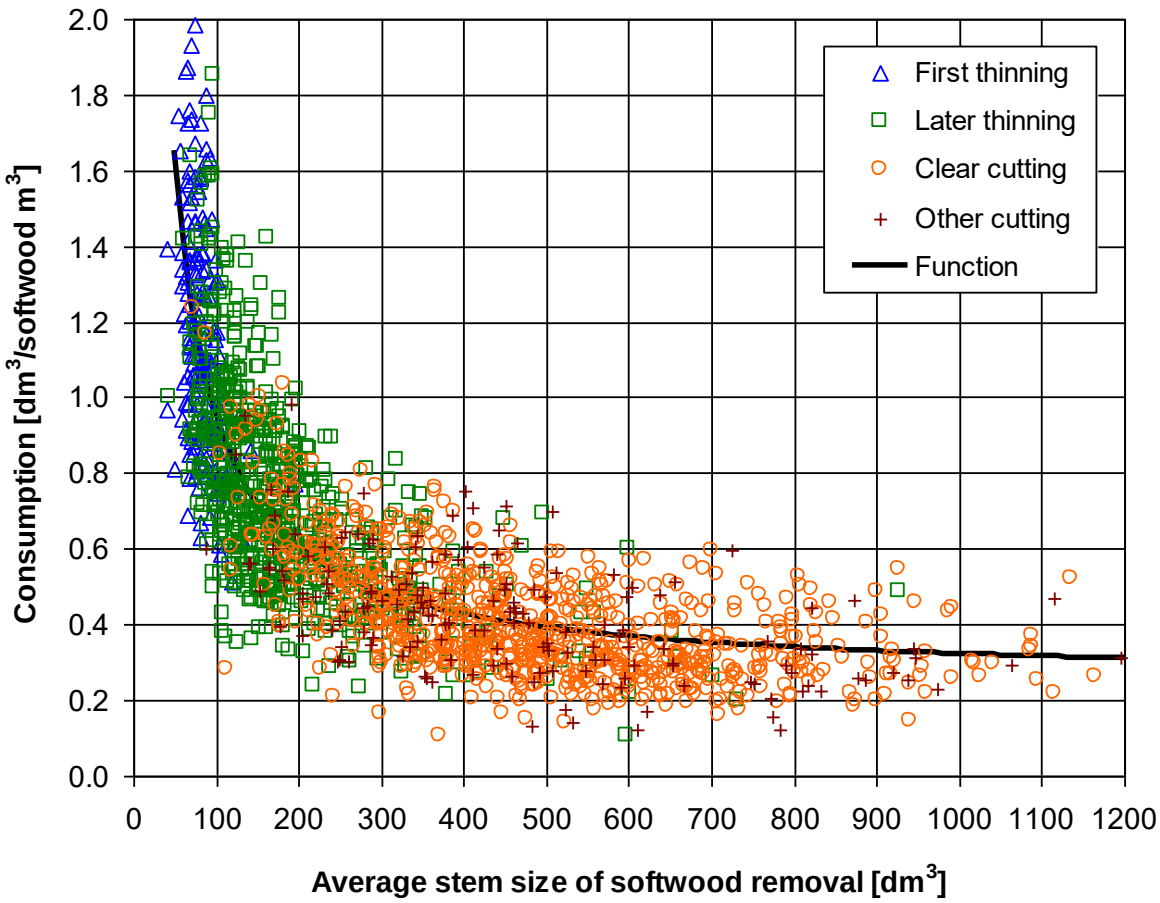

Figure 5. The consumption of stump treatment material as a function of the average stem size of softwood removal in the cutting area by harvesting method

In later thinnings and clear cuttings, the treatment material (i.e. urea and Rotstop) used, as well as the number of holes in the stump treatment guide bar and the adjustment habits by the operator for stump treatment equipment had significant effects on the consumption of stump treatment material in the study. The highest consumption

was with urea and when there were only a few holes (<18 holes) in a guide bar and the harvester operator set abundantly (i.e. by harvesting method) the stump treatment equipment of the harvester.

The average hectare-based consumption of stump treatment material was 51.0 dm^3/hectare in first thinnings (the average softwood removal in the cutting area: 46 m^3/ha and the density of softwood removal: 558 trees/ha), 44.6 dm^3/ha in later thinnings (63 m^3/ha and 402 trees/ha), 80.8 dm^3/ha in clear cuttings (210 m^3/ha and 491 trees/ha) and 58.9 dm^3/ha in other cuttings (140 m^3/ha and 409 trees/ha).

Quality of stump treatment work

The field measurements showed that the quality of stump treatment work was good in the study: 72.2% of the coverage inventories reported that the work quality was good. Correspondingly, 26.4% of the impression of stump treatment work was satisfactory. Only 1.4% of the total stump treatment work inventories were ineligible. The share of less than 85% covered stumps measured in total coverage data was 6.6% and respectively the proportion of 85% or better covered stumps was 93.4%. When analyzing the coverage by stump diameter class, it could be noted that the highest coverage was achieved with the stumps of 20–39 cm (Figure 6). The coverage of the smaller (<20 cm) and larger-diameter (>39 cm) stumps inventoried were significantly lower. In the study, the average coverage rate (i.e. the coverage percentage of all stumps inventoried) was 94.9% in first thinnings and 94.3% in later thinnings. The best (95.1%) coverage rate by harvesting method was in clear-cutting stands.

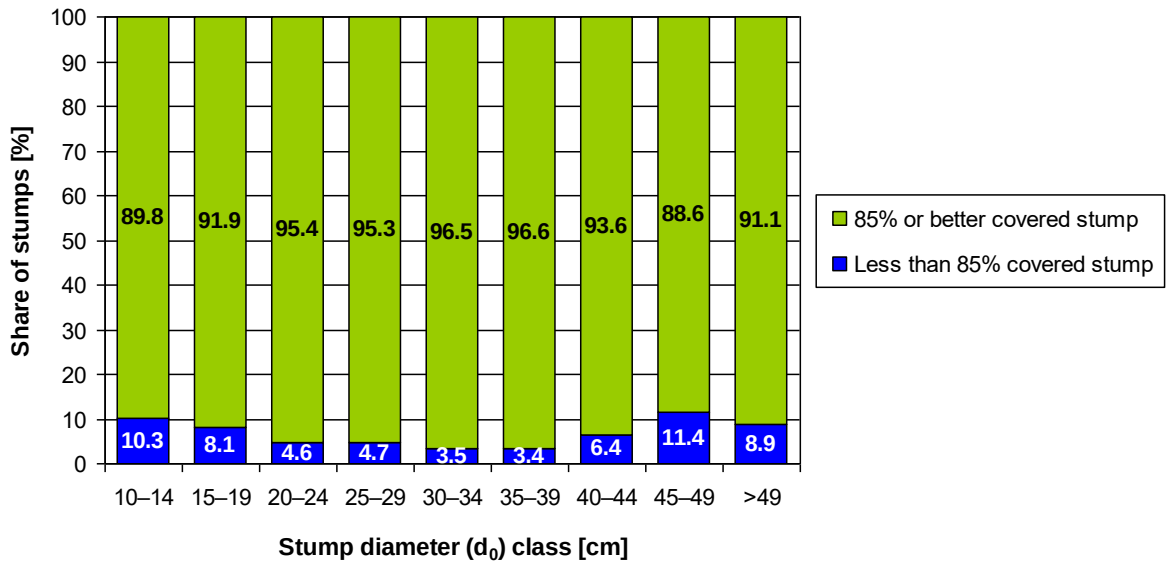

Figure 6. The shares of less than 85% and 85% or better covered stumps inventoried by stump diameter class

There was also significant difference between harvesting methods with unequal stumps in the quality of stump treatment work: In clear cuttings, the coverage rate with small-diameter (<20 cm) stumps was significantly lower (90.7%) than in first and later thinnings (94.4% and 93.8%). Correspondingly, in first-thinning stands, the coverage rate of stumps treated was good with both small (<20 cm) and medium-sized (20–39 cm) stumps. In turn, with the larger-sized (>39 cm) stumps, the coverage rate was the highest (93.9%) in clear cuttings.

When clarifying the effect of the number of holes in a guide bar on the quality of treatment work, the best coverage rate was obtained with small and medium-sized stumps with the guide bar perforated with quite small (<18) number of holes, and with larger-sized (>39 cm) stumps when the guide bar was equipped with relatively great (>27) number of holes. Respectively, when detecting the influence of the operator's adjustment habits of treatment equipment, it could be noticed that the highest coverage rate was achieved:

- with small (<20 cm) stumps when the harvester operator did not set at all the stump treatment equipment of the harvester (95.4%),

- with medium-sized (20–39 cm) stumps when the operator adjusted the treatment equipment in the harvester by harvesting method (96.1%) and

- with large-diameter (>39 cm) stumps when the operator set the treatment equipment after detecting weak stump coverage in spraying (95.8%).

Discussion

Data for the consumption of stump treatment material was almost 0.6 million softwood m^3 and further more than 2.4 million softwood trees cut with 46 harvesters, and the stump treatment material was spread more than 300,000 dm^3. The consumption data was hence relatively large. In the study, the accurate measurement of the consumption of stump treatment material was challenging, as there were no technology for automatic measuring of the consumption of treatment product in the study harvesters. The consumption of treatment products was measured using many measuring methods according to the preferences of the operators. All methods aimed at a minimum accuracy of five dm^3 per measurement. On the basis of operator interviews, each operator thought that he achieved a set target for the measurement accuracy. In the near future, nevertheless, forest machine manufacturers should seriously consider equipping their harvesters with the automatic standard measuring system for the consumption of stump treatment material.

The study results illustrated that the average stem size of softwood removal in the stand has a significant effect on the consumption (dm^3/softwood m^3 cut) of stump treatment material. Furthermore, the softwood removal per hectare explained the consumption (m^3/ha) of stump treatment material in the study. The average consumption of stump treatment material was 51 dm^3/ha in first thinnings, 45 dm^3/ha in later thinnings and 81 dm^3/ha in clear cuttings. The results of the study were in line with the calculations by Mäkelä (2011): the consumption in thinnings 40–60 dm^3/ha and 50–90 dm^3/ha in clear cuttings.

The hypotheses in the study were that when there are lots of holes in the treatment guide bar and the harvester operator does not adjust the controlling system of stump treatment in a harvester, the consumption of stump treatment material is higher than when there are a few holes in the treatment guide bar and the operator sets actively the treatment system of harvester. The study results did not unexpectedly endorse the study hypotheses related to the consumption of treatment material. Even if the consumption of treatment material is the lowest without the adjustments by the operator for the treatment equipment, it can be recommended that the operator controls actively the treatment result in cutting work especially operating in large-diameter forest stands, further sets the stump treatment equipment in the harvester if needed, and thus achieving a high-quality result in his/her stump treatment work.

The coverage of stump surfaces by harvesting method was the best in clear cuttings, but the difference between clear cuttings and thinnings was very small. Consequently, the stump treatment work can be considered being successful and uniform with all harvesting methods in the study. Based on the study results, the quality of stump treatment work can be found to be the best with medium-sized (20–39 cm) stumps, and further the coverage rate with the smaller (<20 cm) and larger (>39 cm) stumps was slightly lower than with medium-sized stumps. Hence, it can be concluded that the holes in the stump treatment guide bar should be chosen according to the stem size of removal in the stand. Besides, the results suggested that in the stands of mostly small and medium-diameter (d_0<39 cm) conifers, the treatment guide bars with relatively little (<18) number of holes are used and at the harvesting sites of larger-diameter trees, the guide bars with a great (>27) number of holes are applied.

Several harvester operators interviewed underlined that the stump treatment is the most difficult in the coniferous stands in which there are a lot of variation in the stem size of removal. Especially in the case of larger-diameter clear cuttings the stump treatment of small stumps is very challenging. To sum up, since the adjustments of the controlling system of treatment equipment and the holes in the treatment guide bar have to be decided in accordance with the dominant trees in the stand, there are nowadays troubles to spray the divergent stumps extremely well. In the future, the forest machine manufacturers could develop more advanced controlling systems of stump treatment for their harvesters, for instance default spraying adjustments for cutting different sized trees, or some adaptive spraying systems accordingly the stem size of removal in the stand.

Because the consumption data was measured as a cutting area-specific and the coverage data as a harvesting site-specific, there were no possibilities to merge the materials and to compare more comprehensively the consumption and coverage data in the study. For this reason, a further study on the consumption and coverage could be performed to optimize the consumption of stump treatment material subjected to the high-quality coverage rate in the coniferous forests.

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PREDICTING THE TRAFFIC OF A FOREST ROAD NETWORK

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Abstract: *The knowledge of the forestry and non-forestry traffic of a forest road network in a frequented region is valuable for the forest manager. Based on the expected non-forestry traffic one can plan forest operations and wood transportation in a way that minimize the disturbance of recreational forest visitors while keeping operation costs low. A method was developed and tested that can estimate the traffic composition of a forest road from wood harvest plans, tourist attractions, road properties and inbound visitor numbers. A sample area was selected near Budapest, the capital of Hungary, due to its high visitor rates. The harvest plans provided wood quantities to be transported and thus transport vehicle numbers and expected routes could be calculated. The overall visitor number of the sample area was determined by traffic counting at the entrance points. The modeled flow of recreational visitors was driven by the 'gravity force' of the tourist attractions, the 'resistance' of the different types and conditions of road surfaces and the agility of visitors. These factors came from the results of an online questionnaire that was planned to measure the road preferences of tourists. With the help of this method the road network of the sample area was evaluated and the conflict points were determined. The effect of the possible solutions at the conflict zones was analyzed by the novel method. Thus, it is expected that the overall visitor satisfaction will increase while forest operations can be carried out at the same cost level.*

Keywords: forest road network planning, road management, road traffic, recreation

REFORESTATION OF DRYING AREAS IN AN INNOVATIVE WAY

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Abstract: *Due to the climate changes, afforestation becomes more and more difficult. The direct sunshine burns the plantation, causes increased drying of the soil, and leads to economical loss for the owner. New afforestation technologies, innovations are needed for adapting climate change and rise the efficiency of the reforestation plantage. In the cooperation of researchers and a forestry corporation, an own-initiative field trial was established with alley cropping systems for supporting afforestation. The agroforestry system was planted for producing feed for livestock, but the technology proved to be surprisingly favorable for seedlings. Near to the trial, control areas were designated to compare mortality and the yield in the plots, using the same management technics. The experiment showed, that the association of seedlings and crops has positive effect both on the yield and the mortality of trees. The low-growing corn varieties improved the micro-climatic parameters and protected the seedling from drying and the burning effect of direct sunshine, but let enough light through, for growth.*

Keywords: agroforestry, afforestation, intercropping, reforestation

NEW PRINCIPLE FOR HARVESTER HEADS FOR HARDWOOD

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Abstract: *The success of Cut-to-length logging (CTL) is based on the evolutionary development of harvester heads from the seventies on, that compressed the tasks of feller, buncher, swing machine and Knuckleboom Loader in one compact unit. While using the Scandinavian technology in Central Europe, where 50 % of forest stands are hardwood, the existing harvester heads show the limits of their performance. Especially curved trunks, bigger or steep branches and a thin and sensitive bark results in lower productivity, worse conversion respectively devaluation of forest products up to damage of the head. The handling of fallen tree parts like forked stems is problematically. Actually, there is no harvester head for hardwood on market that is as well adapted as conventional harvester heads on coniferious trees. The Chair of Forest Technology at the Technische Universität Dresden developed a new kind of harvester head for hardwood (saw log and industrial wood) up to a DBH of 50 cm, which is patented. The separate functions of delimbing, feeding, cutting at top and bottom and picking-up show innovative solutions. Especially the delimbing knifes shows a new kind of shape, of array and of effect. The concept was engineered in detail under purpose of minimal weight and volume and is realised as a prototype that will be tested in spring 2017. With the new harvester head, it should be possible to convert arbitrarily grown hard wood trees in an effective and careful way to saw log and pulp wood products.*

Keywords: hardwood harvester head, Central European forestry technology

RESEARCH TRENDS IN EUROPEAN FOREST FUEL SUPPLY CHAINS: A REVIEW OF THE LAST TEN YEARS (2007-2017)

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Abstract: *Forest fuel is a renewable source that has the potential to substitute fossil fuels in several application fields. The use of forest biomass helps to reduce the emissions of greenhouse gases and supports rural areas by fostering income and jobs. Nevertheless, the earnings when producing forest fuels are small and therefore efficient supply chains are necessary which guarantee the delivery the high quality products at competitive costs. Whereby 20 years ago research was focusing on developing and analysing suitable supply chains and machines which have the potential to become state-of-the-art, now the main interest is on improving the quality of the final product and to increase the efficiency of logistics, machines or the configuration of the machines. This paper provides a review of research trends of the last ten years focusing on harvesting, storage, comminution and transport of forest biomass in Europe. The most promising research trends are multi-stem and integrated fuel- and pulpwood harvesting, moisture content management in storage and transport, improving drying performance by specific treatments and models, improving the product quality by implementing best suitable methods and tools tailored to wood characteristics, adapting chipper and truck configuration, and multi-criteria assessment of supply chains. It is expected that further research is needed on these topics and that (semi)automatic process management and data collection will increasingly support research and innovation in future.*

Keywords: fuel wood, supply chains, research trends

STATE-OF-THE-ART OF LOG AND BIOMASS TRANSPORTATION: A COMPARATIVE ANALYSIS BETWEEN SPAIN AND AUSTRALIA

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Abstract: *The transport of wood and biomass from the forest to customer sites accounts for more than 50% of the delivered costs. In both Spain and Australia, the transport is performed mostly by trucks, although in some cases, transport by rail is used in a second or intermediate phase. The article presents a comparative analysis of the legal conditions, characteristics of the haulage companies and their integration in the supply chain, as well as the technical conditions of the vehicles employed in both countries. Also, the article addresses the technological innovations that facilitate the transport management to optimize routing and the stock of wood and biomass at loading areas.*

Keywords: transport, wood and biomass, costs, legislation, planning, Spain, Australia

Introduction

Australia and Spain are two countries that are correlatively in the geographic antipodes of the globe but that present some interesting parallels in the socioeconomic and territorial aspects of their respective forest sectors. An exploration of these forest sectors can allow drawing conclusions regarding trends and possible improvements of both countries, specifically in the transport of the wood and biomass products.

The area covered by forests in Australia amounts to 124.7 million hectares, which represents about 16% of the country's surface. Spain despite having a total area 15 times smaller than Australia its forest area is only 4.5 times the Australian. From the perspective of this article it is remarkable the 2 million hectares of Australian plantations of Eucalyptus sp. And Pinus radiata D. Don. These two species have great presence in Spain, with 633,000 ha of eucalyptus and almost 300,000 of Pinus radiata D. Don. Important mention in the Spanish case is poplar (Populus sp.), with close to 100,000 ha of plantations (SECF, 2010).

As for the total volume of roundwood produced in Australia in 2016 (25.3 million m^3), the vast majority was produced from plantation forests (21.3 million m^3), and a much lower volume (4 million m^3) was produced from natural forests. The production of roundwood in Spain is approximately 14 million m^3, 50% of which is conifers, where Pinus pinaster and Pinus radiata stands out, with the remaining 50% consisting of hardwoods, which is dominated mainly by eucalyptus (SGAPC, 2014). The breakdown of Australian harvesting indicates a production of 14.5 million m^3 for conifers and almost 7.5 million m^3 for hardwoods, almost all eucalyptus (ABARES, 2015). In both countries, the production of roundwood is concentrated on plantations, where the production of pulplogs has been gaining relevance in contrast to the production of sawlogs.

In economic terms, the forestry sector in Australia contributes with 0.5% of the Gross Domestic Product (GDP), which is lower than the contribution of the sector in the Spanish economy, which contributes with 1% of the GDP. In Australia, about 70,500 people are employed in forestry, harvesting and manufacturing activities,

compared to 116,000 in Spain (SGAPC, 2014). The forestry sector in Australia generates income from the sale of products and services that amount to € 14 billion compared to € 6.6 billion in Spain.

The objective of this article is to conduct a comparative analysis of transport operations between Spain and Australia, including the major elements of their supply chains, current legislation, vehicle configurations and technological implementation for improving the efficiency of the transport operations.

Methodology

For the elaboration of this article we have compared roundwood and biomass supply chains, the legislation of each country, and the most common truck configurations. In doing that, we have contrasted bibliography, legislation and the knowledge of the sector of the signatory authors of the article. Finally, a review is made with the technological improvements developed in Australia with the greatest potential to be implemented in Spain.

Results and Discussion
Supply chains and dominant transport modes

Globally, the transport of roundwood and biomass from the forest to consumption centers accounts for up to half of the operational costs in the forest supply chains, which means millions of dollars for the forestry industry. Given the high level of transport costs, even small improvements in efficiency can mean significant cost savings (Acuna and Sessions, 2014). This importance, not only economic but also strategic for the mobilization of wood and biomass, has received little attention of forestry research centers, universities and the Administration in Spain. This is reflected in the few publications been published and the absence of relevant research projects in this area.

The forest and forest products industry in both countries depends to a large extent on road transport. About 86.6% of Australia's freight transport is transported by road, 12.0% by rail and only 1.4%t by sea (Cameron, 2005). These figures are similar in Spain, where 90.9% of the roundwood for pulp is transported by road, 6.6% by and 2.5 by sea (ACIE, 2013). Transport by road is the main mode for the mobilization of forest products especially for medium and short transport distances (<200 km). In many regions of Australia, the existence of flat areas and the relatively easy access to construction materials allows lower forest road building costs (Lambert and Quill, 2006). The marginal contribution of transport by rail is explained by similar reasons in both countries: lack of rail networks, insufficient volumes to justify rail operations, and the lower flexibility associated with this transport mode.

Most the volume of the logs harvested in Spain is chipped and delivered to pulp mills and particle board mills, while in Australia, logs from softwood species are used to produce lumber, while logs from hardwood species are chipped to produce export woodchips. In both countries, mechanized cut-to-length is the dominant harvesting system (short logs). In parts of Australia, in-field chipping is very common as some cost reductions in transported are achieved with this system. Although is not the predominant system, this option is also present in Spain but to produce fuel that is delivered to biomass and pellet plants.

Table 1. Most common equipment employed in Australia and Spain

	Australia		Spain
Harvesting system	Cut-to-length (2.5-6 m short logs) with chipping at destination	In-field chipping	Cut-to-length (2.5 m short logs)
Felling/Processing	Harvester	Harvester or Feller buncher	Harvester or Manual felling
Extraction	Forwarder	Forwarder or Grapple skidder	Forwarder
Loading	Forwarder or dedicated loader	Chipper	Self-unloading crane mounted on truck
Transport	Truck and semitrailer, or multiple trailers	Chip-van truck	Truck and semitrailer
Unloading	Wheeled front loader	Hydraulic dumpers	Self-unloading crane mounted on truck

In both countries for the case of short logs, log lengths must be adapted to the width and maximum permissible length of the trailers and semitrailers used for transport. In the case of in-field chipping, a mobile chipper is used to produce woodchips with a certain size specification. In Australia, this system is mainly used to reduce the handling of small logs. Debarking of logs is done at the roadside (chain and flail debarkers) before chipping. It is important to point out that the smaller size of the harvest units in Spain makes it necessary the use of cranes mounted on trucks for loading and unloading the load.

Legislation on maximum GVM and truck configurations

In Australia, the maximum legal GVM is substantially higher than in Spain, which explains the differences in transport cost between the two countries. In Australia, there are regulations at State level that specify the truck configurations that can circulate on each type of road. Table 2 shows the most common truck configurations and their specifications, in both the State of Tasmania (Australia), and Spain. The rigid truck (6x6) is commonly used in forest coupes with difficult access due to low road standards (small radius of curvature, high grades, etc.). It is evident the much lower maximum GVM allowed in Spain (40 t) in comparison to that of Australia (62.5 t).

Table 2. Truck configurations in Tasmania (Australia) and Spain

Configuration	**Design**	**Max. legal GVM - (tonnes)**		**Max. length of truck + semitrailer(s) - (m)**	
		Australia	**Spain**	**Australia**	**Spain**
Rigid truck 6x6		**Not used**	**26.0**	**Not used**	**12.0**
One semitrailer		**45.0**	**40.0**	**19.0**	**18.75**
Two semitrailers (B-double)		**57.0**	**40.0**	**21.0**	**18.75**
Three semitrailers (tri-tri B-double)		**62.5**	**Not used**	**25.0**	**Not used**

Truck and semitrailer is one the most common configurations in both countries. These trucks generally transport long logs (10-12 m) of Eucalyptus sp., which in Tasmania represents 80% of the volume transported. In Spain, the truck and semitrailer with a mounted crane is used for short wood (2.5 m), cross load and diameter less than 20 cm.

In Australia, other truck configurations with more than one semitrailer allow a larger GVM. It is the case of B-double that usually transport short logs (5-6 m) in the first bay and long logs (10-12 m) in the second bay. In the case of trucks with three semi-trailers (tri-tri B-doubles), they only transport short logs (5-6 m) from cut-to-length operations, and they require roads with very high standards.

For the transport of woodchips, semitrailers of up to 90 m^3 equipped with moving floor for self-discharge are the most used in Spain (Tolosana, 2009). In Australia for the transport of woodchips, similar trucks are used but with a trailer, forming a road train, which can increase transport loads by more than 50%. In the past, the major limitation of this configuration was related to the unloading at ports. In the 90's, hydraulic platforms were introduced at port terminals (Figure 1), which revolutionized the chip transportation industry.

Figure 1. Truck configuration for the transport of woodchips and unloading system in Australia

The main benefit of woodchips transport lies in the opportunity to increase transport capacity, shorter loading/unloading times, and the fact that the cargo is not visible to the general public. Loading can be done with chippers with a chip ejection system located above the truck or from the rear door of the trailer. However, woodchips present more problems for their storage, and their quality is affected by weather conditions. This limits the supply chains based on in-field chipping when there is no enough planning to supply woodchips timely.

In northern Spain, bundling of residues is a common practice. The advantage of this system compared to chipping is that the transport of bundles is made with the same trucks as those used for transporting roundwood (Figure 2).

Figure 2. Semitrailer for the transport of bundles with protective mesh

The competitiveness of the Spanish forest sector has been reduced with the current legislation which restricts the maximum legal GVM. This is a major difference between Australia and Spain, as well as with other EU countries, where vehicles can exceed a GVM of 44 tonnes with five-axle vehicles (prime mover with 2-drive axes and a 3-axle semitrailers). Portugal and France, neighboring countries with Spain, allow greater loads; in the case of Portugal a GVM of up to 60 t (5-axle vehicle) is allowed for the transport of roundwood and forest products (Olabe and Val, 2012). In Spain, 44-t with 5-axle trucks are only allowed for a prime mover with 3-drive axles, and for travel distances <150 km. Campos and Martínez (2013) point out that the possibility of

increasing GVM up to 44 t is a measure that could reduce transport costs by 11.5% (€/t-km basis) and increase the productivity of haulage and loading equipment. This measure might also have a direct impact on the current supply chains and could increase the supply radius to customers, generating new opportunities for the harvest of units located in remote rural areas.

It should be noted that some States in Australia have some of the largest and most heavily loaded vehicle configurations in the world, which in some cases may exceed 120 t of GVM. Such is the case of the so-called "road train" configuration that can be used on specific routes in the Northern Territory, Western Australia and Victoria. This configuration basically consists of a truck with a semi-trailer plus two or three trailers. For the transport of roundwood, these vehicles can generally transport over 80 t depending on axle configuration and type of route. It has been estimated that shifting trucks with a semi-trailer to trucks with two semi-trailers could reduce the size of the fleet by 25%, however, it should be noted that the adoption of larger configurations in certain regions of Australia has required improvement to the infrastructure, changes to legislation, and implementation of education programs (Lambert and Quill, 2006). In Spain, these road trains could have a potential in consolidated wood supply routes, such as the North-Center axis, the East-West axis, and international axes such as Southwest French-North of Spain or Northeast of Spain-North of Portugal.

A problem concerning transport safety is related to the maximum height of the load transported. This has led to several Australian States to introduce legislation on this subject, specifying the maximum height of the load and the type of tie-down systems to be used to restraint the load. Finally, in the case of transporting logs with bark, a common problem is the amount of bark that emerges from the logs during transport, which has also led to implement practices for securing the loads.

In Spain, the trucks dedicated to the transport of roundwood have the chassis adapted, with light aluminium panels, and a wooden platform. They usually carry a crane for self loading and unloading. The use of this crane endows the drivers with autonomy, but reduces the carrying capacity by approximately 2 t. In Australia, there is greater variation in the tare of the trucks, which significantly impacts the net payload to be transported. Thus, considering the current rate structure of forest transport in Australia (pay per green ton), increasing payload represents one of the greatest opportunities to reduce transport costs, where each extra kilogram in net load represents between € 3.5 and 7 of saving per year. Increasing net load reduces costs and can also reduce fuel usage and carbon emissions by 3% to 5% for each tonne increase in payload.

The risk that represent the slippery surface of debarked logs of Eucalyptus has created the need to change the legislation in the codes of forest practices existing in some states like Tasmania and Western Australia. Thus, legal regulations have been put in place which require the use of protection systems located on the back of trailers and semi-trailers (Figure 3), which must meet certain engineering requirements, materials used and construction specifications.

Figure 3. Protective rear guard used in semitrailers for the transport of Eucalyptus logs in Tasmania, Australia

In a study carried out in Australia (Brown, 2008), the variation of the tare of four truck configurations: semitrailer, with two semi-trailers (B-double), and with semi-trailer + Train and road-train) was studied. Table 4 shows a summary of the study results, including cost, fuel consumption and CO2 equivalent emissions per tonne of transported wood. Considering only the impact of the tare, savings of € 1.14 to more than € 3.75 per tonne are possible depending on the configuration class. In addition, it is also possible to save fuel and emissions.

In both countries, changes are taking place to allow the circulation of vehicles with a greater load capacity. In Spain since 2016 there is the possibility of running vehicles with the EMS (European Modular System) configuration, named megatrucks, with a GVM of up to 60 t, but limited to maximum distances of 150 km. The latter regulation limits its practice as average transport distances in the forest sector exceed 300 km (Picos, 2011).

In Australia, some changes have also taken place in order to increase the GVM that is already far higher than in Spain. The National Road Transport Commission (NRTC) introduced in 2006, the Performance Based Standards (PBS) program. This program was accompanied by new legislation, under which it is allowed designing and using alternative configurations of larger vehicles on roads that until that time were only enabled for lower tonnage configurations. To be approved, the proposed configuration must meet a series of performance requirements in terms of impact on infrastructure, safety and social acceptability. It must pass a series of tests of longitudinal performance (at slow and high speed), directional performance (at slow and high speed), and impact to infrastructure. Since the introduction of the program, three new configurations have been proposed with equal or better performance on routes that are limited only to trucks with a semi-trailer. Figure 4 shows one of these configurations, which corresponds to a truck with two semitrailers (Quad B-double) to which a fourth automatic directional axis has been added. It is designed for the transport of woodchips and allows a 20-t increase in net payload for a truck with two conventional semi-trailers (NTC, 2007).

Table 3. Effect of tare on costs, fuel consumption, and GHG emissions

Configuration	Tare weight scenario	Average tare (kg)	Per tonnes transported		
			Cost (€)	Fuel (L)	Emissions (kg CO2)
Semitrailers – 42.5 t GVM	Lightest tare	15,374	11,83	3,65	9,87
	Average	18,432	13,50	4,27	11,53
	Heaviest tare	21,343	15,58	5,03	13,58
Two semitrailers (B-double, 62.5 t GVM)	Lightest tare	20,272	8,44	2,97	8,01
	Average	22,651	9,00	3,20	8,64
	Heaviest tare	27,907	10,56	3,85	10,41
Semitrailer + trailer (pocket-train, 79 t GVM)	Lightest tare	23,976	7,60	2,71	7,32
	Average	29,205	8,51	3,11	8,41
	Heaviest tare	36,188	10,09	3,8	10,27
Semitrailer + trailer (pocket-train, 82. t GVM)	Lightest tare	26,830	7,40	2,83	7,63
	Average	29,450	7,82	3,02	8,17
	Heaviest tare	33,409	8,54	3,36	9,08

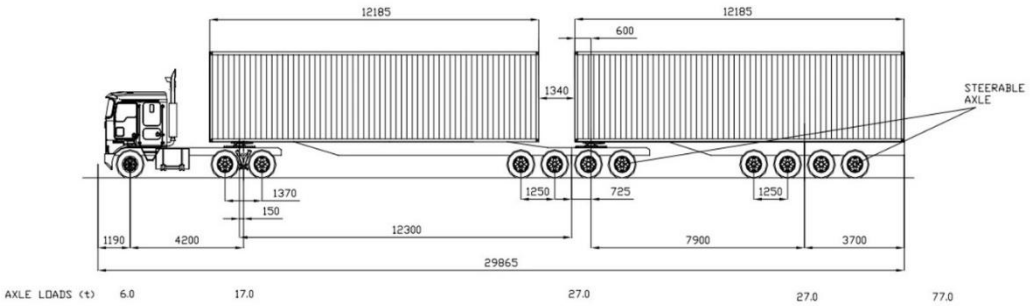

Figure 3. Configuration of a high productivity vehicle in Australia (Quad B-double)

Managing moisture content to improve transport efficiency

A promising line of research concerns with controlling and managing the MC of roundwood and biomass in the forest before transportation to customers, which can lead to substantial savings in transport costs. Drying maximizes the volume capacity of trucks while meeting legal GVM, with the consequent reduction in transport costs (Acuna et al. 2017, Belart et al. 2017).

Transport rates in both Spain and Australia depend on distance and weight. This commercial mechanism (payment per tonne) encourages the quick delivery of the wood after harvesting, although this increases transport costs on a per volumetric or dry tonne basis. In some cases, the humidity of the products delivered is usually higher than the humidity specified by the mills. These issues represent a big opportunity for the implementation of moisture management control mechanisms along the supply chain.

In Australia, when wet logs are moved from forest coupes to customer sites, most trucks only occupy between 60% and 80% of the volume capacity without exceeding the maximum legal GVM, which causes a significant increase in transportation costs on a per cubic meter basis. Figure 5 shows the effect of moisture content (MC) on the volume capacity (expressed in %) for a semitrailer moving 10-m Eucalyptus nitens logs in Tasmania, Australia. This configuration has a transport capacity of 30.5 solid m^3, with a maximum legal GVM 45.5 tonnes (net load of 29.5 t assuming a tare weight of 16 t).

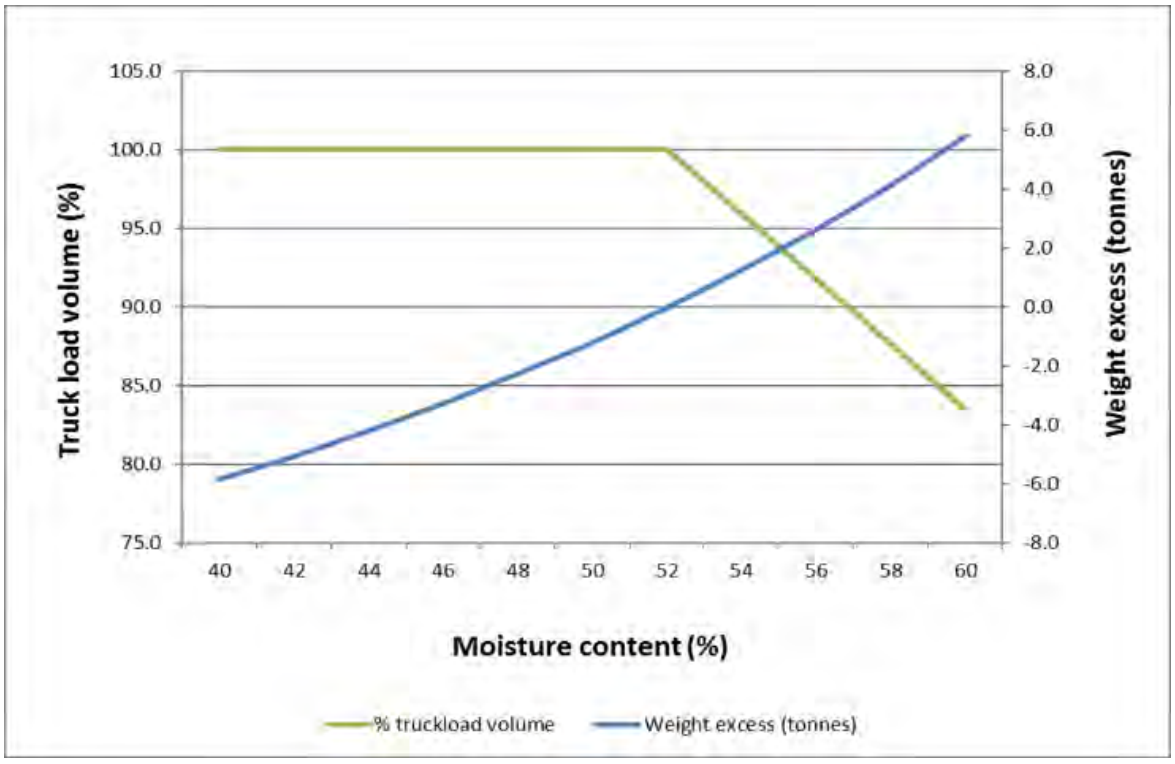

Figure 5. Effect of MC on transport capacity. Example for semitrailers moving long Eucalyptus nitens logs in Tasmania, Australia

After harvesting, logs have a MC of approximately 60%, and therefore, the load capacity of the truck is restricted by the legal maximum GVM. With a moisture content of 60%, it is only possible to load the truck with approximately 82% of total available volume without exceeding the legal maximum GVM of 45.5 t. This 82% corresponds to 25 solid m^3 of the available total of 30,5 solid m^3. It is observed in Figure 5 that, to maximize the volume capacity of the truck without exceeding the maximum legal GVM, it is necessary to reduce the MC to 52%. With a MC lower than 52%, the maximum load to be transported is limited by the volume capacity of the truck, and not by its weight.

For the previous example, Figure 6 shows the effect of MC on transport cost per m^3 and on the fleet size required to transport an annual volume of 1 million tonnes of logs. In the case of the transport cost per m^3, this is minimized (15 €/m^3) when the MC is 52% or less, since that at that point, the amount of volume to be transported (30.5 m^3) is maximized. With MC values greater than 52%, it is no longer possible to maximize truck volume without exceeding the legal maximum weight. Therefore, in this range the transport cost increases gradually as the MC increases, reaching a value of 18 €/m^3 when the CH is 60%. In this example, the saving in transport costs reaches € 3/m^3 when reducing MC from 60% to 52%. In the Spanish case, this could represent a saving of approximately 10%, or about € 400,000 annually, for a large company (paper mill or board industry).
Another important impact of reducing MC is on the size of the fleet required to deliver a given annual volume of roundwood to mills. Assuming a volume of 300,000 m^3 to be supplied annually, and 3 daily trips per truck, 31

trucks are required daily to move this volume if the MC is 52% or less. If the MC is greater than 52%, the number of trucks required to move the same volume of wood increases gradually, reaching 38 trucks when the CH is 60%, which represents an increase of 22.6%.

Internationally, the problem of transporting wood with a high MC has been acknowledged by the forest industry. Several forest companies have started to implement roundwood and biomass drying programs in the forest, and to use state-of-the-art technologies such as laser systems, stereoscopic cameras and 3D reconstruction software for automated measurement of truckloads at pulpmills and sawmills. Payment systems and commercial agreements have also begun to be implemented based on the volumetric measurements made with these technologies (Acuna, 2017).

In Australia, the time of harvest depends on the owner (i.e forest company), and the transportation of the products from the forest to the plants of consumption is organized by the haulage contractor, with some control by the forest company. This brings some process management efficiencies but produces inefficiencies for the overall transport process, especially when several types of products are to be delivered to different customers. In Spain, it is the buyer of the timber who assumes the management of the transport, but usually in coordination with the customers. In both cases, the transport operations are executed according to the levels of production in the forest as well as customer demand. However, other integrated delivery schemes allow the centralized management of transport operations, considering the concatenation of operations in a scenario of origins and destinations that changes over time. Many other industries include this type of transportation planning for the daily scheduling and dispatch of the truck fleet, aiming at reducing costs and improving the coordination of trucks and products delivered to destinations. The difficulty of implementing these systems lies in that the conditions of transport are determined by three independent economic agents, the customer, the buyer of the timber, and the haulage contractor.

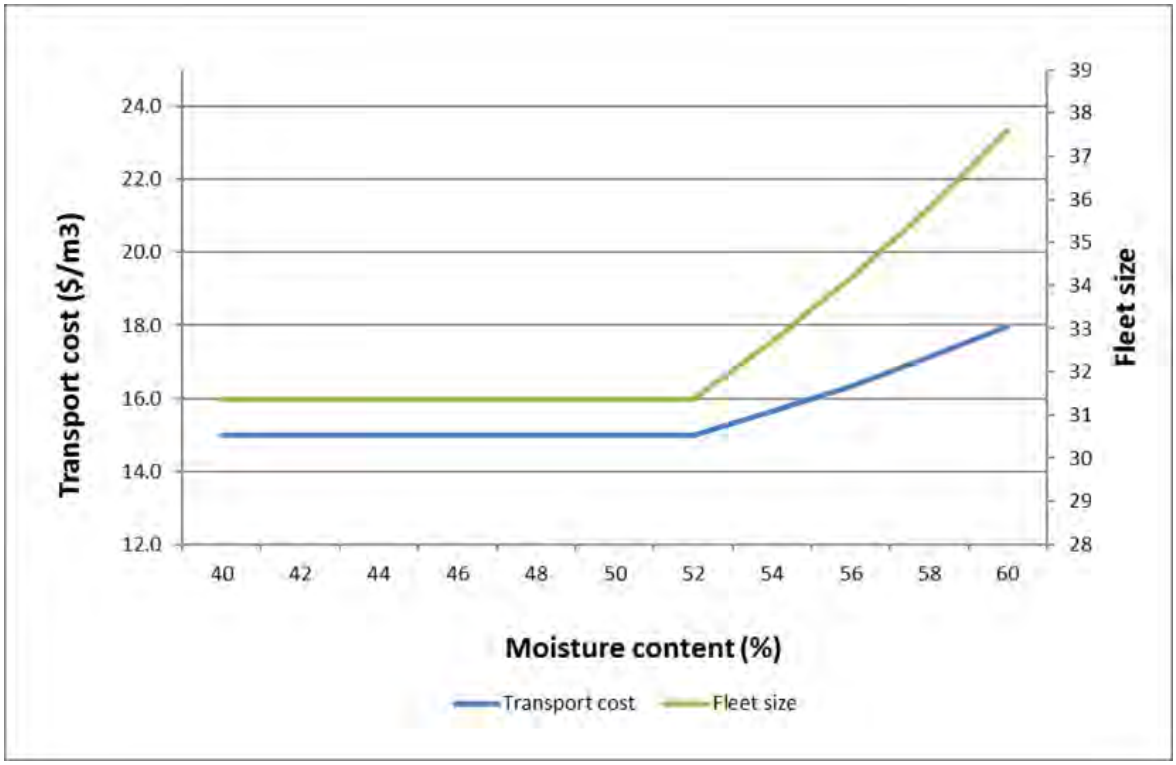

Figure 6. Effect of MC on transport cost and fleet size. Example for semitrailers moving long Eucalyptus nitens logs in Tasmania, Australia

A very common practice in Spain is the search for profitable returns (backhauls) for distances over 150 km. It is sought to minimize the number of medium and long distance empty trips by looking for complementary loaded trips, which may be of products other than roundwood. This practice makes the planning of operations even more complex, but necessary for an optimal management of the trucking operations. The practice of returns is less common in the Australian forestry sector. Another important difference between the two countries is the size of the harvest units. Small harvest units in Spain increase harvesting and haulage costs (Tolosana, 2015). This

atomization multiplies the possibility of incomplete loads, and makes transport planning more complex. This in part explains why according to the data from the Permanent Road Transport Survey (Picos, 2011), forest trucks only move an average of 72% of the maximum net payload.

Improving transport operations in Australia

In Australia, although the adoption of models and computational tools for forest transport planning has not been extensive, some companies are considering the implementation of monthly and daily planning systems in order to reduce transportation costs and meet the requirements of its customers. The following is a summary of two transport planning tools developed in Australia: MCPLAN and FastTRUCK (Acuna, 2017):

MCPLAN is a tool developed and designed to optimize timber and biomass supply chains (Acuna et al. 2017). It provides spatial and temporal solutions, which include volumes to be harvested per period and supply point, drying times for roundwood and biomass, and flows from supply to demand points. MCPLAN is a useful tool for a company with an integrated supply and demand of products. MCPLAN is a tool that runs a linear programming (PL) model implemented with Visual Basic™ macros and solved with the What's best™ solver add-in for MS Excel™. The objective function of the PL problem minimizes the total supply chain cost, which includes the costs of harvesting, drying, transport and chipping. The model also includes some restrictions to ensure that the volume of roundwood and waste available in each area of supply is not exceeded and that the monthly demand of the consumer plants for these products is met, among others. Recently, MCPLAN was used in Asturias, Spain, to study and analyze the effect of MC on storage, chipping and transport costs delivered to plants and power plants under different operating and drying MC scenarios (Acuna et al. 2017).

FastTRUCK is a software tool developed to assist transport and forest managers in solving the daily truck scheduling problem. FastTRUCK uses a standard Simulated Annealing (SA) procedure, which is encoded in the C++ programming language, using an object-oriented design (Acuna & Sessions, 2014). The tool has been implemented in the Qt programming framework to provide users with a friendly graphical interface (Figure 7) so that they can easily import input data from MS Excel™, review and modify parameters, display numerical and graphical solutions, and export output data back to MS Excel™.

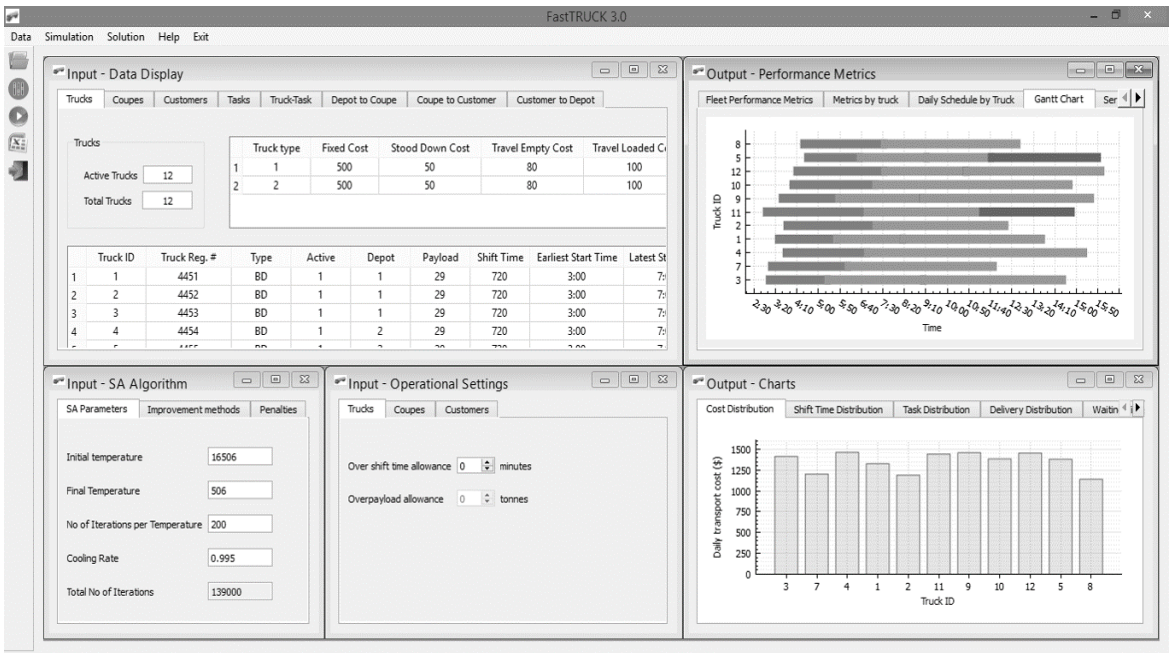

Figure 7. Graphical user interface of FastTRUCK scheduler.

The use of FastTRUCK allows forest companies to reduce costs in their daily transport operations, and its integration with flow optimization tools such as MCPLAN (which provides the transport tasks that are used as an input by FastTRUCK), provide solutions that help pinpoint inefficiencies across the planning spectrum which involves annual, monthly and daily transport decisions. Once a run is completed, FastTRUCK provides a report

containing critical statistics at a fleet and truck level. These include among others, optimal fleet size, total and unit cost, daily volume moved from wood pickup points to customer sites, average truck utilization, and average waiting time. In addition to performance metrics, the model generates a work schedule for the trucks which can be used as a guide by dispatchers to control the allocation of trucks to tasks during the day.

Conclusions

Although it is recognized that the efficient transport of roundwood and biomass is of a high importance for the overall profitability of the forest sector, little has been done in Spain to introduce new transport management systems and technologies, and truck configurations. In Australia, innovations are being developed and implemented to improve the economic and environmental efficiency of transport. The percentage improvement margins might seem not large in terms of unit weight or volume, but considering the total volumes of raw material that are mobilized annually, both forest companies and haulage contractors can see substantial improvement in their profitability. In Spain, the current initiatives have focused on a regulatory change by the Administration that allows a greater load per vehicle; other initiatives which have been presented in this paper should also be included in the discussions.

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PRE-FEASIBILITY STUDY OF SUPPLY SYSTEMS BASED ON ARTIFICIAL DRYING OF FOREST CHIPS MADE OF DELIMBED STEMS

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Abstract: *This study was aimed at determining the maximum cost level of artificial drying required for cost-efficient operation by means of system analysis, in which the harvesting potential and procurement cost of alternative fuel chip production systems were compared at the stand and regional level. The accumulation and procurement cost of chips made of delimbed stems were estimated within a 100 km radius from a hypothetical end use facility located in Rovaniemi in North Finland. The comparisons of alternative supply chains started with organizing the timber purchasing and procurement activities, continued onto logging, transporting, chipping and delivery of fuel chips to the end-user. Transporting costs were calculated according to new higher permissible dimensions and weight limits for truck-trailers. Stumpage prices, tied up capital, dry matter losses and moisture content of harvested timber were also considered in the study. The results were expressed as Euros per solid cubic meter (€ m^{-3}) or Euros per megawatt hour (€ MWh^{-1}). Moisture content of artificially dried fuel chips made of fresh timber was 20%, 30% and 40% in the comparisons. Moisture content of fuel chips based on natural drying during storing was 40% respectively.*

Keywords: fuel chips, heating value, procurement, harvesting

CHARACTERISTICS AND IMPROVEMENT OF FORESTRY WORKERS TRAINING IN CROATIA

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Abstract*: Vocational training of the workers in forestry sector is considered as a key element for safe operations in forestry and a basic condition of quality and effectiveness of labour in forest production. This paper discusses the key issues of forestry workers training in Croatia, and especially deals with the providers of vocational training, their profile, services and training procedures. Based on the conducted analysis, paper also elaborates and proposes measures necessary for improvements in the forestry workers training system. The research was conducted during 2016 and it included 94 legal entities authorized for occupational safety training in the Republic of Croatia. The characteristics of legal entities providing training for forestry workers, with the respect to a) safe working practice training and b) vocational training for operating machinery (chainsaw and/or skidder), were researched by using questionnaire. Parallel to the questionnaire, on-line website search and analysis of legal entities was conducted in order to determine their profile and services they provide. Research results show that 30.85% of investigated legal entities provides only training for safe working practice, 15.96% provides both trainings – safe work practice and vocational training for operating machinery, 5.32% of investigated entities provides only vocational training for operating machinery, 31.91% does not carry out any form of training in forestry, while 15.96% did not want to answer questions. On the other hand, 15.96% of the same legal entities, which do not carry out any training or did not answer this question, have on their official website stated services for vocational training in operating machinery (chainsaw and/or skidder). The key findings of the conducted research have pointed out the great heterogeneity amongst providers of forestry workers training, and certain reductions or limitations in the current training programs, both from the aspect of duration of the theoretical and practical training, and the use of non-transparent criteria and standards in the assessment of carried out training. As an example of successful solution in forestry workers training, European Chainsaw Standard model (ECS) is shortly presented in the paper. ECS represents developed system of training certification where, through forestry training centers, training knowledge and skills must be confirmed by the mandatory inspection and certification. Regarding possible implementation of European Chainsaw Standard model, training status of forestry chainsaw workers in Croatia is additionally discussed. In connection to this, paper also provides an overview of legislative and organizational requirements for the application of previously developed European model (ECS) in the building of certification system for training of forestry workers in Croatia.*

Keywords: forestry, chainsaw worker, health and safety, vocational training, certification, Croatia

OPENING UP OF SEMI-MOUNTAINOUS FOREST AREA AND ENVIRONMENT

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Abstract: *The roads of the forest complex Kimmeria - Xanthi - Geraka serves quite well the needs of the region both logging and tourism. Nonetheless, however, its completion and improvement will create favorable conditions to meet the requirements of modern forestry. This paper aims to improve forest road network and the skidding and transport conditions of wood to meet the conditions for a rational management of the forest. With the completion of the proposed road network in forest complex of Kimmeria - Xanthi - Geraka will create favorable conditions that will influence, facilitate and improve substantially: Carrying out the skidding of wood with modern instruments and new methods, both in terms of silvicultural goals, and technical requirements; Creating for both the skidding and for the transport of wood favorable conditions for technical and economical point of view, which substantially affect the extent and intensity of the forest operation; Better performance of forest operations; The movement of forest personnel and forest workers for better implementation, surveillance and protection of the forest; Transportation of materials and equipment for carrying out any work of afforestation etc; The increase in tourism and the exploitation of sites appropriate for recreation.*

Keywords: forest operations, sustainable, rational, exploitation, improvement

OPENING UP OF A GREEK MOUNTAINOUS FOREST AREA FOR TIMBER TRANSPORTATION AND PROTECTION

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Abstract: *The projects related to forest opening up constitute fundamental infrastructure projects for the development of our mountainous and semi-mountainous national economy. In the beginning, timber transportation and connection between forest settlements served as the sole purpose of forest opening up. However, nowadays, the perspective of forest opening up as being an important preventive measure of forest protection, which is a basic pillar of a multipurpose forestry system of the Greek Mediterranean mountains, is gaining ground. The productive forest ecosystems of Greece are mainly found in semi-mountainous, mountainous and inaccessible areas with high relief, adverse territorial and climatic conditions and uneven distribution of vegetation; a reality which hinders the design of forest network to be used as a guarantee for the development of the mountainous areas. The public forest complex in the region of Vria-Ritini of the Pieria Prefecture has been selected as the research area. The recording and the digital processing of geographic data is materialized through the implementation of contemporary methods of spatial analysis and instruments of precise depiction which have provided the framework of spatial distribution. In this paper, the construction of a model mobile crane of wire rope at a remote tree cluster with steep slopes and altitudes up to 2,000m. with its two-dimensional usage contributing both to the forest complex protection as a firebreak zone and the facilitation of the timber transport of large volume wood stock is suggested. Nowadays, the basic purpose is the environmental opening up of mountainous ecosystems and the safe access through them.*

Keywords: Forest opening up, development of mountainous areas, timber transportation

APPLICATION OF PERT & CPM FOR FOREST UTILIZATION PLANNING

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Abstract*: This study was carried out in order to use of PERT and CPM in forest utilization planning. The current study was done in Darab-Kola forests and it was also tried to use the modern PERT and CPM in order to properly plan the logging project. Firstly, logging data of one cycle was collected and it was then processed and prioritized and after that the software input was determined. In the next stage, by putting input into the QSB software and running it, the output was provided. Data analysis addressed that 229 days are needed as a required normal time to complete the project which can be reduced to 171 days with a principal and appropriate management so that the quality would not lose. However, respecting traditional form of utilization, it takes much greater time more than estimated time. So, concerning the long time needed for work process, the project costs increases accordingly. But it would not happen in case of accurate logging planning. In this research, it was suggested that the time and costs of utilization operation could be managed using PERT and CPM and finally obtained an appropriate outcome by applying them in order to improve the work as well. Application of the above mentioned methods has a favorable effect on increasing efficiency of the production indices. Moreover, such management methods can determine the related obstacles on the way of forest utilization and also remove them from the work procedure.*

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

TRAINEES' PERCEPTIONS OF LOGGER TRAINING: THE EFFECT OF COURSE DEMOGRAPHIC VARIATION ON SURVEY OUTCOMES

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Abstract: *Logger training has received a strong impulse in the past decade, in an attempt to improve work safety and increase the competitive capacity of the forest industry. Training courses have become a fundamental step in the path towards logger certification, which has been promoted in many countries across the globe. Therefore, the question arises about the efficiency of these courses in transferring new competence to the intended users. Given the very large effort invested in logger training, it makes sense to search for the most efficient way to achieve its main objectives. The authors analyzed the participant evaluation forms collected from ca. 100 logger training courses, held in Piemonte - northern Italy - from 2008 to 2016. Evaluations were structured according to different subjects, including: contents, resources, organization, teaching staff and competence gains. Evaluation results were associated with the participant demographics recorded for each course, including: age, occupation, residence, nationality etc. Statistical analysis allowed disclosing significant relationships between user satisfaction and user type. This way, one detected the main general strengths and weakness of all current courses, as well as specific strengths and weaknesses that concern specific user types. These results may lead to refining course design according to user profile, with the intent of increasing both efficiency and satisfaction.*

Keywords: education, safety, operator, company

PRODUCTIVITY OF CTL HARVESTING BY OPERATORS' AGE AND EXPERIENCE

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Abstract: *The aim of the study was to examine the influence of operators' age and experience on mechanized cut-to-length (CTL) harvesting productivity in clear cutting and thinning. The data were long-term data from 28 operators and 38 CTL harvesters collected from southern Finland. Recorded productivities were converted to relative productivities and average productivity models were created. Case specific productivities were compared to modelled values, and productivity ratio models including separate lower and upper quartile models by age and experience were produced. The peak productivity was in the age range of 40 to 45 years, after which there was a slight decrease. The relative productivity at the age of 45 years in clear cuttings was 17.8% higher and in thinnings 14.9% higher than at the age of 25 years. The relative lower quartile productivity increased from age 25 to 45 years 38.6% in clear cuttings and 29.4% in thinnings. The relative upper quartile productivity increased only 5.7 % in clear cuttings and in thinnings, there was no statistical relation between age and upper quartile productivity. Experience of 20 years produced 23.6% higher relative productivity in clear cuttings than experience of 3 years and 16.2% higher in thinnings, respectively. Increased experience improved lower quartile relative productivity 43.1% in clear cuttings and 29.1% in thinnings from 3 years' experience to 20 years' experience. Statistical analysis showed that there was no statistical correlation between upper quartile productivity and experience among studied CTL harvester operators.*

Keywords: human influence, harvester operator, learning, ageing, experience

SIMULATION OF BOOM-CORRIDOR THINNING USING A MULTI-TREE FELLING-HEAD MOUNTED ON A PROCESSOR-BUNDLER

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Abstract: *In the Nordic-Baltic region delayed pre-commercial thinnings have become a problem due to the high operational costs in relation to the value of the harvested biomaterial. However, ignoration of silvicultural acts during this early part of the rotation period risks future incomes. Although this problem is generally acknowledged, efficient biomass harvesting-cleaning systems for over-dense stands are few. Therefore, two following prototypes are of interest: Cintoc, double-crane small-tree processor-bundler, and Flowcut, multi-tree felling-head for continuous cutting. Cintoc's novelty is an automated robot crane which retrieves accumulated (tree-)bunches from the operator-controlled felling-head. The robot crane delivers bunches to the automated bundler where they are compressed, bundled, and finally dropped off. Flowcut uses a fixed saw sword and four pairs of accumulation arms for continuous cutting and accumulation. We simulated Cintoc, equipped with Flowcut, using field-study data from Flowcut boom-corridor thinning in over-dense stand as input-data. Simulated system configuration was found sensitive for inconstant number of harvested trees per boom-corridor, which in turn is typical for thinning of over-dense stands. Firstly, in 16% of work cycles, this sensitiveness caused waiting time for the operator-controlled felling-head. Although waiting times were short, they must be avoided as felling-head productivity affects directly the system's overall productivity. Secondly, this sensitiveness made retrieving of harvested material from felling-head to the robot crane inefficient, which also directly affects the overall productivity. Despite the weaknesses, the system's overall productivity was similar with closest rival, Fixteri. Moreover, the weaknesses are not fundamental but can be solved by work-methodological and technical adjustments.*

Keywords: pre-commercial thinning, silviculture, bioenergy, discrete event simulation

DETERMINING THE VIBRATIONS TRANSMITTED BY ELECTRIC CHAINSAWS IN CONIFER CROSS-CUTTING OPERATIONS

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Abstract: *In forest operations, motor-manual tree felling and processing by chainsaw are very common in many Countries. In fact, the introduction of mechanised harvesting is limited in several Countries due to terrain conditions (e.g. steep terrain), ownership fragmentation thus making it difficult to introduce safe mechanised methods. Workers engaged in motor-manual operations using chainsaws are exposed to unfavourable environmental conditions that can lead to occupational diseases over time. The main hazards associated with chainsaw use include noise, vibration stresses, and the exposure to wood dust and exhaust gases.*

In this study the vibrations transmitted to the hand-arm system during cross-cutting operation were measured. They are responsible of negative consequences for the vascular, neurological and muscular systems and for the bony tissues. In order to analyse the outcome of different factors on both vibration characteristics and forest workers exposure in chainsaw handling, the following aspects were considered:

- *chainsaws: two cordless electric chainsaws powered by Li-Ion batteries were compared to two wired electric chainsaws;*
- *forest operators: chainsaw were handled by three forest workers with high training level and experience;*

The chainsaw vibrations were measured in conifer cross-cutting operations.

The main results obtained allow to state some considerations:

- *the values of vibrations transmitted to the operator resulted lower for cordless electric chainsaw than wired electric ones;*
- *operator behaviour in chainsaw's handling may influence the amount of vibrations measured.*

Cordless electric chainsaws appear functional and suitable especially for pruning and garden operation on small wood diameters (about 20 cm), while wired models are more functional for non-professional use.

Keywords: vibrations, chainsaw, batteries, safety

DETERMINATION OF FOREST ROAD SURFACE ROUGHNESS BY KINECT DEPTH IMAGING

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Abstract: *Roughness is a dynamic property of the gravel road surface which affects safety, ride comfort as well as vehicle tire life and maintenance cost. A rapid survey of gravel road condition is fundamental for an effective maintenance planning and for the definition of the priority of interventions. Different non-contact techniques such as laser scanning, ultrasonic sensors and photogrammetry have been recently proposed to reconstruct three-dimensional topography of road sur-face and to allow extraction of roughness metrics. The application of Microsoft Kinect™ RGB-depth camera is here proposed and discussed for collection of 3D data sets from to sup-port the quantification of surface roughness of gravel roads. The objectives of the work are: i) to verify the applicability of the Kinect sensor for to characterization of different forest roads, ii) to identify the appropriateness and potential of different roughness parameters and iii) to analyze the correlation with vibrations recoded by 3-axes accelerometers installed in the frame of different vehicles. The test took advantage of the implementation of the Kinect depth camera for surface rough-ness determination of 4 different forest gravel roads and of one well maintained asphalt road as reference surface. Different vehicles (a mountain bike, an off-road motorcycle, an ATV vehicle, a 4WD car and a compact crossover) were included in the experiment in order to verify the vibration intensity when traveling with different road conditions. Finally, correlation between the extracted roughness indexes and the vibration levels of the tested vehicles were verified. Coefficient of determination comprised between 0.83 and 0.97 were detected between average surface roughness and standard deviation of relative accelerations, with higher values in the case of lighter vehicles.*

Keywords: gravel road, roughness, vibrations, RGB-depth camera

PLANNING OF FOREST HARVEST

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Abstract: *Performance of logging machines and technologies is usually modeled with functions depending on either assortment volume or mid-length diameter. These predictors are rather parameters of the harvested timber. When the timber is still standing, they have to be determined by means of volume and assortment models. Perhaps, a better idea is to apply the performance equation to the assortment table and then to fit the results to an equation depending on breast-height diameter. This operation was made with the Bulgarian standard performance model which is essentially a combination of the German EST and the Check performance standards for timber extraction with tractors and horses. The equations obtained are quite easier to use for planning of logging. The transformation error is minimal.*

Keywords: logging, performance, preliminary calculations

WHAT DENSITY OF STRIP ROADS FOR EARLY THINNING? PRODUCTIVITY AND COST OF VARIOUS MECHANISED THINNING OPERATIONS IN 2nd AGE CLASS PINE STAND

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Abstract: *Small harvesters used for early thinning usually have short cranes, less than 10m in length, which is rather impractical in stands where the distance between strip roads is a standard 20 m. The aim of this research was to find out how the distance between strip roads and a different organisation of thinning (T) operations impacts productivity and the cost of harvester (H) and forwarder (F) use. The research was carried out in a 31-year-old pine stand (11.27 ha) in which three different HT operations were designed: HTA - with midfield and one harvester pass, HTB - with midfield and two harvester passes, and HTC - without midfield and one harvester pass. On the midfield the trees were cut with a chainsaw and felled towards the nearest strip road. In all the proposed operations, a Vimek 404 T5 harvester (with 4.6 m long crane) and a Vimek 606 TT forwarder were used. The average productivities were similar: 4.84, 4.55 and 4.50 m3 h-1 in HTA, HTB and HTC, respectively. The costs for both machines (including the chainsaw use in HTA and HTB) were the lowest in HTC (€ 13.41 m-3) and the highest in TB (€ 15.34 m-3). In HTA, the costs amounted to € 14.10 m-3. Taking into account two aspects - the density of the strip roads and the cost of the thinning operation - HTA should be recommended in 2nd age pine stands as it is only 5% more expensive than HTC, but needs 50% fewer strip roads in the forest.*

Keywords: midfield, small harvester, short crane, chainsaw

THE ANALYSIS OF CONIFEROUS LOGS TOP DIAMETER MEASUREMENT ACCURACY UNDER BARK USING HARVESTER AND 3D SYSTEMS

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Abstract: *High productivity and more value-added production are the main strategies for Latvia sawmills. Sawing the appropriate products from each log and group of logs pre-sorted according to roundwood top diameter values under bark has always been actual for each sawmill. The requirements of sawn timber specification have been used for preparation of the roundwood specification where top diameters, max. diameters and lenght parameters have been determined. These parameters have been reflected in a harvesting task where for each top diameter group the appropriate lenght dimensions are identified. Technological process has been organized by adjusting the cut to each log as they are sawn according to sawn timber specification. Therefore, almost all larger sawmills in Latvia are pre-sorting the logs by top diameter values devided in groups. The top diameter (cm) groups of coniferous logs harvested in Latvia are: 6x10; 10x14; 12x18; 14x18; 18x28; 28>. Coniferous logs harvested according to the harvesting task requirements regarding to the top diameters have to be rejected or reducted in lenght in case if the parameters measured in sawmills using 3D systems won`t correspond to specification. The purpose of this study is to assess the impact of harvester calibration on the ac-curacy of coniferous logs top diameter measurements under bark by Measuring Diameter in Short Intervals using electronic 3D systems.*

Keywords: harvester calibration, coniferous logs, top diameters

TIMBER HARVESTING METHODS IN EASTERN EUROPEAN COUNTRIES

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Abstract: *The social and economic changes that began over 25 years ago in post-communist Eastern Europe and the countries of the former Soviet Union also affected the forestry sector. Forested areas were privatized in many countries, and timber harvesting, also in state-owned forests, was contracted out to private sector logging companies. An analysis was conducted of the following countries: Belarus, Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia, and Ukraine. The basic parameters of forestry were characterized for each country. Special attention was paid to the methods of timber harvesting. The main findings of the study are that various methods are used in Eastern Europe depending on site and forest conditions. In some countries, especially the wealthier ones, a dynamic increase in the cut-to-length method is observed, with the use of harvesters and forwarders.*

Keywords: forests privatization, cut-to-length method, tree-length method, timber harvesting costs, work productivity

YARDING PRE-BUNCHED STEMS IN THINNING OPERATIONS: ESTIMATES ON TIME CONSUMPTION

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Abstract: *Harvesting operations in steep terrain are particularly challenging, especially in environmentally sensitive areas and in very dense forests that are prone to more damage when using mechanized equipment. A possible approach to limit the damage is that of integrating animal and mechanical equipment. A study was carried out to see what operational variables and to what extent are they affecting the time consumption of yarding pre-bunched stems in thinning operations applied to coniferous stands. Following a time and motion study of yarding operations it was found that the extraction distance and lateral yarding distance affected the variation of yarding cycle time. Within a work cycle, load attachment and detachment accounted for almost 65%, the rest being shared by other typical cable yarding functions. The statistics and models presented in this study may be of help in production planning, research and optimization.*

Keywords: pre-bunching, animal logging, cable yarding, steep terrain, time consumption, modelling

THE SPEED OF SOUND THROUGH THE WOOD OF HORSE CHESTNUT TREES (*AESCULUS HIPPOCASTANUM* LIN.)

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Abstract: *The aim of this study was to highlight the way and the propagation speed of sound into the wood of trees. In this regard, were chosen 15 trees of horse chestnut (Aesculus hippocastanum Lin.) situated in a park from Brasov city, Romania. The investigations assumed the fixing of the sensors on the trunk of trees, at levels of 50, 100 and 150 cm above the ground. The research was conducted using an acoustic scanner (tomograph) and were analysed healthy trees and also trees with visible defects. It was found that the minimum values for speed of sound into the wood were between 147-893 m/s and the maximum values between 1275-2550 m/s, but the most of times, speeds ranged between 1001-1500 m/s. Based on the speeds of sound, it was found that the presence of the frost-cracks into the wood of horse chestnut trees can be detected using acoustic tomography. However, it is very important that, in assessing the quality of wood from standing trees and assessing of their stability, to take into account no only to the investigations made with acoustic scanner (tomograph), which offers clues only on the quality of wood at the analysed level, but also on the other tests, including the visual inspection.*

Keywords: quality of wood, speed of sound, acoustic tomograph

DETERMINING THE BEST NUMBER OF TRANSVERSAL DRAINAGE FOR FOREST ROAD BY EMPLOYING HYDROLOGICAL MODELS

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Abstract: *Several factors are involved in forest road destruction that most of them are generating as a result of rainfall runoff which directly threaten forest road pavement. To minimize these damages a well-designed drainage system appropriate to situation in watershed that reliably estimate number and diameter of culverts is needed. In this study by employing a famous hydrological model called Soil Conservation Service (SCS), Geographic Information System (GIS) and field survey, the study area was divided to 42 sub-basins. In each sub-basin, then the delivered runoff and peak flows moment were calculated using the factors of soil hydrologic groups, land use, hydrology situation, curve number and time of concentration. Proper location, diameter and number of culverts showed that the existing cross drains and their diameters were suitable to pass high possible volume of water in this area. Results showed that all of the installed culverts along the forest road had a diameter of 60 cm, while considering the result of SCS model including all effective factors they should be at least 80 cm. Result also showed that land use changing and deforestation are the main causes of high rate of runoff in the study area. On the other hand, improper maintenance of roads has been caused widespread destruction along the road.*

Keywords: drainage, forest roads, GIS, peak discharge

EFFECTS OF SKID TRAIL SLOPE ON SURFACE RUNOFF AND SOIL PROPERTIES IN THE NORTHERN FOREST OF IRAN

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Abstract: *The generation of surface runoff was studied on skid trails in the temperate forest of Iran. The aim of this study was to evaluate the effects of traffic frequency and skid trail slope on runoff and soil physical properties. Three levels of passes (i.e. 5, 10 and 15), and three levels of slope (i.e. < 10%, 10%-20% and > 20%) were studied. Surface runoff volume was greatest at the skid trail in the 15 passes and > 20% slope, and was the lowest at the skid trail with the 5 passes and < 10% slope. The undisturbed area did not generate any runoff during the observation period. The results of correlation analysis showed that the bulk density, macroporosity, rut depth, and litter cover of the skid trail had statistically significant effects on runoff. Surface runoff volume is negatively correlated with litter mass and macroporosity, but also is positively correlated with compaction and rut depth.*

Keywords: bulk density, macroporosity, runoff, rut depth, skidding

ASSESSING THE EFFECT OF ROOT NODULES OF ALDER TREES ON SOIL REINFORCEMENT AND SLOPES STABILITY

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Abstract: *Alder (Alnus Subcordata) is the most common tree at the edge of Caspian forest roads. These trees can presence on steep slopes with saturated soil. There is Symbiotic bacteria (Frankia) on the root of these trees that are important to fixing nitrogen. In addition, accumulation of these bacteria can create nodules surrounding roots that can be used for soil reinforcement. The result of this study showed that the resultant of root tensile strength and slope stability increased with increasing accumulation of nodules. According to the result, it can be understood that root nodule is a natural anchor and natural anchoring of Alder roots makes it best option to choice in the soil bio-engineering projects.*

Keywords: alder roots, anchoring, soil bio-engineering, slope stability

THE INFLUENCE OF SOILING ON THE BREAKING STRENGTH OF COVERED AND UNCOVERED 12-STRAND UHMPE- ROPES FOR FORESTRY APPLICATIONS

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Abstract: *Previous investigations have shown that the breaking force of synthetic ropes for forest applications was reduced by 20% after only a short period of use and without noticeable wear. The cause of this breaking force reduction could be the penetrating dirt between the fibers. Within this research project rope samples of different rope types will be exposed under usual field conditions in a varying extent of soiling and then its tensile strength will be tested. The results of the investigation are intended to show if and to what extent the breaking force in covered respectively non-covered ropes is influenced by soiling. The findings from this research project may facilitate the proper dimensioning of UHMPE winch ropes in order to meet the normatively required safety factor of 2 for winch ropes when using these synthetic ropes.*

Keywords: synthetic rope, tensile strength, breaking force, winch rope, safety factor

Introduction

Investigations carried out in 2013 about the correlation of the breaking strength of the ropes with their wear for the development of discard criteria for UHMPE synthethic ropes have shown that the breaking strength of the synthetic ropes decreases by approx. 20% after short contact with the ground without *noticeable or* measurable wear. Thereafter, the breaking strength is clearly correlated with the measured fiber loss by wear (NEMESTOTHY, et al, 2013).

In view of the work carried out in this project, this breaking force reduction can have 3 reasons:

(A) Penetrating dirt between the fibers.
(B) Cleaning the rope samples with high pressure cleaner
(C) Measurement of the fiber strands to determine the abrasion

Within this research project rope samples of different rope types where been exposed under usual field conditions in a varying extent of soiling and after cleaning and measuring them partly its tensile strength was been tested. The results of the investigations are intended to show if and to what extent the breaking force in covered respectively non-covered ropes is influenced by soiling, cleaning and measuring.

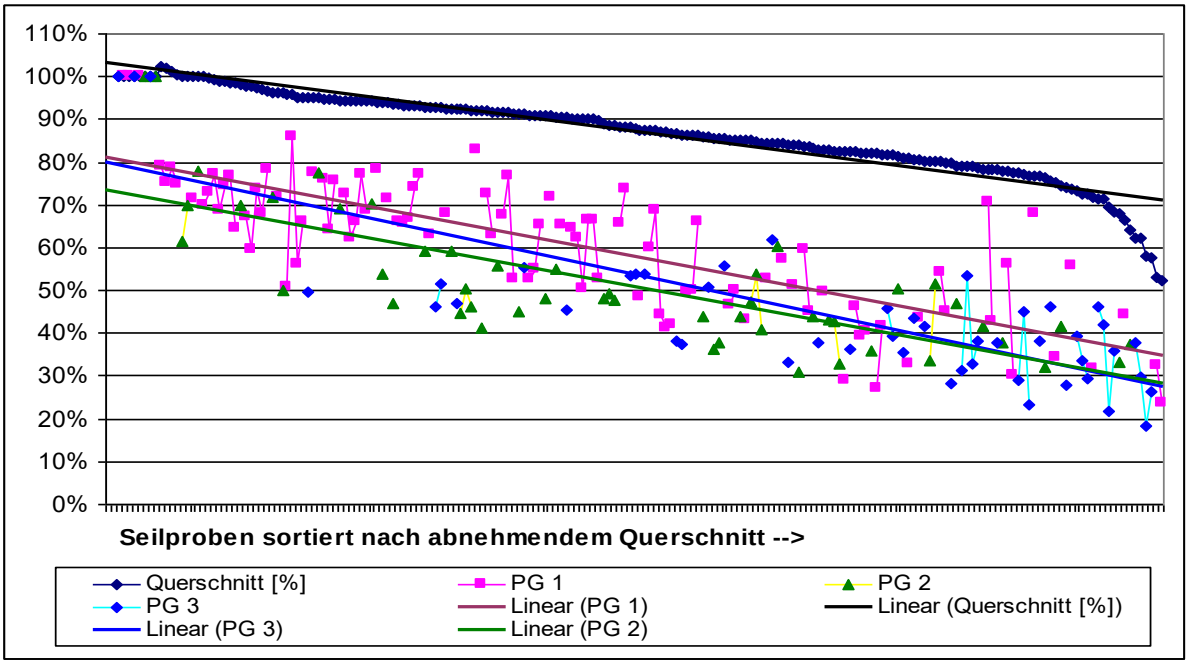

Figure 1. Breaking force in relation to the cross section in % of the data of new ropes

State of knowledge

The investigation of textile personal safety ropes made of PE, contaminated with standardized road pollution and partly washed afterwards, showed that the breaking strength of the ropes was reduced by about 32% due to the dirt entry without subsequent cleaning. Through the subsequent washing process, the breaking force loss was reduced to about 24% of its original breaking force. Washing has shown a positive effect in this case (Teufelberger GmbH, 2014).

Dyneema © ropes were not included in these studies. The considerable breaking strength loss of the ropes made of other fiber materials contaminated with dirt, however, suggests that contamination can also affect the breaking force of the Dyneema © ropes.

Goal of this Projekt

The aim of the project was to investigate the influence of soiling - but also the cleaning with high-pressure cleaners as well as the circumferential measurement of the strands - on the breaking force of UHMPE synthetic ropes. The exact knowledge of the effect of the cleaning process and the measurement is necessary to verify the results of the researches for the development of discard criteria (Dafne Project 100206 Ropesecurity 2+).

On the other hand the ability to assess the effect of dirt on the high-strength ropes is necessary when the UHMPE synthetic ropes are used as winch ropes in order to meet the normatively required double safety.

Material and Methods
Rope samples

Dyneema © Ropes of different styles from two manufacturers have been used. Three of the ropes used were constructed as an open 12-strand hollow braid. However, they differed markedly in the intensity of the pre-stretching (compaction) as well as in the composition of the strands, which consist of a different number of threads or only 1 fiber bundle, as well as in the type of impregnation.

The fourth rope, consisting of a load-bearing core rope made of 12-strand UHMPE fiber braid, covered by a jacket of "Dyneema ©" fiber, was investigated for comparative purposes.

Table 1. Plan of rope samples with different treatment

		Unsoiled reference-rope samples	Soiled in loose state			Soiled in tensioned state (approx. 500 daN tesioningforce by manual winch)			**Sum of soiled rope samples ****	**Sum of treatment variants**
			Flysch brown soil	Calcareous soil (Rendzina)	Test track material	Flysch brown soil	Calcareous soil (Rendzina)	Test track material		
Dynaforce	uncleaned	3	1	1	1	1	1	1	**6**	**9**
	cleaned	1	1	1	1	1	1	1	**6**	**7**
	cleaned + measured	2	1	1	1	1	1	1	**6**	**8**
Stratos Winch light H	uncleaned	0*	1	1	1	1	1	1	**6**	**6**
	cleaned	2	1	1	1	1	1	1	**6**	**8**
	cleaned + measured	2	1	1	1	1	1	1	**6**	**8**
Stratos Winch light S	uncleaned	2	1	1	1	1	1	1	**6**	**8**
	cleaned	0	1	0	1	0	1	1	**4**	**4**
	cleaned + measured	2	0	1	0	1	0	1	**3**	**5**
Stratos Winch Pro	uncleaned	2	0	1	1	1	0	1	**4**	**6**
	cleaned	0	1	0	1	0	1	0	**3**	**3**
Open braided rope samples treatment variants	**uncleaned ****	**5**	**3**	**3**	**3**	**3**	**3**	**3**	**18**	**23**
	cleaned**	**3**	**3**	**2**	**3**	**2**	**3**	**3**	**16**	**19**
	cleaned + measured **	**6**	**2**	**3**	**2**	**3**	**2**	**3**	**15**	**21**
Sum of open braided rope samples**		**14**	**8**	**8**	**8**	**8**	**8**	**9**	**49**	**63**
Sum of covered rope samples**		**2**	**1**	**1**	**2**	**1**	**1**	**1**	**7**	**9**
Total number of samples		**16**	**9**	**9**	**10**	**9**	**9**	**10**	**56**	**72**

*unsoiled, uncleaned rope samples of Stratos Winch light H were not tested since the cleaned samples broke at max. breaking force in their spliced eyes
** The coloured cumulative values are relevant for statistical evaluation

Preparation of the rope samples

In order to be able to clamp the test pieces for the breaking force test, loops were spliced at their two ends. Subsequently, the rope samples were contaminated with different soil material, washed and measured according to the sample plan.

Production of soil substrates for soiling the rope samples

Three soil substrates were selected for the contamination of the ropes, which often occur in Austrian forests and on the other hand represent different extremes with regard to skeletal proportions:

1. Calcareous soil (Rendzina), high skeletal part, sharp-edged grains

2. Flysch-brown soil, minimal skeletal fraction, high fine content

3. Test track soil, mixture of brown soil and calcareous gravel or sand

Contamination of the ropes with the different soil substrates

The forest floor substrates were suspended for the treatment of the ropes in a ratio of 1 part by weight of water to 3 parts by weight of soil by means of a blunger to form a suspension which was more or less viscous depending on the soil substrate.

In order to achieve a similar soiling of the ropes as can be seen in the course of working with rope winches, pairs of rope samples were formed with the same treatment, in which case one of the rope samples from the pair was treated in loose state and the second rope of the test pair was tensioned for the same treatment with a hand winch with a tensile force of approx. 500 daN. The loose rope samples were dipped in the freshly mixed suspension and were moved back and forth with simultaneous rotation about their own axis. The tensioned rope samples were poured over with the freshly mixed suspension and additionally treated by kneading the suspension with hand into the rope.

In order to simulate the practice situation when pulling the ropes into the winch and to incorporate the dirt into the rope efficiently, both the loosely soiled and the tensioned soiled ropes were subjected to manual deflection 10 times over two deflection rollers with a deflection of 180 ° respectively.

Cleaning

Cleaning of the ropes was carried out with a Kärcher 595 high-pressure cleaner with cold clean water without detergent. The high pressure cleaner generates a working pressure of approx. 90 bars according to the built-in manometer. To prohibit escaping during washing, the ropes were placed for washing in a 20 mm wide and 15 mm deep groove milled in a piece of wood. The cleaning operation was carried out with a lance of approx. 10 cm distance over the whole length of soiling (approximately 40 cm), the lance being slowly moved back and forth between the end points of the soiled section. After approx. 1 minute, the rope was rotated by 180 ° around its own axis and also cleaned 1 minute from the other side. Subsequently, the ropes were suspended and air dried.

Figures 2 and 3. Cleaning process with small Kärcher 595 high pressure cleaner

Measurement of the ropes

In order to be able to check any damage to the strands by this measuring process, 50 % of the washed and dried ropes were measured at the circumference of the strands using the method developed by the BFW.

In the case of the sheathed rope "Stratos Winch Pro", no reference rope samples were produced in the treatment variant "washed" or "washed and measured" since it was known from previous investigations that the washing with pure water has no influence on the strength of clean ropes. Further it is not possible and not necessary to measure the strands of these ropes because of the coat in any case. Only a part of the rope samples contaminated with earth suspension was washed.

Testing the breaking force

The breaking force was tested on a rope testing machine of the type Denison 500 kN with hydraulic force application at Teufelberger GmbH in Wels. The test machine is designed for cable tests with a maximum breaking force of 500 kN. The relative repeatability of the test machine lies in the measuring range used at 0.02%, the extended measurement uncertainty at 0.25% of the measured value (= ± 0.5 kN) (factory calibration certificate for tensile and compression testing machines, 2012). The breaking force was measured with a test speed of 60 mm / min. For testing, the rope samples with the two spliced eyes were inserted into the testing machine. The diameter of the studs used for this purpose on the hanger is 40 mm (Stratos winch light H - 50 mm). The path of the test vehicle and the applied tractive force are recorded automatically and the maximum force = breaking force at the end of the test procedure is displayed on the screen.

Statistical evaluation

The statistical analysis of the data was carried out at the Institute for Forest Inventory of the Federal Research Center for Forests by Berger Ambros with SPSS in the form of the two-sided T-test and the Wilcoxon signed-rank test, which led to the same results. The descriptive statistical evaluation of the data was done with MS-Excel. In a primary step, in order to be able to compare the data of the different products, the relative values for the breaking force of the worked rope samples were calculated from the absolute breaking force values with respect to the respective reference values of the unsoiled rope samples. Before further evaluations could be done, it was investigated whether the different rope products had a comparable reaction in case of soiling and post treatment variants. It was found, that the two highly compacted rope products showed nearly the same reaction, but the rope product “Stratos Winch L S” was affected considerably more strongly than the other two (Figure 6). So the product “Stratos Winch L S” was not taken into account in the further evaluation. The data from the remaining 2 rope products were then sorted and evaluated according to the three main themes, the influence of the contamination as a function of the rope condition (loose, tensioned), the influence of different soil substrates as well as the influence of the post treatment of the soiled ropes (as done in the project “Ropesecurity 2 +”: cleaned, measured).

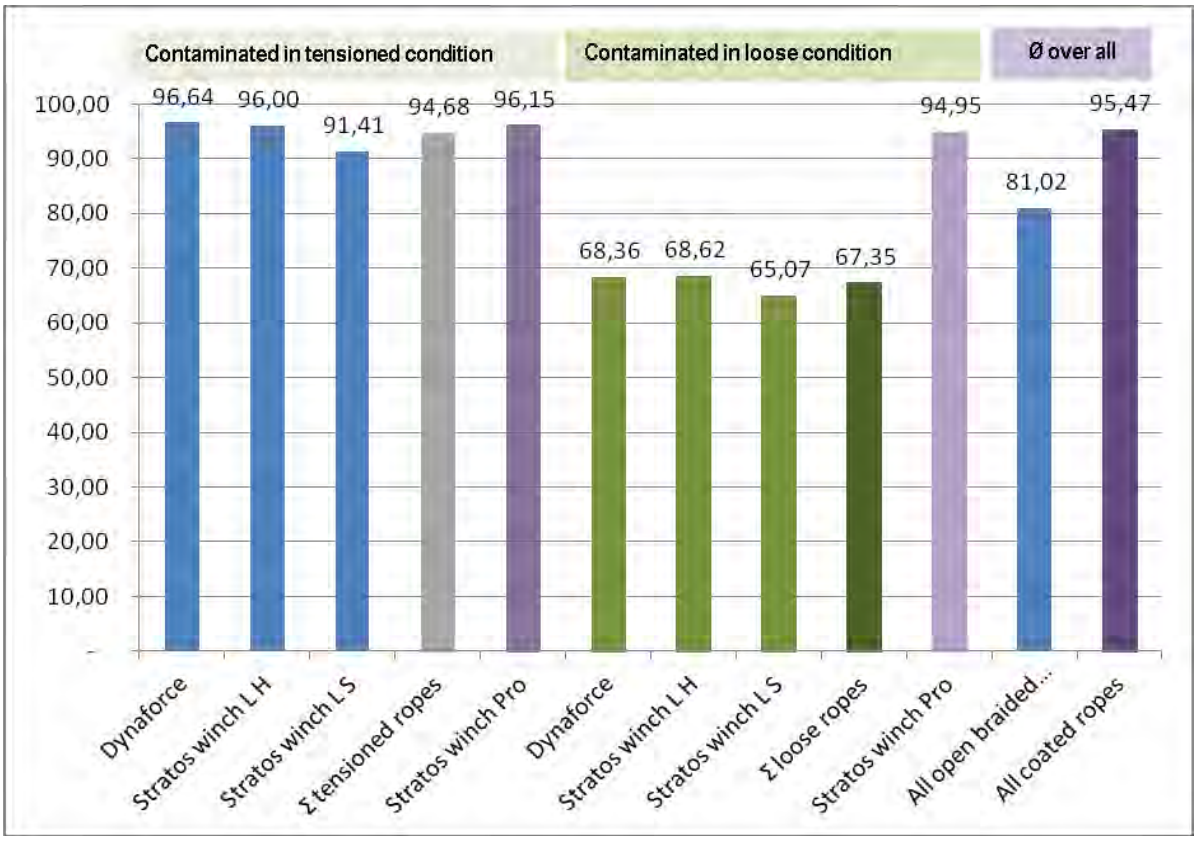

Figure 6. Reaction of rope products to soil contamination in % relative to the reference values

Results

Effect of contamination as a function of rope condition

It is as a matter of course that in the case of loose ropes penetration of the soil suspensions is much more efficient than with the tensioned ropes. Correspondingly, the reduction in the breaking force in the loosely polluted ropes reaching up to 32 % has been significantly higher than in the case of the ropes soiled in tensioned state (see Figure 7). But also the ropes contaminated in tensioned state reacted with a significant loss of breaking force, albeit only to a small extent of approximately 3.5 %.

The T test showed a p-value of 0.00273 for the loss of breaking force at the ropes soiled in tensioned state, according to that the breaking force drop by 3.5% is significantly associated with soil contamination. For the ropes soiled in loose state, the T-test showed a p-value of nearly 0. This states that the relationship between the loss of breaking force and the soiling can be assumed to be verified.

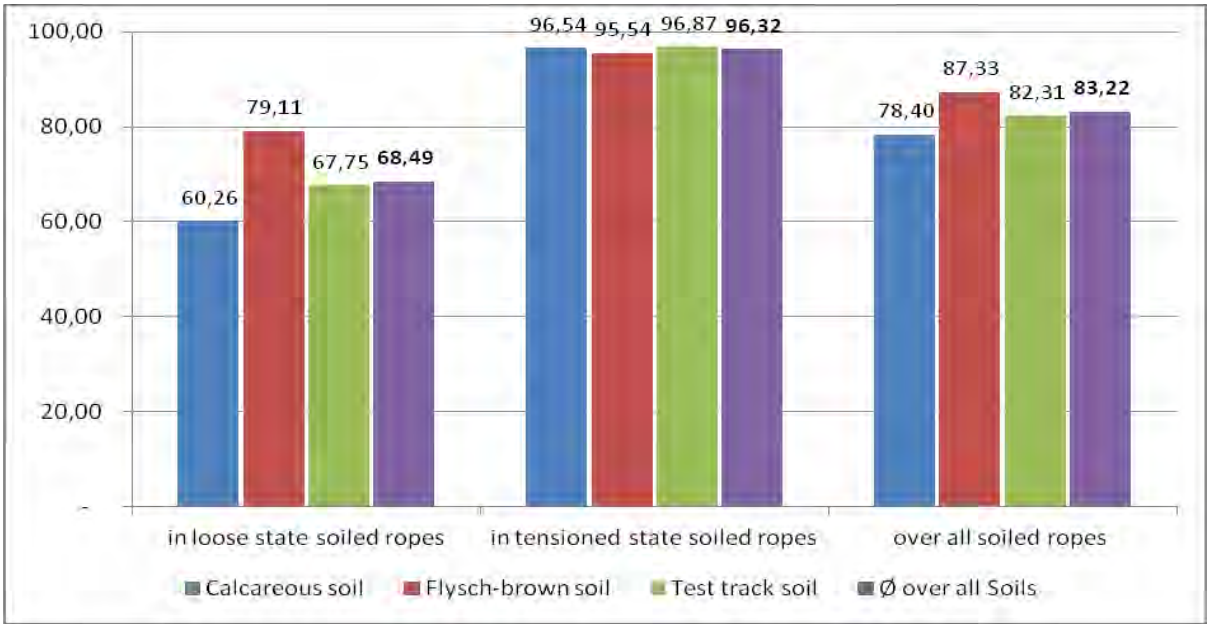

Figure 7. Effect of different soil substrates on strained and loose ropes. Breaking force as a % of the reference breaking force

Differences in the impact of different soil substrates

All of the 3 soil substrates reduced the breaking force of the ropes significantly. However, as can be seen in Figure 8 and Figure 9, the fine-grained Flysch brown soil has a significantly lower breaking force-reducing effect as the more skeletal soil substrates from Rendzina and/or Test track soil. This was particularly noticeable in the case of soiling in a loose state (see Figure 7).

The ropes soiled in tensioned state showed no considerable difference in the reduction of breaking force by different soil substrates (see Figure 7). As a result of the cleaning process, however, the effect of the more skeletal soils was not diminished, but rather increased somewhat, which made the difference to Flysch brown soil clearer (see Figure 9).

The p-value calculated from the statistical tests shows, with 0.03219, a weakly significant difference between the breaking force loss when contaminating with Flysch brown soil against the loss of breaking force in the case of contamination with the other two soil substrates.

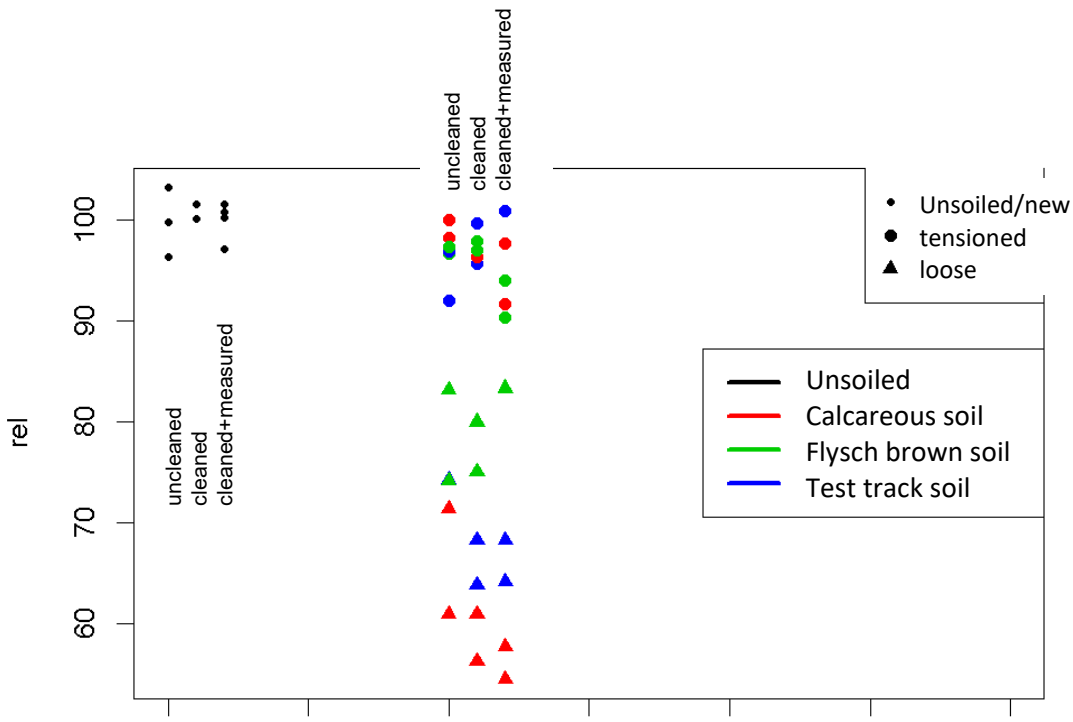

Figure 8. Distribution of the tested breakingforce of the rope samples polluted with different soil substrates in tensioned and loose state

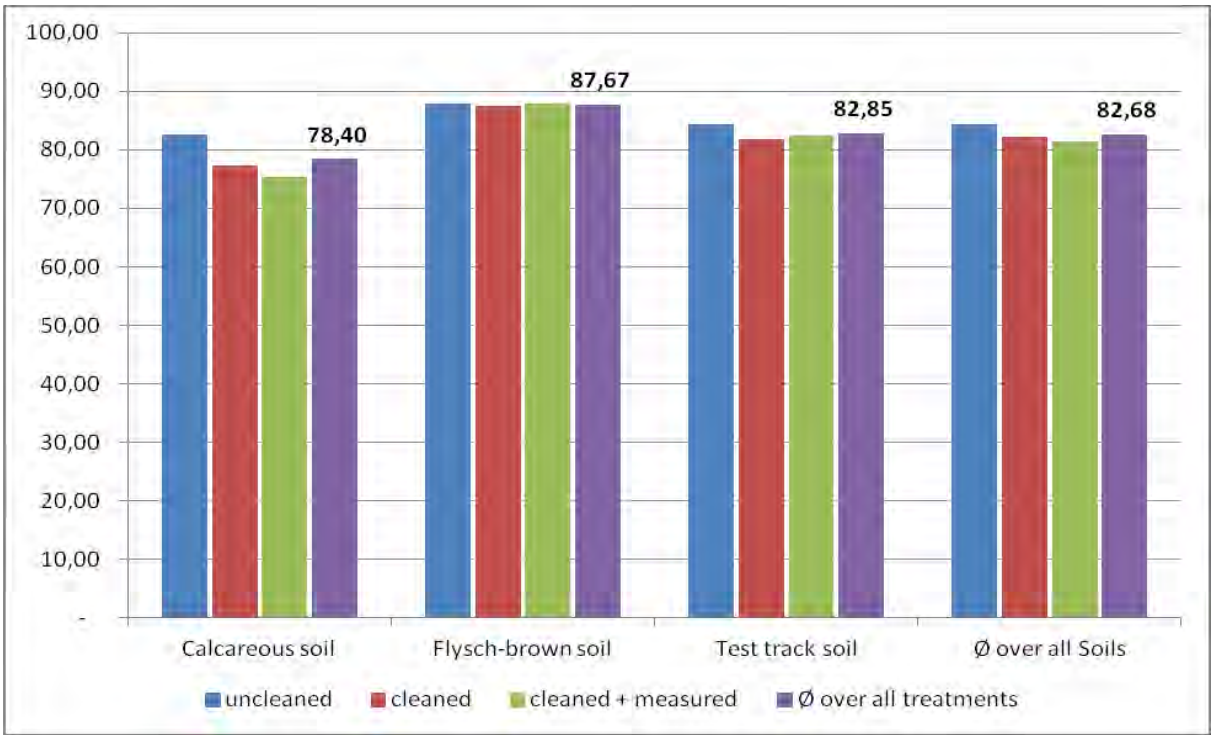

Figure 9: Effect of different soil substrates in combination with the post-treatment on the breaking force of the ropes. Mean values from tensioned and loosely contaminated rope sample pairs

Effect of cleaning with high-pressure cleaner and measurement of the rope strands

This question serves to clarify possible causes of 20% loss of breaking force of the sytethic ropes, which have only been in short contact with the ground. The following three factors could cause the sudden loss of breaking force:

(A) Cleaning with a high-pressure cleaner
(B) The measurement of the rope strands by means of a wrap with a yarn
(C) The soiling of the ropes by ground contact

It was therefore investigated whether the cleaning process alone or cleaning and measuring of the non-contaminated reference ropes or of the rope samples with contamination by different soil substrates has led to an impairment of the breaking force. As shown in Figure 10, an effect thru the cleaning process as well as thru the measuring process of the rope samples, contaminated in loose state is not clearly apparent. At the non-contaminated reference ropes (Figure 11, right side) the influence of post-treatment (washing, measuring) is extremely low (not measurable). The post treatment also had no effect on the rope samples confronted in tensioned state with the various soil substrates. On the other hand, a noticeable difference between the treatment variants "uncleaned", "cleaned", and "cleaned & measured" was manifested in the samples contaminated with soil substrates in loose state.

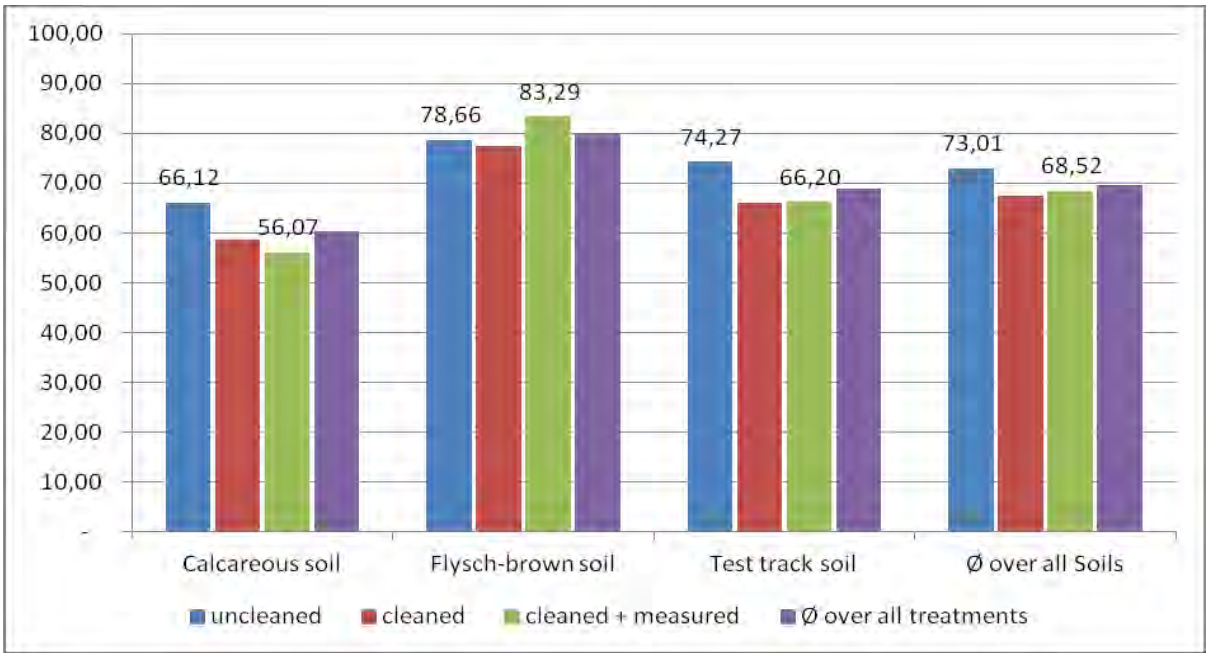

Figure 10. Residual force as a percentage of the initial value after treatment with different soil substrates in a loose state as a function of the post treatment

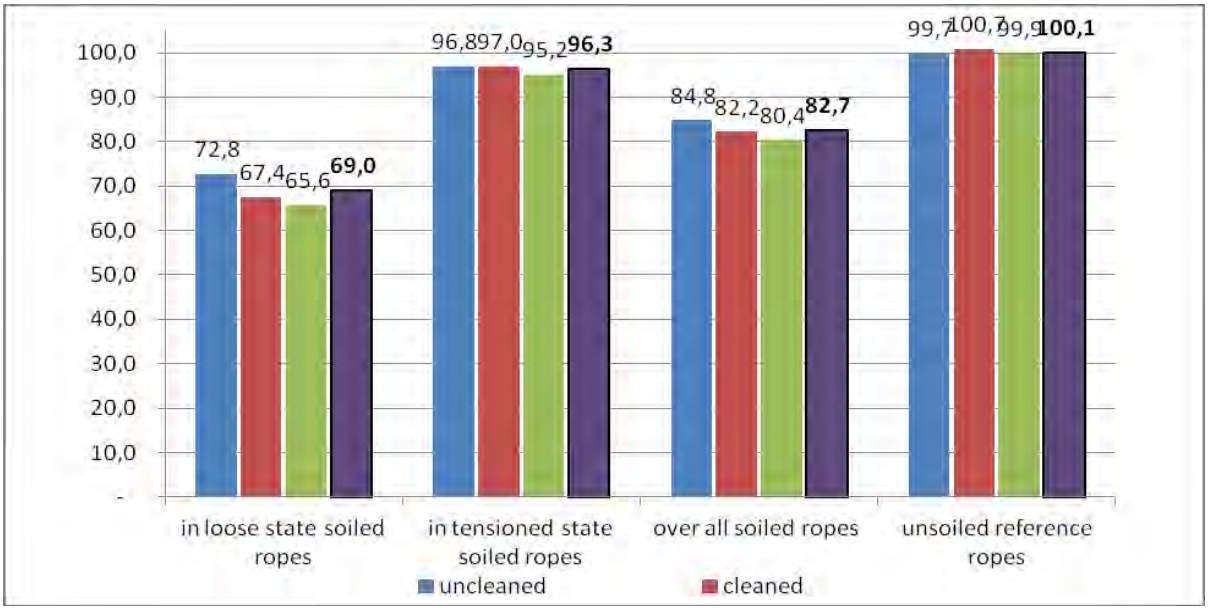

Figure 11. Comparison of the average breaking force of the ropes over all products after different treatment

The statistical analysis of the data material has shown that the influence of washing and measurement is very low and not significant. The calculated p-value for uncleaned ropes versus washed ropes including measured ropes was 0.37143. The data distribution in Figure 8 makes this clearly visible. The deviations thus lie within the range of variation of the breaking force of spliced synthetic ropes. The most interesting results in this context, the results of the samples contaminated with test track soil show a considerable breaking force reduction by washing, but no further reduction by measurement (see Figure 10). This was also found by optical analysis of the rope samples after tearing - most of the measured ropes were not torn at their measuring point. The majority of the ropes tore at the splicing shoulder, which as a rule is always the weakest part of the rope samples.

Covered ropes versus open braided rope

With a few rope samples, an attempt was made to find an indication of a possible difference in the effect of forest soil substrates on covered ropes compared to the non-covered ropes.

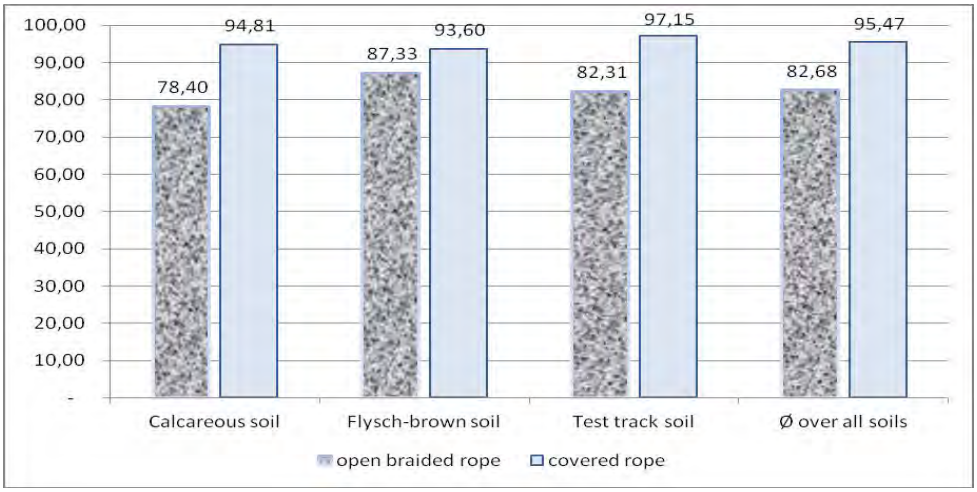

Figure 12. Residual breaking force of the covered rope after treatment with 3 soil substrates compared to the average values of the open (non-sheathed) ropes

As shown in Figure 12, the covered ropes are better equipped against dirt. While open braided ropes lost in mediate about 17% of breaking force, the covered ropes lost only about 4.5% compared to the initial breaking force. Compared to the minimum breaking force specified by the manufacturer, the covered ropes had not any loss of breaking force. On the other hand, the open braided ropes lost 18% of their breaking force compared to the minimum breaking force specified by the manufacturer due to contamination with soil material.

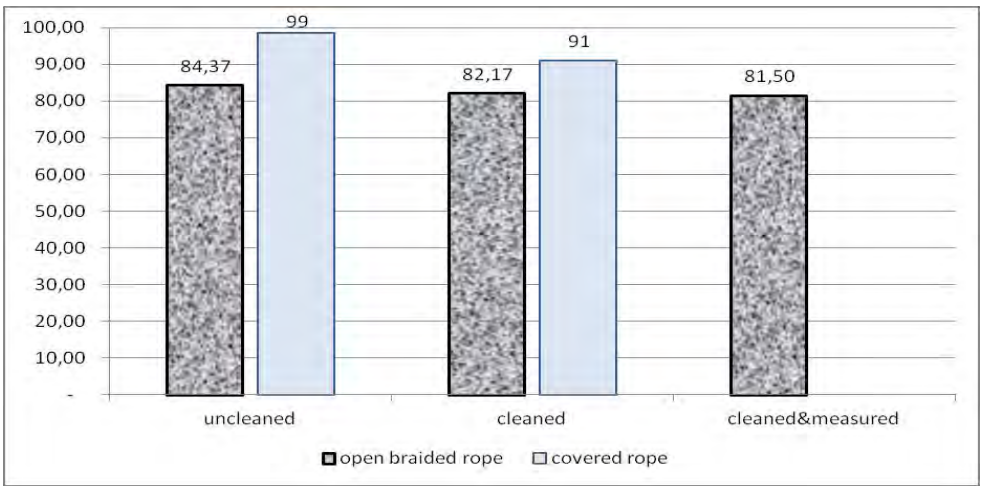

Figure 13. Effect of cleaning the ropes on the breaking force

The result of the comparison of cleaned with uncleaned rope samples shows a decrease of the breaking force by cleaning. By washing with the high-pressure cleaner, dirt particles were apparently infiltrated into the core of the rope. Because of the low number of samples (3 washed / 4 unwashed), however, the validity with regard to the covered rope is very low.

Summary & Conclusion

A total of 72 rope samples were produced and their breaking force tested after different treatment. 56 rope samples were contaminated with 3 different soil substrates. Contamination was carried out with an aqueous treatment of the soil substrates, half of the test specimens being preloaded with approximately 500 daN and the other half being treated in the loose state. All contaminated ropes were post treated via deflection rollers. Two thirds of the samples were washed and then dried naturally. Half of the washed ropes were measured using the BFW method.

The evaluation has shown that there is a clear connection between the breaking load loss of the tested rope samples and the contamination with different soil substrates. Furthermore, the loss of the breaking force of the loosely roughed ropes with an average of -31.5% is comparable to the results of the tests with PE ropes and is many times higher than the significant but with 3.5% very small loss of breaking force of the other pair of the ropes soiled in tensioned state. The post treatment by washing with the high-pressure cleaner and measuring the strands has shown a small but not significant change in the breaking force compared to the non-cleaned rope samples.

This allows the conclusion that the breaking force reduction of the fiber ropes after short contact with the soil material of the test track without any detectable or measurable wear of the rope is to be attributed with a high probability to the disturbance of the fibers by introduced dirt particles. The washing and measuring of the rope cross section has only very small and therefore negligible influence on the determined residual breaking force.

The contact of the non-covered ropes with loose, suspended soil has led to a breakage reduction of around 30% (16 to 45%) as a direct consequence. For covered ropes the breaking force reduction by soiling was about 3 to 6% whereby the washing of the ropes with high pressure cleaner clearly led to an further deterioration.

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MAP OF STONE QUARRIES AND GRAVEL PITS IN ROMANIA: POSSIBILITIES TO USE THE MATERIALS IN FOREST ROAD CONSTRUCTION

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Abstract: *As products of stone quarries or gravel pits, natural aggregates such as the crushed stone and gravel are essential components in constructing forest roads. Nevertheless, in many cases, the road systems 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. Although the operations in stone quarries and gravel pits are often seen as environmental impacting activities by changing the land use category and the extraction of non-renewable natural aggregates, their existence is necessary. In practice, it is recommended, whenever possible, to use local materials in road construction, but the local impact caused by the extraction must be accounted. 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 agregates, quarry, gravel pit

INNOVATING FORESTRY USING 3D GEOSPATIAL TECHNOLOGY BASED ON GEOSLAM MOBILE SCANNER

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Abstract: *The world's forests and forestry sector are facing unprecedented biological, political, social, and climatic challenges. The development of appropriate, novel forest management and restoration approaches that adequately consider the complexity of this system represent a step in the right direction. Forest ecosystems are adaptive systems which provide a better alternative for both production and conservation oriented forests and forestry only if they are mapped properly, in their complexity. Monitoring and understanding forests has never been more important in the actual socio-ecological context. Establishing accurate 3D maps of forest ecosystems in various stages (pre-harvesting, harvesting, planting) are all vital activities for forest managers. But many of these forest spaces are complex and difficult to access. Precise mapping that take readings from forests are often made with huge time allocation and considerable costs, since in most of the forests many of the novel technologies fail in accuracy or efficiency (GNSS, GSM, TLS etc.). Forestry professionals all need access to user-friendly technology that is easy to install and use, but is robust and reliable enough to do the job quickly and accurately. They need tools that enable them to survey outdoor, complex or difficult to access spaces and within minutes build a highly accurate 3D model. In this paper, we present several case-studies on applicability of GEOSLAM lightweight, handheld laser scanner in different and complex forest environments, where we test the accuracy and efficiency of 3D geospatial technology for innovating forestry.*

Keywords: point cloud, Simultaneous Localization and Mapping (SLAM), scanner, geospatial

ACCURACY, EFFICIENCY AND USABILITY OF PHOTO-OPTICAL PILE MEASUREMENT SYSTEMS IN THE WOOD SUPPLY CHAIN

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Abstract: *The digital photo-optical measurement of road-side log pile volume is gaining increasing attention within the wood supply chain throughout Europe in recent years. Manufacturers promise efficiency and accuracy gains as well as the advantage of documentation and reproducibility resulting in transparency increase for the stakeholders. Consequently, we see increases in the number of systems and tools on the one hand and refinement regarding the algorithms and improved accuracies on the other. However, huge differences exist between these mostly tablet or smartphone based systems regarding their accuracy, characteristics and usability depending on user type and operating system. In this study five of the prevailing systems have been compared measuring several sawlog and industrial wood piles (hardwood and softwood) against traditional road-side measurements, harvester measurement and mill measurement for, amongst others, their accuracy, costs, time consumption and usability - with surprising results, i.e. differences between the photo-optical systems as well as in relation to the harvester and mill measurement results.*

Keywords: photo-optical measurement, log volume, wood supply chain, accuracy

PLANNING OF SKID ROADS AFTER FOREST FIRE IN TURKEY (A CASE STUDY OF ADRASAN FOREST ENTERPRISE)

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Abstract: *Forest fires are very important for our country's forests. Especially, forest fires have inflicted great losses on the Mediterranean and Aegean areas. Until the last five years, the forest area loss is too much during forest fires. For our country, forest fires gives great harm to the natural life and besides, forest fires cause economic losses. Adrasan region is located in Antalya province and this region is a touristic attraction. Adrasan forest fire has occurred in June, 2014. In this fire were burned 140 hectares area and 14810 m³ trees. Burned area is completely Pinus brutia forest. After the fire, the burned area should be planted in a year. Therefore, trees inside burned area should be completely emptied. Products are in the form timber and industrial wood. Within the Adrasan region, firstly, skid road is opened. Average slope of region is between 10% and 80%. The slope of skid road is changed between 10% and 18%. The different type farm tractors are used to burn area. Tractors are done skidding and transporting. The slopes of some skid roads are very high and this situation is very dangerous for workers and tractors in this area. In this study, skid roads planning are investigated in burn area. The skid roads are done planning after forest fires in these very important areas. The skid roads constructions are very difficult and dangerous when skid road planning isn't done then. Also, the forest area is divided into sections unnecessarily. The skid road planning should be finish before forest fire. Especially, skid road planning should be in fire sensitive areas. So, after the forest fires, the extraction operations will be fast, economical and safety.*

Keywords: forest fire, skid road, skid road planning, extraction

INVESTIGATION OF TIMBER SKIDDING WITH MULES IN MEDITERRANEAN REGION OF TURKEY

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Abstract*: Timber logging and skidding may be done in one step by means of mules when terrain's slope and skidding distance is small. Animal logging and skidding operations is one of the traditional hauling systems in some regions of Turkey. But, the use of mules in skidding operation is very decreases in recent years. This paper present research results of the productivity of mules skidding using timber harvesting method in karstic region of Turkey. Time measurements are done during skidding operations with mules. The elements of the skidding work phases were identified, 30 cycles were recorded for this study, skidding distance, slope, number of timber and stem size. In this study, skidding distances are changed between 105 and 154 meters. The average skidding distance is 135 meters. Hourly productivity is 1.142 m³/ hr for average skidding distance. The total cost of mules skidding operations is calculated as 11.55 $/ m³.*

Keywords: mule, skidding, productivity, mediterranean region

THE USE OF GIS FOR CREATION OF REPAIR PLANNING AT FOREST ROADS

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Abstract: *Designing low-volume forest roads is a complex engineering problem involving economic, environmental, and social requirements. Construction and maintenance costs are the largest components in the total cost of producing timber for industrial uses. Planning forest road networks depends on social requirements and functional using criteria of forest since they provide access to forest villages, rural settlements, and recreational areas. The major repair works are carried out on the roads unused for a long time or big damaged from use. Also, major repair is applied to insufficient technical infrastructure roads. Today, major repair work without the plan and the way the project is prepared according to the requirement. In this case, these operations are carried out save the day although not for the future studies. The study area is selected as research area of Istanbul University, Faculty of Forestry, Research and Practice Forest. The situation of all forest roads and drainage constructions inside study area will determinate. The total data with done works will collect. This data will analysis with ArcGIS 9.3 computer programmer. Field studies are determined to damage and in need of care places of forest roads, these areas will be prepared for the project. With the help of these projects within the area of the existing forest road repair projects of regional enacted. Forestry activities projects as computer-aided planning to promote and design training programs more efficiently to make the following general information and briefly described the reasons created. Besides, these projects are all major repair work done on the roads in the field of research establish the basis.*

Keywords: forest road, repair planning, GIS, drainage construction

REVIEW ON TIME STUDY RESEARCHES FOR HARVESTING IN MOUNTAIOUS FORESTS

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Abstract: *Time and motion studies are carried out for determining unit cost, efficiency assessment, business organization, work planning and scheduling, and performance evaluation of the workers and machines. Time studies have also been performed with different time measurement techniques at different level and conditions. Achievement of a detailed time study considering all variants is hardly task for especially motor-manual or manual dominated harvest operations. Therefore, it was encountered the question how the previous time studies could be practically applied with already conditions and what was the performance on productivity estimation and calculation of standard working time. The aim of the paper is to make a criticism on time study researches completed in the past few decades, related to wood harvesting processes. In this concept, previous studies were searched, enumerated, systematically analyzed, and discussed according to various factors. As result, it was determined that the time studies were realized for identifying the need of employment, to estimate work productivity and standard time to calculate unit costs. In the majority of the studies, the cumulative time measuring techniques were used with simple stopwatch via direct observation at the scale of local researches. Most of the studies were to determine the actual/main time and measuring time input was based on elemental time level.*

Keywords: time study, time analysis, harvesting, productivity, work study

MULTIPLE-OBJECTIVE STEM BUCKING IN LOG CUTTING OF NORWAY SPRUCE (PICEA ABIES) STEMS FOR MAXIMIZING MONETARY VALUE OF TIMBER TRADE IN FINLAND

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Abstract*: In this study, timber trade scenarios are considered in a wood procurement region of Finland. This multiple-objective decision environment includes the timber purchase from forest owners and lumber sales from the sawmill to abroad. The decision environment is further complicated by the allocation of a number of log procurement chains to a sawmill during different periods. In practice, this allocation problem has been solved by applying different stem bucking instructions in harvesters. Due to the complex nature of the environment, single-objective solutions cannot be directly used to solve the timber trade problem in a manner that is techno-economically relevant to the forest owners and industries. Therefore, stand parameters and attributes were measured in local wood procurement conditions to improving the solution. Using these measurements the simulation system automatically adjusted the bucking solution to better describe the combinatorial complexity of timber trade. The properties of this methodology are discussed and three stand scenarios of how the system works based on local real-world data and optional monetary value of sawmill are presented for bucking. The study results indicated that the share of log section removal of stands (m3) decreased (1.7%) in bucking of stems on Norway spruce (Picea abies L. Karst.), when monetary value of sawmill was used as the bucking criterion. There was the statistically significant difference in the shares of log section percent between the monetary value bucking and the references. When the monetary value bucking was used, the monetary value of stands (€) was lower (0.6%), but the monetary value of cubic meter (€/m^3) was greater (1.0%). Furthermore, the average length of logs (m) cut was longer and the average volume of logs (m3) was larger (4.9%). In this wood procurement environment the relative production value of logs delivered to sawmill was greater, but correspondingly the relative timber trade value of stand supplied by forest owners was lower (0.7%) when using the monetary value bucking. The Finnish timber trade market is subject to agreements regarding stem bucking regulations. These agreements should be made on the basis of techno-economic analysis suggested in this study accounting for the effects of local forest operations on the lumber sales of export companies and timber sales of forest owners. This timber trade problem could be solved by applying advanced multi-objective methods in cutting simulations of wood procurement planning.*

Keywords: stem bucking, monetary value, forest owner, forest industry, wood harvesting, cut-to-length method, Norway spruce

Introduction
Operational environment

During the last six years (2010-2015) in Finland, the annual timber trade of industrial round wood of softwood logs has been, on average, 22.2 million solid cubic meters over the bark (m^3) of which the proportion of Norway spruce (*Picea abies* L. Karst.) log cuttings had been 54% (Hakkuukertymä metsäkeskuksittain, 2016). The cut-to-length method of log assortments is used for managing timber trades in a manner that wood procurement of

forest industry is techno-economically relevant to the forest owners and industries. In a customer-driven wood procurement process, stems are bucking into favorable log dimensions at a harvesting site. In this process, the sawmill customers have information about the demand of markets of sawn goods, and thus their timber order for a target distribution of logs is based on the demand of end-product markets (Figure 1). On the other hand, in practice, stem bucking instructions of the forest industry are subject to the available wood supply of timber trade markets (Palander et al., 2009). Therefore, the target distribution also concerns various agreements and regulations for different timber trades of forest owners in raw-material markets (Figure 2).

Figure 1. Demand of end-product markets

In forest stands, harvester's computer calculates optimal bucking proposals for each stem by taking into account the bucking instructions of the stand. The bucking instructions consist of files for target distribution, price matrix and the various other bucking parameters and guidelines. The goodness of bucking outcome can be evaluated with several attributes, for instance using apportionment degree (Malinen & Palander, 2004). When cutting spruce logs stands, a guideline for the harvester operator is utilized as much as possible the bucking proposals by the harvester computer (i.e. automatically bucking), because there is a belief that the bucking outcome of log stems can be maximized at the harvesting site (e.g. Uusitalo et al., 2004; Kivinen, 2007). The harvester operator can also utilize manual bucking with damaged or defected parts of log stems - for instance butt rot, crookedness, top changing, vertical branch, large branch - or some other reasons in a stand. As the manual bucking is used, the operator him-/herself decides the crosscutting point of the log, or in other words, no bucking with the suggestions supplied by the harvester's automatic system. In this respect, the harvester operator can consider local wood procurement conditions to improving the bucking outcome. Furthermore, he/she can adjust the bucking solution to better solve the combinatorial complexity of the timber trade.

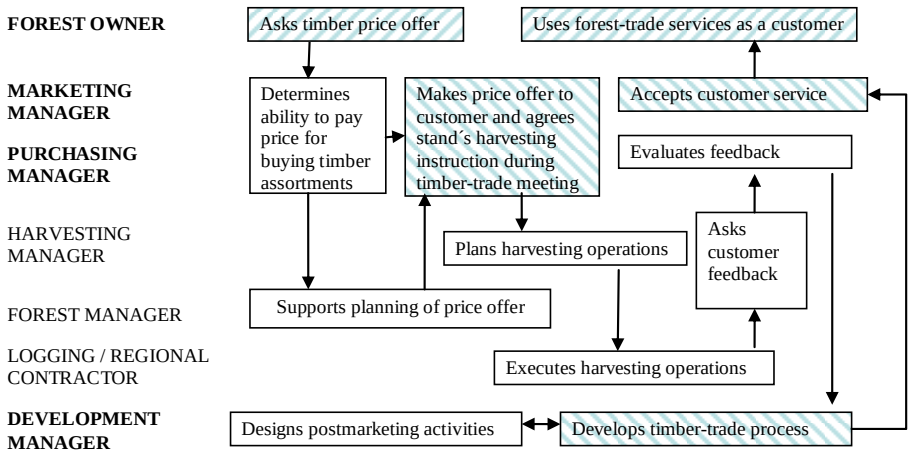

Figure 2. Wood supply of raw-material markets in Finland (Palander et al., 2009)

In addition to the consideration of different log assortments, the quality of spruce stem does not fluctuate much and correspondingly the monetary value differences of lumber grades are quite small. When the value of Scots pine (*Pinus sylvestris* L.) lumber is considered, it is significantly dependent on the quality of the pine stem (e.g. Uusitalo et al., 2004). In this respect, the log section of Scots pine stem is generally regarded as dividing into three quality zones: 1) a knotless or slightly knotty butt zone, 2) the dead knot zone in the middle of the stem, and 3) the fresh knot zone on the upper part of the log section of the stem. Consequently, the quality bucking is conducted and the bucking is not necessarily managed automatically by according to the target and price matrices. Hence, the harvester operator may utilize manual bucking on the log section of pine. In the research by Uusitalo et al. (2004), automatic bucking of pine stems did not markedly lower the amount of good-quality lumber compared to quality bucking with the study material of 100 sample pine stems. Besides, several research groups (Wang et al., 2004; 2009; Akay et al., 2010; 2015; Serin et al., 2010) have compared the bucking options and underlined that the gains of automated or computer-aided bucking are larger than benefits of manual bucking.

In the research by Kärhä et al. 2016, the harvester operators were asked when they utilize most frequently manual bucking. The results indicated that the operators use manual bucking most frequently in poor-quality and relatively small-sized thinning stands, which locate in vigorous forest sites. Correspondingly, a little manual bucking is utilized in high-quality and large-diameter regeneration cuttings which are poor in nutrients. The operators told that the most significant reason for using manual bucking with spruce log stems is rot on log section; then the operator has to sound one off cut piece or several pieces or pulpwood pole(s) from the butt of stem. The second and the third most important reasons for manual bucking were crook in a stem and defect part on log section. More than a half (55%) of the harvester operators regarded automatic bucking as significantly better than manual bucking to produce the highest bucking outcome with spruce log stems. Only 11% of the operators believed that the manual bucking causes clearly better or better bucking outcome than automatic bucking. In the research, the high log percentage received the highest weight for the criterion of good bucking outcome (Figure 3). Its weight was, on average, 29%. Nonetheless, the variation was quite large between the statements, among the harvester operators. In addition to the log percentage, the operators raised the importance of low log reject percentage, high production value of logs, and high apportionment degree as the criteria for the good bucking outcome of mill customer. The weights of these criteria were, on average, 20–25% and the weights were at very similar levels with both spruce and pine log stems.

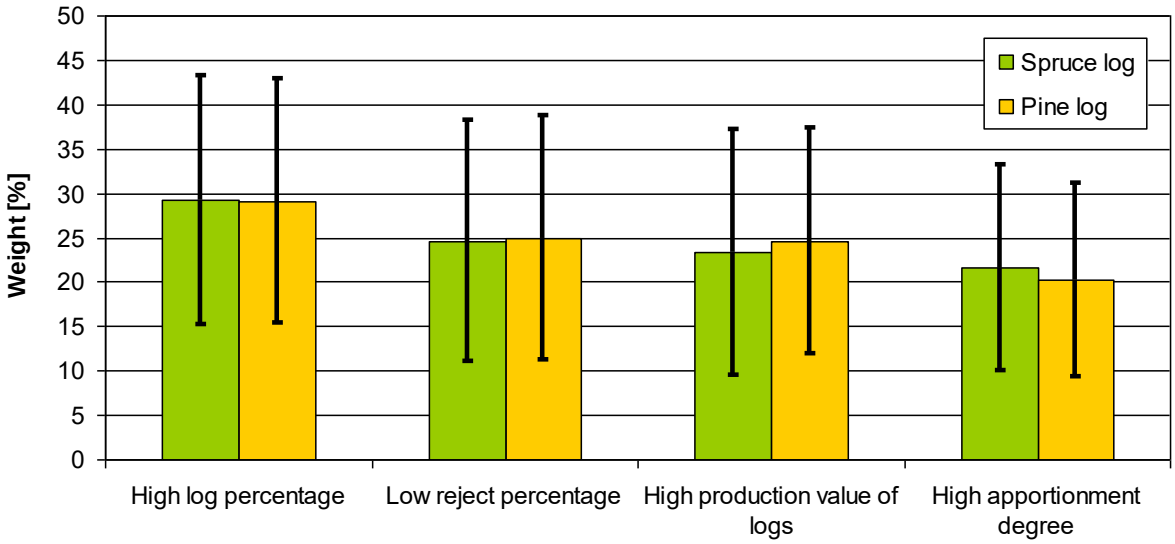

Figure 3. In the view of the operators (n=74), the weights of the selected criteria for the good bucking outcome in cutting log stands. The bars describe the average opinion and the black lines the standard deviation (Kärhä et al., 2016)

In Finland, stem bucking is managed and controlled quite conventionally. Same management systems have been applied during decades, while computers and information networks have been developed largely without any limits for more efficient systems. It is reasonable to ask: could it be beneficial to use different bucking instructions, if average volumes of stems in stand removal are for instance. 450 and 900 dm^3? Actually, the monetary value of the timber trade and the efficiency of stem bucking could be increased at the stand level, if the

bucking instructions are defined using local forest information. As a suggestion, a stand or group of stands could be automatically classified using following parameters and variables that describe stand and trees:

- location / geography,
- site class,
- age,
- cutting method,
- species / shares of tree species,
- average volume of stems in stand removal,
- average diameter of stems in stand removal,
- average length of stems in stand removal,
- quality (e.g. butt rot, branches).

Figure 4 depicts an example for the stand classification based on the local forest information about the average diameter of stems in stand removals.

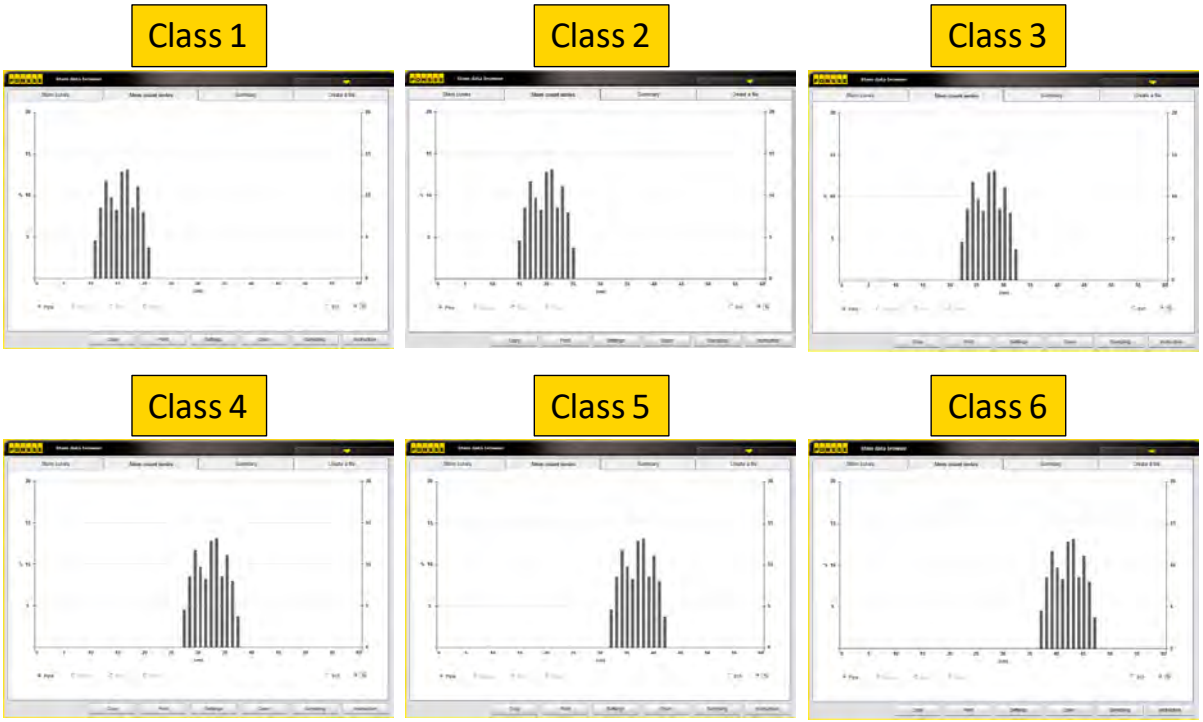

Figure 4. An example of six stand classes of Norway spruce stands, which describes differences between average frequency distributions of stem diameter in stand removal

Aims of the study

So far no comprehensive studies have been carried out on the effects of using stand classification with bucking of softwood (i.e. Norway spruce) log stems in Finland. Therefore, Stora Enso Wood Supply Finland, the University of Eastern Finland, Metsäteho Ltd. and Ponsse Plc. undertook a study on:

- the accuracy of forest information on the stand classification,
- the effects of utilization of stand classification on the bucking outcome,
- the log percentage, relative production value (€/m^3), and production value of stand (€) as the criteria for the good bucking outcome in timber trade.

The hypothesis of our study was: With Norway spruce log stems, the best bucking outcome is achieved for the timber sales of forest owners and the lumber sales of export companies, when the bucking instructions of stands are subjected to the classifications of local forest operations. This could be made by applying advanced multi-objective methods in cutting simulations of wood procurement planning.

Material and methods

The stem bucking and cutting production files of 11 harvesters were collected from July 2013 to June 2014 from the harvesters operating in eastern Finland at the harvesting sites of Stora Enso Wood Supply Finland. The data collection was done at the beginning of August 2014. All harvesters of the study were PONSSE harvesters. There were totally 216 harvesting sites in the study (Figure 5). The total stem data of softwood log section were 60,000 m^3. The volume of stem material varied from 1,848 to 12,897 m^3 per harvester. Utilization of bucking options was examined at the harvesting site level. All figures calculated from the stem data were weighted by the volumes of log sections or logs cut.

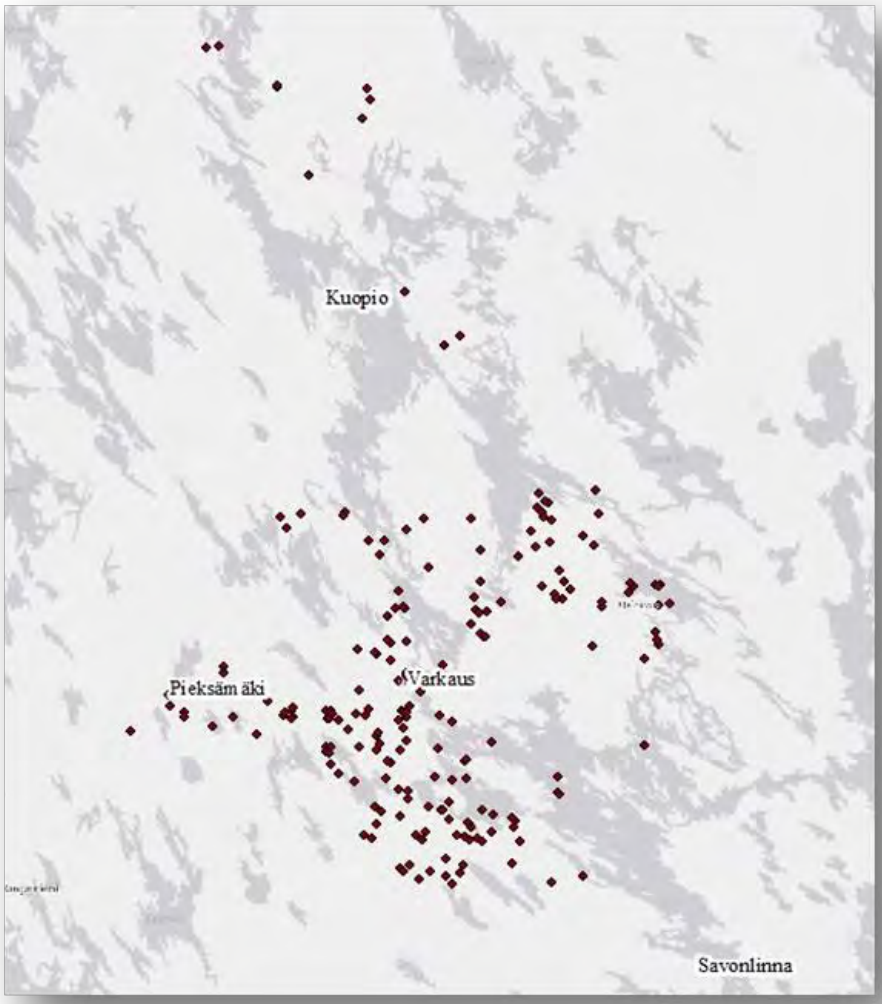

Figure 5. Norway spruce stands and study area

In addition to the harvesters' stem data, in order to investigate the consequences of stand classification, the data from forest information system and sawmill production system were collected. There were six bucking instruction files in production during the study period:

- ✓ 1.7.2013 – 2.9.2013
- ✓ 3.9.2013 – 17.9.2013
- ✓ 18.9.2013 – 7.10.2013
- ✓ 8.10.2013 – 20.10.2013
- ✓ 21.10.2013 – 1.1.2014
- ✓ 2.1.2014 – 30.6.2014.

When analyzing the data and calculating the effects of stand classification on the bucking outcome of stands, the cutting results were considered after the following simulations (Tables 1 & 2):

1) reference using stem bucking instruction files of production,
2) stand classification using planning information provided by timber purchase managers,
3) stand classification using real production information measured by harvester, and
4) log stem's cutting with the production value of the sawmill.

Table 1. Target distributions of stem bucking simulations.

Wood procurement period 2013-2014	Reference*)	Stand classification Class 1 (predicted)	Class 2 (harvester)	Production value
1.7 – 2.9.2013	Target distribution 1	Three target distribution for stand classification	Three target distribution for stand classification	Target distribution 6
3.9 – 17.9.	Target distribution 2			
18.9 – 7.10.	Target distribution 3			
8.10 –20.10.	Target distribution 4			
21.10 – 1.1.	Target distribution 5			
2.1 – 30.6.2014	Target distribution 6			

*) No significant difference between target distributions 1–6.

Table 2. Price matrices of stem bucking simulations.

Wood procurement period 2013-2014	Reference*)	Stand classification Class 1 (predicted)	Class 2 (harvester)	Production value
1.7 – 2.9.2013	Price matrix 1	Price matrix 7	Price matrix 7	Production values of sawmill
3.9 – 17.9.	Price matrix 2			
18.9 – 7.10.	Price matrix 3			
8.10 –20.10.	Price matrix 4			
21.10 – 1.1.	Price matrix 5			
2.1 – 30.6.2014	Price matrix 6			

*) No significant difference between target distributions 1–6.

Two stand classifications were applied in Finnish forests using the limits of the average volume of stems in stand removal for both stand classifications:

- 650 dm^3 ("small stem"),
- 650–860 dm^3 ("medium stem"),
- >860 dm^3 ("large stem").

In the study, the goodness of stem bucking outcome was evaluated with the following attributes;

Forest owner as customer:
- utilization of log section of stem (volume, length, top diameter of log section),
- log percentage,
- log dimensions (volume, length, top diameter of log),
- production value of stand,

Sawmill as customer;
- reject percentage,
- apportionment degree, and
- the relative production value of logs.

Of the attributes of the consequences of stand classification, the reject percentage, apportionment degree, and the production values were investigated at the batch level of harvesting sites (i.e. the combination of 1…n harvesting sites). The rest of the attributes (i.e. the utilization of log section, log percentage, and log dimensions) were the harvesting site-specific (stand-specific) variables.

Results

The accuracy of forest information for stand classification

The results of production depict that the share of Small spruce log stems was, on average, 21% and on the Medium and Large stems, respectively, 41% and 38% (Figure 6). There was statistically significant difference between the shares of produced and predicted Small spruce log stems, when the share of produced log stems was compared to the predictions of purchase managers of the forest industry. They overestimated the volume of Small log stems and underestimated the volumes of Medium and Large stems (Figure 6).

Figure 1 indicated also that there was a huge variation of the shares of manual bucking on harvesting sites of the study. Furthermore, there was a significant difference between the shares of manual bucking by harvester in cutting both spruce and pine log sections (Figure 2).

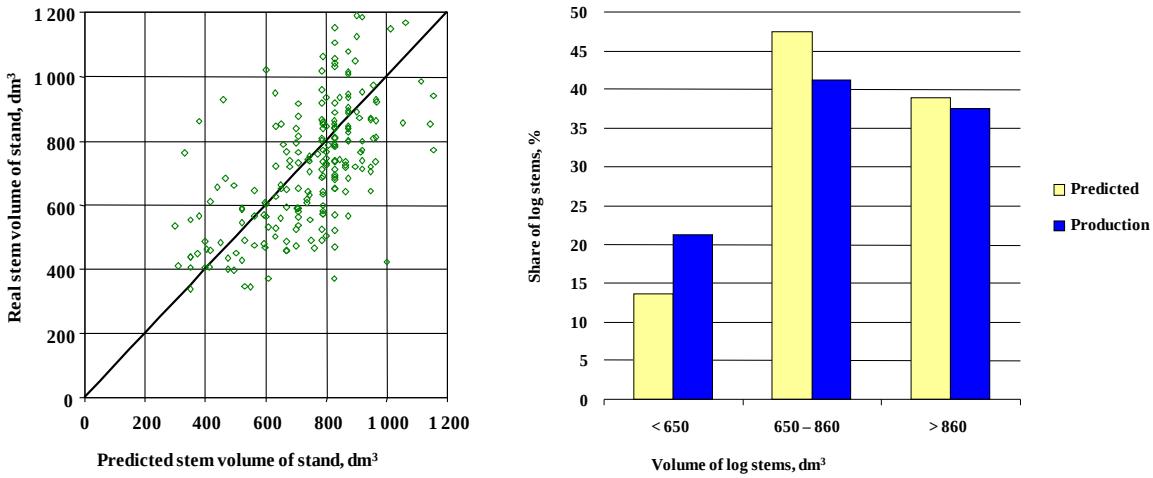

Figure 6. Comparison of produced and predicted stem volumes of Norway spruce stands

The effects of utilization of stand classification on bucking outcome

The consequences of the utilization of stand classification were significant in the study (Table 3). When the accuracy of the forest information for stand classification was high, the utilization of log section of stems was higher: the total volume of logs was larger (0.5%), the number of logs was lower (1.0%), and the average volume of logs was larger (1.5%). When using the approach of sawmill's production value instead of even price matrices, the total volume of logs was smaller (1.5%). Furthermore, the number of logs were lower (6%). Therefore, the average volume of logs was larger (5%).

Table 3. The effects of the utilization of stand classification on bucking with Norway spruce logs

	Reference	Stand classification		
		Class 1	Class 2	Production value
Volume of logs [m³]	65500	65600	65800	64400
Number of logs	287000	283500	284500	269000
Log's volume [dm³]	228	231	232	240

The criteria for successful bucking outcome in timber trade

Three criteria were used for the description of successful bucking outcome in the study. When the log percentage is high, the utilization of log section of stems is higher, which can be used as the criterion of forest owners in the timber trade. Figure 7 shows that the log percentage slightly increased, when the stand classification was used in the stem bucking simulations. However, it decreased (1.7%) in the monetary value approach of sawmill, when the production value of the sawmill was used in the simulation.

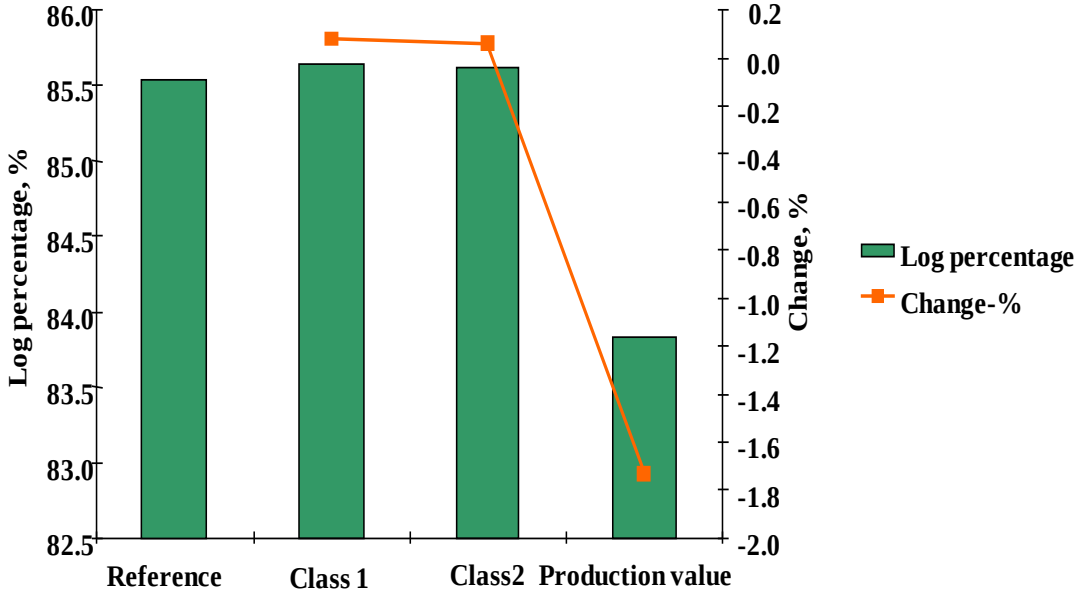

Figure 7. Effects of stand classification and sawmill's production value on log percentage

Figure 8 shows that stands' monetary values (€) increased, when the stand classifications were used in the bucking simulations. In this respect the best result (0.8%) was achieved when the stand classification was used with accurate forest information.

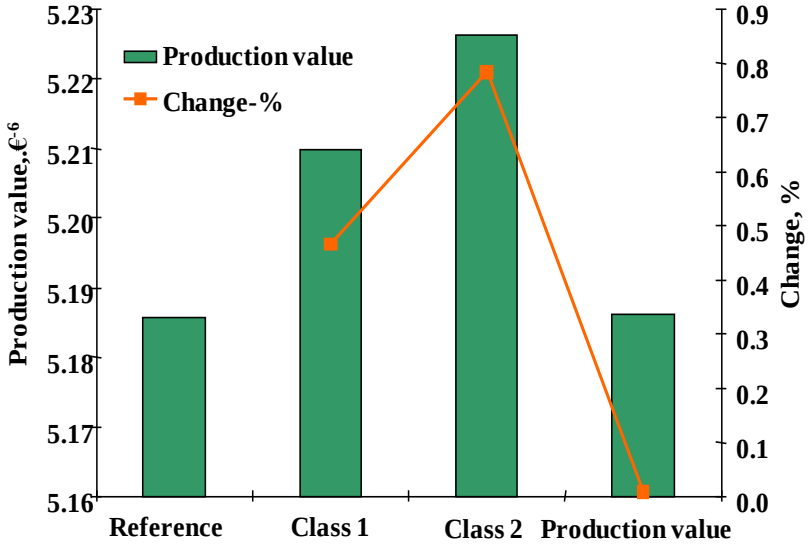

Figure 8. Effects of stand classification and sawmill's production value on stands' value (€)

Next the monetary values were analyzed at the stem level. The relative production value of logs (€/m^3) was lower (1.6%) in the bucking simulation with the reference, when it was compared to the simulation with the production value of the sawmill. Correspondingly, the relative production values of logs were lower (1.3%), when the stand classifications were used in the simulations.

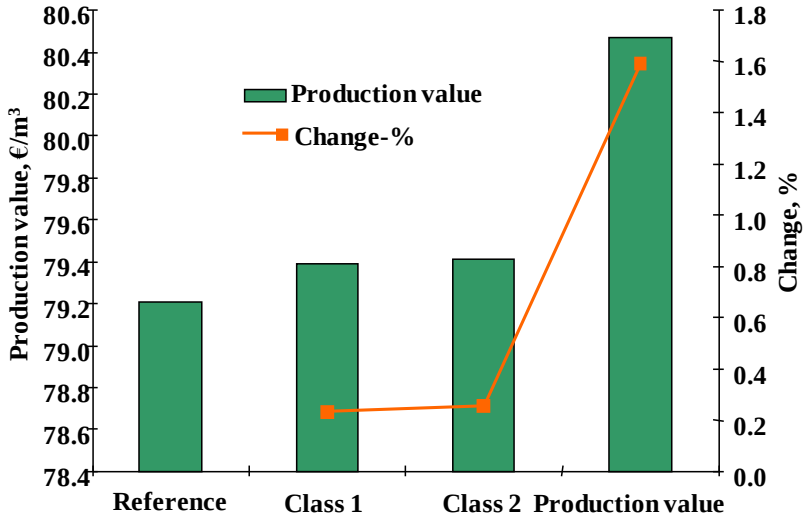

Figure 9. Effects of stand classification and mill's production value on relative production value (€/m^3)

There was a connection of criteria between the results of the simulations in the production values of stems and stands, because the changes of the production values were positive. Nonetheless, the production value of stands was significantly lower when the production value of the sawmill was used as the scenario in the bucking simulations of stems.

Discussion

The data, especially the stem data for the study was large. Correspondingly, the data on the lumber production systems were smaller, but it can be considered that also this data gave reliable findings. In the study, the predictions of stem size of purchase managers were calculated and utilized as the only variable of the local forest information for the stand classification, because current enterprise resource planning data used did not consist of additional forest information. Nevertheless, it can be assumed that there was a large enough variation in the stand classification in this preliminary study (cf. Figure 6). Actually, the results demonstrated that there is a quite large difference between harvesters' production figures and predictions of purchasing managers with volumes of spruce log stems by harvesting site. This is not a desirable situation when you have to maximize the monetary value of the timber trade. Furthermore, the results demonstrated that sawmills' production values could be a potential alternative solution for timber trades instead of the stem size based stand classification.

Depending on the issue, with which criterion the goodness of bucking outcome is evaluated for forest owner and sawmill customers, two recommendations for the utilization of stand classification can be drawn up:

A) If the ultimate target for bucking is to maximize the monetary value of sawmill customer, i.e. production value of logs, then the study results point out that you have to minimize the log percentage with spruce log stems.
B) If the main bucking target is some other one (i.e. other than the high production value of logs in cutting), hence it is useful to maximize the log percentage with spruce log stems.

The monetary value of timber trade can be increased with the utilization of manual bucking. However, it is not a potential approach in the future. Whatever the bucking target is, it can be predicted that the manual bucking share with spruce log stems must be at the lower level than currently. Nowadays, the harvester operator can conduct a quality bucking with pine log stems or value bucking with spruce log stems. It calls, however, extremely close attention in bucking work for the harvester operator. Further, the cost efficient target should be a fully automatic or semi-automatic planning system and harvester's computer-aided bucking based on the stem classification. It will require advanced planning and information systems as well as some mobile laser scanning and machine vision applications for harvesters in the future.

The Finnish timber trade market is subject to agreements regarding stem bucking regulations. Due to the complex nature of the decision environment, single-objective solutions cannot be directly used to solve the timber trade problem in a manner that is techno-economically relevant to the forest owners and industries. The

agreements could be made on the basis of techno-economic analysis suggested in this study accounting for the effects of local forest operations on the lumber sales of export companies and timber sales of forest owners. Further, the timber trade problem could even be solved by applying advanced multi-objective methods in cutting simulations of wood procurement planning. By using e.g. goal programming, the criteria of forest owners and sawmill customers are possible to consider at the same time and to find a compromise solution for stem bucking of stand by determining target values of criteria to stakeholders before wood procurement planning.

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STUDY OF THE CLEARING LIMIT OF ROAD CONSIDERING FEATURES OF DIFFERENT ENVIRONMENTAL UNITS IN A DECIDUOUS FOREST

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Abstract: *This study was conducted in a deciduous forest to determine the mean clearing limit of forest road considering different environmental units. The map of three environmental units was initially produced in GIS. Then, transects on a straight road was randomly selected in each of environmental units and some cross sectional variables of clearing limit including horizontal distance from tree on slope to top of cutslope, width of the cutslope, width of the roadbed, width of the canopy gap and horizontal distance from tree stem on fillslope to road edge were measured. Results showed that the mean clearing limit in environmental unit I, II and III were 11.8, 18 and 16.5 meter, respectively. Moreover, width of clearing limit increased with increasing hillside slope. Finally corrected clearing limit was recommended for each environmental units which can be used for same units.*

Keywords: clearing limit, forest road, environmental units, GIS

DESIGN AND CONSTRUCTION EXPERIENCES WITH SIMPLE SOIL STABILIZATION BASED PAVEMENTS

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Abstract: *The experiences gained from the design and construction of a longer forestry or agricultural road with special focus on the environment and simplicity can help promote up-to-date, environmentally sound and economic methods in road construction. The service road built alongside the Hungarian border provided such experiences. The service road was constructed according to the regulations of the forest roads. The total length of the service road is 160 km, the pavement consists of 40 cm stabilized soil base and 10 cm crushed stone top layer. The road was designed in one month and was built in 75 days. The short deadlines required the application of modern design and construction methods. The design relied on LIDAR derived surface model. The main problems in the construction phase were the huge amount of construction material, the low budget and the short deadlines. Reduced costs were achieved by applying highly mechanized construction methods that used local soils as construction material. Modern soil milling machines allow effective stabilization of clays with hydrated lime, sands with Portland cement and silts with lime-cement mixture. The binder portioning was designed in lab to achieve strength and durability. Self-propelled single-purpose milling machines were able to prepare 1km/day of soil stabilization in 5 meters wideness. The bearing capacity of the compacted stabilization base was between 100 and 150 MPa after 7 days of curing. Pavement condition rating was performed on the whole length of the road six months after the construction. The surface was intact along 95% of the length.*

Keywords: road construction, soil stabilization, PCR

MACHINE COST CALCULATION TO DETERMINE THE FOREST OPERATIONS COSTS

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Abstract: *Forest operations need more and more specific machines and equipment to fulfil the requested requirements. These machinery and technology developments go along with higher investment costs. So for every forest operation there is a need to keep in mind the costs of the system. Therefore the calculation of machine costs is essential. To determine these costs there are different schemes of calculation using various economic methods, e.g. based on absorption costing or on marginal costing. Representatives are the two in Germany widely-used schemes: by Board of Trustees for Forestry Work and Technology (KWF), which is in line with the Food and Agriculture Organization of the United Nations (FAO) cost calculation scheme, and by German Forest Entrepreneur Federation (DFUV). Anyway, there are difficulties to compare these calculations and to implement operation processes in specific. Therefore, these different calculation schemes are compared among each other, but also with calculations used in other industries such as the building sector. Out of this, it is the aim to find a general approach to calculate the harvesting costs for different types of machinery at any time of the forest production process. To correlate the machine costs with the work productivity per hour and the overall process productivity it is essential to distinguish consequently between variable and fixed costs. Furthermore an optimal economic lifetime will be calculated to gain a depreciation period for the pre-calculation of a machine.*

Keywords: cost calculation, machine costs, operation costs

ASSESSING FOREST SECTOR PUBLIC INSTITUTIONAL CAPACITY: A SURVEY OF ROMANIAN FOREST INSPECTORATES

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Abstract: *Forestland restitution process and transition to market economy have triggered important changes in the Romanian forest sector. In this context the newly created network of Forest Inspectorates, along with the central authority in charge with forestry have faced the challenging problem of forest regulatory framework reform and enforcement. This paper assesses the Forest Inspectorates by employing a framework of organizational environment, motivation, capacity and performance, trying to generate useful information for planning and decision making for better outcomes in forest sector regulation and compliance. The study uses a questionnaire survey applied to 320 Forest Inspectorates employees. The responses are compared with the results of a more or less similar survey done back in 2009, indicating that the Inspectorates are still far from realizing their objectives and making relevant progress. Forest Inspectorates score low on effectiveness and motivation while the results of the study indicates that the source of low performance should be searched in the area of legislative framework and the operational management of the Inspectorates. The government should pay a more constructive role in creating less prescriptive and more operational regulations and organizational management systems to improve the performance of the public structures designated to enforce the forestry legislation.*

Keywords: public institutional capacity, forestry, law enforcement, effectiveness

HYBRID SOLUTIONS AS MEASURE TO INCREASE ENERGY EFFICIENCY -A PROTOTYPE OF HYBRID TECHNOLOGY CHIPPER

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Abstract: *The objectives of this study were to test the new hybrid technology chipper, Kesla C 860 H, when chipping pulpwood and logging residues. Productivity, fuel consumption, quality of the chips and noise of the chipping operation was measured and analyzed. The study results were compared to findings examining conventional tractor-powered Kesla C 1060 T and truck-mounted C 1060 A drum chippers. During the time studies, both the chipper and hybrid system were working well, and the truck mounted C 860 H chipper was capable of operating in constricted roadside landings. Chip quality was good and suitable for demanding users having residential small-scale boilers. The productivity results of this study must be considered with some care due to the limited amount of biomass chipped. The chipper and especially the hybrid system are under continuous development, and follow up-studies are needed for a more precise determination of long term productivity, fuel consumption and operating costs. The average chipping productivity of Kesla C 860 H hybrid chipper unit was 11.3 oven dry metric tonnes (odt) per effective hour (E0h) and standard deviation (SD) was 0.9 odt E0h^{-1}, when chipping pulpwood. The average chipping productivity with logging residues was 13.1 odt E0h^{-1} (SD 0.9). Fuel consumption of Kesla C 860 H hybrid chipper was 3.1 litres per odt when chipping pulpwood and 2.9 litres per odt for logging residues.*

Keywords: hybrid technology, chipping, fuel consumption, productivity, particle size, logging residues, pulpwood

OXYGEN EXPENDITURE DURING MOTOR-MANUAL HARVESTING IN THE MEDITERRANEAN FORESTS

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Abstract: *Working conditions and the working environment in forestry have particular features that distinguish forestry work from many other industries. Worksites are usually temporary and scattered; facilities are more difficult to arrange than at permanent work premises; climatic, topographical and biological conditions, and the large share of contractual and seasonal workers, have significant impacts on labor issues and on the welfare of labor. The study report the first results of a survey on the working conditions in the forests of the Mediterranean forests, where the mechanization of the operations is limited, owing to the difficult geomorphological conditions. The forest work is characterized by long working hours per day, limited number of breaks and no regular rotation of tasks. Motor-manual timber harvesting operations, which is still the main harvesting method in Mediterranean forest, are one of the hardest and heaviest types of physical work. This research is performed taking into account the whole cycle of work and the various activities carried in numerous forestry companies. A group of workers has been followed by a precise criteria selection: determinate the physiological cost of each task by measuring oxygen consumption and the heartbeat rate. The stress of dynamic work has been investigated and the measurements were conducted with a portable gas analyzer with a purpose of sampling metabolic and ventilatory data. On the basis of the results obtained, this method could well become a possible tool in implementing prevention measures for all workers involved in forestry industry operations and not only those in the first step of supply chain.*

Keywords: energy cost, metabolic rate, heartbeat frequency, VO_2

TRUNK UTILISATION AS A FACTOR AFFECTING HARVESTER PRODUCTIVITY

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Abstract: *High harvester productivity may erroneously indicate high process efficiency. Finding a right combination between trunk utilisation and harvester productivity helps private forest services to optimize their work output. At the same time, some amount of merchantable timber is left as post-harvesting residues in the forest. The process is especially observed in broadleaved harvesting because it takes a lot of effort to utilise tree crowns for assortments. Analysis of total log length (TLL) from a single tree is not sufficient to estimate trunk utilisation. A significant indicator may be the thinnest diameter of the top log (DTL) processed by a harvester. The aim of the study was to present productivity dependence on DBH and DTL. The research was carried out on 23 birch stands in a thinning operation using 11 different harvester models. On each research area DBH, TLL and DTL were measured for at least 30 consecutive trees with detailed harvester work time studies. A mathematical model was established to provide productivity curves. It was confirmed that smaller DTL results in lower productivity for trees with similar DBH. The conducted research proved that harvesters do not fully utilise merchantable timber for assortments. It means that operating on harvester productivity values with no context of DTL make them incomparable.*

Keywords: birch, optimization, diameter of the top log, timber harvesting efficiency

SCOPES AND LIMITATIONS OF THE USE OF UAV (DRONES) TO SUPPORT FOREST ASSESSMENT AND OPERATIONS - STUDY CASE IN YUNGAS CLOUD FOREST, NORTH ARGENTINA

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Abstract: *To prepare and monitor forest operations, detailed and up-to-date terrain and stand information is a prerequisite, but often lacks in remote areas. UAV (drones) may be a precise and economic alternative to satellite and crewed aircraft for acquisition of remotely sensed data. In order to plan management operations for partly fire degraded Natural Yungas Cloud Forests in Northern Argentina, a fixed wings drone (eBee from the company senseFly), equipped with a NIR camera was employed for data acquisition. Acquired data was checked and validated against ground truth samples. During 10 effective days of flights, 4,000 ha of forest were covered with a resolution of 10 cm/pixel. Via image analysis with the software Pix4D, the following data could be extracted directly from drone imagery: approximated digital terrain model, digital surface model; canopy coverage and existing roads network. Based on inventory sample plots, canopy coverage could be correlated to the basal area of alive trees (R2=0.72) and mature trees (R2=0.56). As a result of the field tests, the use of drones for data acquisition can be recommended in remote forest areas (up to a size of approximately 2000 ha) where up-to-date digital terrain maps are lacking, and especially in cases, where very diverse and irregular stand structures are present. Suitable areas for safe take-off and landing (approximately 200 x 40 m) are sometimes hard to find in remote forest areas. A validation with ground truth checks is necessary, but far less inventory points are needed comparing to conventional methods.*

Keywords: UAV (drones), forest structure assessment, operational planning

EFFECTIVE BIOMASS HANDLING - PREDICTING MODELS & FAST TRACK SUPPLY

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Abstract: *Effective biomass handling is a key issue for cost effective supply chain. Natural drying is used to decrease moisture content of energy wood. Drying is dependent on wood characteristics and weather conditions. Weather-dependent drying models for estimating the optimal storage time based on average moisture changes in fuel wood stacks stored outdoors have been developed for different stem wood and logging residues. Fast track is an alternative operational model where part of the feedstock is taken to the CHP-plant directly from forest without drying and storing. Fast Track is focused on summer and early autumn harvests because top performance of boilers is not needed that time yet. Changes in the legislation of road transportation and progress in the scrubber technology have enabled the use of moister feedstock in Finland. Fast Track-results were calculated by decays of 1%, 2% and 3% per month and with interest rates 3, 8 and 12%. With all of the interest rates, cost at the plant was the lowest with fast track supply method. Chlorine content and corrosion risks are under vigorous research.*

Keywords: energy wood, quality, storing, drying models, natural drying, fast track supply

THE DIALOG TOOL: A SUPPORT DOCUMENT FOR DEEPER TRUST

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Abstract: *A national survey carried out in France in 2012, stressed out that three main conditions are necessary to motivate a forest owner to harvest: financial output, trust in the professional service-provider and "quality" of the logging operation. Thus, the satisfaction of the forest owner, in compliance with sustainable management of the forest, has to be the objective n°1 of a logging operation. The DiaLOG tool was designed for this purpose. Facilitating the dialogue between the forest technician and "new" forest owner, for whom a logging operation is a first, is its primary function. Expectations and also fears of the owner are identified as "High Environmental Quality" criteria to customize the operation accordingly and reassuringly explain what is going to take place in the forest. The document also highlights preventive measures that might be relevant and how they would weight on the financial balance of the operation. As a "support document", the DiaLOG tool was designed to be simple with photos and comprehensive vocabulary. All illustrations can be customized to fit the service and the regional context the user company is offering. Feed-back from professional practitioners who used the tool in 3 European regions in 2016 during SIMWOOD project will also be presented.*

Keywords: forest owner, wood mobilisation, environment, logging operation, satisfaction

Introduction
Objective of the DiaLOG tool

A survey carried out in France, stressed out that three main conditions are necessary to motivate a forest owner to harvest: the price of course, but also the trust in the professional service provider and the quality of the logging operation (*Enquête sur la structure de la forêt privée, in French. 2012. Service de la statistique et de la prospective du ministère de l'agriculture).*

Thus, the satisfaction of the forest owner, in compliance with sustainable management of the forest, has to be the n°1 objective of a logging operation. A satisfied forest owner is an owner who will dare launch other logging operations in the future and who will speak about it positively to his/her circle of acquaintances.

The aim of this study was to build up a dialogue tool, as support document facilitating the dialogue between forest practitioners (service providers) and "new" forest owner, for whom considering a logging operation is a first. It is assumed that the identification of individual "High Environmental Quality" criteria would facilitate mutual understanding. The main objective of this support document is to enable the identification of clear expectations (and also fears) from the owner, to reassure him/her and explain to him/her what is going to take place in his forest. The document also highlights preventive measures that might be relevant and how to take them into account, because they can definitely have an impact on the financial balance of the operation.

It was developed within the EU project SIMWOOD (Sustainable Innovative Mobilisation of Wood 2013-2017). SIMWOOD's overall goal is to promote collaborative wood mobilisation in the context of multifunctional forest management across European forest regions.

SIMWOOD focuses on seven general objectives:

- Understand the current and future motivations of forest owners
- Promote forest governance and joint action of stakeholders
- Develop multifunctional forest management adapted to forest types
- Integrate forest ecosystem services while minimizing environmental impacts
- Establish improved adapted forest harvesting techniques
- Demonstrate collaborative regional initiatives and solutions
- Recommend tailor-made instruments to policymakers
- Encourage broad outreach and exploitation in EU regions

The project consortium comprises 28 partners from Germany, Belgium, Finland, France, Great Britain, Ireland, the Netherlands, Portugal, Sweden, Slovenia and Spain. They investigated the optimum forest use in 14 model regions in the EU. (http://simwood.efi.int).

Methods used to build up the DiaLOG tool

1st step: The support document was elaborated in spring 2015 by Simwood's domain leader of harvesting, on the basis of regional logging quality charts.

The main criteria related to potential environmental impacts were identified and the document was designed accordingly.
The document is quite simple in its form: pictures and simple / comprehensive vocabulary. Pictures make it easier to understand and avoid long discussions and misunderstandings. All the pictures can be customized to the company and to their context. However it is important to choose illustrations which reflect the reality. If the situation looks too beautiful to be true, the risk is high to end up with an owner disappointed with the reality and reluctant to ever mobilize wood again. The document has to be used with a map of the plot so that the different zones of interest can be properly identified and located.

2nd step: Tests of the DiaLOG logging tool were carried out, during the summer 2015-2017, in:

- ✓ South-Eastern Ireland by the company Irish Wood Producers *(test with 6 forest owners),*
- ✓ Grand Est (France) by the cooperative Forêts et Bois de l'Est *(test with 1 forest owner and tool reviewed by all staff of the cooperative),*
- ✓ Bavaria and Lower Saxony by the German Center of Forest Work and Forest Technology KWF *(discussion with 2 forest entrepreneurs, also timber buyers working with private forest owners)*.

3rd step: Adjustments of the tool and promotion for its use (2017)
The final document contains 13 slides and can be used in paper or electronic format. For each item, tips for a good use of the DiaLOG tool for Top Environmental Performance and Results are set out for the practitioners.

Results: the DiaLOG tool

Slide 6: Cover page
TIPS FOR A GOOD USE. You can add the Logo of your company

Slide 2: *Tips FOR A GOOD USE. The aim is to remind the objective of the silvicultural operation, to be sure that the forest owner and the company are on the same page. This document has to be used as a supplement to the information currently available on silvicultural operations.*

Slide 3: *TIPS FOR A GOOD USE. Inform the forest owner of the future changes of the landscape after the intervention, he/she should not to be surprised - or even worst disappointed (!) - by the final result of the logging operation. Identify also zones where landscape is a sensitive topic.*

Slide 4: *TIPS FOR A GOOD USE. The objectives are to identify, besides the statutory requirements, the species to be protected (and often the periods when logging will be banned) and to discover if the owner feels a specific connection to the trees: a beautiful oak, a tree planted by the grandfather, specific bushes…*

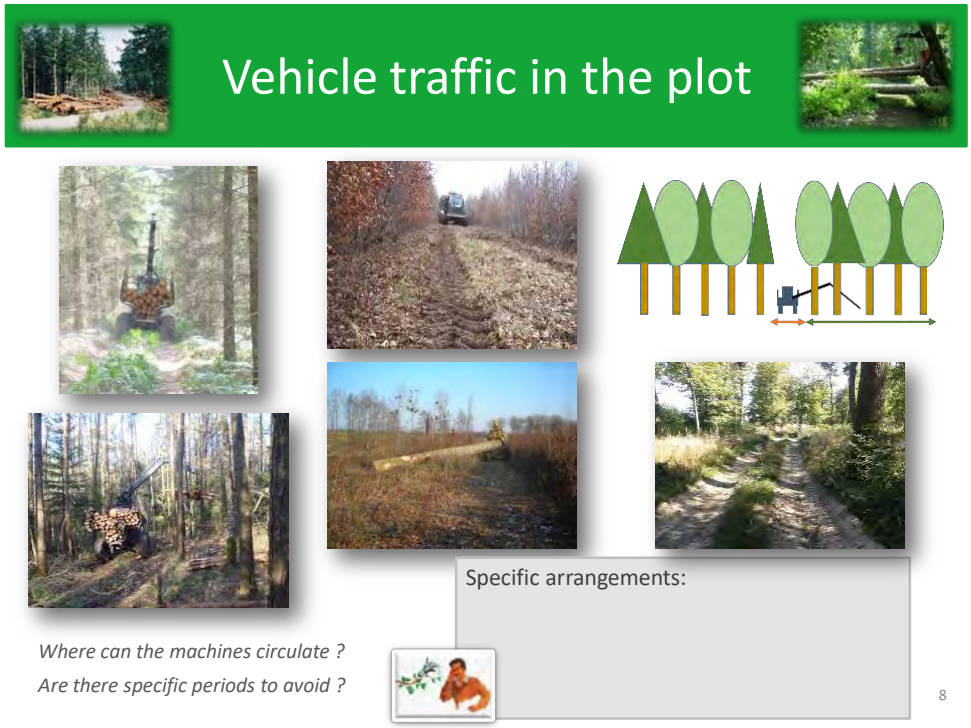
Slide 5: *TIPS FOR A GOOD USE; Identify and explain what will be done to protect streams, water sources, wetlands… and what is allowed in relation to those specific spot. Former and recent construction, ruins or vestiges should also be taken into account*.

Slide 6: *TIPS FOR A GOOD USE. Inform and increase the forest owner's awareness on the logging systems and its characteristics (harvesting machines). Technical aspects with an impact on the operation should be specified: dimensions of machines which influence the width of the skid trails to be opened, length of the crane and respective outreach potential, the impact of obstacles…*

Identify possible resentment from local population because of the noise.

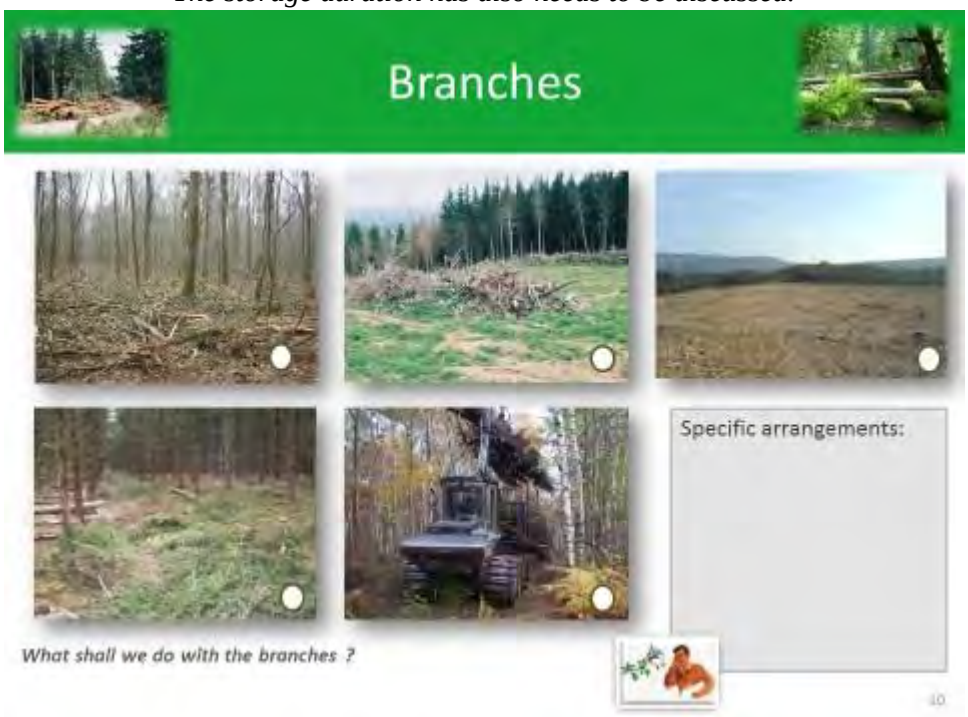
Photos can be changed: machines from your company, your trustworthy forest contractors at work…

Slide 7: *TIPS FOR A GOOD USE. Inform and increase the forest owner's awareness on the logging systems and its characteristics (forwarding or skidding machines).*
Photos can be changed: machines from your company, your trustworthy forest contractors at work…



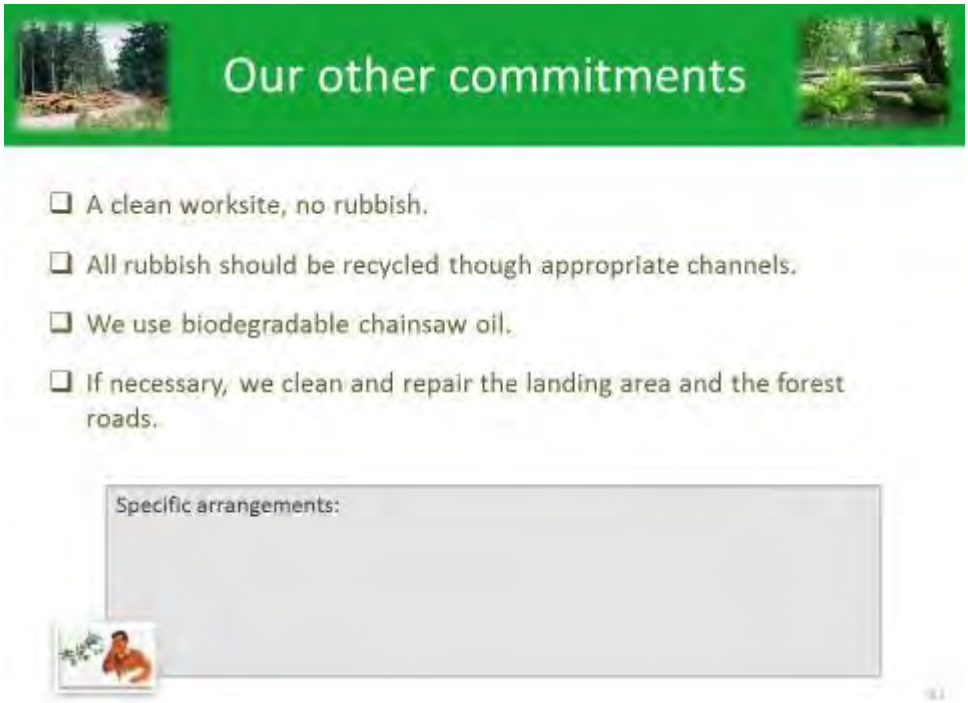
Slide 8*: TIPS FOR A GOOD USE. Several themes have to be discussed: soil preservation and efficient traffic only on forest tracks (strip roads); forest track's width linked to the machines (4 m are necessary to avoid damages on the remaining trees); spacing between the forest tracks linked to the outreach capacity of the crane (if the felling is mechanized); and specific areas to be avoided.*

Slide 9: *TIPS FOR A GOOD USE. Inform the forest owner that the landing area has to be well-dimensioned and accessible to trucks.*
The storage duration has also needs to be discussed.

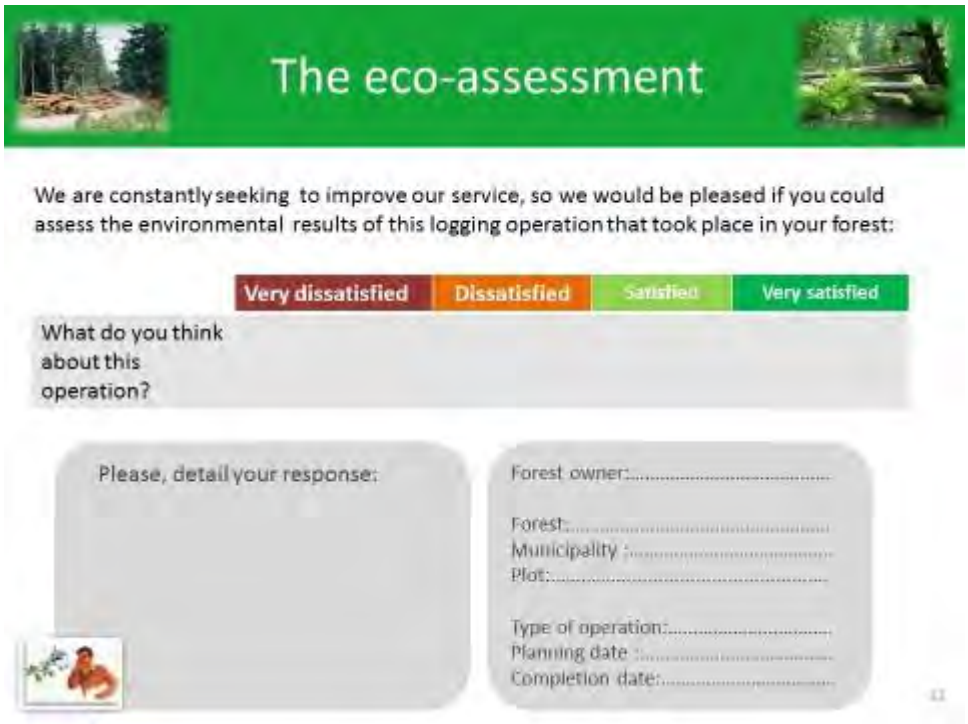


Slide 10: *TIPS FOR A GOOD USE. Processing branches is often a sensitive issue (Forest look usually "messier" than a French-style garden):*

- *Are they any expectation towards visual aspects? Removal is usually only done for bioenergy, burning has to be avoided.*
- *What about crowns: are they going to be processed for firewood?*
- *Soil fertility has to be taken into account.*



Slide 11: *TIPS FOR A GOOD USE. You can add PEFC, FSC certification or others*.



Slide 12: *TIPS FOR A GOOD USE. A very important step, to be done with the forest owner at the end of the work/discussion. Could be merged with a global assessment.*

Slide 13: *Last slide*

Discussion on the basis of the feed-back from practitioners (South East Ireland, Grand Est France, Bavaria and Lower Saxony)

This pan European tool was tested by 2 companies (Irish Wood Producers and a French cooperative Forêts et Bois de l'Est) and discussed in Germany by the German Center of Forest Work and Forest Technology KWF (with 2 forest entrepreneurs, also timber buyers working with private forest owners).

Feedback on the form

Pictures were changed, adapted to their context (Grand Est) and it was suggested to change them in order to consider regional and silvicultural practices (Bavaria and Lower Saxony), or to adapt the photos (e.g. machines of the companies which will operate in the forests, forest photos close to the owner's forest (Grand Est).
Irish Wood Producers included elements from the DiaLOG tool in additional documents they already use (health and safety assessment; forest activity contract). They also mentioned that the DiaLOG tool is useful to make the forest owner aware of the health and safety elements as a part of the tool.
For all practitioners, all items were seen as relevant (Ireland, Grand Est, Bavaria and Lower Saxony), especially aspects of soil and tree damages, silvicultural objectives of the measure and evaluation of the procedure (Bavaria and Lower Saxony).

General interest of the DiaLOG tool to identify clearly forest owner's expectations (and fears)

Some comments from the practitioners.

- ✓ "*The owner was interested by the information concerning the different ways to harvest*". Thus, it can also be considered as an information/training tool to increase the forest owner's knowledge.
- ✓ "*including it in essential documents, makes its use more critical and a greater awareness achievable at the outset*".
- ✓ "*it can also be a decision support tool for the forest owner to choose the best contractor*"
- ✓ "*marketing tool for the entrepreneur to convince forest owner to contract*"

- ✓ "*it's a good support document for the discussion*"
- ✓ It was also suggested to "*create posters of similar for site field visits*".

After this test period, the Irish and French companies decided to use the DiaLOG tool in their day to day job. Their main motivation is to ease the dialogue and satisfaction of the forest owner.

Conclusion

The DiaLOG tool is a "support document" quite simple in his form: photos and simple, comprehensive vocabulary. The DiaLOG tool is just one document or tool focused on environmental criteria. Thus, it has to be used in addition to all available documents.

As mentioned all pictures can be changed and adapted to the company and the local context. This customization is even useful for the appropriation by the practitioners. However, everyone should be aware to choose realistic photos of what the company can really achieve. Everyone should also have in mind that the satisfaction of the forest owner has to be the n°1 objective, in order to create trust in logging operations from the 1st experience.

The DiaLOG tool does not pretend to solve all the problems of wood mobilization, such as typical economic issues, but it certainly helps to improve the necessary dialogue between forest owners and practitioners.

Acknowledgements

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A special thanks goes to the practitioners who tested the DiaLOG tool and thus helped to improve it: the company Irish Wood Producers, the cooperative Forêts et Bois de l'Est and the German Center of Forest Work and Forest Technology KWF. We also express our gratitude to our SIMWOOD partner EFI for their advice and support.

CHALLENGES IN ROAD CONSTRUCTION AND TIMBER HARVESTING IN JAPAN

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Abstract: *The stratum of accretionary wedges inclined, and it made dip slope and opposite slope. Granite magma intruded among accretionary wedges, and later granite itself became decomposed soil. Much annual perspiration nearly 2,000 mm caused by monsoon attacks forest road, and innovative technologies for road construction are required. There occurred numerous circular slips and deep-seated landslide from ancient days. For the inclined stratum at Shimanto belt composed of sedimentary rocks, deep excavation for preparing structural foundation of road was invented. After deep excavation until the depth of ensuring road width, small blocks of compacted subsoil were piled up. It is difficult to make high cutting slope at smooth soil area, and the retaining wall by log structure is effective for spur roads. Underground water comes out through crushing zones is often troublesome. When crashing zone and dip slope overlap, the valley head is unstable and the beginning area of land slide, and it is dangerous to construct road. Some forest road retaining technologies has been introduced recently in Japan. When crossing the crushing zone by simple structures, cage or L-shaped steel retaining wall is effective because the weight of stones and rocks in the structure presses down the road foundation with high water permeability. It is important to adopt the most appropriate roading method according to soil, geology and terrain conditions.*

Keywords: accretionary wedge, crashing zone, dip slope, retaining wall, reinforced soil wall

AN STUDY AT DIFFERENT SCALES OF THE POTENCIAL OF BIOMASS USE: GIS, YIELDS, COSTS AND LOGISTICS

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Abstract: *To optimize biomass exploitation, it is essential to develop fully its use for energy purposes. This depends largely on availability and costs of acquiring the resource, as well as the profitability and reliability of the forest harvesting system. The production and extraction of forest biomass must be mechanized as much as possible, and in an efficient way, in order to improve productivity, reduce costs and limit environmental impacts. Here, a global methodology is presented, an approach allowing an integrated study at different scales (regional, municipality and local) which includes: the quantification, description and georeferencing of existing biomass resources for a whole region (using GIS methods), productivity and costs studies of the machines involved in the harvesting system, and full logistical analysis of the supply chain from the perspective of optimizing transport and minimizing both economic and environmental costs. The study focuses on the most common system used in the area to harvest woodfuel (crown and bark, which remains on the ground after harvesting Eucalyptus globulus Labill. for pulp production. It considers bundling, forwarding and transporting phases. Furthermore, to estimate the carbon emissions of the machinery used, the system boundary was expanded to take into account the manual felling, mechanized processing and chipping at plant phases. As this methodology facilitates joined up planning by considering logistical, economical and environmental factors, it will contribute greatly to informing the decision making of foresters and energy consumers alike.*

Keywords: biomass, GIS, productivity, cost, carbon emissions.

PROCESS OPTIMIZATION IN THE FORESTRY BY USING RFID-TECHNOLOGY AND NAVIGATION SOLUTIONS - RECENT RESEARCH RESULTS

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Abstract: *Navigation solutions in forest operations are necessary to digitize and to identify skidding roads and tracks and to navigate forest machines during their complete operations. This allows keeping the machines on the provided tracks in the forest stands and minimizes soil compaction and damages on standing trees. Furthermore enables the precise position of the machine and in case of harvesters the position of the acting harvester head the system to allocate the forest owner automatically on the basis of digital forest maps. Precise machine allocation is also the key information for comprehensive process optimization in terms of performance, holding tracks trafficable and cost efficiency. Recent research approaches to navigate forest machines and to identify the allocation of skidding roads and tracks by using state-of-the-art satellite signals and different solutions for signal corrections will be summarized. Additionally the stage of development of an adapted RFID-marking system for softwood logs including their optional automated application will be introduced. Further research work in that field is ongoing and preliminary results can be shown. Especially results out of a terrestrial navigation system on temporarily radio network development will be presented.*

A PERSPECTIVE ON THE REQUIREMENTS OF "FOREST ENGINEERING" BY IMPLEMENTATION OF THE SIXTH FIVE-YEAR ECONOMIC AND SOCIAL DEVELOPMENT PLAN OF IRAN (1396 - 1400)

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Abstract: *Mid-term development plans of the Islamic Republic of Iran that are developed for five-year periods and are approved by the Islamic Parliament contain laws and regulations that the government is obliged to implement. In "the sixth five-year economic and social development plan" which is going to start from the year 1396 (April, 2017), an article is passed that forbids any form of commercial and industrial utilizations of the country's forests (in the form of wood) from the beginning of the fourth year of the plan (i.e. 2020). Iran has about 14 million hectares of forests in 5 growing zones namely, Hyrcanian, Zagros, Arasbaran, Irano-Turanian, and Persian gulf-Ommani zones. Up to now, only the Hyrcanian zone, with an area of 2 million hectares, has difference executive plans such as selective cutting base on "close-to-nature" method, through implementation of "forest management plans" in around 1.1 million hectares. Climate change, dust storms, quantitative and qualitative changes in area of forest resources, and development of ecosystem approch and ecological viewpoints has led to such a decision in the government level. Undoubtedly, during the utilization ban period, forest engineering science (road building, utilization and transportation) which is closely connected to forest resources utilization would undergo some changes towards stagnation. So, manufacture and import of forest utilization machinery in this period is unlikely and the focus should be shifted to mechanization of forest rehabilitation, development, protection, and conservation. This study discusses the utilization period when mechanizations entered the Iranian forests, and by analysis of the requirements of the future period, it make predictions about the type of mechanization in these forests after implementation of this law.*

Keywords: five-year mid-term plan law, mechanization, Iranian forests

MULTIOBJECTIVE OPTIMIZATION OF TIMBER AND BIOENERGY SUPPLY CHAIN FROM BEETLE-KILLED BIOMASS IN COLORADO

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Abstract: *In the northern Colorado Rocky Mountains, harvesting beetle infested forest stands provides an opportunity to utilize resources that are otherwise wasted. While sound wood can be still used for traditional timber products, degraded wood and logging residues can provide a feedstock for bioenergy. Although with a potential for reducing greenhouse gas (GHG) emissions, bioenergy utilization has been constrained due to high costs of harvesting and transportation. In addition, management of timber production and use of bioenergy feedstock are commonly done separately and linkage between them is seldom considered. In this study, we develop and apply a multi-objective optimization approach to integrate economic and environmental objectives in the supply chain for both timber and bioenergy products. The economic objective is measured by the total net revenue and the environmental objective is measured by the net reduction in GHG emissions. Upstream forest harvesting decisions are considered as decision variables in the supply chain optimization. The resulting Pareto optimal curves show the trade-offs between objectives. As the management goal changes from fully economic-driven to fully environment-driven, the whole-tree harvesting method is selected for more harvesting units to prepare logging residues as a by-product, resulting in an increasing amount of bioenergy products. Meanwhile, the economic objective decreases from $4.42 million to $3.19 million, while the environmental objective improves from 166 kton CO2-eq to 211 kton CO2-eq.*

Keywords: multi-objective optimization, beetle-killed biomass, salvage harvesting, GHG, bioenergy

REDUCING FUEL CONSUMPTION AND IMPROVING CHIP QUALITY BY ADJUSTING CHIPPER SETTINGS

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Abstract: *The fuel consumption of disc chippers is very high, even for the latest models available. This indicator is an important economic factor to the process, and so is chip quality in pulp production industry. Chipper users are always looking for improvements, in order to decrease costs, maintain company internal inflation under control, and keep themselves competitive. This study evaluates two actions to reduce fuel consumption in a large industrial chipper. One action consists in using a circuit to automatically reduce the rotational regime of the engine (idle) when the machine is not working, while the other action consists in reducing the rotational regime of the machine during work, playing on the power/torque curve. The consumption was measured for 30 days for each treatment, in three shifts continuous operation. Chip quality was checked through the measurements of 10 samples per treatment, in order to determine particle-size distribution and bark content. These actions resulted in a significant reduction of fuel consumption, compared with the standard settings. Consumption was 4% lower using the circuit, and 20% lower setting the in-feed speed at 1820 RPM. Neither action had any impact on chip quality.*

Keywords: diesel consumption, in-field chipping, quality, hardwood pulp

OPTIMAL TIMBER SUPPLY IN TIME SLOTS WITH INTEGRATED PLANNING OF HARVEST AND TRANSPORT OPERATIONS

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Abstract: *Optimal timber supply in time slots and an integrated planning of harvest and transport operations are the keys to improve the economic situation of a forest enterprise. The yearly sustainable harvest volume of all forest enterprise's compartments is the base for sale negotiations with customers and contracts with delivery commitments for different quantities of an assortment in time slots. Then the optimal distribution of main assortments is determined with minimized transport distances from compartments to customers. This does not yet deliver answers, which compartments are to be selected to satisfy the agreed demand in time slots according to the optimal distribution. For this reason a practical example was created with 168 single compartments, five customers and a harvest volume of 525,000 m³. The planning period of one year was divided in four quarters as time slots and the forest region was partitioned in different zones with quarterly changing harvest costs. The changing quarterly harvest cost in the zones, the changing quarterly demand of the customers and the optimal distribution are the constraints to build harvest groups with minimized harvest costs by linear programming. Inside the groups the optimal harvest sequence agrees to the shortest path. Along this harvest sequence the number of harvest teams can be determined. Considering the progress of the harvest operations, the locations of piles and the needed transport capacity is computable weekly. This results in an even weekly supply of the customers according to the agreed demand in quarterly time slots.*

Keywords: linear programming, time slots, optimized harvest sequence, integrated planning of harvest and transport

A NEW TECHNIQUE FOR PRECOMMERCIAL THINNING USING A CLEARING SAW DESIGNED FOR TOP SPACING

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Abstract: *Delaying precommercial thinning (PCT) of dense stands is recommended for some species to promote a longer branch-free butt log. Delayed thinning, however, causes a significant reduction in workers' productivity because of the increased stem size to cut relative to the limitations of the brush saws commonly used, rendering this option impractical. The recent commercial availability of a different configuration of clearing saw, using a chainsaw on a pole with a flexible shaft (the engine is mounted on a harness on the user's back), offers new possibilities. It appears to offer more flexibility in movements and in stem sizes that can be cut, hence, offers the opportunity to re-invent how PCT can be performed in older stands. A time study was performed over 13 days in a 16 year-old dense hardwood stand to determine workers' productivity of using this new saw, in a treatment that would make use of its advantages. Instructions asked for releasing only the best crop trees, leaving all other stems standing, and allowed cutting stems at any height. On average, 70 trees per productive hour (PH) were released, which is half of what is normally observed in a standard PCT treatment. On the other hand, 0,23 hectares / PH were treated, which is more than four times that of standard PCT. The saw permitted relatively easy movements through unthinned areas and appeared efficient at cutting hardwoods up to 12 cm dbh. Results suggest that this technique could make it feasible to delay PCT beyond the usual operable period.*

Keywords: thinning, productivity, spacing, delayed thinning

DETERMINING CHIPPER MAINTENANCE COST AS A FUNCTION OF CHIPPER TYPE, AGE AND ANNUAL USE

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Abstract: *Chippers are considered high-maintenance machines, and yet very little hard data is available about their maintenance cost. Therefore, empirical data was gathered from 25 chippers in Italy, using a standardized data-collection questionnaire. Owners were asked to provide data about machine maintenance and repairs, separately for the main machine components (i.e. chipper, carrier and loader). Furthermore, owners provided data about machine age (years), initial and resale price, total use (hours), total production volume (tonnes) and fuel use. The sample included a large variety of machines, from small chippers powered by tractors with 60 kW engines to large industrial machines with independent engines up to 400 kW. Mean machine age was 6 years, with a maximum of 13 years. Mean total use was 4700 h, with a maximum of 19500 h. Maintenance cost ranged from 5 to 44 €/h, or 1 to 7 €/tonne. As an average, repairs accounted for 20% of the total maintenance and repair cost, which was approximately equivalent to 70% of the annual depreciation cost. However, the relationship between maintenance and depreciation is weak. The information contained in the study is important for machine cost calculation, were often rule-of-thumb assumptions are used in the absence of empirical data.*

Keywords: biomass, energy, economics

REHABILITATION OF SEMI-MOUNTAINOUS FOREST AREA USING BIOCLIMATIC FOREST CONSTRUCTIONS

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Abstract: *Forest constructions are structures erected for serving the forest exploitation and utilization of its products, including recreation. The construction principals of a standard forest village with wooden lodgings apply principles of bioclimatic design and use ecological building materials. It highlights the area and helps to maintain the natural beauty of the forest. Accurate analysis of the area of the forest village requires the creation of topographic plan with great precision. Topographical drawing in AutoCAD in coordinate system HGRS '87 with contour interval 2 meters with the help of geodetic GPS was created. The aim of this paper was the rehabilitation of a semi-mountainous area taking into consideration environmental, economic, ergonomic and architectural constrains with the help of Google earth. The area of the camp outside the village of Dadia of Evros Prefecture was granted by the army to the Forest Office of Soufli and remains unexploited until today. The installations were recorded and shown together with the topographic diagram and an image from Google earth for the under study area. All the proposed facilities are presented in a Google earth image and in a three dimensional view. The forest village will be composed of 20 wooden lodges with a capacity of 4 persons each. The lodges will be designed around the bioclimatic design, in order to exercise the least impact on the natural environment and to meet the needs of residents for a comfortable and relaxed living. The landscaping was based on better utilization and lower environmental cost of construction in the landscape.*

Keywords: landscape, Google earth, AutoCAD, forest constructions, forest village, geodetic GPS

SUSTAINABLE ALTERNATIVE TOURISM AND COMPATIBLE FOREST OPENING UP WORKS

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Abstract: *The development of the semi mountainous and mountainous regions is related with the development of sustainable alternative tourism, which, as all the aspects of economic growth, causes negative impacts to the environment. This is peculiar because this particular human activity often causes degradation of the natural and structural environment but on the other hand, uses the environment as a feedstock for its development. The semi mountainous forest areas not only because of their position but and as ecosystems are the link between coastal, island and mountain regions. It is the backbone of the country. The combination between the technology of the digital photogrammetry and the GIS technology was used in order to evaluate the compatibility between the general forest opening up works and the natural environment. In order to evaluate the compatibility, practical criteria of the intensity of the human influence as well as criteria of the environment absorption to the opening up works were used. The digital maps and the spatial analysis allowed the efficient and reliable evaluation of these criteria. The results prove that the usage of this method provides the ability to evaluate the compatibility of the existing opening up works with the natural environment and the possibility to choose the most compatible for the environment solution, in order to achieve not only a sustainable forest management but also a development of different aspects of alternative tourism. The sustainable development of the mountainous areas of Greece targets regional and social cohesion in the framework of specific strategic targets.*

Keywords: Forest opening up, sustainable alternative tourism, natural environment, digital photogrammetry, GIS.

APPLICATION OF MULTI-CRITERIA DECISION-MAKING IN FOREST ROAD NETWORK PLANNING IN THE FRUŠKA GORA NATIONAL PARK IN SERBIA

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Abstract: *The construction of forest road infrastructure begins long before its physical realization, through a systematic series of defined planning and design procedures. Under the current conditions of integrated management, in which forests and forest roads have multifunctional character, the economic criterion mustn't be the only one in forest opening. When solving real problems, such as forest road network planning in special purpose forests, it is very often necessary to make a decision that simultaneously achieves several often conflicting goals. Decision making becomes even more complex when multiple criteria are involved. Multi-criteria analysis integrated into GIS can provide adequate manipulation and presentation of data with consistent evaluation, based on a number of factors that can have an impact on the analysis of specific problems. This paper will present the possibility of using multi-criteria decision-making in the planning of a forest road network in special purpose forests of the Fruska Gora National Park in Serbia.*

Keywords: forest roads, multi-criteria decision making, GIS, special purpose forests, the Fruska gora National Park

OPTIMIZED CLEARING AND EARLY THINNING BY SPACER AND MOTORSAW

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Abstract: *In January 2007 the storm Kyrill destroyed 50.000 ha of forest stands in the federal state of North Rhine-Westphalia. 15,7 Million cubic meters fall. ¾ of the stands are private forests. Today, after 10 years, many stands are still not cleaned or thinned. With increasing age the cleaning gets more expensive year by year because of increasing diameters and shifting stand structure. The stands also need clearings to enhance their stability. For late thinnings the Husqvarna FBX 535 (so called "spacer") is an evaluated (Jacke 2013) appropriate machine which can easily be managed by a single forest worker. We made time studies for two systems in early thinnings in a 10 year old mixed spruce dominated stand: (1) spacer/motorsaw combination for a schematic reduction of stem number and debranching/CTL 2m logs (logs just 5m next to logging trail); extraction by forwarder and (2) motorsaw for a future crop tree orientated thinning plus felling and debranching/CTL of 2m logs (logs just 5m next to logging trail) from the areas between future crop trees; extraction by forwarder. Processing the 2m logs by chainsaw up to a diameter of 13 cm is non-profitable. Including processing timber 36,9 h_{PSH15}/ha are needed for schematic reduction and 24,6 h_{PSH15}/ha for the future crop tree method. Without using any timber (clearing only) 33 h_{PSH15}/ha are needed for schematic reduction and 12,1 h_{PSH15}/ha for the future tree method.*

Keywords: early thinning, cleaning, spacer, motorsaw, time study

DEVELOPMENT OF THE NEW METHOD FOR ASSESSING CONDITION OF FOREST ROAD SURFACE

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Abstract: *Forest roads are characterized by low traffic conditions (Fertal 1994), in terms of number of vehicles, but on the other hand there are great values of ground pressure which appears between wheels of timber truck units and forest road surface, pressures values often exceed 80 kN (Trzciński and Kaczmarzyk 2006). Stated, cause damage of the upper and lower layer of forest road. There are several methods for assessing condition of forest road surface in the world which are mainly used for assessing state of public roads, but they can be used in forestry. Assessing condition of forest road surface was done by measuring vibrations with special developed software for Android OS installed on Huawei MediaPad 7 Lite. Software measured vibrations in all three axes, coordinates of device, speed of vehicle and time. Aim of this research was to determine accuracy of collected data so that this method can be used for scientific and practical purposes. Research was carried out on the segment of forest road during driving of a vehicle equipped with measuring device. Tests were performed in both direction of the forest road segment with different measuring frequencies, tire inflation pressures and speeds of vehicle. Values of vibrations were classified and translated on map of forest road by measured data of coordinates of device. Values of vibration were compared with places on the forest road where damages of the forest road surface were noticed. Research results show no significant difference in vibration values between measurement frequencies 1 Hz and 10 Hz. Based on analysis of collected data and obtained results it is clear that it is possible to assess condition of forest road surface by measuring vibrations. The greatest values of vibrations were recorded on the most damaged parts of the forest road. Vibrations do not depend on tire inflation pressure, but ranges of vibrations are decreasing with decreasing the speed of the vehicle. Accuracy of collected data depends on GPS signal quality, so it is recommended that each segment of forest road is recorded twice so that location of damages on forest road can be confirmed with certainty.*

Keywords: forest road surface, forest road damage, vibration measurements, vibration software

IMPROVED ROUTE GENERATION FOR LOGGING TRUCKS, CONSIDERING CURVATURE, HILLINESS AND INTERSECTIONS

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Abstract: *Calibrated Route Finder (CRF), is an online route generation system that finds the best route by balancing several conflicting objectives. The system, which has been in use in Sweden since 2009, uses an innovative inverse optimization process that establishes more than 100 weights to balance distance, speed, social values, environmental impacts, traffic safety, stress, fuel consumption, CO_2 emissions, and costs. Today the system is used by all major forest companies and in 60% of the two million transports in the sector each year. This presentation will describe how methodological and analytic development now enables measurement and inclusion of rules that consider vertical and horizontal curvature, as well as legal and practical issues relating to turning in intersections. This development also enables incorporation and consideration of time delays, fuel consumption, and CO_2 emissions due to deceleration, waiting, and acceleration at intersections in the CRF route generation. Further development, such as an improved remuneration system that better than the current system compensates actual work done by the hauler, will also be discussed.*

Keywords: distance measurement, decision support system, optimization, curvature, hilliness, intersection, remuneration system

Introduction

In Sweden, logging truck operations are paid according to load weight and distance travelled, and it is therefore important to accurately measure that distance. Historically, several different methods to establish the distance have been used in practice, for example manually measuring the distance to an already known point or reading the odometer in the truck. This caused administration and problems in the interaction between buyer and seller of logging transports, and the system was not fair, as the diversity of measurement methods could cause corresponding assignments to be of different length.

To tackle this problem, the forestry sector decided collaboratively to develop a new system, Calibrated Route Finder (CRF), that was to be objective, automatic and transparent. A prerequisite for the development of CRF was the emergence of NVDB, the National Road Data Base managed by the Swedish Road Administration, which came into use in the 1990s (Swedish Road Administration, 2008). NVDB contains information about road features and attributes for all roads in Sweden.

Since the first pilot project in 2009, CRF has been in operation in Sweden, and invoicing of more than 60% of all logging transports is now based on CRF. The system is owned and managed by SDC, the IT company of the forest industry. SDC manages and administers forestry data and acts as an independent organisation, ensuring that invoicing between forest companies and haulers is based on accurate information. The development of CRF is further described in Flisberg et al. (Flisberg et al., 2012).

Route selection is a trade-off between distance and road characteristics, and finding the most efficient route from the landing in the forest to the delivery point at mill or terminal requires many decisions. Finding the shortest or

quickest route is not complicated given access to reliable road data, but such a route may not necessarily be the best one. There are many objectives to balance, both quantitative objectives such as time and fuel consumption, topography, as well as qualitative objectives such as traffic safety and working environment (Figure 1). Also, as the distance forms the basis of payment to the hauler, route selection must be agreed between the hauler and the forest company ordering the transport.

Figure 1. Finding the most efficient route from landing to mill is a matter of balancing many objectives, some of which are shown in the illustration. Illustration by Margareta Nilsson

To capture the above objectives, CRF uses best practice in finding the most efficient route between landing and mill. 1500 Key routes, evenly distributed over Sweden, and negotiated between forest and haulage companies, provides examples of which route should be chosen from landing to mill. The next step in the construction of CRF is to assign weights to a predetermined set of road features, available in the NVDB (Figure 2). These weights are derived through an inverse optimization process where the Key routes act as the optimal solution to a standard minimum-cost route problem. Based on these weights, each road link in the network can then be re-assigned a value describing the resistance applying in each individual link. The system is now ready for use in practical operation. When CRF receives a call from a user, CRF finds the combination of road links between landing and recipient point that gives the lowest total for resistance. The distance is now established, and the route can be displayed on map.

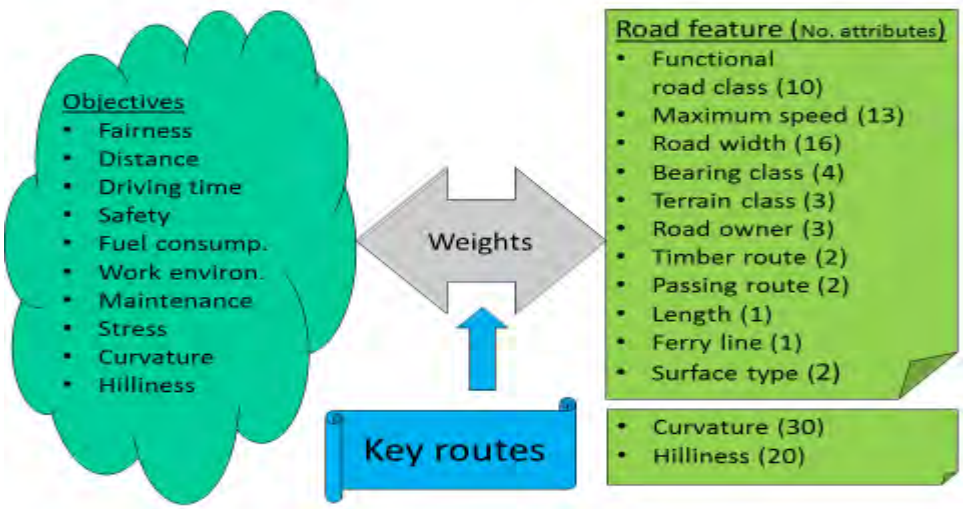

Figure 2. The Key routes act as the optimal solution in the inverse optimization process when weights are established for different road features

CRF is undergoing constant development and refinement, often in response to deviation reports submitted by the end users. During one period, several deviation reports pointed out that CRF chose routes along roads that drivers perceived as having a high degree of vertical and horizontal curvature, factors that are negative for operating speed, fuel consumption and road safety. In order to improve route selection by considering vertical and horizontal curvature, a measure had to be established that represented the operators' perception of these factors, and weights assigned for inclusion in CRF (Svenson et al., 2016). The same applies to intersections, where deceleration, waiting and acceleration also affect operating speed and fuel consumption negatively. The problem with vertical and horizontal curvature and intersections is that these are not reported directly in NVDB, and must be calculated.

Vertical curvature

To establish a gradient feature, increased (or decreased) fuel consumption due to slopes was used. To calculate this, the z-coordinate in NVDB, describing the vertical position of the road topography, was used. Normally, there are several coordinates along each road link and, using these, a slope can be calculated. For each slope, fuel consumption relative to a level surface was determined, using a modified version of the HeavyRoute and Artemis models (André et al., 2009, Ihs et al., 2008). For the entire road link, a weighted average was then calculated, followed by assigning the road link with one of 20 gradient attributes. Together with all the other road features, the gradient feature was then used in the subsequent inverse optimization process.

Horizontal curvature

The increased driving time caused by curvature compared to a straight road section was used to establish a feature describing horizontal curvature. Here, the x and y-coordinates in NVDB, describing the road geometry in the plane, were used. For each coordinate, a (curve) radius could be calculated using adjacent coordinates. Maximum travelling speed for negotiating each curve along the road link was then calculated, and compared to the posted speed limit. If maximum travelling speed to negotiate a curve was lower than the posted speed limit, this indicated deceleration before and acceleration after that single curve, thereby increasing driving time compared to a straight road link. The difference in time taken between the curved road link compared to if the same link had been straight was then used in the subsequent weight setting.

Features describing horizontal and vertical curvature were successful in solving many of the deviation reports relating to curvature, and these features are now integrated in CRF in practical operation.

Intersections

To establish a feature describing the effect of intersections, time and fuel consumption associated with deceleration, stopping and acceleration in various types of intersections must be calculated.

This requires an estimation of how deceleration, stopping and acceleration in intersections affect travelling time. Total time delay in an intersection includes geometric delay, queueing delay, deceleration and acceleration delay, and stopped delay (Sisiopiku and Oh, 2001). At an intersection, only some of the traffic needs to stop. Depending on the type of intersection, i.e. functional road class on the entering and leaving arcs, there are different estimated times of waiting before entering the intersection. Turning left and going straight ahead, which means that traffic from both left and right must be considered, is assumed to take longer than turning right. With information on initial speed after an intersection, the additional fuel consumption needed to accelerate to the nominal speed on the specific arc can be calculated, as well as the fuel consumption caused by waiting at the intersection.

Information about increased time and fuel consumption is then used on the arcs representing each turning option. This information can be used as an extra 'cost' to avoid intersections in route generation, and in calculating total time and fuel consumption for routes. The inclusion of this function in CRF requires an augmented road data network where, unlike the current system, all turning options are represented by an individual arc.

Improved remuneration system

Logging transport is paid according to payload and distance between landing and mill. When a route is chosen by CRF, the system suggests the route that has the lowest total resistance ('cost'). Often, there are two, possibly more, route options that are very similar in resistance, but with considerable difference in length. This means that, according to resistance, the routes are similar, but the remuneration to the hauler will vary greatly. If the system chooses the shorter route; the hauler is paid less than if the system chooses the longer route. Moreover, the shorter routes also often have a higher proportion of gravel roads, narrow roads, hilliness and curvature, which have a significant negative effect on time and fuel consumption. This exacerbates the problem.

The conclusion is that distance is a poor measure of the work performed during a logging assignment. Geographical and topographical variations between assignments are great, and are not satisfactorily reflected in the current remuneration system. An alternative remuneration system could be based on the resistance points from CRF, or from calculated time and fuel consumption, which accounts for more than two-thirds of the transportation cost. This is the focus of one of the ongoing development projects within CRF.

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TECHNICAL PROBLEMS OF WOOD CHIPS UTILIZATION

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Abstract: *The Hungarian renewable energy potential is based on biomass. Wood biomass constitutes the large part of the raw material of operating heating plants. A significant part of raw material comes from forestry as firewood and harvesting losses. A lower part stems from short rotation energy plantation (currently only a few thousand hectare energy plantation are in Hungary), and attempts were made to utilize biomass production of non-conventional areas, as well (e.g. biomass from abandoned land, or located next to line-based facilities). The wood based biomass is utilized by the heating plants mainly as wood chips. This technology proposes more challenges: moisture content decisively influences the fuel value; optimalization of moisture content depends on storage; combustion technique respect is important the fraction distribution etc. Our research is based on the examination of these factors and the demonstration of the problems of wood chip management.*

Keywords: biomass, wood chips, utilization, problems

Introduction

The energy demand has shown a slow growth in Hungary. The country's dependency on energy import is quite high: in 2016 the domestic energy production was 424 436 TJ, while the import was 804 160 TJ, which means that the value of energy import is more than 65%. The share of the renewable energy consumption is around 9% and the solid biomass is around 82% (www.mekh.hu) (Figure 1).

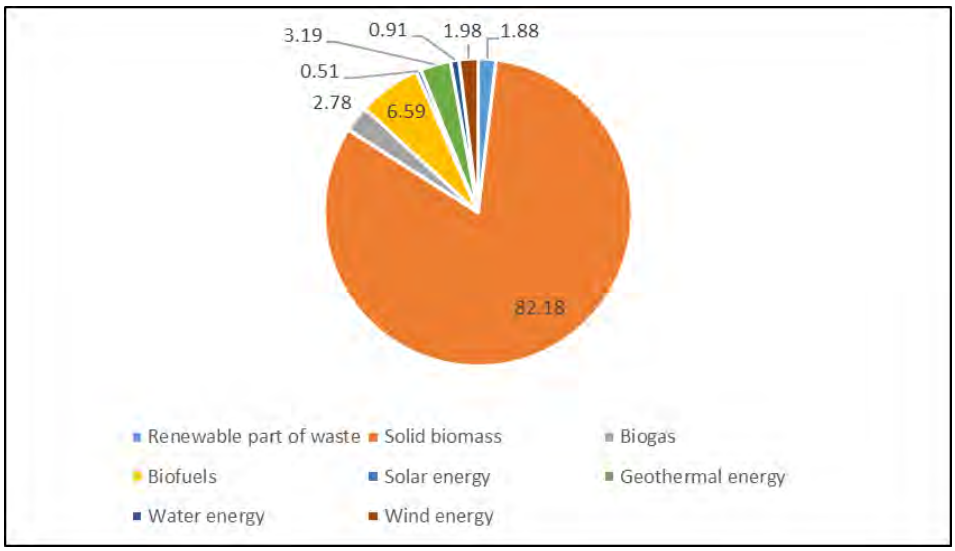

Figure 1. Primary renewable energy utilization in Hungary [%] [2014] (Source: www.mekh.hu)

Hungary's policy on renewable energy is based on the EU strategies. The European Union aims to achieve three main goals by 2020:

- reducing the greenhouse gas emissions by 20%;
- reducing the energy consumption by at least 20%;
- achieving a 20% share of renewable energy in the global energy mix.

Hungary is expected to reach at least 13%. In 2010 the Hungarian Parliament adopted Hungary's Renewable Energy Utilization Action Plan extending the minimum required value of the share of the renewable energy in the global mix from 13% to 14.65%.

The main aim is to increase the use of renewable energy sources in Hungary to 186.3 PJ by 2020, including biomass with the target of 130.8 PJ (Vágvölgyi, 2013).
Hungary's biomass resource is estimated at 350-360 tonnes, representing two thirds of the renewable energy sources. Only one sixth of this resource is currently utilized. Dendromass, i.e. wood-based biomass, constitutes a large part of biomass (Czupy et al, 2012).

According to Molnár et al. (2013), wood used for energy purposes may originate from four sources:

- the firewood of the traditional forest management (public or private sector);
- harvesting losses produced during tree utilization;
- wood industry by-products;
- timber of energy tree crops that is primarily utilized as wood chips.

Figure 2. Dendromass sources (Photo: Szűcs Ferenc)

The benefits of dendromass utilization:

- sustainability;
- stability of the generation capacities;
- low production costs;
- easy manageability and industrial use;
- high calorific value (on average 13 MJ/kg, in case of water content of 25-30%);
- low ash and sulphur content;
- increase in rural employment.

The available quantity of dendromass has been examined several times. According to Molnár et al. (2013), in Hungary ca. 3.5 million tonnes per year can be provided for energy purposes. The data of National Food Chain

Safety Office showed that in recent years the amount of wood cut was 7.5 million gross m^3 per year on average which is 60% of the current growth.

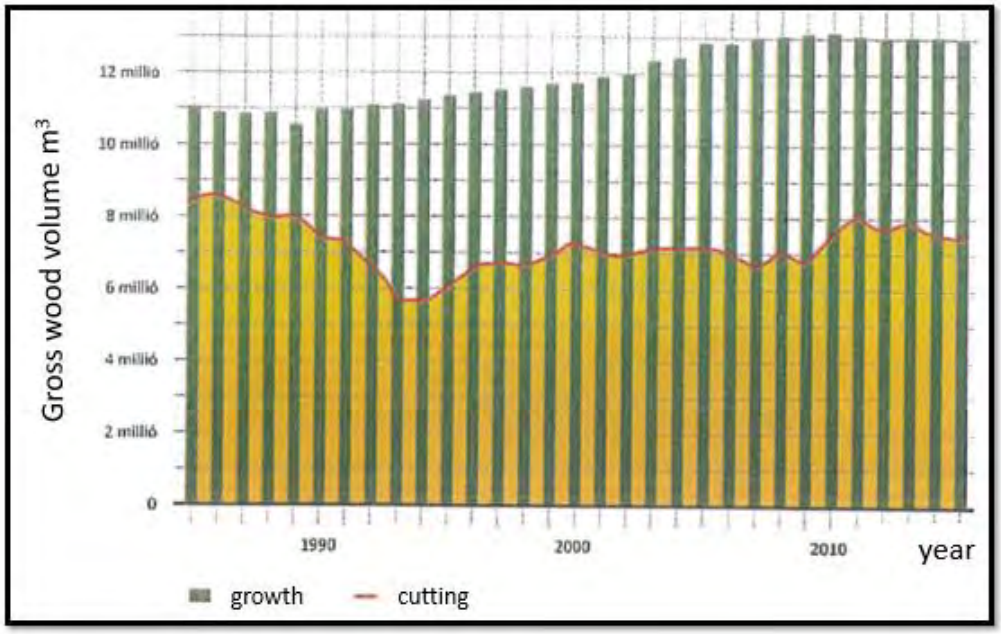

Figure 3. Growth and gross wood cutting in 2015 (Source: NÉBIH, 2015)

Utilization and problems of dendromass at tatabánya power plant

The natural gas-fired power plant was converted to a wood chip-fired one in 2015-2016. The net value of the investment was HUF 6.2 billion. The total capacity of the fluidized bed technology is 94 MW. A 20 MW hot water boiler and two 37 MW steam boilers produce renewable energy. The power plant provides heat and hot water to 23 500 households and 2000 institutions. The plant utilizes 100 000 tonnes of wood chips as fuel per year on average. Dendromass utilization can reduce greenhouse gas emission by 67 000 tonnes per year. 1 m^3 natural gas can be replaced with 2.5 kg wood chips. In order to make the power plant sustainable, the adequate supply of raw materials has to be provided. Between 01.11.2016 and 04.30.2017 the quantity of wood chips was 69 636.52 lutro tonnes delivered by 2798 trucks to the power plant; the average weight of the trucks was 24.89 lutro tonnes/truck (Figure 4).

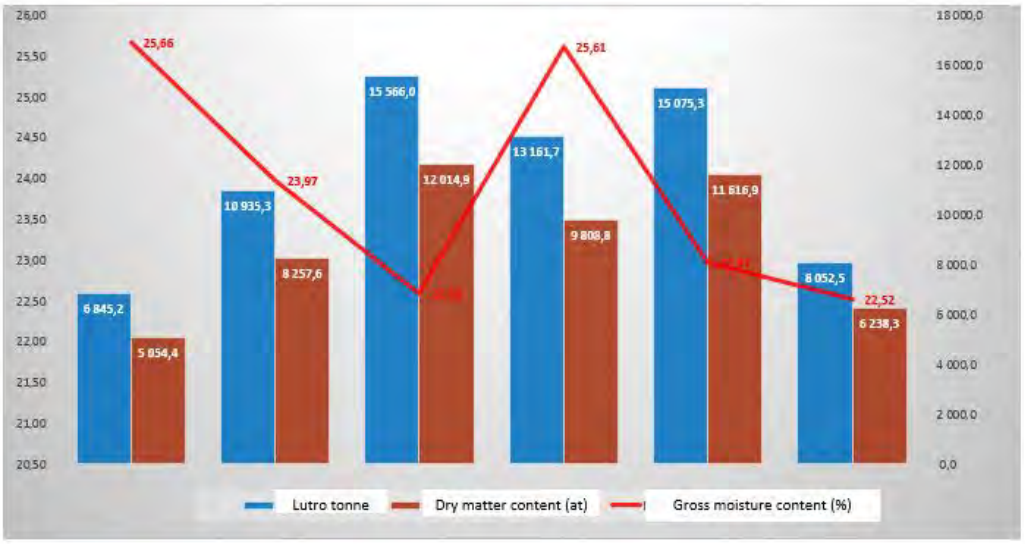

Figure 4. Tatbánya plant delivered dendromass volume and moisture content between 11.2016-04.2017. (Edited by: Szűcs Ferenc)

The basic condition of firewood supply is biomass integration. There are 12 members of the integration. In 2005 Vértes Erdő Ltd. launched its biomass program which provides renewable fuel for Tatabánya Power Plant and Dunaújváros Power Plant in 2017. Thanks to biomass integration, the quantity of wood-based energy fuel marketed by the national forestry is 150 000 tonnes. The integration has currently 27 members, including private and public forestry sectors, out of which 12 are involved in the delivery to the Tatabánya Power Plant. The integration has long-term business benefits for both Vértes Erdő Ltd. and its partners. The supply of materials may come from several sources, e.g. energy tree crops. The article demonstrates the qualities of acacia as well as the operation. The crop is three years old (2nd sprouting), the average number of sprouts is 5/per stem, the size of the area is 13.28, the production quantity is 609.52 tonnes, the yield is 45.89 t/ha, the average gross moisture content is 27.26%, and the dry matter content is 443.9 atro tonnes. Figure 5 illustrates the machines and fuel consumption of energy plantation harvesting.

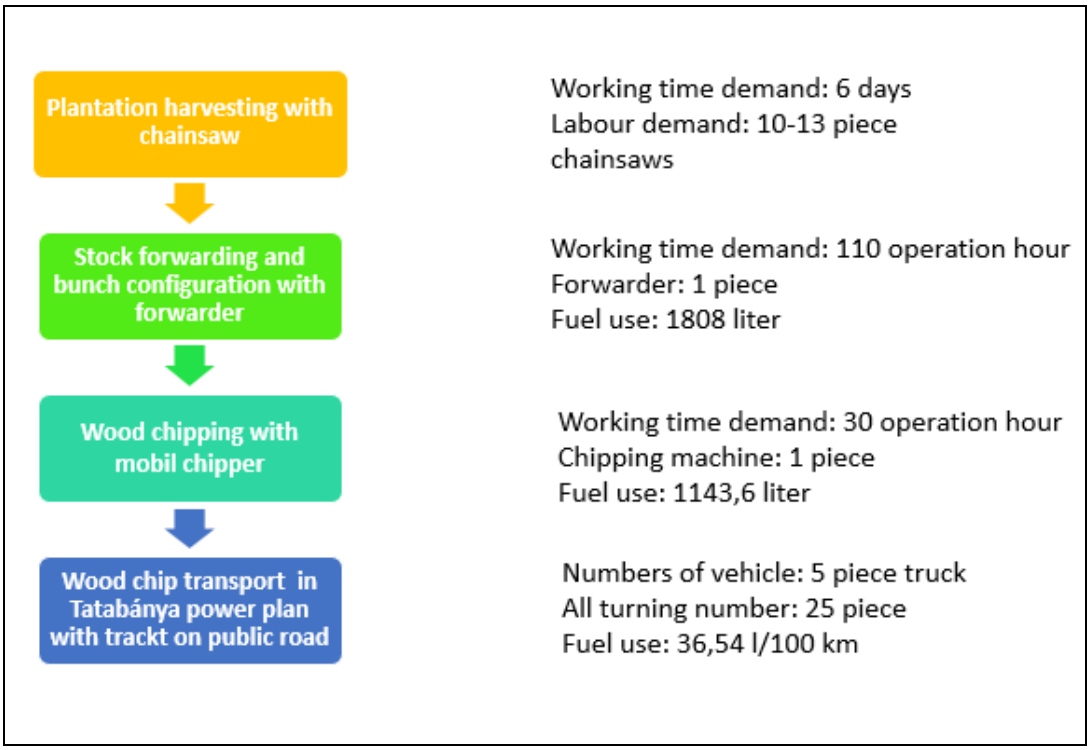

Figure 5. Operations, machines, fuel consuption of energy plantation harvesting (Edited by: Szűcs Ferenc)

The adequate water content (under 30%) can be guaranteed only by the management of wood chips. The storage conditions (the size of chip, the size of the pile, the storage method, the aeration, etc.) affects the quality of wood chip. The moisture content of wood chips is a significant factor, which affects the calorific value and whose quantity has a relation to the temperature of the pile. At the beginning of the storage the moisture content of wood chips is high (ca. 55% in case of poplar chips), which results in a sudden temperature increase in the first phase of the storage. Due to the temperature increase, thermophilic and mesophilic fungi proliferate causing damage to wood and further increasing the temperature (a maximum of around 60% in case of poplar chips) (Horváth et al., 2012). The fungi can significantly impair the energy content and the quality of wood by the dissimilation of lignin; therefore, despite the decrease of the moisture content that improves the calorific value, wood will not be more beneficial in terms of energy utilization (Barkóczy, 2009). The fungi damage wood and may be harmful to human health during the storage. These problems cause dry matter and energy losses and have impact on the quality. Austrian standard ÖNORM M 713 is applied for size classification of wood chips, which distinguishes fine-grade (G30), medium (G50) and coarse wood chips (G100). The most common storage method is G50 due to the simplicity of its utilization. However, research has shown that in case of poplar chips, mainly this size of wood chip generates the above mentioned problems (Horváth et al., 2012). It is expedient to store wood chips in piles for a short time (maximum 3 months) and to turn the pile roughly every two weeks. The basic conditions of fuel supply were the increase of delivery capacity and the establishment of a logistics center. For this purpose, Vértes Erdő Zrt. purchased delivery devices, increased storage capacity and established a logistics center in Gánt. In the center there is a 4000 m^2 depot which allows to meet the demand for safe fuel at

Tatabánya Power Plant, even under unfavourable weather conditions. The logistics center is 30 km far from the plant. The conditions of the production and management of wood chips, and of the water content measurement are given; moreover, a 60 ton weighbridge is also available. Quality problems occurred mainly due to the fraction size of the wood chips. The heating system is technologically unsuitable for selecting wood chips that are longer than 120 mm. These are separated with Doppstadt SM 620 plus type mobile star riddle. The output of the grading equipment is 1 ton/minute providing safe fuel to the heating plant. The selected oversized wood are resized and utilized for energy purposes. Over the period under examination the share of oversized wood chips covers the 2.2% of the total quantity.

Figure 6. Doppstadt SM 620 plus type mobile star riddle (Photo: Szűcs Ferenc)

Conclusion

Hungary currently imports 65% of its energy needs. Renewable energy sources, including biomass utilization, play an essential role in reducing dependency on import. Dendromass, i.e. wood-based biomass, constitutes a significant part of biomass. The authors of the article demonstrated the experience gained in the first heating season of the dendromass heating system, with a total output of 94 MW, established in 2015-2016 in Tatabánya, considering fuel supply and quality of fuel (wood chip). Creating an effective logistics system and guaranteeing the quality of wood chips are key factors: moisture content of less than 30% and the standard size of fraction.

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FIELD PERFORMANCE OF MOTOR-MANUAL FELLING IN WILLOW SHORT ROTATION CROPS

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Abstract: *Willow short rotation crops are a current option for timely obtaining biomass for energetic use, but they often require the use of expensive equipment. Small-scale farmers lack the ability to purchase such equipment, but rather use their own affordable tools. This paper evaluated the field performance of motor-manual shoot felling in a short rotation willow crop. Strong dependence relations were found between the time effectively spent to fell the shoots and the row length. The delay-free time consumption accounted for 81% of the total observed time, while the time effectively spent to fell the shoots accounted for 97%. The net production rate was specific to the mechanization level of technology used, being rather low (0.13 ha h^{-1}). The proportion of delays (19%) affected the field performance resulting in a gross production rate of 0.11 ha h^{-1}. Nevertheless, small-scale willow farmers use this level of technology in harvesting their crops by adapting the crop rotation to very short cycles, possibly to cope with technical limitations of brush cutters. The plantation system, layout, and the weather conditions may act as performance limiting drivers. Also, adequate planning of the operational layout has the potential to increase the field performance.*

Keywords: motor-manual felling, willow crops, field performance, energy procurement, small-scale

NEW TECHNIQUES FOR ESTIMATING THE EXTENT, SEVERITY AND DISTRIBUTION OF SOIL DISTURBANCE FROM MACHINE TRAFFIC DURING CLEARFELL HARVESTING

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Abstract: *A considerable amount of work has been done on the impacts of machines on forest soils over the past 50 years, but reliable measures on the extent of the site actually impacted, and the distribution of categories of soil disturbance are virtually non-existent. The conventional way of estimating traffic extent is to lay out line transects in a post-harvest stand, then manually evaluate the frequency and condition of wheel ruts and extrapolate this across the site. However, it is known that wheel rutting is not randomly distributed across a site, but often clustered in more susceptible areas, which places questions on the validity of the conventional method of estimation. Also, this method is labour demanding and cannot realistically be applied in forest management, but only at a research scale. This study presents the use of UAV image generated surface models in visually classifying the extent and severity of vehicle traffic on harvesting sites. It then applies various combinations of line-transects (straight, cross, triangular) to the surface models in assessing how well each represents the true status of the site. The study included six relatively flat sites harvested with a cut-to-length (CTL) system (harvester and a forwarder), corresponding in total some 20 ha. Evidence of wheel traffic was traced from the surface models in a GIS environment. Distances and areas covered by the machines were summed, while the severity of the damage was visually assessed and categorised. Results to be presented include the total distance driven by machines and extent of damage per hectare, the proportion of the site that is impacted, and the level of representation achieved from each transect type.*

Keywords: site impact, environmental performance, post-harvest survey, wheel rutting

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a H2020 project promoting environmental performance in forest operations.

SOIL PROTECTION IN WOOD HARVESTING: INSIGHTS FROM PRODUCTION-, INDUSTRIAL- AND INSTITUTIONAL ECONOMICS

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Abstract: *The protection of forest soil is an issue of increasing concern to Central European forestry. The focus lies on the impact of forest harvesting machinery on soil and the resulting risks to the forest ecosystem in general and to soil fertility in particular. The economic dimen-sion of the issue becomes increasingly apparent when wet weather hampers the planning and execution of forestry operations. Public interest has also increased: damage to the forest floor is viewed negatively by the population as well as nature conservationists, and attracts media attention. With the overall sustainability of forest management at stake, the issue entails major ecological as well as economic and political challenges. The presentation examines physical soil protection from various economic perspectives, focusing on (i) production economics, (ii) industrial economics and (iii) institutional economics. The findings of this comprehensive approach contribute to a better understanding the complexity of this private and public good. Possible challenges in the future are posed by climate change and increasing demand for re-sources. These could massively exacerbate the problem of forest soil protection and drive up its costs and impact the competitiveness of forest enterprises and products. Further economic analysis is needed to improve decision making in soil protection to ensure sustainable forest management.*

Keywords: soil protection, soil compaction, timber harvesting, economics

MODELLING THE TREE GROWTH RESPONSE IN RELATION TO FOREST ROADS IN POPLAR FOREST STANDS

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Abstract: *Forest roads play a key role in the sustainable management of forest resources. They provide access to timber and non-timber forest products and fulfill also other functions related to forest management. The Romanian forest management relies on forest roads and a substantial development of the forest road network is expected on short-medium term. Yet, by the construction of new forest roads, the forest habitats are fragmented and the local growth conditions are changed. This study evaluates the growth conditions in forests located near the forest roads for a representative Romanian poplar plantation. Parameters such as the dbh, height, canopy development and pruning condition are modelled in relation to tree location relative to the forest roads for a wide set of data. The results of this study may be helpful in decision making processes related to the forest management and to the forest road network development.*

Keywords: forest roads, models, growth, conditions, location, dynamic

DISC SAW FELLER-BUNCHER PRODUCTIVITY ANALYSIS IN A HOLM-OAK (*Quercus ilex*) COPPICE BIOMASS HARVESTING OPERATION IN CENTRAL SPAIN

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Abstract: *A disc saw John Deere 130 kW feller-buncher has been tried to perform a selective felling of a dense holm oak (Quercus ilex) coppice in Central Spain, with an average density of 5250 trees·ha^{-1}, an average dbh around 6 cm and an average height of 4 m. The treatment consisted on leaving around a 10% of standards, performing a very strong thinning (as an average, 2/3 of basal area). A height-dbh equation and a dry weight table have been fitted for this Species' coppices. The productivity has been analyzed in average conditions and, as part of a factorial experiment, in 25x25 plots with different stand and treatment conditions. Average felling and bunching productivity is 3,2 odt per productive machine hour. A productivity equation has been fitted, being the main identified explicative variables the unit dry weight of the extracted trees and the percentage of extracted basal area. The rest of harvesting costs – whole trees forwarding, roadside chipping and chip transport – have also been analyzed. The final costs are ranging from 71 to 87 €/odt of chips delivered to the power plant, under the studied conditions, for a transport distance of 80 km and considering a 15% of indirect and fixed costs over the direct harvesting costs. Some possible improvements in operations efficiency and cost have been proposed.*

Keywords: mechanized felling, circular saw, felling head, traditional coppice, forest energy.

Introduction

For what concern forest operations, the deployment of appropriate equipment and work systems for each specific forest type is crucial for the economic sustainability of the whole supply chain (Enache et al. 2015). This is even more important in the case of coppice forests, where the low size of stems require the use of specific solutions and machinery both for the economic (Spinelli et al. 2009) and environmental sustainability of the operations (Laschi et al. 2016).

In general, a higher mechanization level leads to higher productivity and lower unit costs for woody products from coppice forests (Laina et al. 2013). Moreover, increasing the mechanization level in forest operations contributes in reducing both the risks and the frequency of accidents and/or occupational diseases (Albizu et al., 2013). For all these reasons, further mechanization is desirable. Nevertheless, harvesting of coppice forests is technically and economically difficult, because of the small stem size and the occurrence of multiple stems on the same stump. One of the main problems seems to remain the capacity of a harvester head to approach stems growing in a clump (Schweier et al. 2015).

One of the possible technologies for mechanized felling is based on a circular saw mounted on a felling – bunching head. This technology has been tried with good results in short rotation coppices (Iwarsson, 2008) because of their speed, not much power needed and ability to manage multiple stems in a continuous way. These type of felling heads have been tried recently in Mediterranean coppices of oak, chestnut, locust and poplar

(Schweier et al, 2015), finding less mechanized felling efficiency if compared to SRCs, regardless the cutting technology, but very low cuts and little damages when using disc saw.

In the Spanish Castile & León Region, forests and other wooded areas cover more than 50% of total surface area. Forest area has increased by 41% during the past 20 years and this is the most important region in Spain in terms of growing stock (153.7 M m^3). The extraction rate in the region's forests (balance between felling and increment) is about 20%, while the demand of woody biomass is recently increasing. Furthermore, mechanization level is very low in hardwood stands (less than 15%, according to EU FP7-KBBE SIMWOOD Project Reports, 2016). Coppices are very frequent, being the most abundant Species holm oak (*Quercus ilex*) and deciduous oak (*Quercus pyrenaica*).

As the Spanish forest public Company SOMACYL has begun in 2017 field trials of mechanized felling in these Species' coppices, a time and work study has been designed to evaluate the results in terms of productivity and cost.

Objectives

The main goals of the present study are:

- Characterizing the coppice felling operations performed regarding their dasometric conditions.
- Developing a height equation and a dry weigh table to facilitate the future evaluation of similar stands.
- Evaluating the productivity of the felling operation through a factorial study, trying to identify the main factors affecting productivity and to develop productivity predictive equations.
- Estimating the cost range of the harvesting operations, including whole trees extraction, chipping and chip transport, under the studied conditions.

Material and Methods

The selected base machine is a John Deere 643J with 130 kW and a weight of 12,7 tonnes, equipped with a felling head JD FD45, with 51 cm of cut capacity, 0.64 m^2 of accumulation capacity and a weight of 2,2 tonnes. This felling head is mounted straight in two short articulated arms in the machine front without a boom to reach the trees to fell, so the machine has to circulate and get quite close to each stool to be felled (Figure 1).

The studied stand is a holm oak (*Quercus ilex* L.) dense coppice, with an average initial density of 5.250 trees/ha, with an average dbh around 6 cm and average height of 4 m, with an initial basal area of 13,3 m^2/ha. The average situation after the coppice treatment will be a 68% average reduction of basal area, leaving some 450 standards per ha (reducing the number of trees in around 90% from their original density).

The development of the weigh table and the dasometric characterization of the plots that were to be time-studied required a double forest inventory, pre and post harvesting.

Pre-harvest inventory

Several (9) 25x25 m^2 plots were randomly distributed in this forest site. On each plot, the dbhs of all the trees were measured and they were marked with colored paint. The limits of the plots – N-S and E-W lines - were marked with colored plastic tape and painted wooden poles at its corners. The silvicultural treatment was performed around the plots prior to the time study, so that the machine operator could work in close-to-real conditions within the plots. This work was planned together with the operation managers working for the responsible enterprise, SOMACYL.

Figure 1. Disc saw feller-buncher studied in the holm oak stand

Post-harvest inventory

Just after the work, the bunches were counted and the number of trees per bunch estimated. 10 felled trees per plot were measured in dbh and height, and 3-4 felled trees per plot were taken from the bunches, measured in dbh and height, crosscut if necessary and weighted in order to fit the weight table. A sample was taken and weighted for moisture determination. The remaining stand was measured (dbhs) all over the 25x25 m original plot.

Dasometric characterization, height-dbh equation and weight table fitting

The treatment conditions were obtained from the inventories comparison. Height-dbh equations and weight tables were fitted using standard statistic software Statgraphics Centurion XVII. The selected variable for weigth tables was dry weight, estimated by oven drying biomass samples from the measured and weighted trees.

Time study and production evaluation

Regarding felling and bunching time study, each processing cycle was recorded individually, using a Husky Hunter hand-held field computer running the dedicated Siwork3 time study software (Kofman 1995). A cycle was defined as the time to process a single bunch. Productive time was separated from delay time.

To assess the production from each plot, the forwarder piled the whole trees from it in a separate roadside bunch that was marked and, afterwards, chipped and transported to the plant to be weighted and sampled for determination of moisture content.

During the forwarder extraction, several cycles were time-studied (a whole day shift), measuring the number of trips and the loaded bunches to get an approximate estimation of productivity and cost of extraction.

To assess the operational costs, as the machines were rented by the contracting enterprise SOMACYL, the actual hourly renting cost – or the unit cost for chipping and chip transport - were used as references, although it would be possible to reduce this cost by self-management.

Results

Dasometric characterization

As a result of the inventories' comparison, the conditions of the coppice thinnings on each one of the nine plots are reflected in Table 1. The treatment has been a strong coppice felling leaving between 6 and 18% of the initial number of trees as standards.

Table 1. Dasometric conditions of the studied coppice plots

PLOT	density pre-harvesting	basal area pre-harvesting	density post-harvesting	basal area post-harvesting	Δ % trees felled	Δ% extracted basal area
	tree ha^{-1}	m^2 ha^{-1}	tree ha^{-1}	m^2 ha^{-1}	%	%
1	3984	11,6	320	5,6	-92	-52
2	7040	14,2	464	4,7	-93	-67
3	3456	10,0	384	2,7	-89	-73
4	3488	12	480	6,0	-86	-51
5	7856	13,6	496	1,6	-94	-88
6	6000	15,1	432	4,0	-93	-73
7	7920	18,3	448	3,1	-94	-83
8	5344	17,5	560	6,7	-90	-62
9	2224	7,3	400	2,6	-82	-65
AVERAGE	**5256,9**	**13,3**	**442,7**	**4,1**	**-90,4**	**-68,3**

The extracted biomass weight from the chipped whole trees ranged between 29,1 and 77,1 fresh tonnes ha^{-1} (average 48,7 fresh tonnes·ha^{-1}). Having into account the chips' moisture - as an average, 25,7% on humid basis - the whole tree chips dry weight ranged between 21,6 and 55,8 odt·ha^{-1} (the average was 36,1 odt·ha^{-1}).

Height-dbh equation and Dry weight table

To fit the height-dbh equation, 94 trees were measured to fit this curve. The range of measured dbhs was 1,5 to 14,2 cm (average 6,5 cm), while the correspondent height ranged from 1,7 to 6,5 m (average 3,8 m). The best fit was obtained with an allometric equation with dbh as predictive variable, after using a logarithmic-linear transformation. The equation was refitted by nonlinear regression techniques. The results are reflected in the Table 2 and Figure 2.

To fit the dry weight table, 31 trees were measured and weighted, selecting a different sample from the used for the height-dbh curve. The range of dry weights were 1,1 to 78,5 kg (being the average 14,5 dry kg). The moistures ranged from 25,8 to 36,1% - humid basis -, averaging 33,5%. The measured dbh ranged from 1,7 to 14,3 cm (average 5,7) and the heights ranged from 2,2 to 6,3 m.

To fit the weight table, dbh and height were selected as independent variables, but the results of the multiple regression and the logarithmic transformation used for the allometric equation fitting showed the weak significance of height as explicative variable, so finally only dbh was selected as independent variable.
The best fitting statistics correspond to the quadratic equation, shown in Table 3 and Figure 3.

Table 2. Statistic parameters for Height – dbh curve

Non Linear Regression: Tree height = F(dbh)

Function: $A \cdot dbh^B$

Estimation Results			*Confidence Interval for 95% Asimptotical*	
Parameter	*Estimated*	*Error Standard Asimptotical*	*Inferior*	*Superior*
A	1,63906	0,103201	1,4341	1,84403
B	0,47018	0,0306883	0,40923	0,53113

Fitted Model: **Height (m) = 1,64·dbh(cm)^{0,47}** (1)

ANOVA

Source	*Squares sum*	*Df*	*Square Average*
Model	1461,29	2	730,646
Residue	28,0254	92	0,304623
Total	1489,32	94	
Total (Corr.)	112,584	93	

R^2 = 75,1 %
R^2 (adjusted by d.f.) = **74,8 %**
Estimation Standard Error = 0,55
Absolute average error = **0,42 (average absolute value of residues, m)**

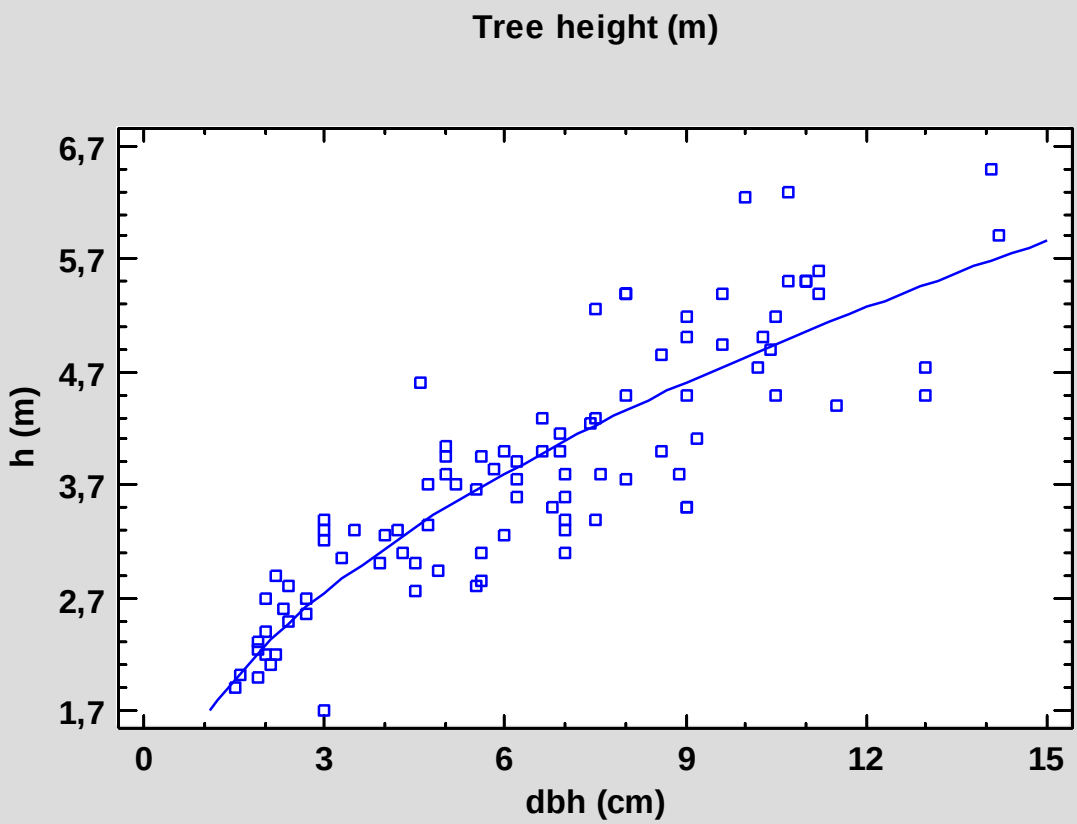

Figure 2. Height - dbh equation for Holm Oak coppice

Table 3. Statistic parameters for Dry Weight – dbh curve

Quadratic regression Polinomial - Dryweight = F(dbh)

Parameter	*Estimated*	*Standard Error*	*T Statistic*	*P-Value*
Constant	3,58617	1,9104	1,87719	0,0709
dbh	-1,53613	0,605749	-2,53592	0,0171
dbh^2	0,468881	0,0405215	11,5712	0,0000

Fitted Model: **Weight (oven dry kg/whole tree) = 3,59-1,536·dbh(cm)+0,469·dbh(cm)^2** (2)

ANOVA

Source	*Squares sum*	*Df*	*Average square*	*F-Ratio*	*P-Value*
Modelo	9224,31	2	4612,15	631,72	0,0000
Residual	204,427	28	7,30097		
Total (Corr.)	9428,73	30			

R^2 = 97,8 %
R^2 (adjusted by d.f.) = **97,7 %**
Estimation Standard Error = 2,7
Absolute average error = **1,73 (average absolute value of residues, dry kg)**
Durbin-Watson statistic = 1,86

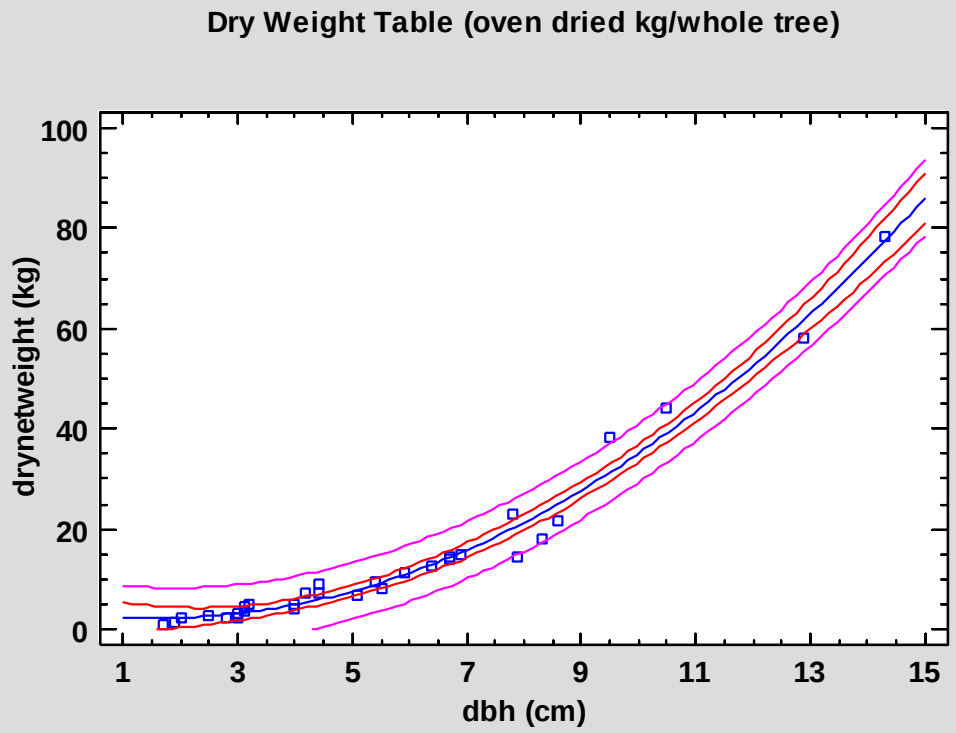

Figure 3. Dry Weight – dbh equation for Holm Oak coppice

Time study

The productivity of the felling and bunching operation ranged between 2,66 and 4,85 odt·pmh^{-1} (oven dry tonnes per productive machine hour). The delays where mostly absent from the felling time in the plots, because the felling time varied between 25 and 54 minutes per plot and no incidents occurred during the surveys. The average productivity of mechanized felling reached 3.8 odt·pmh^{-1} inside the experimental plots.

Besides the study inside the plots, a time-motion assessment working in normal conditions (outside the experimental plots) was carried out. The working time studied outside the experimental plots was 8.60 pmh (productive machine hours), 650 cycles and 102 bunches produced during a complete daily shift. The delays, including daily maintenance activity, accounted for a 10,1% of the total time. The productivity, for an average bunch dry weight estimated as 0,268 odt, reached 3,18 odt pmh-1.

The forwarder used to extract the whole trees was a John Deere 1910E with a power of 186 kW, weighing 19 tonnes and with a load capacity of 19 tonnes, equipped with a press collector Dutch Dragon PC-48 with a weight of 3,7 tonnes (Figure 4). It was also time studied during a complete shift (8,67 pmh, 14 cycles, 225 bunches). Its productivity was 6,99 odt·pmh^{-1}. Delay time was 12,2 % of total time, including daily maintenance.

Figure 4. Forwarder used for the whole tree extraction from the holm oak coppice.

Feller-buncher productivity model.

The factorial study was performed using the data from the 9 studied plots. The considered as candidate factors were Dry weight per tree, Extracted dry weight per hectare, Initial number of trees per hectare, Extracted number of trees per hectare and Percentage of extracted basal area.

The best fit was obtained using a multiple linear regression technique, and the selected variables were Dry weight per tree and Percentage of extracted basal area. The recorded productivities ranged from 2,66 to 4,85 odt·pmh-1 (average value 3,84), while the dry weight per tree ranged from 5,76 to 10,25 kg (average 7,80 kg) and the % of extracted basal area varied among 51% and 88% (average 68,2 %).

As the statistical significance of the constant was weak, it was removed from the model, after what it was refitted as a nonlinear regression, in order to obtain more significant regression statistics. The results are reflected in Table 4 and Figure 5.

Table 4. Productivity model for the feller-buncher in the studied holm oak coppice.

Non Linear Regression: Feller-buncher productivity = F(Dry weigth/tree; %extracted BA)

Function: A·%ExtBA + B·DW

Estimation Results

Parameter	*Estimated*	*Error Standard Asimptotical*	*Confidence Interval for 95% Asimptotical*	
			Inferior	*Superior*
A	0,0333088	0,00548166	0,0203467	0,0462709
B	0,202232	0,0477736	0,089265	0,315199

Fitted Model: **Productivity (odt·pmh^{-1}) = 0,0333·%ExtrBA + 0,202·DW(kg·tree^{-1})** (3)

ANOVA

Source	*Squares sum*	*Df*	*Square Average*
Model	135,526	2	67,7629
Residue	0,614497	7	0,0877853
Total	136,14	9	
Total (Corr.)	3,5989	8	

R^2 = 82,9 %
R^2 (adjusted by d.f.) = **80,5 %**
Estimation Standard Error = 0,30
Absolute average error = **0,23 (average absolute value of residues, odt·pmh^{-1})**
Durbin-Watson statistic = 2,25

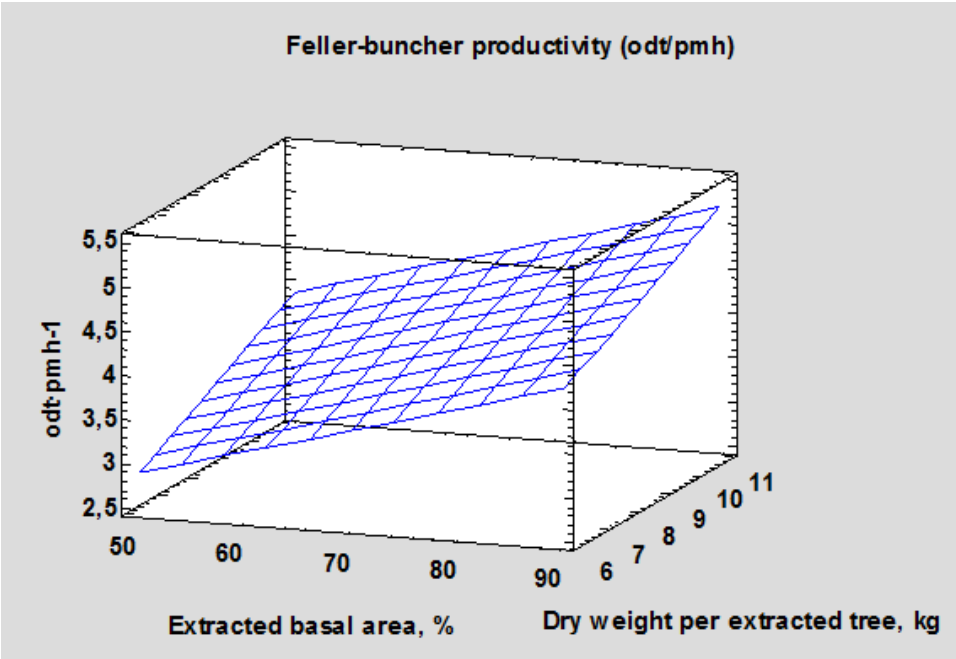

Figure 5. Productivity model for feller-buncher in the studied holm-oak coppice.

Cost estimation

The renting cost of the machines were established on an hourly basis (€per smh - scheduled machine hour - for felling and bunching, and on a fresh tone basis (€/fresh tone) for chipping and chip transport to the power plant (transportation distance = 80 km, one way).

Given the average moisture of the chips produced in the studied chipping operations of 21,7% (humid basis) and assuming that the utilization coefficient (pmh/smh) were 0,9, the average unit costs are reflected in Table 5. The total direct unit cost would be 66,64 €/odt. If this cost is increased by 15% (indirect and fixed costs), the average unit total cost will equal 76,6 €/odt of chips unloaded in the power plant.

Table 5. Average operational unit costs, based on renting costs

Operation	Renting hourly cost (€/smh)	Renting hourly cost (€/pmh)	Average productivity (odt/pmh)	Average unit cost (renting, €/fresh tonne)	Average unit cost (€/odt)
Felling and bunching	**90**	100	3,18	----	**31,45**
Forwarding	**71,5**	79.4	6,99	----	**11,36**
Chipping	----	----	----	**11,0**	**14,05**
Chip transport (dist=80 km)	----	----	----	**7,66**	**9,78**
Total (direct costs)	----	----	----	----	**66,64**
+ 15% indirect and fixed costs	----	----	----	----	**76,64**

Regarding the influence of the identified felling productivity factors on this cost, if we correct the productivity equation (3) using the ratio between the average productivity in normal conditions and the average productivity inside the studied plots (3,18/3,84 = 0,83), the new productivity equation would be:

$$\textbf{Productivity (odt·pmh}^{-1}\textbf{) = 0,0276·\%ExtrBA +0,168 ·DW(kg·tree}^{-1}\textbf{)} \quad (4)$$

And the unit cost of feller-buncher:

$$\textbf{Unit cost (€/odt) = 100/[0,0276·\%ExtrBA +0,168 ·DW(kg·tree}^{-1}\textbf{)]} \quad (5)$$

Comparing the two worst and best plots (minimum and maximum tree size and % of extracted basal area), the results are shown in Table 6.

Table 6. Maximum and minimum coppice biomass harvesting unit cost in the observed conditions

Observed conditions	Dry weight per tree (o.d. kg)	% of basal area extracted	Felling & bunching unit cost (€/odt)	Rest of unit costs (€/odt)	Total unit cost (incl 15% of indirect and fixed costs), €/odt
Worst plot (Plot 1)	6,17	52	40,5	35,19	87,04
Best plot (Plot 3)	10,25	73	26,8		71,29

The increase in felling and bunching direct unit cost from the best observed conditions to the worst ones is 51% (same as the increase in productivity from the worst to the best observed conditions). The correspondent total cost would increase a 22%, only considering the increase in felling and bunching costs.

Conclusions

Productivity of the disc saw felling head tested in traditional coppice forest in Spain is comparable with other studied operations in Mediterranean coppices (Laina et al, 2013; Schweier et al, 2015). It may be considered even slightly better having into account the smaller dimensions of the trees – average dbh around 6 cm – and/or the selective character of the treatment, consistent in leaving an average 10% of standards in even-aged coppice stands with an average initial density of 5250 trees·ha^{-1}.

A height-dbh curve and a dry weight table with dbh as independent variable have been developed for these kind of holm oak coppices, common in Central Spain, providing a tool for estimating the biomass production in such stands.

Feller and bunching productivity has been analyzed, identifying as the main affecting factors the unit dry weight of the extracted trees and the percentage of extracted basal area, so the productivity grows with stem size and if the felling is less selective. Between the observed stand conditions, the estimated felling productivity grows a 51% between a stand with Dry weight per tree = 6,2 kg and %ExtrBA=52% and other stand with Dry weight per tree = 10,3 kg and %ExtrBA = 73%.

The analysis of the unit costs, based on the renting cost of the machines, the transport cost to a power plant located at 80 km from the coppice forest, and considering a 15% of indirect and fixed costs, gives estimations between 71,3 and 87,0 €/odt of chips delivered to the plant (average for the studied coppice conditions of 76,6 €/odt). This cost is greater than the present market prices, so subsidies may be needed, at least in the smaller unit volume stands and more selective treatments.

The main possibilities to improve the operational cost-efficiency may consist on using a lighter disc saw feller-buncher (the one used is oversized for the felled trees dimensions), self-managing the operations – instead of renting the machines - and of course reducing the transport distances, greater than those commonly recommended for forest biomass for energy.

Further tasks to complete the harvesting analysis are the short-term quality and environmental effects analysis (data already recorded) and the mid-term results of the mechanization regarding regeneration and stand health.

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USING OF FINE KINNEY RISK ASSESSMENT METHOD IN THE WOOD PRODUCTION PROCESS

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Abstract: *One of the heaviest and most dangerous forestry activities carried out in open and hard terrain is the harvesting operations. Approximately 63% of 22.3 million hectares of forested areas, which make up about 28% of Turkey's surface area, are operated for economic functioning. About 17 million m3/year of wood material have been produced by about 300 000 harvest workers in Turkey. The wood production process consists of five main steps as preparation, cutting, branching, bucking and peeling. The importance of occupational health and safety in the wood production process has increased as a result of increasing in awareness of the society about the environment and health issues today. Risk assessment has required in the European Union Council directives, the International Labor Organization (ILO) conventions and occupational health and safety law in Turkey. This situation has brought forward the identification of hazards related workplace, the nature of the work, the tools used or the workers in the forestry activities and the necessity of risk assessment. There are a number of the qualitative and the quantitative risk assessment methods but there is no clear consensus on which method should be used. The person who will perform the risk assessment chooses the most appropriate method according to the characteristics of the work. In the literature, the risk assessment of the wood harvesting activities was made by 5 X 5 matrix risk assessment method which takes into consideration only the probability and intensity parameters. In this study, in order to reveal risk assessment by the Fine Kinney method which taking into consideration the probability, intensity and the frequency parameters, each step of the wood production was considered separately and the potential hazard situations determined.*

Keywords: risk analyze, fine kinney, logging activity

ANALYSIS OF CHIPPING OPERATIONS AND CHIP QUALITY FOR BIOPRODUCTS

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Abstract: *A whole-tree chipping operation was investigated on two mixed hardwood harvesting sites in eastern Ohio. The harvesting system observed included a Morbark 27RXL whole-tree chipper, Timbco 425 feller-buncher, two grapple skidders, and transportation by truck with chip-van trailers. Production and machine rate data were collected through time-motion study methods for 50 major (truckload) cycles of the chipper. Major cycle time duration ranged from 13 to 50 minutes with an average of 27 minutes producing 23.54 green tons of chips on average per major chipping cycle. The volume of stems being chipped was recorded between skidding and chipping processes, while a video camera was used to record the timing for each cycle of the chipper. The chipping time data were then further broken down into elemental times of feeding, chipping, and loading. Trucking transportation distance was 76 and 97 miles roundtrip, respectively for the two harvest sites, trucking cycles ranged from 106 to 220 minutes with an average of 162 minutes per round trip truck cycle. Samples of chips were randomly taken from 36 cycles of the chipping operation to evaluate wood properties and characteristics of the chips for potential use as a biomass feedstock. Initial results of chip properties testing include 37% moisture content, 0.2121 g/cm^3 bulk density, 13.54% bark content and 18.829 Mj/Kg heating value. Results from this study will be useful for further development of woody biomass utilization for bioenergy and bioproducts.*

Keywords: biomass, bioenergy, machine rate, time-motion study

Introduction

There have been numerous studies of the production rate and associated cost of timber harvesting systems in West Virginia ranging from manual felling operations to mechanical harvesting (Wang et al. 2004a) (Wang et al. 2004b). However there has been little focus in the area integration of in-woods chipping operations as an addition to harvesting systems in the Appalachian region. In the southern pine region many studies have shown the ability to capture additional revenue by harvesting material that is otherwise left as a wasted byproduct of timber harvest (Baker et al. 2010; Aman et al. 2011). Incorporating these chipping methods into harvesting practices in the Appalachian region could help loggers to capture additional revenue during timber harvest and help to further develop a market for wood fuels.

Baker et al. (2010) found that biomass chipping with a small chipper appears feasible at roundwood to chip ratios between 3:1 and 6:1 where 30 t ha-1 or less is recovered, Baker concluded that a higher ratio underutilized the chipper and a lower ratio reduced roundwood production. Pairing a small chipper with a roundwood operation was found most feasible in a clearcut harvest operation as opposed to thinnings where roundwood production is challenged by tight operating space (Baker et al. 2010). Studies in Echols County, GA examining three combinations of treatments for roundwood and chip harvesting found significant differences between the chip yield for treatments of chipping only tops and limbs (3.8 tons per acre) compared to chipping tops, limbs, and understory (10.8 tons per acre) with both treatments being an addition to roundwood harvest, the study

concluded that roundwood production is minimally affected by the addition of a small chipper to a ground based harvesting system(Westbrook et al. 2006).

For small scale operations that cannot fully commit to chip harvesting alone chipping attachments and temporary conversion kits for traditional harvesting equipment have been explored to allow periodical chipping by traditional harvesting crews. Temporary conversion of a John Deere forager with a Pezzolato chipping conversion kit was assessed for performance and cost in comparison to traditional chipping machines (Manzone and Spinelli 2013). Manzone and Spinelli (2013) found that the converted forager proved to be as effective and efficient as an equally sized traditional chipper and could be advantageous to operations that only utilize a chipper part-time.

Aman et al. 2011 compared three biomass harvesting systems including both horizontal grinders and whole tree chippers concluding that utilization rate of whole tree chippers, 44%, was slightly higher than that of horizontal grinders, 38%. Trucking transportation delays were found to have the most significant impact on production rates across all 3 operational systems (Aman et al. 2011). A data pool of 63 chipping production studies found the average total delay factor to be 38.7% and average machine utilization rate to be 73.8% across 524 hours of pooled observations (Spinelli and Visser 2009).

The total delivered cost of producing chips is a function of the fixed and operational costs as well as the machine utilization rate and the production rate. It is widely accepted that the most cost effective method of collecting forest harvest residues is to extract the material to a roadside landing at time of primary harvest, since a secondary harvest to collect the debris from the felling area results in low productivity and is very cost inefficient. An economic analysis of three roadside chipping operations concluded roadside chipping an economically feasible method of collecting logging residue (Desrochers et al. 1993).

Methods and Data

Production and machine rate data was collected in cooperation with Yoder Lumber Company in eastern Ohio on two harvest locations near Zanesville, OH and Gnadenhutten, OH. The Zanesville site was a 275.6 acre tract with 54 acres clearcut and 28 acres select-cut, the Gnaddenhutten site was a large tract of mining company property being clearcut in 20-40 acre blocks in preparation for strip-mining (Table 1). Both harvest sites had gentle to moderate slopes and were composed of major species including American beech (Fagus grandifolia), black oak (Quercus velutina), northern red oak (Quercus rubra), red maple (Acer rubrum), and yellow-poplar (Liriodendron tulipifera).The harvesting system observed was comprised of one Timbco 425 feller-buncher, one Caterpillar 525C grapple skidder, one John Deere 648 GIII grapple skidder and a Morbark 27RXL whole-tree chipper. The product was transported from harvesting site to destination by semi-truck transportation with chip-van trailers.

Table 7. Harvest site characteristics

	Zanesville	Gnaddenhutten
Acreage	275.6 acre farm tract, 54 ac clearcut, 28 ac select cut	1,000 acre + mine property, 40 ac clearcut sections
Species Composition	Mixed hardwood	Mixed hardwood
Harvest Method	Mechanical with chipping	Mechanical with chipping
Average diameter of harvested stems	6.32 in (16.05 cm)	6.13 in (15.57 cm)
Average height of harvested stems	28.33 ft (8.6 m)	40.78 ft (12.4 m)

Elemental functions of the chipper were split into major cycles and minor cycles. A major chipping cycle defined as each time period in which one chip-van trailer is loaded with chips. A minor chipping cycle is defined as duration of time to process one knuckle-boom grapple of stems through chipper and loaded into the chip van. The chipper was observed for a duration of 47 major (truckload) cycles. Elemental time functions of the chipper were defined as:

-Grappling: time spent inserting stems into the chipper with attached knuckle-boom grapple
-Chipping: time the machine spends processing stem into chips

-Loading: time used to blow chips from chipper into chip van trailer
-Delay: time spent performing a task not in the standard elemental functions
Because some or all of these elements were at times be occurring simultaneously a total cycle time was also recorded for each minor cycle. The payload in green tons of chips produced per major cycle was obtained from the truck drivers as each truck was weighed when unloading at the destination facility. Each payload weight could then be linked to its respective major chipping cycle so that production in green tons of chips is known for each major chipping cycle. Species, diameter, and length were recorded for each stem after being skidded to the landing site prior to being fed into the chipper. Local volume equations were then used to calculate volumes for felled stems (Wiant 1986, Avery and Burkhart 2002). Estimates of hourly cost and production were calculated using machine rate methods (Miyata 1980). Chip samples were randomly collected and bagged from numerous truckload cycles and labeled accordingly so that physical and chemical wood properties and characteristics of the chips could be evaluated upon return to the West Virginia University Renewable Materials and Bioenergy Laboratory.

Trucking transportation was observed for each corresponding major cycle of the chipper, a trucking cycle is defined as traveling loaded from chipping site to destination, unloading chips, and return trip traveling empty back to the chipping site. Total cycle time, origin location, destination, and mileage were observed for each trucking cycle. Any delays encountered by any machine during the time study was recorded along with the cause and duration of the delay. A delay is defined as any amount of time spent by a machine not performing a task within its standard elemental functions. Delay cause was defined into two categories as mechanical or non-mechanical delays.

Sampled wood chips were analyzed to evaluate wood properties and characteristics of the chips for potential use as a biomass feedstock. Green weight was determined for each chip sample using a balance, then all samples were placed in a laboratory oven for 48 hours at 103 degrees Celsius then an oven-dry weight was recorded. Chips were then placed back into the oven for an additional 24 hours and a second oven-dry weight was recorded to ensure complete drying, less than 2% difference was observed between the oven-dry weights therefore samples were assumed dry and moisture content was calculated on green basis. Bulk density of the samples chips was then determined using the method oven dry weight divide oven dry volume. Volume of oven-dry chips was measured to calculate bulk density using a 250mL graduated cylinder. Two replicate twenty gram sub-samples were then separated from each original sample one sub-sample was ground as is to one millimeter using a hammermill grinder, and the other sub-sample was debarked to determine bark content and then proceeded to the grinding stage. Bark content was determined by manually separating the bark from the wood with a utility knife. Each separated portion was then weighted and then divided by the total sample weight to return bark content percentage. After grinding, heating value was determined using the Parr 6300 Oxygen Bomb Calorimeter and Parr Pellet Press, five repetitions of approximately 0.5 grams were used for each sample. Plans for future work include analysis for heating value of debarked samples to compare with samples containing bark.

Results

Major chipping cycle time duration ranged 13 to 50 minutes with an average of 27 minutes, chips produced ranged from 19.49 to 27.48 green tons producing an average payload of 23.54 green tons of chips. The mechanized harvesting and chipping crew produced an average of 6 chip-van loads per day or approximately 144 tons of chips per day. Round trip distance to mill was 97 miles, harvest site 1 and 76 miles, harvest site 2 (Table 3). Total minutes for round trip cycle of truck including travel to mill, unloading, and return to chipping site averaged 187 minutes for site 1 and 135 minutes for site 2. Payload for each truckload, and corresponding major chipping cycle averaged 23.63 green tons for harvest site 1 and 23.47 green tons for harvest site 2.

Table 8. Major Chipping Cycle Time and Produciton

	Total Time (mins)	Payload (green tons)	Loads per Day
Mean	26.76	23.54	6.13
Minimum	13.26	19.49	1
Maximum	50.27	27.48	10
St. Deviation	9.74	2.09	

Table 9. Trucking Transportation Cycle Time and Production

Harvest Site	Distance to Mill (round trip mi)	Mean time per round trip (mins)	Payload (green tons)
#1	97	187	23.63
#2	76	135	23.47

Total elapsed time for minor chipping cycles ranged from 7 seconds to 7 minutes 12 seconds and averaged 44 seconds. Grappling time for each minor cycle ranged from 2 seconds to 1 minute 35 seconds averaging 15 seconds. The chipping element ranged from 5 seconds to 2 minutes 12 seconds for minor chip cycles with an average of 28 seconds. Loading ranges from 3 seconds to 2 minutes 13 seconds, and delays averaged 1 minute 34 seconds (Table 4). The chipper on average processes 43 Doyle board feet every 44 seconds of production equivalent to 3.518 MBF Doyle per productive machine hour (PMH).

Table 10. Statistics for Minor Chipping Cycle

Variable	Total Time (mins:sec)	Grappling (mins:sec)	Chipping (mins:sec)	Loading Truck (mins:sec)	Delay (mins:sec)	Number of Stems	Volume (Doyle BF)
Mean	0:44	0:15	0:28	0:28	1:34	2.3	43
Std. Deviation	0.77	0.23	0.29	0.29	2.44	1.51	33.02
Minimum	0:07	0:02	0:05	0:03		1	3.09
Maximum	7:12	1:35	2:12	2:13		9	160.43

A linear regression model of the chipping elements found that grapple time and number of stems were the most significant variables affecting the total cycle time for the whole-tree chipper (Table 5). Other variables included in the regression model were chipping time, loading time, and board foot volume per cycle.

Table 11. Linear Regression Model of Chipping Elements

Residuals:					
Min	1Q	Median	3Q	Max	
-1.1529	-0.2582	-0.0964	0.0418	6.4541	
Coefficients:					
	Estimate	Std. Error	t value	Pr (>|t|)	
(Intercept)	0.0085842	0.1579955	0.054	0.9567	
Grapple	0.6137518	0.2621451	2.341	0.0206	*
Chip	0.9106965	1.2505602	0.728	0.4677	
Load	-0.0868614	1.2476609	-0.070	0.9446	
Stems	0.0991974	0.0387436	2.560	0.0115	*
Volume	-0.0009521	0.0017796	-0.535	0.5935	
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					
Residual standard error: 0.6997 on 142 degrees of freedom					
Multiple R-squared: 0.1932, Adjusted R-squared: 0.1647					
F-statistic: 6.799 on 5 and 142 DF, p-value: 1.03e-05					

Moisture content of sampled chips ranged from 32% to 45% with an average of 37.39% green basis (Figure 1). Bulk density of the chips was found to be 0.2121 g/cm^3 using the graduated cylinder method (Table 6). Bark content ranged from 2% to 26% with an average of 13.54%. Heating value of samples containing bark ranged from 7,912.544 Btu/lb (18.404 MJ/kg) to 8,330.0201 Btu/lb (19.376 MJ/kg) with an average of 8,094.902 Btu/lb (18.829 MJ/kg).

Table 12. Wood Chip Properties

	Mean	Minimum	Maximum	St. Deviation
Moisture Content	37.39%	32.85%	45.61%	0.041
Bulk Density (g/cm³)	0.2121	0.1557	0.2548	0.026
Bark Content	13.54%	1.99%	25.86%	0.101
Heating Value (Btu/lb)	8,094.902	7,912.544	8,330.0201	109.193

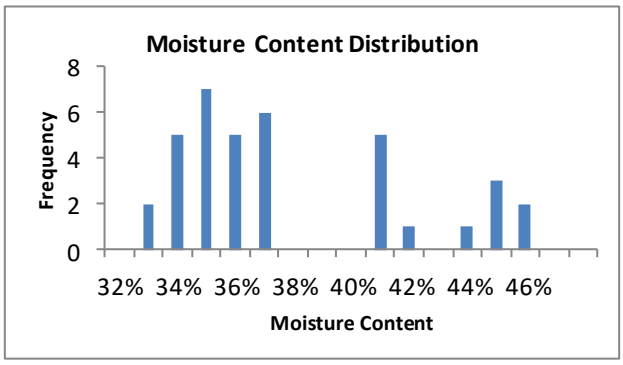

Figure 5. Moisture content distribution for sampled chips

Discussion

Total cycle time for chipping was found to be most affected by grappling time and number of stems. This could be explained due to the fact that these two elements are affected by the movements and operations of the operator controlling the knuckle-boom grapple attached to the chipper while the chipping and loading elements are stationary and mechanically driven. This results in more variance in the grapple time and number of stems collected per grapple. The chipper was found capable of processing 43 Doyle board feet every 44 seconds on average which results in processing 3.518 MBF per Productive Machine Hour. Initial chip property analysis found averages of 37.39% moisture content, 0.2121 g/cm^3, 13.54% bark content, and 18.829MJ/kg heating value of the chips. Further property analysis will be performed to compare a clean debarked chip to the chip containing bark and further determine suitability for bioproduct and bioenergy applications.

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FOREST PRODUCTS TRANSPORT BY ACTIVATING UPGRADED FOREST ROAD AND INTERMEDIATE DEPOTS

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Abstract: *Transportation distance of forest products is extending with the enlarged scale of sawmills or biomass energy plants and the procurement area is getting further from the demand. Trucks with higher capacity, it means 4-axis trucks here, is currently focused for the efficient transportation, but there exists the gap of standards between low-volume roads for 2-axis trucks in harvesting sites and primary forest roads for 4-axle trucks, which may require depots for re-loading. There was a nationwide program on constructing higher standard forest roads as primary roads on the ridge of mountain in interior mountainous regions all over Japan, which had been applied from 1956 to 2009. The primary roads will be available to introduce 4-axil trucks into the interior regions. In this study, the transportation of forest products was simulated in an actual model area with 8,900 ha alongside of 70 km of upgraded road by using GIS and linear programming model considering the moisture content of forest products and the ratio of loaded driving time. The intermediate/terminal depots along the primary roads were proved effective and their appropriate locations were proposed. Upgraded ridge forest road will effectively connect regions over the mountain, and will also realize lowering the total transportation cost.*

Keywords: bioenergy logistics, intermediate depot, loading ratio, mountain ridge road, primary forest road, upgrading road

IN SITU MONITORING OF FOREST ROAD SURFACE WITH TERRESTRIAL LASER SCANNER

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Abstract: *Low volume road like forest roads constantly are changing over time due to different factors and these changes effects traffic safety. The aim of the study is to investigate how the volumetric degradation could be tracked using Terrestrial Laser Scanner (TLS) and how volumetric changes were related to traffic during one year. Within the scope of this study, the optimal point cloud density and data acquisition pattern were determined to obtain TLS based degradation. The optimal horizontal distance between two TLS stations was evaluated as 20m while the minimum sensor height was evaluated as 2m. With this pattern, the average point cloud density was obtained as 4mm. Data acquisition was performed 5 times in 3 month periods so that 1 year observation was carried out. All point cloud data were transformed to raster Road Surface Model (RSM) at 0.01m grid resolution to eliminate the point cloud density heterogeneity and to obtain seasonal volumetric degradation data. According to results, net gains are calculated as 25.62m^3; 16.96m^3; 16.86m^3; 21.51m^3 while net losses were calculated as 19.73m^3; 15.32m^3; 26.91m^3; 40.31m^3 during one year in four seasons. 3 camera traps were used to observe traffic characterization along the road. Seasonal total number of vehicle passes (820; 778; 936; 2064) and tonnages (2389; 1920.2; 1505.3; 3598.2) were interpreted. The results of statistical analysis were indicated that, high correlation was found between traffic and degradation. Also, TLS can be used effectively in monitoring changes on RSM.*

Keywords: terrestrial laser scanner, road surface model, traffic

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DETERMINANTS OF HARVESTING EFFICIENCY OF GENETICALLY MODIFIED POPLAR (POPULUS TRICHOCARPA)

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Abstract: *Wood supply in Poland does not meet the expectations of the processing industry. Amount of timber from sustainably managed forests is limited by the size of the resource base and the rules of nature protection. Importing of wood is unprofitable, primarily due to high transport costs. For these reasons are established plantations of fast growing trees and shrubs that are adapted to relatively cool and dry climate. The most popular are species are willow and poplar. Willow wood is used primarily for energy purposes, but the scale of cultivation and production is not growing. There are competitive, more cost-effective source of biomass. Wood harvested from plantations of poplar is used for paper production. There is a slow increase in the scale of production poplar wood. Properties of poplar wood cause that it is not a desirable material for the energy industry. Grown in Poland varieties of poplar (derived mostly from Italy) are not resistant to low temperatures. There is a belief that new varieties of poplar can be an attractive source of biomass. It has been derived new genetically modified line of poplar (Populus trichocarpa) with enhanced performance of gain of dry matter and water use efficiency. It is also characterized by better resistance to low temperatures. The modified structure of cells causes that the mass of wood becomes useful for the production of bioethanol. The modified structure of cells causes the mass of wood becomes useful for the production of bioethanol. This will be a new impulse to the development of cultivation of poplar. Changes in wood tissue structure and trees parameters, can affect the performance and efficiency of the processes of harvesting and processing. Have been conducted comparative study of the characteristics of the new variety of poplar and these so far grown in Poland. Mechanical properties, resistance to chain saw cutting and power cutting, dimensions and shape of tree trunk and branches and trees positioning at the plantations were evaluated. The results will be used to develop the recommended harvesting system of new variety of poplar (Populus trichocarpa).*

Keywords: poplar, genetic modification, wood properties, harvesting efficiency

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